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EDITORIAL

It is my proud privilege to welcome you all to the IGRNET International Conference at Paris, France in association with ISER. I am happy to see the papers from all part of the world and some of the best paper published in this proceedings. This proceeding brings out the various Research papers from diverse areas of Science, Engineering, Technology and Management. This platform is intended to provide a platform for researchers, educators and professionals to present their discoveries and innovative practice and to explore future trends and applications in the field Science and Engineering. However, this conference will also provide a forum for dissemination of knowledge on both theoretical and applied research on the above said area with an ultimate aim to bridge the gap between these coherent disciplines of knowledge. Thus the forum accelerates the trend of development of technology for next generation. Our goal is to make the Conference proceedings useful and interesting to audiences involved in research in these areas, as well as to those involved in design, implementation and operation, to achieve the goal.

I once again give thanks to the Institute of Research and Journals, TheIRES, ISERD for organizing this event in Paris, France. I am sure the contributions by the authors shall add value to the research community. I also thank all the International Advisory members and Reviewers for making this event a Successful one.

Editor-In-Chief

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REDUCING VEHICLE INTERIOR NOISE CAUSED BY FLOOR PANELS

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Abstract - Absorption and damping materials are used to control noise and vibration in the automotive industry. It is reasonable to utilize FE analysis to determine the location of damping materials in order to reduce the time and cost associated with developing a new automobile. In this study, a finite element model of the front, center, and rear floors, as well as all adjacent panels, was created. Frequency Response Analysis (FRA) are performed, and the dynamic behavior of the model is studied using the MSC Nastran software. Although covering all areas of the front and center floors with damping material is the most effective method for reducing noise, doing so causes the mass to increase significantly, which creates complications. To find the optimal solution, the results of the analysis were reviewed, and damping materials were proposed to cover critical areas. The floor's mass would increase by 2.6% as a result of applying the optimal method.

Keywords - NVH, FEM, Damping Material, Floor panel

I. INTRODUCTION

The subjective experience of automotive driving is mostly influenced by noise, and excessive interior noise significantly affects the ride comfort and NVH performance of a vehicle. Thus, interior sound quality (SQ) has become an important factor for automakers and customers [1] [2]. Frequency-wise, the internal noise can be separated into three parts: high-frequency airborne noise at frequencies over 500 Hz created by the vehicle's systems and aerodynamic disturbances that transfer through the cabin and are audible to the passengers; mid- and low-frequency structural sounds below 500 Hz caused by the transmission of mechanical inputs (engine, trains) through the car body frame [3] [4]. The use of sound insulation and absorption materials in a vehicle can be an effective method to minimize the level of high-frequency airborne noise. [4]

In recent years, active noise control (ANC) approaches have emerged as a significant area of research interest due to their viability and efficiency in controlling low-frequency noise. Active noise control, commonly known as ANC, is based on the superposition of waves in an inverse phase, and its implementation may be separated into two different categories: active sound control (ASC) and active vibration control (AVC) [5] In the modern automotive industry, two primary techniques are widely employed to reduce mid-frequency (20-500 Hz) noise: The first technique involves filtering mechanical inputs close to vibratory sources. The purpose of engine mounts, for example, is to limit energy transfer between the engine and the vehicle's body frame. The second method is based on passive damping systems, which are typically located on the noise-radiating panels [6]. Typically, passive damping systems consist of viscoelastic constrained layer patches. This type of system effectively dissipates vibratory energy through the shearing deformation of the viscoelastic layer [7]. To design intelligent (lightweight, affordable, durable, robust, and efficient) passive-damping systems, it is necessary to have accurate Finite Element (FE) models that can predict the frequency responses of structures containing viscoelastic materials. Additionally, computer-aided design phases are typically shorter. In order to rapidly evaluate a large number of potential technical solutions during the design phase, it is necessary to generate models at a low cost and find solutions quickly. Based on linear FE analysis, there are a few existing techniques for modeling damping treatment. They can be classified primarily into two categories. In the first category (the most conventional approach), only the distributed mass of the treatment material is added to the metal part's finite element, and the viscoelastic nature of such panels is largely ignored. The treatment layer is explicitly modeled as additional elements on top of the metal elements in the second category [8–12]. Although the simple mass method (the first category) requires almost no additional modeling, it does not account for other potential effects such as damping and stiffness changes. The explicit modeling method, on the other hand, while accounting for said potential effects, can further complicate the modeling process. In this study, the viscoelastic layer is modeled as a solid element, and its associated material properties are introduced into the Nastran software in an appropriate manner.

II. MODEL

MSC.Nastran 2010 was used for the finite element analysis. Samand BIW (body in white) panels were completely modeled and analyzed; however, just the underbody panels were requested in the result output as the main area of focus in this study The viscoelastic layer was modelled with eight node solid

elements with isotropic material properties. Panels were modelled by shell elements and damping pads by solid elements.
Unit force excitation over the 0–500 Hz range was applied to the engine center of gravity. This excitation transferred to the body through engine mounts modelled by springs. Vehicle suspensions were modeled by springs, and the ground nodes were constrained.

2.1.Material modeling

The material properties for viscoelastic damping material consist of shear modulus and loss factor, shown in **Fig.1** and **Fig.2**, respectively. The loss factor was entered as structural element damping (GE) on the material card of the finite element model. The viscoelastic damping material has frequency- and temperature-dependent properties. An ambient temperature of 20 degrees Celsius was assumed [9]

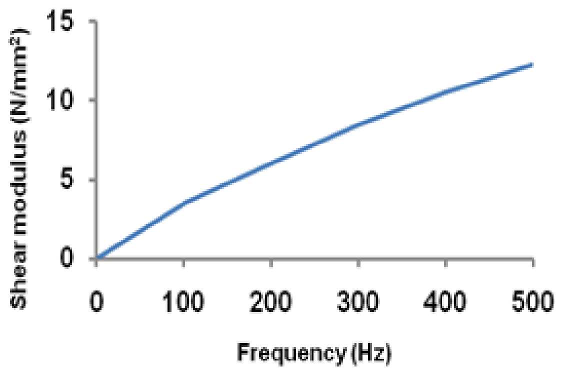

Fig.1. Shear modulus of the damping materials C-1002 (EAR Corporation)

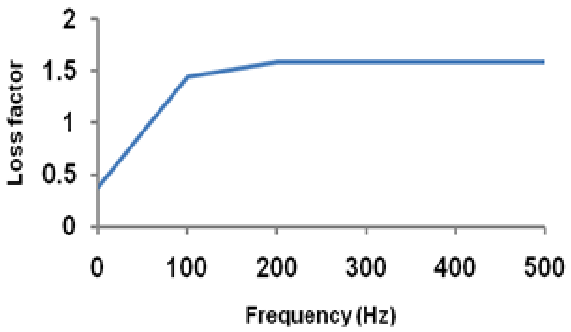

Fig.2. Loss factor of the damping materials C-1002 (EAR Corporation)

The dynamic behavior of viscoelastic materials is characterized by a strong dependence on frequency; and under sinusoidal excitation, these materials exhibit a steady-state response in which the stress lags the associated strain. The general three-dimensional state of stress can then be described in terms of a complex frequency-dependent shear modulus and a real constant value for Poisson's ratio.
MSC.Nastran provides the ability to represent a single complex frequency-dependent scalar material modulus of the form.

$$G\,(f) = G^{'}(f) + iG"(f) \qquad (1)$$

where $G^{'}(f)$ is the shear storage modulus and $G"(f)$ is the shear loss modulus.

$$\eta = \frac{G"}{G'} \qquad (2)$$

This ratio is denoted as the shear loss factor.
The above formulation of viscoelastic (frequency-dependent) material properties can be utilized in direct frequency response analysis, which requires the damping components of the dynamic matrices as well as some special input data, such as the TR (f) and TI (f) functions.

$$TR(f) = \frac{1}{g_{REF}}\left[\frac{G^{'}(f)}{G_{REF}} - 1\right] \qquad (3)$$

$$TI(f) = \frac{1}{g_{REF}}\left[\frac{G"(f)}{G_{REF}} - g\right] \qquad (4)$$

where G_{REF} is the reference modulus, g_{REF} is the reference element damping, and g is the overall structural damping.

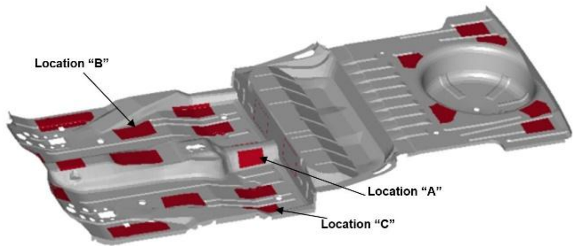

Fig.3. Underbody panels and damping area

2.2. Analysis method

As previously noted, the viscoelastic material has frequency dependent material properties. The modal frequency response solution does not allow for frequency dependent material properties, so the direct frequency response solution, which included 200 modes up to a frequency between 0 and 500 Hz, was used to predict the response to unit force excitation.

In the first step, the model was run without any damping pads using the direct frequency response method. Reviewing the results in the underbody area, about twenty one points that had the highest vibration were selected as areas of focus. In the second step, viscoelastic damping pads were modeled by placing solid elements on top of the areas selected in the first step, and again, the FE model was run using the same method. **Fig.3** shows damping treatment areas.

III. RESULT AND DISCUSSION

Due to the wide variety of vibration amplitudes encountered in engineering, it is convenient to express the measured amplitude in decibels relative to a constant value. Therefore, the velocity outputs for twenty one selected points are converted to decibels and plotted over frequency for both padded and non-padded models. As an example, **Figs.4-9** show the effect of padding treatment in points A, B, and C (illustrated in **Fig.3**).

In **Fig.4**, **Fig.6**, and **Fig.8**, velocity amplitudes of both padded and unpadded models are depicted in terms of frequency. The velocity amplitude is converted to decibels and plotted in terms of frequency in **Fig.5**, **Fig.7**, and **Fig.9** so that the padding treatment effect can be comprehended with greater clarity.

As is apparent, padding has a significant effect on noise reduction at points A and B, whereas its effect at point D is insufficient. At point D, the pad has a reduced velocity amplitude in the high frequency range while introducing undesirable vibrations at frequencies below 350 Hz. Consequently, damping pads are not employed at point D. These three points serve as an illustration of how post-processing has been performed and how the final padding location is selected.

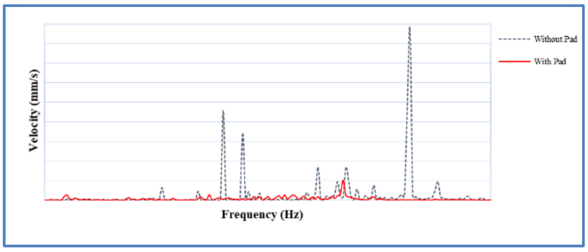

Fig.4. Velocity in terms of frequency at point A

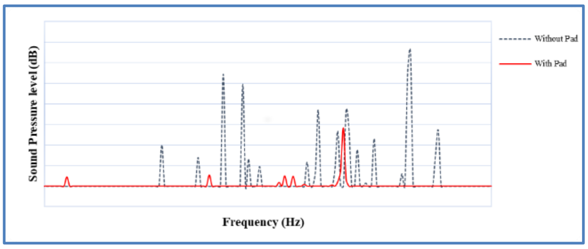

Fig.5. Sound pressure level in terms of frequency at point A

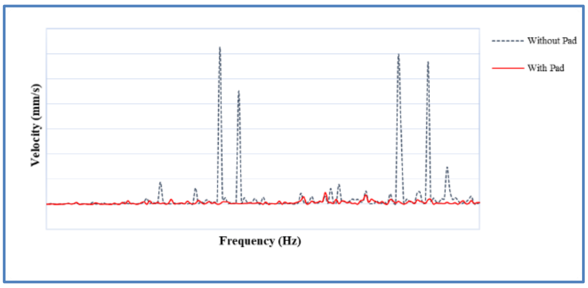

Fig.6. Velocity in terms of frequency at point B

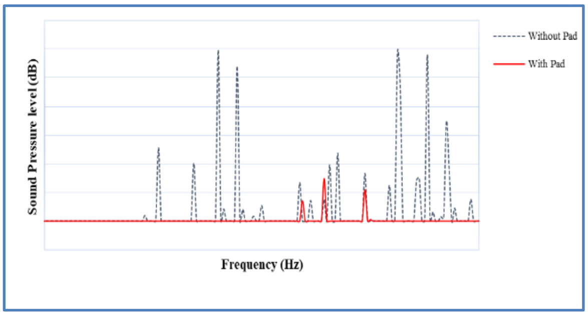

Fig.7. Sound pressure level in terms of frequency at point B

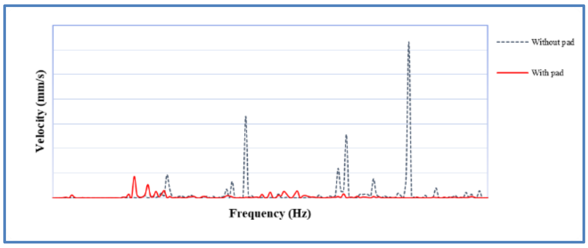

Fig.8. Velocity in terms of frequency at point C

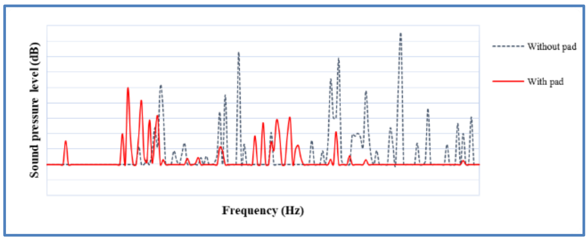

Fig.9. Sound pressure level in terms of frequency at point C

IV. CONCLUSIONS

In selected areas, viscoelastic pads were used to reduce noise. These pads were modeled as solid elements with eight nodes. To model viscoelastic materials in Msc.Nastran, specific input data, including loss factor and frequency-dependent shear modulus, are required. In this study, a direct frequency response solution was employed because the modal frequency response cannot be used to model viscoelastic materials, which have frequency-dependent properties. On the basis of the initial analysis, twenty-one points were chosen to be covered with damping pads. After analyzing the effect of damping pads on local vibrations, twelve areas with the most effective damping treatment were retained, while other pads were removed. **Fig.10** depicts the final placement of damping pads.

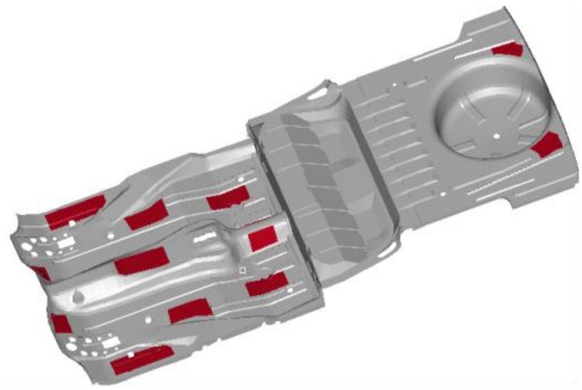

Fig.10. Final locations for damping pads

ACKNOWLEDGEMENTS

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NUMERICAL AND EXPERIMENTAL MEASUREMENT OF RESIDUAL STRESS IN SUSPENSION A-ARM USING INCREMENTAL HOLE-DRILLING METHOD

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Abstract - Residual stress is a kind of stress that remains in mechanical components even after removing external forces. Residual stress mainly happens during the production process of a component, which, in turn, significantly affects its design and performance. The standard ASTM E837-01 analyzes residual stresses in components with flat surfaces using the drilling method and presents stress calibration coefficients with a constant stress profile. However, there is not a special standard to measure residual stress in curved components utilizing the drilling method. In this study, the considered model, which is a vehicle A-Arm, is simulated first; then, a dynamic analysis is done under a road load profile using ANSYS software, and the critical points of the specimen are determined; in the next step, a residual strain measurement test is performed using central drilling based on the standard; after calculating residual stresses experimentally, some suggestions are presented to reduce adverse residual stresses and enhance the component's life.

Keywords - Residual Stress, A-Arm, Hole-Drilling Method, Calibration Coefficient, ASTM Standard, Software Analysis

I. INTRODUCTION

Residual stresses are self-balancing stresses that are confined inside a component. Residual stresses in a structure play an important role in life prediction, structural reliability evaluation, and structure design [1]. The lateral-torsional buckling resistance of castellated beams can be significantly affected by the manufacturing processes of cutting and welding, which significantly contribute to the residual stresses in castellated beams [2]. Residual stresses in metals are caused by specimen yielding, welding, casting, rolling, incorrect assembly, etc. However, residual stresses are not always harmful. Specifically, some mechanical surface treatment methods (e.g., shot peening, case hardening) are employed to generate a compressive residual stress field in the surface area of a structure as a work hardening method for improving the fatigue characteristics [1]. Researchers have investigated the hole-drilling approach using the rosette strain gauge and the digital image correlation (DIC) method to measure residual stress. [3]

In addition to the methods already described, innovations are being explored. Using digital image correlation (DIC) combined with the hole-drilling technique to detect residual stress in H-shaped steel beams in conjunction with the finite element method (FEM) to solve for the predicted coefficients is one example. [3] Another example is determining the size and direction of the primary residual stress components in a non-equibiaxial residual stress field at the nanoscale, a novel approach based on nanoindentation[4]. The DIC approach has lately been expanded due to its benefits; however, the Hole-Drilling method is the only residual stress measuring method included in the ASTM standard. Using Mohr's circle, a study is carried out to compare the results of residual stress measurements by the hole-drilling and DIC methods on a composite plate [5].

Residual stresses in mechanical components are commonly measured using Hole-Drilling. Recent research has linked surface strains during incremental drilling to residual-stress distribution. Researchers worldwide have proposed various calibration methods with varying accuracy. This simple and reliable "semi-destructive method" causes only local destruction and doesn't significantly reduce specimen performance. Mathar's 1934 hole-drilling residual stress method [6]. This method is used when residual stresses are uniform throughout a part's depth. This method is for microscopic, isotropic, and homogeneous materials. Many studies [7] generalized this method for any isotropic material defining pro-calibration risk.

A finite element simulation predicts A-Arm residual stresses during manufacturing [8]. Internal residual tension may cause subsurface fatigue cracking at high contact pressures. High traction or braking shear loads or local heating and thermal stress from high power dissipation can also aggravate fatigue [9]. Akbulut [10] optimized a control arm by finding critical zones and determining optimum thickness using elasto-plastic analysis.

II. PROCESS SPECIFICATIONS, TECHNICAL POINTS, AND OPERATION CONDITIONS

The suspension arm is stamped from a 3.50 mm thick sheet of steel (S 460 MC, referring to EN standards). The material is assumed to be homogeneous and isotropic, with elastic-plastic behavior and isotropic hardening. According to standard steel data and specifications on S 460 MC steel, we consider the

Young modulus E = 210 GPa, the Poisson coefficient ν= 0.3, and the plasticity tangent modulus E= 0.84 GPa. The Minimum guaranteed yield stress and limit stress are σy= Rp0.2= 460 MPa and Rm= 520 Mpa, respectively, while the minimum ultimate strain is A% = 14%.

III. MODELING AND DYNAMIC ANALYSIS OF A-ARM

A-Arm Modeling in CATIA Software is shown in **Fig.1**.

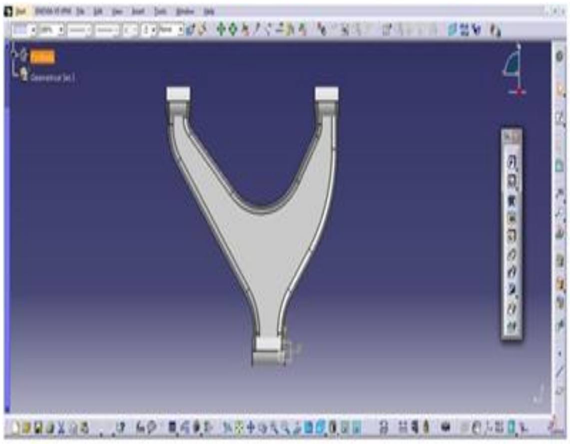

Fig.1. The modeled part in CATIA software

In order to perform a dynamic analysis, the following assumptions have been considered:

1. Vehicle mass: 1500 kg
2. The bumper is a circular rod with a 30 mm diameter.
3. Vehicle speed: 50 km/h.
4. The applied force to the arm by the bumper is 0.4 of the vehicle weight.
5. Due to existence of a tire, the arm region that is under pressure will be expanded, and the maximum force will be decreased. Thus, it is assumed that a rectangular region will be under pressure. The width of this rectangle is 20 mm (due to the arm’s shape), and its length is also considered 20 mm.
6. The external diameter of a vehicle tire is considered 20 inches. So, to move at a speed of 50 km/h, the tire travels 8.7 rounds per second.

Contact time can be obtained approximately as follows: Since the tire travels 246.9 mm during the whole contact time of tire-bumper, the time travel equals $t = \frac{246.9\times10^{-3}}{50\times\frac{1000}{360}} = 0.01798\ \text{sec}$

As shown in **Fig.2** time function of the applied force is considered a half sinusoidal cycle. The force increases from zero amount and zero time, maximizes at time $t = 0.00899$ and then decreases and equals zero at time 0.01798 sec.

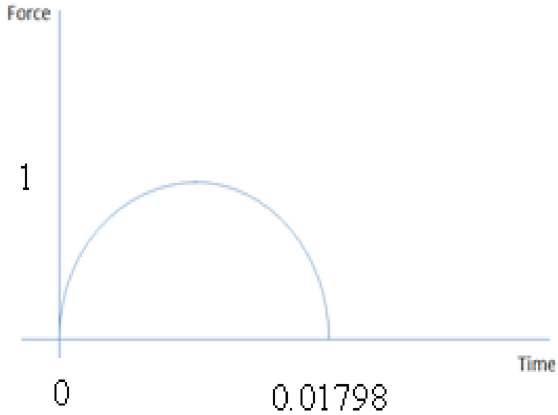

Fig.2. Time function of the applied force

Because the half cycle happens at 0.01798 sec, the sinusoidal function is obtained as follows:

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2\times0.01798} = 174.700745$$

$$F = \sin(\omega t) = \sin(174.700745\times t)$$

The natural distribution of the most mechanical processes is defined as Gaussian (a bell-shaped function). As shown in **Fig.3** the positional distribution is considered to be this function.

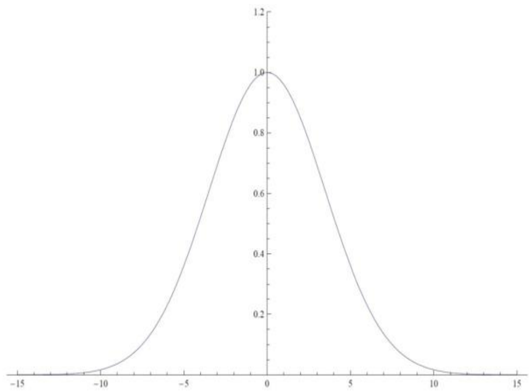

Fig.3. Positional distribution of contact force (the middle zero point is the contact region)

So the force distribution changes with position and time. Simulation is done transiently, dependent on time and position. The Solid186 element is used for analysis. In the contact region and for the holes of the screws, finer elements have been used. Support conditions are considered fixed on the inner surface of the screw hole.

In the middle of the contact region, where the pressure reaches its maximum amount and at the moment $t = 0.01798$ sec the maximum applied pressure is 16.8 MPa. The whole contact time (0.01798 sec) is modeled as 18 time steps in ANSYS. Specifically, the process is modeled as 18 discrete steps. The time of each step is demonstrated in **Table 1**.

Available Data Sets:

Set	Time	Load Step	Substep	Cumulative
1	9.98889E-04	1	1	1
2	1.99778E-03	1	2	2
3	2.99667E-03	1	3	3
4	3.99556E-03	1	4	4
5	4.99444E-03	1	5	5
6	5.99333E-03	1	6	6
7	6.99222E-03	1	7	7
8	7.99111E-03	1	8	8
9	8.99000E-03	1	9	9
10	9.98889E-03	1	10	10
11	1.09878E-02	1	11	11
12	1.19867E-02	1	12	12
13	1.29856E-02	1	13	13
14	1.39844E-02	1	14	14
15	1.49833E-02	1	15	15
16	1.59822E-02	1	16	16
17	1.69811E-02	1	17	17
18	1.79800E-02	1	18	18

Table 1: time steps in ANSYS

3.1. Time changes of stress in y direction (σ_y)

Time changes of stress in the y direction, which are shown in **Fig.4**and **Fig.5**, illustrate the process of applying pressure to the A-Arm.

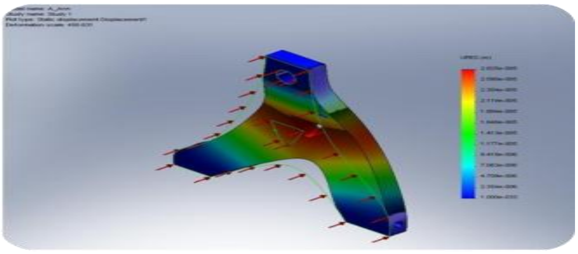

Fig.4. Yield Stress distribution in y direction (σ_y) at the time 0.000998889 sec (Principal stress)

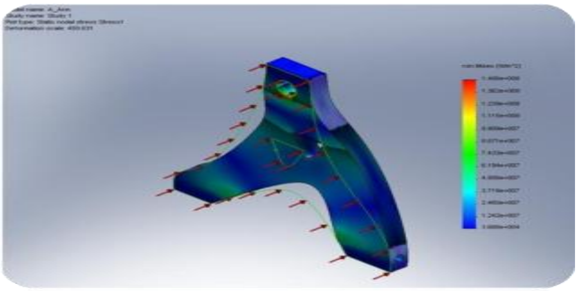

Fig.5. Von-Mises Stress distribution in y direction (σ_y) at the time 0.000998889 sec (Von Mises)

IV. TEST METHOD PRINCIPLES WITH INCREMENTAL HOLE-DRILLING STRAIN GAUGES

Residual stress measurement with traditional methods is not possible for most of the materials, especially materials with an opaque appearance, while the strain sensors measure only strain changes and are not dependent on the production process or the appearance of the specimen. To measure confined residual stresses inside a specimen by this sensor, the residual stresses should be released with a common method in the presence of these sensors. Thus, the released strain can be measured. Hole-Drilling strain gauge is a modern technique that is utilized to measure residual stresses using released strains. Briefly, this method can be divided into six major stages:

- Installing three-element strain gauge on the specimen where the residual stress is to be measured.
- Connecting wire networks of the gauge to the strain indicative section.
- Installing accurate drilling guide bush at the center of the strain gauge.
- Making a small hole on the specimen after resetting and balancing the device.
- Reading released strain of the residual stress inside the specimen.
- Using available relations and obtaining maximum stress and its angle to the strain gauges

The mentioned method has been standardized in ASTM E837. Using this standard and having reasonable relationships between residual stress and the released strain, this modern method can be easily utilized. It should be noted that this method is not limited to the laboratory and can be used in a work environment for components with different shapes and dimensions.

This is a half-destruction method since the drilled hole is small and doesn't have a major effect on the strength of the specimen (the hole size is usually about 8 to 8.4 mm in diameter and depth). For large components that are tested with this method, the hole can sometimes be eliminated using a machining method like grinding.

Drilling the specimen releases the inside residual stresses around the drilled zone. Since normal and shear stresses perpendicular to the hole surface are zero, the elimination of these stresses at the hole surface changes the stress measure around the drilled zone, and these stress changes cause strain in these zones. The released stresses can be obtained by measuring these strains and using the stress-strain relation.

In most practical cases, the drilled hole is dead-ended, and its depth and diameter are approximately equal. Also, the hole depth is small in comparison to the specimen thickness. Due to the complexity of dead-ended hole equations, accurate mathematical equations of the residual stress-strain relation are not available. However, experimental coefficients can be used. Thus, the mathematical equations of a complete hole are calculated for a low, thick, and wide specimen, and then these equations are extended for a dead-ended hole and for a thick specimen with different shapes and dimensions. Calibration coefficients are determined by experimental and finite element methods.

4.1. Experimental Tests of Stress Measurement

To measure calibration coefficients, the experimental test of four-point bending of a flat sheet is being used. The fundamental equations of the drilling method are obtained for volume components. The aim of this test is to analyze the effect of the low thickness of the sheet on the results accuracy of stress measurement and, in particular, to determine the validity of the calibration coefficients in stress calculation in thick components. Usually, calibration coefficient figures for flat sheets are available, while there is no such data for curved surfaces. However, if the curvature is not severe, the available data can be used with some acceptable error.

4.2. Calibration Coefficients Determination Using the Finite Element Method

In this part, the calibration coefficients are determined using two FEM simulations, and then the four-point bending test is used for accuracy evaluation. To determine calibration coefficients An and Bn, two separate simulations are used. To determine An, biaxial sheet drawing is utilized, and a constant stress is applied to the sheet in the direction of 1 and 3 strain gauges and simulated with a finite element model in ANSYS software. To calculate theBn coefficient, the previous conditions are kept, but the loading is changed, and the pure shear test conditions are used.

Process	A_n	B_n	Height
1	-1362	2004	0.0-0.2
2	-1691	2900	0.2-0.4
3	-1875	2701	0.4-0.6
4	-1608	2844	0.6-0.8
5	-941	158	0.8-1.0

Table 2: Determination of A_n and B_n coefficients

A CNC milling machine, which has an AC BOSCH motor with 27000 rpm, is used for drilling. The most commonly used strain gauge is the TML or ERS-2-23 kind. Blade milling of 2 mm diameter is used for drilling. The data logger of Vishay measurements group P3 is highly accurate. A very low advance rate is being used for drilling. Drilling is done in five steps, and enough time is dedicated after each step for heat transfer to prevent heat strains from affecting the recorded data. The clue TML of the cyanoacrylate CN kind is used to attach the strain gauge.

Technical Specifications		Component
Part Name	A-Arm Renauult Logen	Logan A-Arm
Material	Steel (S 460MC) or Cast Iron	
Weight	514 gr	
Volume	64 cm^3	
Thickness	0.7 mm	

Table 3: Technical Specifications of the Component

4.3. Experimental Test of Residual Stress Using the Drilling Method on the A-Arm: Preparing the Test Specimen

Ideally, the surface of the test specimen must be clean and smooth. Pollution and cortex must be eliminated in the case of existence. However, any removal of the original material must be done in such a way that no residual stress is produced, and hence no change in the measured stress occurs. Milling and machining are the processes that cause large stresses to a minimum depth of 0.005 in (125 µm). The effect of etching with acid is not so obvious. Some researchers report that etching causes stress, while others believe that its effect is negligible. In any case, etching with acid is not desirable since it causes roughness on the specimen's surface. The only safe method for surface finishing the specimen without causing stress is to polish it electrically, namely, by using the test specimen as the anode of an electric cell. Surface roughness must be avoided strictly, because the raised points of a rough surface may not be exposed to stress similar to that of the specimen. On the other hand, rough surfaces don't provide good deflection. The position and the way the rosettes are installed on the specimen are shown in Fig.8. On the specimen, two sensitive points can be chosen, considering the finite element analysis. Regarding the importance of perpendicularity of the mill to the surface, one CNC device is being used.

4.4. Selection of Proper Points for Rosette Installation

In order to determine this profile, specific numbers of coordinates are required on the specimen. Determination of an accurate residual stress profile on the specimen needs these coordinates to have a high accuracy final guess and also have residual stress data of the arm being received from proper numbers of points. For the choice of rosette installation position, FEM analysis is used, and the gauges are installed at the resulting critical points, as can be seen in Fig.6.

Fig.6. Position of rosettes installation

As shown in **Fig.7**,the sample is fixed to the fixture, and considering that the coordinates of the rosettes' centers are specified, the drill is located over it and the drilling operation is performed.

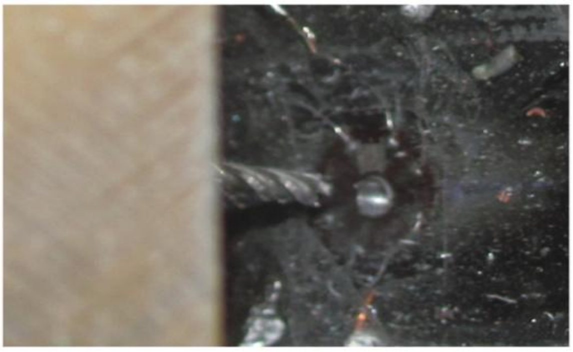

Fig.7. Drilling of the cleaned specimen

In this method, by drilling the place considered for measuring residual stresses, the stresses are released at that point, and deflection happens around the hole due to the stresses release. Now, by measuring and analyzing the mentioned deflections, the residual stresses can be measured at the so-called position. By increasing the hole depth, residual stresses can be measured at more depths; however, the measurement accuracy will be decreased.

4.5.Test Procedure and Obtained Diagrams

The Final depth of the drilled hole is 1 mm, and 7 steps of drilling are chosen. After cleaning the surface and installing rosettes in their positions, the specimen is fixed to the CNC device, and the drilling is performed precisely. 0.1 mm is removed at each time, and then the specimen is transferred to the hole drilling device for residual stress measurement.

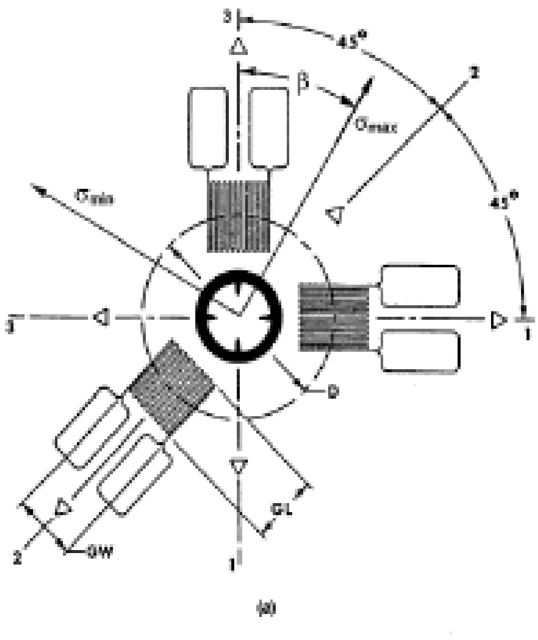

Fig.8. Rosette arrangement for determining residual stress

After connecting the rosette's wires to the data logger device, the related figure of residual stress for every depth and point can be read. This test is done at six points on the arm where the rosette installation is possible.

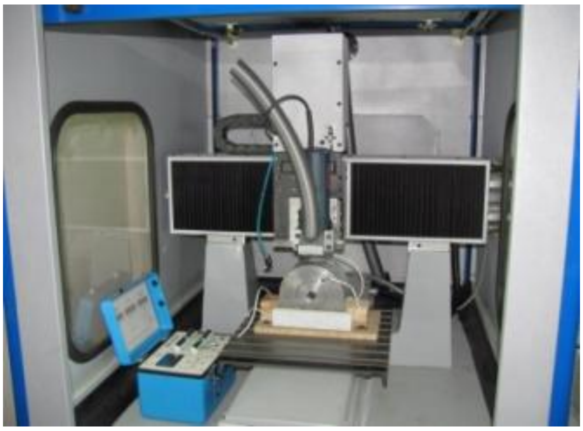

Fig.9. Residual stress measurement device using hole drilling method at IUST

Fig.10. Data logger device for calling residual strains

The data logger shows strain, and to convert it to residual stress, calibration coefficients are used, and these stresses are the average of the released stresses at each step.

V. RESULTS

Equations:

$$\varepsilon_1 = A(\sigma_x + \sigma_y) + B(\sigma_x - \sigma_y)\cos 2\alpha \qquad (5\text{-}1)$$

$$\varepsilon_2 = A(\sigma_x + \sigma_y) + B(\sigma_x - \sigma_y)\sin 2\alpha \qquad (5\text{-}2)$$

$$\varepsilon_3 = A(\sigma_x + \sigma_y) - B(\sigma_x - \sigma_y)\cos 2\alpha \qquad (5\text{-}3)$$

Rosette 1 and 2:

Points 1 and 2 have the same loading situation. After placing the specimen in the fixture and drilling with a step of 0.1 mm, the released strains are called in the data logger device and are demonstrated with calibration coefficients as radial, shear, and hoop stresses.

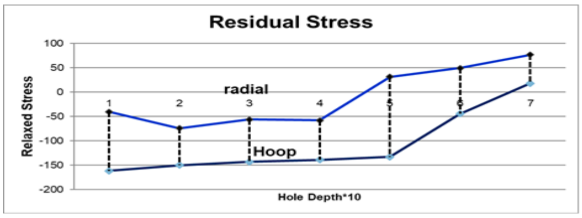

Fig.11. Measured results No. 1 and 2 inner holes

According to the obtained chart of relaxed stresses, points 1 and 2 have both positive and negative residual stresses. Punching, the forming process, overloading, and machining direction can be good reasons for this. (Negatives can be critical because this area is under tension.)

Rosettes 3, 5 and 6:

Point 3, 5 and 6 have the same loading situation after placing the specimen in the fixture and drilling with a step of 0.1 mm. The released strains are called in the data logger device and are illustrated with calibration coefficients as radial, shear, and hoop stresses.

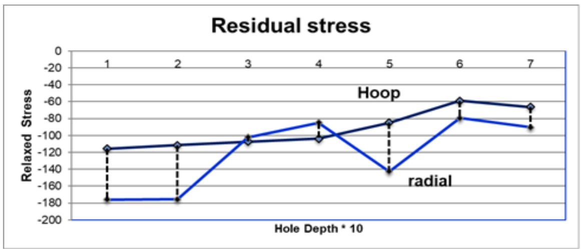

Fig.12. Measured results No. 3, 5, and 6 outer holes

It is obtained from drilling test results at points 3, 5, and 6 that both radial and hoop stresses are negative, and this area is very critical according to dynamic load results and residual stress measurements. As can be seen, A-Arms often fails in this area. Wrong installing, Forming process, Thermal gradient and Machining direction are the reasons of remaining negative stresses in this area.

Rosette 4:

After placing the specimen in the fixture and drilling with a step of 0.1 mm, the released strains are called in the data logger device and are illustrated with calibration coefficients as radial, shear, and hoop stresses.

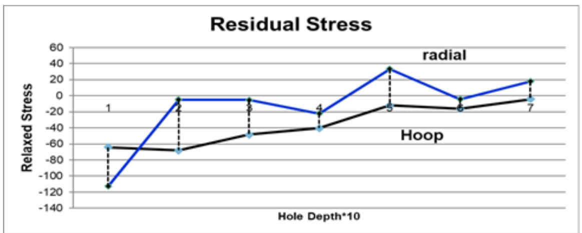

Fig.13. Measured results No. 4 outer hole

Both radial and hoop stresses are negative in point 4, and this area is also critical according to dynamic load results and residual stress measurements, but this area is safer than points 3 and 1. Multi-Stage forming processes and machining directions may be the reasons for the remaining negative stresses in this area.

COCLUSION

As it is obtained from the dynamic analysis of ANSYS, there are different conditions for stress distribution at the three points where the residual stresses are measured. It can be understood that the punching, forming, and bushing areas of the arm are more critical during travel, which causes unexpected fractures that must be prevented. Production process improvement, correct assembly, etc. can be considered as potential solutions.

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AUTOMOTIVE DECELERATION RATE CHANGES ACCORDING TO AXLES BRAKING FORCE DISTRIBUTION

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Abstract - In this study, the braking efficiency of motor vehicles under various operating conditions, such as road conditions, tire type, and vehicle loading, is analyzed. In addition, the distribution of braking force on the front and rear axles is optimized to improve braking efficiency. This article examines the relationship between the type of braking and the vehicle's safety under braking conditions, specifically when the wheels do not lock or when the front wheels lock before the rear wheels. In braking mode, the vehicle model is considered two-dimensional, and longitudinal motion equations are used. The influence of operating conditions and load on the optimal distribution of braking force on the front axle is also investigated. The results indicate that the optimal distribution of braking force on the front axle can be used to design a controller that prevents the rear wheels from locking prematurely.

Keywords - Braking Efficiency, Vehicle Deceleration, Road Adhesion Coefficient, Rolling Resistance Coefficient

I. INTRODUCTION

The primary and most fundamental function of brakes is to decelerate and ultimately stop the vehicle. The braking system should be capable of bringing the vehicle to a stop with the shortest possible stopping distance [1]. The braking force originates from the braking system and spreads over the tire-road contact surface. When no wheels are locked, the distribution of braking force between the rear and front axles is determined by the design of the brake system. To maximize a vehicle's braking capacity (the ideal state), both wheels must be on the verge of locking simultaneously. Under these conditions, the maximum braking force of the front and rear axles expands simultaneously at the tire's contact surface with the road, indicating that the vehicle's braking capacity is being utilized optimally.
This distribution of braking force is dependent on vehicle design parameters, vehicle loading, and contact surface or road conditions. Under all other conditions, the front or rear wheels will lock first, causing the loss of vehicle steering control and directional stability. On the basis of this analysis, the interrelationship between the sequential locking of the tires, the deceleration that can be achieved prior to the locking of each wheel, and the design parameters and operating conditions of the vehicle can be defined [2]. The effect of brake system components' parameters on passenger car dynamic behavior has been investigated [3]. Various factors, such as tire slip, can also affect the performance of anti-lock brakes [4].

Wheel slip can be a challenging problem due to the complex behavior of the tire and strong nonlinearity in the braking process. It can increase the stopping distance and negatively affect the directional stability of the vehicle [5]. Various algorithms, such as object-oriented programming, are used to design the controller of the anti-lock braking system [6]. This article investigates the effect of car design parameters, such as the height of the center of mass above the ground and the distance between the two axles, car loading, including passengers and the trunk load, and a full or empty fuel tank, as well as the condition of the contact surface or road conditions, on the braking characteristics or deceleration of a passenger car. By modifying the aforementioned parameters, the distribution of braking force for which both wheels are on the verge of locking is altered. Changing the parameters results in the optimal distribution value, and the change in optimal value is represented in terms of changes in the parameters.

II. BRAKING CHARACTERISTICS OF A TWO-AXLE VEHICLE

The main external loads applied to a two-axle vehicle in longitudinal motion are shown in **Fig.1**. The braking force originates from the braking system and is spread over the tire-road contact surface. As long as the braking force under the wheels is less than the tire-road adhesion limit, the braking force is obtained from Eq.1.

$$F_b = \frac{T_b - \sum I\alpha}{r} \qquad (1)$$

where T_b is the braking torque, I is the rotational iertia of the wheel, α is the corresponding angular deceleration, and r is the wheel's rolling radius.

During braking, other resistance forces influence the vehicle's movement in addition to the braking force. These forces include the aerodynamic resistance force, the rolling resistance force of the tires, the slope resistance force, and the power transmission system's resistance forces. Loads are transferred from the rear wheels to the front wheels during braking. In this instance, for the sake of simplicity, the resistance of the power transmission system and the aerodynamic resistance force are disregarded.

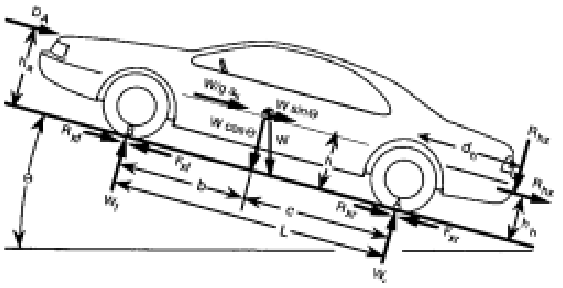

Fig.1. Dynamics of longitudinal movement of a two-axle vehicle

Additionally, we assume that the vehicle brakes on a smooth, straight road and that the rolling resistance force is constant. The following expressions describe the front and rear axle braking forces (F_{bf} and F_{br}, respectively) determined by the design of the braking system.

$$F_{bf} = K_{bf}.F_b = K_{bf}.W\left(\frac{a}{g} - f_r\right)$$
$$F_{br} = K_{br}.F_b = (1 - K_{bf}).W\left(\frac{a}{g} - f_r\right) \quad (2)$$

Here, K_{bf} and K_{br} represent the ratio of the front and rear axle braking forces to the total braking force F_b, respectively, and are determined by the braking system's overall design; W is the total vehicle weight; a is the vehicle's deceleration; and f_r is the tire's rolling resistance coefficient. It should be noted that when no wheels are locked, the distribution of braking force between the rear and front axles is determined by the brake system's design.

The distribution of braking forces in conventional braking systems is determined by the hydraulic (or pneumatic) pressure and the area of the brake cylinder (or chamber) in the front and rear brakes. The front wheels are locked when:

$$F_{bf} = mW_f \quad (3)$$

where m is the road adhesion coefficient and W_f is the front axle load.
This equation can be used to determine the vehicle's deceleration in terms of the gravitational acceleration g when the front wheels are on the verge of locking up, as shown in the following equation.

$$\left(\frac{a}{g}\right)_f = \frac{m\frac{l_2}{l} + K_{bf}.f_r}{K_{bf} - m\frac{h}{l}} \quad (4)$$

where l_1 and l_2 are respectively the distances from the front and rear axles to the car's center of mass, h is the height of the car's center of mass above the ground, and l is the distance between the axles. Similarly, it can be shown that when the rear wheels are on the verge of locking up, the deceleration is as follows:

$$\left(\frac{a}{g}\right)_r = \frac{m\frac{l_1}{l} + (1 - K_{bf}).f_r}{(1 - K_{bf}) + m\frac{h}{l}} \quad (5)$$

On a given road surface, the front tires of a vehicle with specified specifications and a specific braking force distribution will lock first if:

$$\left(\frac{a}{g}\right)_r > \left(\frac{a}{g}\right)_f \quad (6)$$

And the rear tires will lock first if:

$$\left(\frac{a}{g}\right)_f > \left(\frac{a}{g}\right)_r \quad (7)$$

In order to maximize a vehicle's braking capability (the ideal state), both wheels must be on the verge of locking simultaneously, and that means:

$$\left(\frac{a}{g}\right)_f = \left(\frac{a}{g}\right)_r \quad (8)$$

Under these conditions, the maximum braking force of the front and rear axles expands simultaneously at the tire's contact surface with the road, indicating that the vehicle's braking capacity is being utilized optimally. To determine the brake force distribution at which both wheels are on the verge of locking,since $\left(\frac{a}{g}\right)_f = \left(\frac{a}{g}\right)_r$, the following equation can be derived:

$$K_{bf}^* = m\frac{h}{l} + \frac{1}{l}(l_2 + f_r.h) \quad (9)$$

For K_{bf}^*, Maximum vehicle deceleration (in terms of gravitational acceleration g) is achieved by locking the front and rear wheels simultaneously (optimal use of the vehicle's braking capacity). This unique distribution of braking force is a function of the following parameters, as is evident.

1. Vehicle design parameters (h, l)
2. Vehicle loading (l_2) including: passenger, trunk load, and full or empty fuel tank
3. Contact surface situation or road conditions (μ, f_r)

From the preceding analysis, it can be concluded that, for a vehicle with given specifications and a constant brake force distribution, the front and rear wheels will lock on a given road surface only at the same deceleration.

III. BRAKING CHARACTERISTICS OF A PASSENGER CAR

This example investigates the braking characteristics of a passenger car as a function of the distribution of braking force on the front axle under loaded and unloaded conditions. In the loaded mode, the car's total weight is W_{loaded} , while in the unloaded mode, it is $W_{unloaded}$. l is the distance between the two axles, and h is the height of the center of mass above the ground. The ratio $\frac{h}{l} = 0.17$ is the same for both loaded and unloaded modes. Also, the adhesion coefficient of the road is $\mu = 0.85$.

$l(cm)$	$h(cm)$	$W_{unloaded}$ (KN)	W_{loaded} (KN)
315	54	19.4	26.1

Table 1: The passenger car characteristics

Fig.2 depicts the changes in deceleration of the vehicle in terms of g $(\frac{a}{g})$ based on the distribution of the braking force on the front axle for both cases of front wheels on the verge of locking (dashed line) and rear wheels on the verge of locking (solid line).

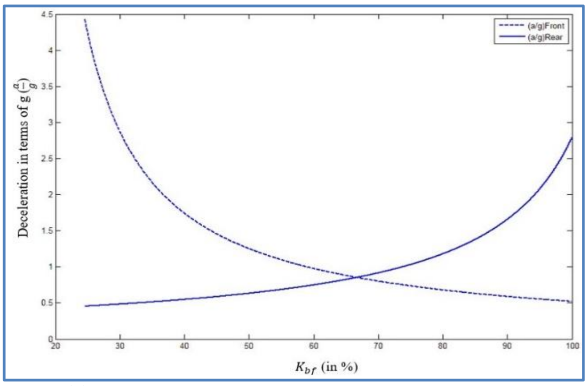

Fig.2. $\left(\frac{a}{g}\right)$ **of the front and rear axlesin terms of thedistribution of the braking force on the front axle**

By applying Eqs. 6 and 7, the achievable deceleration limits for the car with each of its wheels on the verge of locking up under loaded and unloaded conditions are calculated. These limits are depicted in **Fig.3** in terms of the changes in K_{bf} for both the loaded (solid line) and unloaded (dashed line) modes. This chart can be used to determine the braking characteristics of a passenger vehicle under various conditions of operation.

To achieve the maximum deceleration ($0.85g$), which demonstrates the optimal use of the braking capability of the road surface with the adhesion coefficient $\mu = 0.85$, in the unloaded mode, 66.7% of the total braking forces must be applied to the front wheels. To reach the maximum deceleration value after loading, 63.5% of the total braking force must be applied to the front wheels. Therefore, the optimal distribution of braking force differs by 3.2% between loaded and unloaded modes. Consequently, an agreement has been reached regarding the optimal point between the two modes.

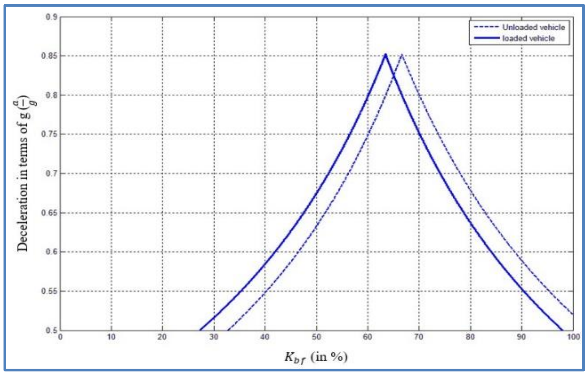

Fig.3. Braking characteristics of the passenger car as a function of the distribution of the braking force on the front axle

This compromise point corresponds to the intersection of the graphs representing the loaded and unloaded modes. By applying 65% of the braking force to the front wheels, the passenger car can achieve a maximum deceleration of $0.82g$ without locking any of the wheels in both loaded and unloaded modes. This point is a compromise between the two modes. [2]

The following equation can also be used to obtain this point:

$$\left(\frac{a}{g}\right)_{f,loaded} = \left(\frac{a}{g}\right)_{r,unloaded}$$

$$K_{bf,optimum} = m\frac{h}{l} + \frac{1}{l_2 - l_2' + l} \cdot (h.f_r + l_2) \quad (10)$$

where l_1' and l_2' are the distances between the front and rear axles and the center of mass of the vehicle in the loaded mode, repectively. **Fig.4** depicts variations in the optimal distribution of braking force on the front axle ($K_{bf,optimum}$) as a function of the change in the distance between the rear axle and the vehicle's center of mass in the loaded mode (l_2').

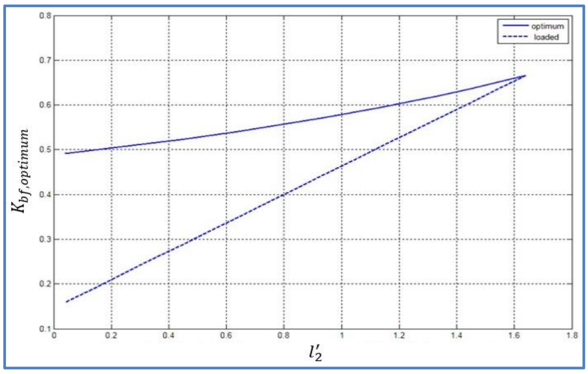

Fig.4. The optimal point of distribution of braking force on the front axle in terms of the change in the distance between the rear axle and the center of mass of the car

As shown in **Fig.4** and Eq.10, as l_2' increases (moving the car's center of mass to the front), the optimal value of distribution $K_{bf,optimum}$ increases, indicating that a greater proportion of the braking force must be applied to the front axle, and vice versa, moving the vehicle's center of mass to the rear and decreasing l_2' (adding passengers and cargo) necessitates applying a smaller proportion of the braking force to the front axle.

3.1. Braking characteristics of the IKCO Samand

Using the information provided about the IKCO Samand, it is possible to compare its braking characteristics to those of the previously described passenger car. The IKCO Samand's loading is the same as the passenger car; however,the center of mass has been moved to the rear by 8.5 cm. **Fig.5** depicts the braking efficiency for both loaded (solid line) and unloaded (dashed line) modes. As is evident from **Fig.5**, when the IKCO Samand chassis design is taken into account, the maximum deceleration values are obtained at larger K_{bf} values.

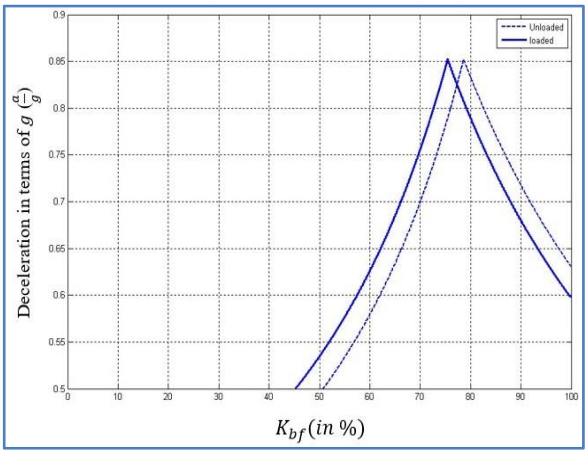

Fig.5. Braking characteristics of the IKCO Samand as a function of the distribution of the braking force on the front axle

3.2. The effect of the amount and manner of loading the car and moving the center of mass

As an example, a light truck is investigated. This example intends to investigate the effect and manner of loading on a vehicle's braking characteristics. **Table 2** lists the braking characteristics of the aforementioned light truck. The ratio $\frac{h}{l}$ is the same for both loaded and unloaded modes.

m	$\frac{h}{l}$	$W_{unloaded}\ (KN)$	$W_{loaded}\ (KN)$
0.85	0.18	26.69	44.48

Table 2: The characteristics of the light truck

Fig.6depicts the effect of braking force distribution, i.e., changes, on the braking efficiency of the light truck in both loaded (solid line) and unloaded (dashed line) modes.

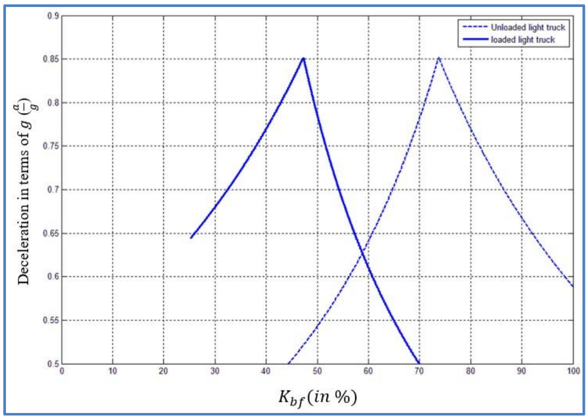

Fig.6 Braking characteristics of the light truck as a function of the distribution of the braking force on the front axle

73.76% of the total braking force must be applied to the front wheels to achieve the maximum deceleration in the unloaded mode. Maximum deceleration is achieved by applying 47.32% of the total braking force to the front wheels when the vehicle is loaded. Therefore, the optimal distribution of braking force differs by 26.44% between unloaded and loaded modes.

	$\left(\frac{l_1}{l}\right)_{unloade}$	$\left(\frac{l_2}{l}\right)_{unloade}$	$\left(\frac{l_1}{l}\right)_{loade}$	$\left(\frac{l_2}{l}\right)_{unloade}$
Passan ger car	0.48	0.52	0.51	0.49
Light truck	0.416	0.584	0.68	0.32

Table 3: Comparison of the characteristics of the light truck and the passenger car in unloaded and loaded modes

The difference in braking characteristics between the two modes (unloaded and loaded) in the light truck is significantly greater than in the passenger car due to the large difference in load between the unloaded and loaded modes (17.8 KN) compared to the passenger car (6.7 KN), the large displacement of the center of mass, and the large difference between the $\left(\frac{l_1}{l}\right)$ and $\left(\frac{l_2}{l}\right)$ in the light truck between unloaded and loaded modes. In selecting the optimal point, there is thus a compromise between the two modes. With this compromise, the passenger car can achieve a maximum deceleration of 0.627g without locking any of the wheels in both loaded and unloaded modes by distributing 59% of the braking force to the front wheels. [2]

3.3. The effect of road adhesion coefficient

In this example, the passenger car previously described is the base case. The road adhesion coefficient is considered to be $\mu_1 = 0.85$ in the base state. In the new state, $\mu_2 = 0.65$ is considered. **Fig.7** depicts the distribution of braking force, i.e., variations in the braking efficiency K_{bf} of the passenger car in unloaded and loaded modes for two road conditions $\mu_1 = 0.85$ and $\mu_2 = 0.65$.

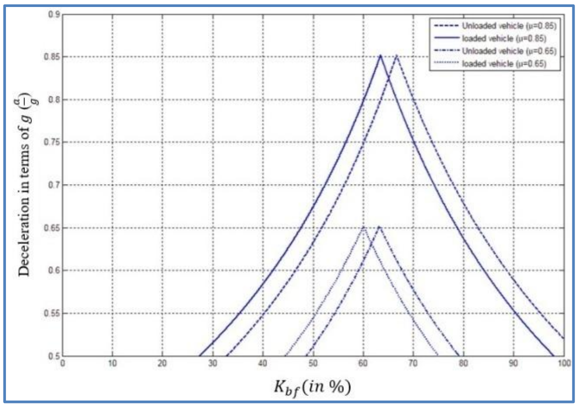

Fig.7. Braking characteristics of the passenger car under different road conditions

Fig.7demonstrates that when the coefficient of road adhesion is decreased by 0.2, the maximum acceleration rate, which is directly proportional to m, also decreases by 0.2, while the value of K_{bf} at which maximum deceleration is obtained, remains unchanged.

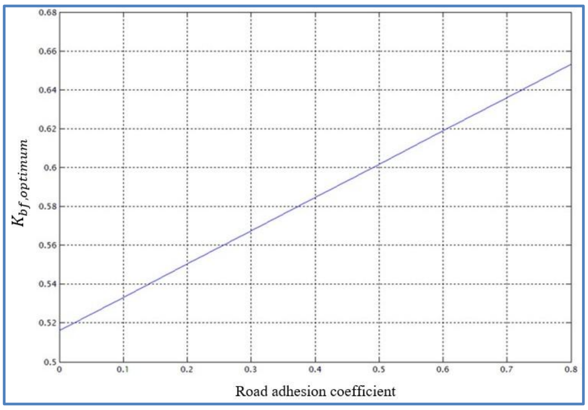

Fig.8. $K_{bf,optimum}$ in terms of road adhesion coefficient

As shown in Fig.8, the optimal value of K_{bf} increases as the adhesion coefficient of the road increases.

3.4. Effect of rolling resistance coefficient

The base state is considered the previously mentioned passenger car. In the base state, the rolling resistance coefficient was considered to be $f_{r1} = 0.002$. In the new state, it is considered to be $f_{r1} = 0.02$. **Fig.9** depicts the distribution of braking force, i.e., changes in K_{bf} as the coefficient of rolling resistance varies for the passenger car in unloaded and loaded modes for the two cases previously discussed. The rolling resistance coefficient follows the same trend as the road adhesion coefficient, meaning the value of K_{bf} for which the maximum deceleration is obtained remains unchanged, but the decrease in the maximum deceleration is very negligible considering f_r is increased tenfold.

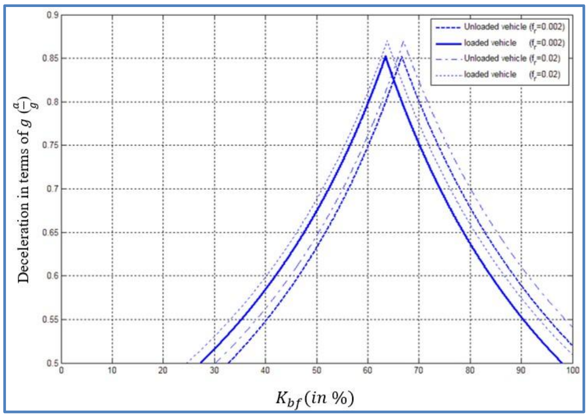

Fig.9. Braking characteristics of the passenger car with different rolling resistance coefficients

CONCLUSIONS

The analyses demonstrate the complexity of the braking process. It is demonstrated that the optimal distribution of braking force, which causes the maximum deceleration, varies depending on the vehicle's loading conditions, design parameters, and road surface conditions. According to the results, the coefficient of road adhesion and the coefficient of road rolling resistance have the greatest impact on the value of deceleration. However, the loading condition and inherent characteristics of the vehicle (such as h, l_1, l_2) can change the distribution of braking force associated with maximum deceleration but not the maximum deceleration value itself.

In practice, however, operating conditions vary greatly; therefore, for a given vehicle with a constant braking force distribution, the maximum braking force of the front and rear wheels can only develop simultaneously under a specific set of loading and road conditions, and the maximum deceleration can only be attained under these conditions. Under all other conditions, the maximum possible deceleration without losing steering control or directional stability will be decreased.

In fact, pressure proportional valves or load-sensing proportioning valves have been utilized to improve braking efficiency. Pressure proportioning valves are typically used to maintain the same pressure in the front and rear wheels up to a certain level and then reduce the rate of rear brake pressure increase. Especially in Europe, load-sensing proportioning valves have been predominantly utilized in heavy-duty vehicles. These valves adjust the brake forces based on the distribution of load between the axles. Anti-lock devices have also been implemented to ensure the steering control or directional stability of a vehicle under all conceivable working conditions. This tool's primary function is to prevent the tires from locking, thereby preserving the tires' ability to generate lateral force. [2] In conventional anti-lock braking systems (ABS), this is accomplished by switching the desired brake torque between different levels based on the wheel velocities and accelerations; however, in more recent algorithms, the wheel acceleration or wheel slip is continuously controlled by model-based controllers [7]. Modern commercial vehicles have an Electronic Stability System (ESC) that corrects the dynamics of the vehicle under the limit of adhesion by autonomously activating the brakes [8]. Recently, electro-mechanical brakes (EMBs) have been developed as a brake-by-wire (BBW) system, which refers to the electric control of brakes. Compared to the conventional hydraulic brake, this system has fewer components, less weight, and superior braking performance [9].

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AN INTELIGENT SYSTEM FOR DETECTING DEFECTS IN PRODUCTS

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Abstract - In this article, we conducted an investigation into the intelligent identification of defects occurring in the injection molding process. The implementation of an intelligent system for defect detection in products brings significant benefits and advancements to quality control and manufacturing procedures. We outlined the various types of defects targeted for detection and the input variables employed in the intelligent algorithms. Subsequently, we presented the construction of our intelligent system. Additionally, we performed a comparison among multiple intelligent algorithms to determine the most accurate classifier. "K-Nearest Neighbors" emerged as the top performer, achieving an accuracy of over 96% for all defect types, closely followed by "Decision Tree" with an accuracy exceeding 95%.

Keywords - Burr; Not Complete; Dark Spot; Defect Detection; Defect Type; AI; IoT

I. INTRODUCTION

The use of artificial intelligence (AI) has become increasingly popular in recent years, with its applications ranging from natural language processing to image and speech recognition. In the field of manufacturing, AI has also shown great potential in detecting defects in plastic or metal products, providing a fast and accurate solution for quality control. This article aims to explore the use of AI techniques in defect detection for injection molding process. Defects in manufactured products can lead to safety hazards, product recalls, and loss of revenue. Therefore, the development of an efficient and effective defect detection system is of utmost importance for manufacturers.

On the other hand we should note that Industry 4.0 (IIoT or smart manufacturing) combines cyber-physical systems, the Internet of Things (IoT) and cloud computing for automation and data exchange, creating the “smart factory”. The main scope is represented by the digital transformation of the manufacturing, providing benefits such as: enhancing productivity, automation and optimization of operation processes, business processes. In terms of IoT, benefits come from manufacturing operations, followed by predictive maintenance and smart maintenance services. Manufacturers all over the world are still in the stage of intention. There is a lack of effort in this transformation because most of them can`t imagine the big picture behind this. Zero Defect Manufacturing (ZDM) with an Industry 4.0 perspective aims to tackle the production processes in the manufacturing industries. It`s implementation was possible thanks to the last decade technology evolution: cloud computing, big data collection, artificial intelligence (AI), machine learning (ML), predictive maintenance, continuous quality control, etc.

Minimization of the losses caused by defects is one of the most important problems that manufacturers are facing. Thus, precision during the production processes is desired, and for this continuous defect identification and specification is required. The defects can have multiple causes: from degradation, to impact, corrosion, weather, machine errors, human errors, etc. As we explained above AI based defect detection systems can help in the automatization and cost and man-power savings of products manufacturing.

This paper presents a workdone within the context of the EU research projects Era-Net Multi AI Development of a multimaterial and multidefect detection and anomaly prediction system based on machine vision, artificial intelligence and IoT[1]which aims to develop an multidefect detection and anomaly prediction system and Horizon FLEX4REs[2] – Data Spaces for Flexible Production lines and supply chains for resilient manufacturing whic (among other thibgs is also looking to build systems for defects detections. Within the context of the two research projects, the authors of this paper constructed an inteligent system for defects detection. In this paper we also describe the types of defects detected.
The paper is organised as follows. First a literature review section is given. Next the types of defects and how they were acuired is presented. After that the inteligent system is described. At the end we draw the conclussions.

[1]https://agile.ro/multiai/
[2]https://www.flex4res.eu/

II. LITERATURE REVIEW AND RELATED WORK

The article "A review of the implementation of artificial intelligence systems for the classification of welding defects" (Konovalenko and Maruschak 2021, 1)(J. Sun et all 2019) provides a perspective on the successful introduction of innovative technology for continuous testing of materials, specifically mechanical joints, rotors, and complex combinations, in production. This technology allows for non-destructive testing of materials, resulting in immediate economic and time benefits compared to conventional methods which involve destroying the material and replacing the respective parts. These capabilities are advantageous for maintenance and preventive maintenance of equipment in operation, among other applications. However, the article also highlights the challenges and limitations encountered in implementing these AI systems. One of the biggest challenges is the need for a large amount of training data to achieve acceptable fault classification accuracy. Additionally, achieving high accuracy for more subtle or hard-to-detect weld defects is difficult.

To address these challenges, the article provides recommendations for better use of AI in this area. These include the use of image preprocessing methods to improve the quality of training data and the use of data validation techniques to assess the accuracy of defect classification systems. The article emphasizes that a methodical approach is necessary to maximize the effectiveness of AI as a powerful tool for welding defect detection and classification. In summary, the article provides a comprehensive overview of the use of AI in welding defect classification, highlighting its benefits and challenges, and offering recommendations for better implementation.

The article "Classification of surface technological defects of rolled metal products with the help of neural networks" (Vishal et al. 2019) presents a method that enables the automation of detecting and classifying some types of technological defects on rolled metal products. By taking advantage of modern computer capabilities, the researchers developed a ResNet50 neural network that classifies and detects precisely three types of defects with an accuracy of approximately 95.8%. To train the classifier, they used 88,000 images from unbalanced experimental data to obtain the best possible results. The advantages of this method include high productivity, quality, speed, and precision, which can improve the efficiency and yield of the procedure.

The article focuses on the use of neural networks, a popular AI method, to classify these defects. It explains how these networks are trained to recognize and classify different types of defects using training data sets. It also examines different types of neural network architectures that can be used for this task. It also provides a detailed analysis of the use of AI in the classification of surface technological defects of rolled metal products and offers suggestions for improving the use of this technology in this field. The article concludes that AI can be a powerful tool for detecting and classifying these defects but emphasizes the need for a methodical approach to maximize its effectiveness.

The article "Automatic Metallic Surface Defect Detection and Recognition with Convolutional Neural Networks" (Tao et al. 2018, 3) focuses on using artificial intelligence (AI) technology to automatically detect and recognize surface defects on metal. These can include scratches, cracks, porosity, or irregular areas, among others. The article discusses the use of convolutional neural networks (CNNs), a popular AI method, for detecting and recognizing these defects. It explains how these networks are trained to recognize and classify different types of defects using training data sets. Additionally, the article examines different types of CNN architectures that can be used for this task.The article also provides recommendations for better use of AI in this field. These include using image pre-processing methods to improve the quality of training data and using data validation techniques to evaluate the accuracy of the defect detection and recognition system. It offers a detailed insight into the use of AI and CNNs for automatic detection and recognition of metal surface defects and provides recommendations for better use of this technology in this field.

The Surface Flaw Detection patent, US10467502B2 (The Surface Flaw Detection patent, US10467502B2 2017) represents a way to create a neural network that can find surface defects in aircraft engine parts. A set of pixelated training images of aircraft engine components showing examples of different classes of surface defects is provided, along with (i) a pre-trained deep learning network and (ii) a machine learning network. The trainable weights of the machine learning network are then trained on the set of training images. The industry has a lot to say about surface inspection, especially when it comes to product quality assurance. Manual labor is usually used to perform surface inspection. Automated inspection processes are becoming more common, however, as a result of improvements in computer vision algorithms and advances in computing power. To manually identify pixel-level ground realities for fault zone locations for Automatic Surface Inspection (ASI), a specialist is usually required. The labeled images are then used as training data. If the data is extensive or there are a variety of problem types, the labeling procedure can take a long time. Surface inspection data typically only contains weak (image-level) labels, which can be noisy, rather than strong (pixel-level) labels.

The patent "Surface defect detection", US10467502B2, (Ren, Hung, and Tan 2017) describes a way to create a neural network that can find surface defects in aircraft engine parts. A set of pixelated training images of aircraft engine components that show examples of different classes of surface defects are provided, along with (i) a pre-trained deep learning network and (ii) a machine learning network. The trainable weights of the machine learning network are then adjusted on the training image set. The industry has much to say about surface inspection, especially when it comes to product quality assurance. Manual labor is usually used to perform surface inspection. Automated inspection processes are becoming more common, however, due to improvements in computer vision algorithms and advances in computing power. To manually identify ground realities at the pixel level for automatic surface inspection (ASI), a specialist is usually required. Labeled images are then used as training data. If the data is expanded or there are a variety of problem types, the labeling procedure can take a long time. Surface inspection data usually only contains weak labels (at the image level), which can be noisy, rather than strong labels (at the pixel level).

The patent "Systems and methods for augmented reality-based visual inspection", US20190096135A1, (Mutto, Trachewsky, and Zuccarino 2018) describes a method for scanning an object by taking photographs and creating a three-dimensional model of the object from the images. It is part of a visual inspection system that can calculate a descriptor of the object based on its three-dimensional model, extract specific metadata of the object based on the descriptor, and calculate a number of inspection results based on the extracted metadata and the three-dimensional model of the object. The system also includes a display device that includes a display, a processor, and memory that contains instructions for the processor to create overlaid data from inspection findings and display the overlaid data. In many circumstances, it can be difficult to identify outliers or defects in the midst of a group of different objects. By identifying defective products and sending only non-defective products to customers, a quality assurance system, for example, could increase the caliber of goods offered to customers. The terms "defect" and "defective" as used here cover cases where a particular instance of an object deviates from a stated specification (e.g., dimensioned incorrectly or having another difference). A canonical or reference model, one or more defect detectors such as trained convolutional neural networks, one or more rule-based comparisons of measurements with predicted measurement values, and more may be included in the mentioned specification, as will be further discussed below. Looking to the related work we can say that using AI for automatic detection of defects is a new existing trends in now-a-days research. Systems of this type are still intial and there is more research to be done in this area. The current article is on this new line of research.

III. TYPE OF DEFECTS AND HOW THEY WERE ACUIRED

Within this project we looked into defects from microfluidic chips(Ying Liu et. All, 2009) that are manufactured thanks to injection moulding. Bellow we give a description of the different types of defects. In injection molding, a burr defect refers to the formation of a thin, raised edge or ridge on a molded part where two mold halves meet. It is also known as a flash or parting line flash. When the two halves of the mold do not fit tightly together, molten plastic can seep between them, resulting in excess material that extends beyond the intended parting line. This excess material forms a thin protrusion or lip known as a burr.

Burrs can occur along the entire perimeter of the part or in localized areas.Burr defects can be caused by various factors, including:

- Inadequate clamping force: Insufficient pressure between the mold halves can lead to material leakage and the formation of burrs.
- Worn or damaged mold: If the mold has worn or damaged surfaces, it may not seal properly, allowing plastic to escape and form burrs.
- Excessive injection pressure or speed: High injection pressures or fast injection speeds can contribute to material leakage and burr formation.
- Poor mold design or manufacturing: Inaccurate mold alignment, improper parting line design, or suboptimal mold construction can contribute to burr defects.

Burr defects are generally undesirable as they can affect the appearance, functionality, and safety of the molded part. They can be minimized or eliminated through proper mold maintenance, design optimization, and control of process parameters during injection molding. In injection molding, a dark spot defect refers to the presence of darker or discolored areas on the surface of a molded part. These spots (A-N Räsänen, J Martikainen. 2011) can vary in size and intensity, and they are often considered defects because they can negatively impact the appearance and quality of the part. There are several potential causes for dark spot defects in injection molding like contaminated material, poor material mixing, mold contamination, inconsistent cooling or heating, mold design or venting issues. To address dark spot defects, it is important to identify and eliminate the root cause. This may involve improving material quality control, ensuring proper mold maintenance and cleanliness, optimizing material mixing and dispersion, and addressing any cooling or heating inconsistencies in the molding process.

The term incomplete part in injection molding refers to a defect where the molded part does not meet the intended specifications or is missing certain features or sections. It can manifest in various ways, including missing sections, inadequate filling, or incomplete molding of the part. There are several common causes of incomplete part defects in injection molding like short shot, insufficient packing or holding pressure, mold or tooling issues, melt or material-related factors. To address incomplete part defects, it is essential to review and optimize various process parameters such as injection pressure, temperature, and cooling time. Additionally, ensuring proper mold maintenance, venting, and design, as well as using suitable materials, can help minimize or eliminate this type of defect.

1. Burr

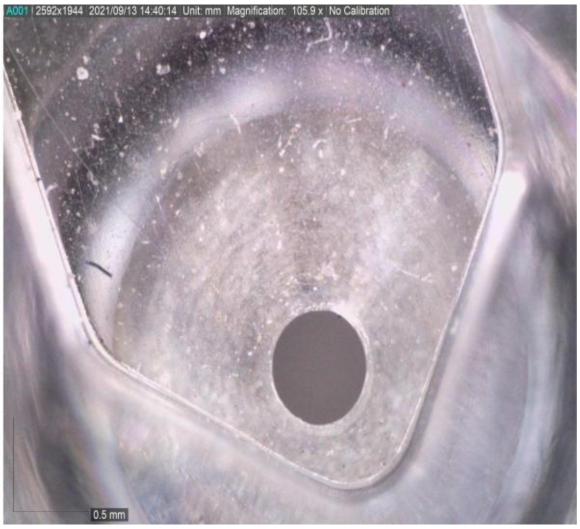

Figure 1. Opening of the luers (passage hole for liquids)

2. Not complete

Figure 2. Incomplete parts

3. Dark spot

Figure 3. Flashes

For the detection of those type of defects an IOT propertary system was developed that was measuring the following parameters that were corelated with the different types of defects: pressure, cushion value, injection pressure after dynamic injection, maximum injection pressure during dynamic phase, Injection time, Cycle time, dosing time, integral pressure curve based on matrix pressure, integral pressure curve (full curve), measured maximum pressure, time of maximum pressure in cavity.

The fallowing is a description of each type of defect. The pressure represents the integral value of hydraulic pressure during the injection process. The cusshion value means the actual value of the cushion material.The injection pressure after dynamic injection is the pressure during the dynamic injection process.The maximum injection pressure during dynamic phase represents the maximum injection pressure during the dynamic phase.The injection time is the time it takes to complete the injection process.

The cycle time is the time it takes to complete a full cycle.The dosing time value represents the time it takes to complete the dosing process.Integral pressure curve based on matrix pressure is used for the integral pressure curve based on the matrix pressure.Integral pressure curve (full curve) is the integral pressure curve for the full cycle.The measured maximum pressure in matrix represents the maximum pressure measured in the matrix.The time of maximum pressure in cavity is the time at which the maximum pressure occurs in the cavity. In the next section we present the AI developed system for the different types of defects in the correlation with those parameters.

IV. DESCRIPTION OF THE AI SYSTEM FOR DEFECTS DETECTION

For constructing the AI system, first the defect data was gathered with the type of parameters described at the end of the previous section and saved in a dataset for training and testing. The dataset marks the raws as either Good parts or Defective parts, specifying the types of defects present in the part. The types of defects that may occur, and for which classification algorithms are used, are: 'Burr', 'Not complete', 'Dark spot' To detect defects, a script has been developed that tests the accuracy of 6 classification algorithms for a given dataset. In the current paper we describe

The 6 classification algorithms used are:

- Logistic Regression;
- Decision Trees;
- K-Nearest Neighbors;
- Linear Discriminant Analysis;
- Naive Bayes;
- Support Vector Machines;

Initially, it is necessary to define the input properties or attributes of a dataset that are used to train models or make predictions. The input attributes are represented as independent variables in the dataset used and were explained at the end of last section. In the first step, the data is prepared for classification and the dataset is divided into the training and testing sets.In order to prepare the data for classification, the 11 properties of the part that are considered to be the most relevant for defect detection are defined, and the user is asked to choose the type of defect for which classification algorithms will be applied later. The next step is the data scaling process. Data scaling is done to bring all the features (properties) of the dataset to a common or comparable scale. This is an important step in data processing, as many machine learning algorithms rely on distances and differences between features to determine patterns and make predictions. There are several techniques for data scaling, such as standard scaling, min-max scaling, and normalization scaling. In our case, min-max scaling is used.

Next, the model is initialized (in the example below, the logistic regression model is used):
logreg = LogisticRegression()
The model is trained with the training set:
logreg.fit(X_train, y_train)
The classifier's accuracy on the training set and the test set is displayed on the screen:
print('Accuracy of Logistic regression classifier on training set: {:.2f}'.format(logreg.score(X_train, y_train)))
print('Accuracy of Logistic regression classifier on test set: {:.2f}'.format(logreg.score(X_test, y_test)))
The predictions on a test input are displayed on the screen:
print(logreg.predict(proba))
Subsequently, the confusion matrix is calculated, displayed, and saved in an image file:
cm = confusion_matrix(y_test, y_pred, labels=logreg.classes_)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=logreg.classes_)
disp.plot()
disp.ax_.set_title('Classifier: Logistic regression; ' + type_of_defect_label)
plt.savefig("conf_matrix_imgs/Logistic_regression", dpi=300)
The above code example uses the "Logistic regression" classification algorithm, but the same steps were followed for the application of the other mentioned algorithms. An example of a confusion matrix can be seen in the figure below (figure 1).

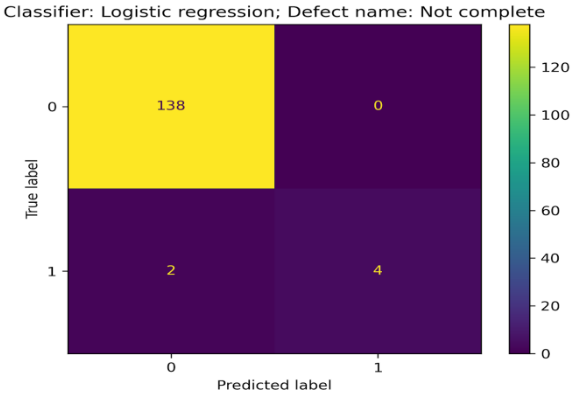

Figure4 - Confusion matrix obtained for the Logistic Regression classifier.

The table below (Table 1) shows the accuracy obtained on the test data for each type of defect and each classification algorithm. The classifier that performed the best, achieving an accuracy of over 96% for all types of defects, is "K-Nearest Neighbors," followed by "Decision Tree" with an accuracy of over 95%. Both KNN and Decision Tree are simple yet robust algorithms that can provide good performance for a wide range of classification problems. This shows that, in some cases, simpler models can be sufficient to solve the problem at hand.

Defect type	Classifier	Accuracy
Burr	Logistic regression	0.930555555555556
	Decission tree	0.965277777777778
	K-Nearest Neighbors	0.965277777777778

	Linear Discriminant Analysis	0.958333333333333
	Naive Bayes	0.652777777777778
	Support Vector Machine	0.930555555555556
Not complete	Logistic regression	0.986111111111111
	Decission tree	0.993055555555556
	K-Nearest Neighbors	0.993055555555556
	Linear Discriminant Analysis	0.993055555555556
	Naive Bayes	0.986111111111111
	Support Vector Machine	0.986111111111111
Dark spot	Logistic regression	0.993055555555556
	Decission tree	0.986111111111111
	K-Nearest Neighbors	0.993055555555556
	Linear Discriminant Analysis	0.972222222222222
	Naive Bayes	0.722222222222222
	Support Vector Machine	0.993055555555556

Table 1. The accuracy obtained after running the algorithm for each defect and each classifier.

From table 1 we can deduce the followings:

- For the ‚Burr' detection type the best accuracy is 0.965277777777778. We obtained this accuracy for ‚Decission tree' and , K-Nearest Neighbors' classifiers.
- The best accuracy for , Not complete' detection type is 0.993055555555556 and it was obtained for clissifiers like , Decission tree', , K-Nearest Neighbors' and , Linear Discriminant Analysis'.
- The best classifiers for ‚Dark spot' detection type are „K-Nearest Neighbors", ‚Logistic regression' and ‚Support Vector Machine', all tree with an accuracy of 0.993055555555556.

V. CONCLUSIONS

In this article we looked into the inteligent detection of defects that are manufactured in the injection moulding process. Injection molding is a versatile and efficient manufacturing process that offers cost-effective production, design flexibility, high-quality outputs, and fast cycle times. By carefully considering its benefits and limitations, manufacturers can utilize injection molding effectively to meet their production needs and deliver high-quality plastic parts and components. An intelligent system for detecting defects in products brings numerous benefits and advancements to quality control and manufacturing processes. In this article we described the types of defects that were tried to be detected and input variables that were used for the inteligent algorithms. Then we described the inteligent system that we constructed. We also compared several inteligent algorithms to determine the one with the best accuracy based on existing classifiers. The classifier that performed the best, achieving an accuracy of over 96% for all types of defects, is "K-Nearest Neighbors," followed by "Decision Tree" with an accuracy of over 95%. Both KNN and Decision Tree are simple yet robust algorithms that can provide good performance for a wide range of classification problems. This shows that, in some cases, simpler models can be sufficient to solve the problem at hand. As future work we want to extend the AI system for more types of defects. Second, one should note that in the paper we described only the AI system for detection. The AI model that is developed and presented in this paper should be integrated into the injection molding process for the automatic detection of product defects. This is also a direction for further work.

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THE USE OF POLICE AUDITING IN THE UNITED STATES

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Abstract - Various policies and programs have been implemented to improve police accountability. This article is written to focus on one specific activity designed for this purpose, police auditing, as used in the United States. Police auditing is an integral part of police accountability programs but has rarely been studied. This paper provides an overview of police auditing and is aimed at achieving a broad understanding of the trends and contents of this activity by using police audit dataset

Keywords - Police Auditing, Accountability, Performance, Compliance.

I. INTRODUCTION

It is widely recognized that police accountability needs to be enhanced to build public trust and make the system more fair and just (1). Various policies and programs have been implemented for this purpose such as use-of-force policy, civilian review, early intervention, data collection on certain activities (2), internal investigation and disciplines (3), body-worn cameras (4), training, and federal oversight (5).Very few empirical studies on police accountability have been done, however, and many gaps remain in the completed studies (6). This article is focused on one specific activity designed to increase police accountability, police auditing.

Police auditing israrely studied but often an integral part of police accountability programs. Over the years many audits have been conducted and various reports have been produced on police performance and compliance (7). This paper is aimed at providing a general understanding of the scope and contents of this activity in the United States. For this purpose, this paper examines the extent auditing has been used, police agencies involved, concerns and issues addressed, and related personnel and organizational structures.

II. LITERATURE REVIEW

Various internal and external programs have been implemented to enhance police accountability. Some “best practices” emerged, including a use-of-force reporting system, a citizen complaint system, and an early intervention system(8,9, &10), along with other programs such as disciplinary measures, internal affairs investigations, body-worn cameras (11&12), implicit bias training, organizational reforms(13), and data collection of fatalities(14).

Externally, citizen and governmental oversight of police (15) have been shown to have some albeit limited effect in lowering instances of misconduct (16& 17). Whether the civilian reviews are effective in improving the complaint system against police remains to be seen (18&19). The most notable government oversight emerged in the process of implementing federal consent decrees. Over the years, consent decree provisions have led to a set of desired practices and conditions for constitutional policing. Some preliminary evidence suggests that reforms under the consent decrees may have made police agencies more accountable (20, 21,&22).

Police auditing may be used to assess if these internal and external programs have been implemented correctly and if they have improved a police department (23&24). The early warning systems (EIS), which are data-driven and designed to identify problematic officers, for example, would be ideal for auditing purposes. Civilian review boards’ measures of complaint data (25) and consent decrees’ outcome measures and compliance conditions are also subject to auditing (26,27&28).

Police auditing as a way to assess efforts to enhance police accountability has rarely been examined. There are limited data and descriptions of various practices (29).As an unconventional approach and an oversight and monitoring mechanism, it needs to be explored systematically in terms of the extent it has been used and contents of completed audit reports. This paper is aimed at providing answers to some general questions on the use of police auditing in the U.S.

III. RESEARCH METHODS

A dataset of police audit reports was created to understand the extent police auditing has been used in the U.S. As most audit reports were required by law to be made available to the public, the audit reports in this dataset were selected online after determining the time-frames and types of audits. It covers twenty-seven years from 1995 to 2022 as police auditing has been used more widely since the 1990s. All audits posted in the time-frame related to police and containing sufficient data were included. Overall,286 police audit reports fit the criteria and were included in the dataset.

A codebook containing seventy-six variables was created to code there ports into the dataset in SPSS. The variables relevant to this article include populations and locations where audits were conducted, years an audit covered, police department size, types of audits, background information, reasons for audits, types of incidents/events triggering audits, subject matters, persons/entities ordering audits, persons/entities conducting audits, frequency of audits, titles of individuals/offices creating audits, auditor qualifications, and auditor independence.

These variables are used to address the following four questions.1) How has police auditing been used across the country over the years? 2) How have different police organizations been audited? 3) What concerns or issues have been addressed? 4) What personnel and entities are involved and what are their organizational structures?

IV. RESULTS

The results are organized in four areas corresponding to the four questions above, using descriptive statistics from the dataset on variables related to locations and time-frames, police organizations, concerns and issues, and personnel/entities and organizations.

Location/Time-frame Variables (Cities, Counties, States, Regions, and Years)
The dataset shows that twenty-eight states and the District of Columbia have used audits to evaluate their state and/or local police departments. This leaves 22 states that have not used or have not posted any police audits. In the states where audits have been used, 67.4% were in states with over 7 million people while 30.9% were in states with less than 7 million population. There are 131 locations that were audited, including cities, counties, states, provinces, and regions, 52.8% of which with over 500,000 people and 47.2% with less than 500,000 people. Nationwide, 12.9% were done in the Northeast, 17.5 in the Southeast, 16.1% in the Northwest, 38.5 in the Southwest, and 9.8% in the Midwest. The numbers of audits have been on the increase over the twenty-seven years covered. Nine (3%) were done in the first five years from 1995 to 1999, 23 (7.9%) in the second five years from 2000 to 2004, 34 (11.8%) in the third five years from 2005 to 2009, 109 (38%) in the fourth five years from 2010 to 2014, and 74 (25.8) in the fifth five years from 2015 to 2019. The most recent five years are incomplete as only about two and a half years from 2020 to mid-2022 were available at the time of the study, in which 37 (12.9) were conducted, a significant number nonetheless.

Police Variables (Sizes, Frequencies, Types of Audits, and Expectations)
The audited police organizations vary in size, but larger departments tend to be audited more. Most programs (59.4%) were audited once only during the time period studied. Types of audits received were mostly on compliance and performance, followed by financial related audits and comprehensive audits that combine financial, performance, and compliance components. Most of the audits (73.8%) were expected by the police while 26.2% were either not expected or this information was not provided.

Issues Variables (Backgrounds, Concerns, Reasons, Incidents, and Subject Matters)
Background information was provided in 92% of the audits. Most audits fall under routine planning (45.1%) and government concerns (37.6%), followed by police concerns (12.2%) and specific events or incidents (4.9%). Similarly, on specific reasons for the audits,61.5% were due to routine audit plans and26.5% due to concerns about compliance, followed by 6.6% about questionable operating practices and 5.2% about financial and administrative issues. Majority of the audits were not triggered by specific incidents/events as 2.8% were due to public protests and increase in crime/incidents.

Regarding subject matters, finance, cash, and/or fund-related audits occupy38.9% of the audits, policies/procedures and operations28.2%,crime/arrest statistics and crime evidence16.7%, human resource policies 9%, and police oversight 6.3%.

Personnel and Organizational Variables (Orders, Entities, Persons, Qualifications, and Independence)
Most of the audits were ordered externally as 77.2% were ordered by a parent government while 22.7% were requested internally by the police themselves. Eighty-five percent were external audits while 15% were internal audits. Specific persons or entities who requested an audit include mayors/local government units(45.7%), state/ regional/ national governments (21.6%), and police departments (21.3%), and county/district governments (8%).City-level office of internal audit/city auditor or controller/audit services conducted64.6% of the audit, state/ provincial/ regional/ national government auditing offices performed 25.2%, private accounting/ management/ consulting firm 5.9%, and police departments 3.1%.

Specific titles of individuals or offices that conducted the audits include individuals that are part of or associated with the city government (63.2%) including Independent Police Review Director/Auditor (3.8%), state or higher level auditors (24.6%). Auditor qualifications were noted in 41.6% and not noted in 58.4% of the audits. Highest percentage of auditors, 25.9%,had two or more certifications, licenses, and/or qualifications, followed by 12.6% who were Certified Public Accountant (CPA); 2% who were Certified Internal

Auditor (CIA), Certified Fraud Examiner (CFE), Certified Law Enforcement Auditor (CLEA), Certified Government Auditing Professional (CGAP); and 1.0% with professional experience and educational credentials. Subject matter experts were hired/involved in 10.1% of the audits.

All audits provided some information on structural independence. Most audits, 51.4%, were done by auditors whose independence could be determined by multiple factors, i.e., government code/charter, organizational structure, and appointment and reporting procedures, 27.6% by auditors structured in a manner that provides organizational independence, 13.3% by auditors with authority from government code/charter, and 7.7% by auditors appointed by and reporting to city council or another government body.

V. DISCUSSION

This study provides an overview of police auditing in the U.S. by examining how police auditing been used across the country over the years, how different police organizations have been audited, what concerns or issues have been addressed, and what organizational structure has been established in police auditing in terms of personnel and entities involved.

The dataset used for this analysis indicate that audits have not been used evenly across the country but have been on the increase overall over the years. Twenty-two states have not utilized auditing as a way to hold their police accountable. States with larger populations use audits more. Locations with larger populations have received more audits than smaller jurisdictions. More audits are conducted in the Southwest than in other regions of the country while the Northeast has the smallest share of the audits. Overtime, the numbers of audits have been on the increase. The decrease in the most recent five years may have to do with the Trump administration, which curtailed federal consent decrees and discouraged auditing in general, but the percentage is still significantly higher than earlier years.

The audits were not evenly conducted across different police organizations although types of audits received were similar. Larger departments tend to be audited more than small and mid-size departments. Most programs were audited irregularly as they were audited once only during the period studied. Types of audits received were mostly on compliance and performance, which occupy two-thirds of the audits, with the remainder either including a financial-related or financial statement component or involving finances only. The process was mostly expected as most police programs were aware of or prepared for the audits.

Issues variables indicate that most audits were done due to routine planning and government concerns including police concerns (12.2%) but not due to specific events or incidents such as public protests. Specific concerns include compliance and performance, operating practices, and financial and administrative issues. Specific subject matters include finance and human resources, policies/procedures and operations, crime/arrest statistics and crime evidence, and police oversight.

Personnel variables indicate that most audits were ordered or requested externally and less than a quarter were requested and conducted by the police themselves. City-level government offices such as city auditors and controllers conducted more of the audits. But specialized city offices such as Independent Police Review Division, Office of Police Audit Review Board/Independent Police Auditor, and Independent Police Review Director/Auditor, and Board of Supervisors did only about 6% of the audits. Auditors usually have either one or two or more certifications, licenses, and/or qualifications with a small number with professional experience and educational credentials. Subject matter experts were hired/involved in about 10% of the audits only.

Organizationally, all audits provided information on structural independence. Most audits were done by auditors whose independence could be determined by government code/charter, by organizational structure that provides independence from audited entities, and/or by appointment and reporting procedures.

VI. CONCLUSIONS

The use of police auditing is increasing over the years but not evenly across the country. A significant number of states has not utilized auditing as a way to hold their police accountable. States and locations with larger populations have received more audits, larger departments tend to be audited more, and more audits are conducted in the Southwestern region of the country. For those that were audited, audits were used irregularly. Types of audits received were mostly on compliance, performance, and finances. Most audits were done due to routine planning and government concerns. Specific issues addressed include finance and human resources, policies/procedures and operations, crimes, and police oversight.

The state of the art of police auditing remains a work in progress. A lack of specialized knowledge pertaining to auditing the police remains. Most audits were conducted at the city-level government offices but specialized offices that focus on police oversight such as Independent Police Review Division and Office of Independent Police Auditor did only a small share of the audits. A specialized professional police auditing program established as an essential part of the police function remains rare. Auditors usually possess financial, accounting, and auditing certifications and/or licenses but not police expertise and subject matter experts were rarely hired/involved in the audits.

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NUTRIGENOMIC EFFECT OF THE MICROALGAE

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Abstract - Aphanizomenon flos-aquae (AFA), an edible microalgae, contains numerous biomolecules potentially capable of preventing certain pathologies. Numerous algae-derived biomolecules have been investigated for their role in disease prevention and health, and for their potential use as dietary supplements. These photosynthetic microorganisms show commercial interest due to their ability to produce biomass. Furthermore, microalgae are generally considered an excellent source of vitamins, minerals and bioactive molecules which make them suitable for introduction into the cosmetic, pharmaceutical and food industries.

However, to date there are no studies on the nutrigenomic effects of AFA. Therefore, we conducted research to test whether AFA could be an epigenetic modulator. In particular, we evaluated its ability to modulate DNA methylation in vitro, using an intestinal cell line. Our results indicate that AFA shows no toxicity on in vitro cells, even at high concentrations, and modulates DNA methylation globally, with particular relevance in the context of inflammation-induced epigenetic effect. AFA is able to reverse the demethylating effect induced by IL-1β on the IL8 gene promoter, and consequently reduce its expression. Preliminary results therefore suggest that AFA could play a significant role in the regulation of gene expression through the modulation of DNA methylation. These observations contribute to the understanding of the epigenetic mechanisms involved in the interaction between AFA and intestinal cells, providing interesting insights for further research on the potential use of AFA as a modulating agent of inflammation and gene expression. Therefore, the intake of AFA by humans or marine organisms could have beneficial effects on health.

Keywords - Microalgae, Aphanizomenon Flos-aquae, Nutrigenomic, DNA Methylation.

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A CRITICAL STUDY OF TIME MANAGEMENT: NEED, STEPS IN THE PROCESS & DIFFICULTIES

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Abstract - The concept ofTime Management is of prime importance for a person working in both social and professional life. It is rightly said that time management is life management. Effective time management helps leaders, entrepreneurs, and small business owners and employees to achieve their goals. Managing our time wisely improves work-life balance and increases happiness. Good time management also reduces stress and allows us to achieve our goals faster and easier. Time management benefits us in every area of your life. Time management is important to help us prioritise better and increase our productivity. Good time management also makes us more intentional about how to invest our time. Managing our time helps us work smarter, not harder. So, we can get more things done in less time and capture bigger opportunities. Good time management helps us work smarter, not harder, ensuring us of getting more productive work done in less time. This paper aims at focusing on the Time Management**,** its need, steps in the process &difficulties.

Keywords - Time Management, Need, Steps in the Process, Difficulties.

I. INTRODUCTION

Effective time management means that we take control of our time and energy. Taking control of our time enables us to achieve bigger and better results in less time, without the stress. The objective of time management is to maximise the time we spend on specific activities that help us achieve our goals faster. The benefits of managing time allow us to reduce time on unimportant work and increase time on important work. Good time management enables us to achieve greater levels of performance and productivity. Essential time management skills include prioritising, goal setting, and delegation. Effective time management includes better scheduling, improved decision-making, better organisation, and time leverage.

- Time Management refers to managing time effectively so that the right time is allocated to the right activity.
- Effective time management allows individuals to assign specific time slots to activities as per their importance.
- Time Management refers to making the best use of time as time is always limited.

Significance/Importance of Effective Time Management:
The significance of effective time management is as follows:

i. Improves quality of life:
Effective time management improves the quality of life. By managing the time, some of the most common problems such as stress and lack of time for personal interests, can be solved easily. Because of effective time management, maximum works can be completed within limited time.

ii. Reduces frustration:
Time is the only tool that can make or break you. This is applicable, especially when you have to create a balance between your professional and personal life in your hectic and tiresome routine. To serve the purpose, you would have to find time to do everything that your heart desires. By managing our time in a proper manner, we will get rid of all frustration.

iii. Gives peace of mind:
The peace of mind is required to lead a healthy and disease-free life. Restlessness and stress are the root causes behind the lack of peace. Stress makes us to think and perform work in an undesirable way and this leads to chains of emotions which adversely affect on the relationships with people around us. By managing the time wisely, we will be able to give ourselves and our loved ones the much-desired time and attention.

iv. Increases energy level:
Effective time management increases the energy level of professionals to a great extent. This is because proper time management makes us organized and systematic in our duties. It makes us to save money and energy too. By proper time management, the unhandled jobs and unfinished business can be done within the deadline. Managing our time correctly will boost up one's energy level than the past. This, in turn enables us to concentrate on the task at hand, without bothering about the pending ones.

v. Less stress
Managing our time reduces our stress level and it boosts our confidence**.** Taking control of our time also reduces stress and anxiety. Good time management means meeting tight deadlines and planning our time. Managing our time ensures us that

we don't feel tired all the time. Good time management enables us to be more productive with the time we have. With less stress, we feel easy and more confident about how to invest our time. Less stress increases productivity and helps us sleep better.

Vi. Better work-life balance

One of the most important benefits of time management is a better work-life balance. If we achieve a better work-life balance, we can be more productive at work and have more time to spend on our most important relationships. Work-life balance creates a good balance between our professional life and personal life. An essential benefit of good time management is that we understand the value of time. We also get clear ideas about achieving our goals in less time.

Vii. Greater focus

Effective time management increases our focus by eliminating distractions. Greater focus allows us to capture bigger opportunities. It also allows us to spend more time on the projects, goals, and people that matter. Good time management doesn't mean expanding our to-do list and working longer. Time management means working smarter, not harder. When we manage our time, we can have a greater focus on our most productive activities. This helps build positive habits. It also ensures us of spending more time on the activities that help us reach our goals.

Viii. Less procrastination

Procrastination is the habit of postponing the activities for some future time. It happens when we don't manage our time. When we aren't clear and focused on our goals, it's easy to procrastinate. Poor time management results in distraction and procrastination. When we are clear and focused on our goals, we spend more time for working on our biggest priorities.

Various steps in time management:

Time Management is the act or process of planning and exercising conscious control over the amount of time spent on specific activities, especially to increase effectiveness, efficiency or productivity. It is the process of organising and planning of time between specific activities and priorities. The benefits of time management include better habits and greater productivity. Improved time management increases our focus, builds confidence, and allows us to plan our time more effectively.

Various steps in time management are as follows:

1. Know How You Spend Your Time:

Keeping a time log is a helpful way to determine how we are using our time. We can start by recording what we do during our intervals, for a week or two. We should further evaluate the results. We should ask ourselves if we did everything that was needed. This way, we should determine the tasks which require the most time. We need to determine the time of day when we are most productive. We should identify where most of our time is devoted – job, family, personal, recreation, etc. Identifying our most time-consuming tasks and determining whether we are investing our time in the most important activities can help us to determine a course of action. In addition, having a good sense of the amount of time required for routine tasks can help us to be more realistic in planning and estimating how much time is available for other activities.

2. Set Priorities:

Setting our priorities is necessary for effective time management. By understanding and implementing Covey's time management matrix, we can set our priorities. Managing our time effectively requires a distinction between what is important and what is urgent. Experts agree that the most important tasks usually aren't the most urgent tasks. However, we tend to let the urgent dominate our lives. Covey has categorized our activities into four quadrants in their Time Management Matrix: urgent, not urgent, important and not important.

3. Use a Planning Tool:

Time management experts recommend using a personal planning tool to improve our productivity. Examples of personal planning tools include electronic planners, pocket diaries, calendars, Google calendar, computer programs, wall charts, index cards and notebooks. Writing down your tasks, schedules, and memory joggers can free your mind to focus on your priorities. The key is to find one planning tool that works for you and use that tool consistently. Some reminders when using a planning tool are:

• Always record your information on the tool itself.
• Review your planning tool daily.
• Carry your planning tool with you.
• Remember to keep a list of your priorities in your planning tool and refer to it often.
• Synchronize electronic planners with your computer.
• Keep a back-up system.

4. Get Organized:

Most people find that disorganization results in poor time management. Professional organizers recommend that you first get rid of the clutter.

1. Throw it away, delete it, or otherwise get rid of it.
2. Delegate it: give it to someone else to do, file, or respond.
3. Act on it yourself. Then throw it away or file it.
4. File it temporarily until it needs action or until additional information is received.

5. File it permanently where you can easily find it later.

5. Schedule Your Time Appropriately:
Even the busiest people find time for what they want to do and feel is important. Scheduling is not just recording what we have to do (e.g., meetings and appointments), it is also making a time commitment to the things we want to do. Good scheduling requires that we know ourselves. Using our time log, we should determine those times during the day when we are most productive, alert and energetic. We should block out time for our high priority activities and protect that time from interruptions.

6. Delegate: Get Help from Others:
Delegation means assigning responsibility of a task to someone else, freeing up some of your time for tasks that require your expertise. Delegation begins by identifying tasks that others can do and then selecting the appropriate person(s) to do them. You need to select someone with the appropriate skills, experience, interest, and authority needed to accomplish the task. Be as specific as possible in defining the task and your expectations, but allow the person some freedom to personalize the task. Occasionally check to determine how well the person is progressing. Finally, don’t forget to reward the person for a job well done or make suggestions for improvements if needed.

7. Stop Procrastinating:
Procrastination is the act of postponing our works/tasks.We may be putting off tasks for a variety of reasons. We perhaps procrastinate the tasks which seem to be unpleasant. We can break down the tasks into smaller segments that require less time commitment and result in specific, realistic deadlines. If we have trouble in getting started, we may need to complete a preparatory task such as collecting materials etc.

8. Manage External Time Wasters:
Our time may be impacted by external factors imposed by other people and situations. We can decrease or eliminate time spent in these activities by implementing some simple tips listed below.

- Use voice mail and set aside time to return calls.
- Avoid lengthy talk. Stay focused on the reason for the call.
- Stand up while you talk on the phone. You are more likely to keep the conversation brief.
- Take any necessary action immediately following the call.
- Set aside times of the day for receiving calls and let others know when you are available.
- Keep phone numbers readily available near the telephone.
- Establish blocks of time when you are available for visits.
- Tell the visitor politely that you cannot meet with them at this time and schedule the visit
- for a more convenient time.
- Set a mutually agreeable time limit for the visit.
- When someone comes to the door, stand up and have your meeting standing.
- Know the purpose of the meeting in advance.
- Arrive on time.
- Start and end the meeting on time.
- Prepare an agenda and stick to it. Use a timed agenda, if necessary.
- Don’t schedule meetings unless they are necessary and have a specific purpose or agenda.

9. Avoid Multi-tasking:
Multi-tasking is the act of doing multiple works at specific time. In order to save time, people usually prefer multi-tasking. Recent psychological studies have shown that multi-tasking does not actually save time. In fact, we lose time when switching from one task to another, resulting in a loss of productivity. Routine multi-tasking may lead to difficulty in concentrating and maintaining focus when needed. So, it’s better to avoid multi-tasking.

10. Stay Healthy:
The care and attention we give to ourselves is an important investment of time. Scheduling time to relax, or do nothing, can help us rejuvenate both physically and mentally, enabling us to accomplish tasks more quickly and easily. Poor time management can result in fatigue, moodiness, and more frequent illness. To reduce stress, we should reward ourselves for a time management success.

II. DIFFICULTIES IN TIME MANAGEMENT

There are many difficulties in time management. They are as follows:

1. Low motivation:
Sometimes, finding the motivation to complete important tasks can be the first obstacle to good time management. For example, you might have experienced a situation when you have plenty of time to complete a particular task but you don't feel like doing so, and so it is left undone. Finding motivation is a common challenge, and thankfully it is possible to overcome this time management challenge.

2. Procrastination habits:
Procrastination is the common experience of putting a task off until there is little time remaining before a deadline. People may procrastinate for a variety of reasons including habit, perfectionism and unclear goals. It is possible to conquer procrastination and

accomplish your goals effectively. One way to address procrastination is to set a timer for a short period of time and begin working.

3. Too little time:
Some people face the time-management challenge of too little time to complete their goals. This may be the result of a multitude of necessary objectives, and those tasks may be equally important. This feeling may also have to do with a large quantity of less-important tasks. If you feel as if you have too many tasks to accomplish and too little time to finish them, you might try prioritizing your to-do list and eliminating tasks that don't have any real consequences if left undone. You may also try delegating tasks to other individuals on your team who you trust.

4. Attempted multitasking:
Multitasking can sometimes feel like an effective way to manage time. Often, however, multitasking can make those tasks take longer than they normally would. This is because multitasking involves switching between tasks rapidly, which can affect a person's decision-making process. Multitasking can sometimes also affect work quality because one task never gets your undivided attention. If possible, try concentrating on one objective at a time. You may find that this makes your work more effective and efficient. If you are working in a situation that does not allow for single-tasking, try using lists or taking occasional breaks to relieve some of the mental stress.

5. Overbooking:
Taking on too many tasks can be a challenge for time management. Although it is often easy to accept new tasks with enthusiasm, later it becomes difficult to manage time. We should accept new tasks carefully by considering our current workload. If you are already overbooked, consider trying another time management strategy such as delegating or collaboration.

6. Not enough rest:
Sometimes, hard-working individuals sleep for fewer hours per day or choose to avoid breaks in hopes of having extra time to be more productive. Reducing or eliminating time off may feel productive in the short term but it usually makes you less effective due to the lack of rest. Productivity often increases with well-rested energy. If you can, rest when you need to and are able. Try establishing a consistent sleep schedule to ensure adequate rest at night. We can take short breaks during our day to refresh our energy.

7. Forgetting to delegate:
Another time management challenge you might face is knowing when to delegate. Many professionals like to accomplish tasks independently. Sometimes, however, this can become an issue with time management when there are too many tasks and not enough time to complete them. Consider delegating tasks to team members you trust. If you are in a position of team member, consider collaborating with colleagues to enhance effective time management across your team.

8. Lack of organization:
Many people also find that messiness can impede their time management and productivity. Staying organized is often an important element of good time management because it helps you spend more of your time accomplishing objectives, and less time switching between tasks or searching for items.

9. Multiple interruptions/ distractions:
Distractions such as too much socialization, electronic devices and less-important tasks can sometimes get in the way of strong time management at the workplace. Many of these kinds of distractions are common enough that they are easily overlooked. So, we need to avoid such distractions for effective time management.

10. Rigid planning:
Rigid planning is one of the challenges for effective time management. If the planning is rigid, it becomes difficult to face and solve the problems that enter at the eleventh hour. When unavoidable interruptions arise, we need to spare some of our time for coping with them. So, there should be little flexibility in the planning so that things can run smoothly.

11. Trouble prioritizing:
Knowing which tasks are most important and urgent can be a crucial time management skill. Different stakeholders may have different expectations. In such conditions, it becomes difficult to prioritize tasks. If prioritization is one of your time management challenges, try to collaborate with a colleague or even refer to a trusted mentor to help decide which tasks are most important for a given period of time.

12. Perfectionism:
Attention to detail can be a valuable asset in the workplace. Perfectionism can interfere with productive time management. This is because this habit can cause you to spend more time than necessary on details that might not have a significant impact on the overall outcome of your work. If you find that perfectionism is interfering with your time management, try to spare time for the important aspects only so that the time for unnecessary things can be saved.

13. Finding difficult to say no to people:
Most of the people are finding hard or difficult to say no to people which becomes a hurdle in time management. Many times, we do things which are of

less use to us, just for the sake of other people. So, one must always learn to say no at times to utilize time for his/her own productivity.

III. CONCLUSION

Time Management is the act or process of planning and exercising conscious control over the amount of time spent on specific activities, especially to increase effectiveness, efficiency or productivity. It is the process of organising and planning of time between specific activities and priorities. The benefits of time management include better habits and greater productivity. Improved time management increases our focus, builds confidence, and allows us to plan our time more effectively.

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INOVATION PERFORMANCE MANAGEMENT IN CONTEXT OF COVID-19: CASE STUDY OF EMERGING ECONOMIES

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Abstract - By comparing the innovative performance in 2020 with those before the Covid-19 epidemic, this paper finds that European emerging economies increased their efforts and levels of innovation investment in the Covid-19 pandemic. Meanwhile, R&D spending, patent filings, and scientific output all remained buoyant in 2020, continuing to build on strong innovative performance before the crisis. By using data from the Global Innovation Index, we further show that substantial differences have emerged between emerging countries in Europe. Although some economies managed to improve in most areas of innovation performance (for example, Estonia), others fell well short of previous results (Romania and Latvia). Others were only able to improve in some areas, such as knowledge and creative output (Czech Republic), and human capital and research and market sophistication (Slovakia, Poland, Lithuania, and Bulgaria). We further compared the results with those obtained for South East Asia, confirming a dynamic improvement in the innovation performance of emerging economies in that region, also leading to a significant reduction of the gap during the Covid-19 period.

Keywords - Covid-19, Emerging Economy, Innovation, Performance, Policy Response.

I. INTRODUCTION

The Covid-19 pandemic is responsible for widespread casualties and serious cause of human suffering around the world. It is a major crisis in public health that has also triggered a severe economic crisis, as production in the affected countries grinds to a halt, consumption and confidence plummets, and stock markets react negatively to the increased uncertainty (Roper and Turner, 2020).

This study discusses how the Covid-19 pandemic affected the innovative performance of European emerging economies by providing initial evidence and early impact evaluations. Here, we also compare policy reactions of different emerging economies to promote their economic resilience. Some of the European emerging countries, such as the Czech Republic, Slovakia and Latvia, responded to the Covid-19 pandemic by fostering innovation policies. In fact, many countries have taken measures to help companies innovate. This is particularly relevant for small and medium enterprises (SMEs) because they are lagging behind in their ability to adopt new technologies. By supporting the uptake of new technologies, companies to meet the challenges posed by the Covid-19 pandemic. These innovation policies are intended to address not only pressing short-term problems of companies, but also support the structural resilience of the whole economies. In several countries, such as Poland, Latvia, and Czech Republic, this support is targeted at start-ups and companies to assist them in identifying responses to the Covid-19 epidemic. In most countries, these innovation policy measures are intended to better cope with the impact of the pandemic by strengthening the innovation activities of companies.
With recovery packages being rolled out in emerging economies, innovation is forthcoming in the areas of healthcare, pharmaceuticals, green energy, and digital technologies, creating an increased need for funding. This, in turn, indicates that innovation gaps are likely to become even more pronounced in the coming years. Our results show that some innovation systems in European emerging economies have become increasingly vulnerable, requiring targeted policies to support them, especially in the most negatively affected sectors, including automotive and hospitality.

The remainder of this study is structured as follows. Section 2 reviews the literature on the effects of the Covid-19 pandemic on innovation activities. Section 3 shows the results of our empirical research, which compares the innovation performance of emerging economies before and during the Covid-19 period. The final section concludes with some recommendations for further research.

II. RELATED LITERATURE

Many previous studies have shown that investment in research and development (R&D) and innovation in firms is highly procyclical, that is, investments increase during recovery and decrease strongly in crises (Roper and Turner, 2020). In particular, financial constraints may have the greatest impact on small-scale investments in R&D and innovation. Roper and Turner (2020) highlight that evidence from the prior global financial crisis indicates that these investments will increase the likelihood of survival and growth. Similarly, Paunovic and Anicic (2021) provide additional empirical evidence from SMEs in Serbia during the Covid-19 crisis, with the level of networking and business digitalization as an important factor of innovation responses of SMEs. In fact, these responses appear to offer an effective way to overcome the impacts of the Covid-19 crisis.

Caballero-Morales (2021) also reported a greater impact on SMEs from emerging economies, which justifies the impact by very limited resources and vulnerable supply chains and business relationships. Interestingly, Han and Qian (2020) found that Chinese firms' innovative capabilities (both for large companies and SMEs) increased during the Covid-19 period, but the effect varied between industries. To reduce the adverse effects of the Covid-19 crisis, innovation activity is considered to be an important aspect of SMEs recovery of SMEs during and after the Covid-19 period. Similarly, Lee and Trimi (2021) suggested that sustainable innovation is crucial to recovery, representing a core organizational competence during and after the Covid-19 period.

The importance of collaborative innovation activities during the Covid-19 crisis was also suggested by Michie (2020) and Montani and Stagliano (2022). The results of Montani and Stagliano (2022) indicate that the innovative potential of employees can be improved by sharing knowledge. Similarly, Puslecki et al. (2021) showed that collaborative innovation activities led to many innovative projects given the challenges raised by the Covid-19 pandemic. Furthermore, market orientation was reportedly a proactive predecessor, with 51% of companies taking a positive role in stimulating the mediation of knowledge sharing and 63% of businesses taking an innovative role in business performance (Christa and Kristinae, 2021).

Another stream of research focuses of the types on innovations introduced during the Covid-19 period. Abi Younes et al. (2020) highlight that the development of drugs and vaccines was fully justifiable in order to overcome the Covid-19 crisis. Market failure economic theory and the elasticity of science were suggested as critical concepts that should be reflected in science, technology, and innovation policy during the crisis. Dahlke et al. (2021) identified a variety of Covid-19 innovations, with social needs gaining increased attention during the Covid-19 period. Using a similar content-based analysis, Li et al. (2021) were able to identify various innovation activities in the hospitality industry during the Covid-19 crisis. Akpan et al. (2021) concluded that technology that creates social businesses, IoT (Internet of Things), virtual reality (VR) technologies, and CRM (customer relationship management) systems are key to reducing business costs. For example, Amankwah-Amoah (2021) provided an overview of innovations rooted in the Covid-19 pandemic within the airline industry. Informational cyberloafing has also been identified to be positively linked to the innovative performance of employees by improving the sense of their work (Zhong et al., 2022). Looking at shareholders' perspective, Sharma et al. (2021) evaluated the effectiveness of Covid-19 innovations, showing that product innovations implemented during the Covid-19 period were particularly effective.

Recent research has also discussed the challenges and opportunities associated with the Covid-19 pandemic. Ebersberger and Kuckertz (2021) argue that the changing environment offers unique challenges and opportunities for innovative activities and solutions. In particular, innovative start-ups were found to be the best in terms of innovation response time during the Covid-19 pandemic. Guderian et al. (2021) adds that the changing markets were exploited by many companies, but the reaction time was crucial in this regard. Patent analytics was recommended to help firms improve their innovation response speed.
Although the previous literature focused on several important aspects of the Covid-19 pandemic on the innovation activities of companies, we found no research assessing the effects of the Covid-19 pandemic on national innovation systems. In this study, we focus on the national innovation systems of emerging economies due to their increased vulnerability to economic crises.

III. EMPIRICAL RESULTS

Data for our analysis were collected from the Global Innovation Index (WIPO, 2021) and, for comparison purposes, from the edition preceding the Covid-19 pandemic (WIPO, 2019). The latest database was released in the middle of the Covid-19 pandemic, covering the year 2020 and aiming to provide governments and other stakeholders with the best practice for producing effective national innovation systems. Generally, it was concluded that many important indicators of innovation activity continued to grow in the monitored period, such as expenditures in R&D, the number of scientific outputs, the amount of venture capital, and the number of intellectual property filings. The Global Innovation Index is composed of seven pillars, namely institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs and creative outputs. Seven to 15 indicators are evaluated within each of these pillars to calculate the overall score, allowing the final ranking of the countries. In Table I, the results for the nine European emerging economies are compared in terms of the seven pillars of the Global Innovation Index. The average results indicate that these countries improved in terms of market sophistication and knowledge and technology outputs, whereas a substantial decrease can be observed for business sophistication and creative outputs. However, there are considerable differences between individual countries. For example, Bulgaria has turned from one of the worst countries in terms of creative outputs to one of the best in just two years due to a considerable increase in intangible assets and online creativity. Likewise, improvements in knowledge creation and knowledge diffusion shifted Bulgaria to one of the best performing countries in terms of knowledge and technology outputs. On the contrary, the sharp decrease in business sophistication was due to the decrease in the percentage of firms offering formal training. A similar problem was observed for Poland.

Country	Inst.	HC	Infr.	MS
Bulgaria	69.8 (+1.5)	31.7 (+1.1)	51.7 (-2.0)	45.1 (-2.4)
Czech Rep.	76.9 (-1.7)	43.0 (-0.4)	56.0 (-0.4)	49.5 (-3.1)
Estonia	81.1 (-0.6)	42.9 (-0.8)	59.8 (-1.7)	66.4 (+13.8)
Hungary	71.7 (+0.1)	42.5 (+1.5)	52.6 (-0.1)	46.6 (+0.9)
Latvia	78.9 (-1.7)	37.7 (-0.8)	45.1 (-5.4)	50.1 (-0.4)
Lithuania	76.4 (+0.4)	38.7 (+2.4)	49.9 (-1.8)	53.7 (+3.8)
Poland	73.2 (-0.4)	42.3 (-1.1)	50.1 (-2.7)	48.3 (+0.4)
Romania	68.1 (+1.0)	28.9 (-0.2)	51.5 (-3.0)	44.7 (+1.5)
Slovakia	72.8 (-0.5)	32.8 (+0.4)	50.5 (-3.7)	44.9 (-2.5)
Average	74.3 (-0.2)	37.8 (+0.2)	51.9 (-2.3)	49.9 (+1.3)
	BS	KTO	CO	
Bulgaria	32.6 (-9.7)	36.0 (+4.6)	41.1 (+7.3)	
Czech Rep.	43.5 (-2.8)	48.2 (+4.4)	40.3 (-2.8)	
Estonia	39.9 (-2.7)	38.4 (+2.4)	45.3 (-6.4)	
Hungary	37.5 (-3.3)	39.5 (-3.3)	30.9 (-3.7)	
Latvia	34.1 (-3.3)	27.8 (-0.3)	33.8 (-9.0)	
Lithuania	31.5 (-6.5)	25.8 (+1.4)	33.6 (-6.7)	
Poland	34.2 (-4.2)	30.6 (-0.3)	29.6 (-2.8)	
Romania	28.0 (-5.6)	31.8 (+1.5)	22.2 (-3.6)	
Slovakia	32.5 (-3.1)	34.3 (+0.3)	33.0 (-4.1)	
Average	34.9 (-4.6)	34.7 (+1.2)	34.4 (-3.5)	

Table I: Pillars of the Global Innovation Index 2021 for European emerging countries (comparison with 2019).

Legend: Inst. – institutions, HC – human capital, Infr. – infrastructure, MS – market sophistication, BS – business sophistication, KTO – knowledge and technology outputs, CO – creative outputs.

Source: WIPO (2019, 2021).

For multiple countries, we found that creative output decreased due to low level of intangible assets (e.g., Estonia, Lithuania, Slovakia, and Latvia). The Czech Republic experienced an increase in knowledge and technology output as its performance improved in terms of knowledge creation and knowledge diffusion. In contrast, the market sophistication of the Czech Republic worsened, while the opposite was observed for Estonia due to the increase in investments. Some emerging countries also struggled with infrastructure, especially Latvia, with substantial reduction of ICTs, ecological sustainability, and general infrastructure. For others, market sophistication was the main problem during the outbreak of the Covid-19 pandemic (Lithuania and Romania, both having a lack of knowledge workers and inadequate knowledge absorption).

To statistically evaluate these results, we performed a series of Student's paired t-tests to highlight significant differences. We found that the European emerging countries significantly deteriorated in terms of infrastructure (at $p<0.05$, from 54.2 to 51.9), business sophistication (at $p<0.05$, from 39.4 to 34.9) and creative outputs (at $p<0.05$, from z 38.0 to 34.4).

In the next step, we examine the regional effects on the innovation performance, taking Asian emerging countries for comparison. Table II shows the results for five emerging countries from Asia. We can observe some similar patterns in these results. It should be noted that the pillars of infrastructure (at $p<0.10$, from 46.0 to 41.1) and business sophistication (at $p<0.10$, from 34.5 to 30.7) decreased significantly during the Covid-19 pandemic, similar to the European emerging countries.

Country	Inst.	HC	Infr.	MS
Indonesia	51.2 (-3.0)	22.4 (+1.1)	41.4 (-2.8)	48.5 (-0.3)
Malaysia	72.3 (+0.7)	40.6 (-3.6)	46.7 (-5.1)	55.3 (-2.5)
Philippines	56.3 (+0.3)	27.9 (+3.3)	36.1 (-12.4)	42.9 (+4.6)
Thailand	64.2 (-1.6)	31.7 (-3.0)	43.0 (-0.6)	55.6 (-0.9)
Vietnam	58.8 (+0.2)	28.1 (-3.0)	38.2 (-3.8)	57.2 (+0.2)
Average	60.6 (-0.7)	30.1 (-1.0)	41.1 (-4.9)	51.9 (+0.2)
	BS	KTO	CO	
Indonesia	17.5 (-8.2)	18.3 (+0.7)	17.5 (-6.5)	

Malaysia	34.1 (-4.8)	33.4 (-1.3)	34.5 (+1.7)
Philippines	36.3 (-4.6)	37.1 (-3.4)	24.2 (-3.5)
Thailand	34.7 (-2.4)	29.7 (-1.6)	27.3 (-2.7)
Vietnam	30.8 (+0.8)	29.4 (-6.2)	33.4 (+1.1)
Average	30.7 (-3.8)	29.6 (-2.4)	27.4 (-2.0)

Table II: Pillars of the Global Innovation Index 2021 for Asian emerging countries (comparison with 2019).

Legend: Inst. – institutions, HC – human capital, Infr. – infrastructure, MS – market sophistication, BS – business sophistication, KTO – knowledge and technology outputs, CO – creative outputs.
Source: WIPO (2019, 2021).

Again, Student's paired t-tests were performed to reveal significant changes. We can also observe differences between individual emerging countries, with Indonesia lagging behind in terms of both creative outputs (a very low level of intangible assets was the main reason) and business sophistication (low levels of innovation linkages and knowledge absorption). As the ease of borrowing improved in Philippines, its market sophistication also increased. However, deteriorating infrastructure has become a major weakness in this country. When comparing the mean performance between the emerging European and Asian countries, we observed that the European countries significantly outperformed the Asian counterparts in most of the innovation pillars (at $p<0.05$). Only market sophistication was an exception. While recovery packages were implemented in most economies, health and digital technologies were at the forefront of innovation activities. Technological advances can be observed not only in pharma and health, but also in energy engineering and logistics. However, more vulnerable sectors required targeted policies in emerging countries, such as the automotive industry and hospitality. To demonstrate these efforts in emerging European economies, Table III shows the main categories of support towards innovation activities during the Covid-19 pandemic.

Country	Help find new markets	Teleworking / digitalization	Innovation support	Trai-ning
Bulgaria	-	-	-	-
Czech R.	✓	-	✓	-
Estonia	-	✓	-	-
Hungary	-	-	-	-
Latvia	-	✓	✓	-
Lithuania	-	-	-	-
Poland	-	-	✓	-
Romania	-	-	-	-
Slovakia	-	-	-	-

Table III: Policy responses to the Covid-19 pandemic
Source: OECD (2020)

The governments of these countries focused on supporting the innovation activities directly or promoted teleworking and digitalization, while forgetting training / redeployment activities. New sales channels were promoted only in the Czech Republic by introducing an emergency package for exporters. The Czech government also implemented two programs, the Covid-19 technology program and the Rise Up program, to support projects and innovative solutions directly fighting against the pandemic. Regarding teleworking and digitalization, Estonia supported digital education by spreading tools developed by start-ups. Similarly, fintech initiatives were supported in Latvia to improve SME financial sources. Hackathons among SMEs were also supported in Latvia and Poland to initiate innovative solutions to the Covid-19 crisis.

IV. CONCLUSIONS

To sum up, we compared the innovative performance of emerging countries before and during the Covid-19 epidemic. We find that both European and Asian emerging economies increased their efforts and levels of innovation investment during the Covid-19 pandemic, while struggling with infrastructure and business sophistication, which is not surprising given the adverse effects of the crisis on supply chains and the whole economies. Using data from the Global Innovation Index, this article has provided a comparative analysis of the pillars of innovation performance of emerging countries. This study has also provided an overview of supporting policies introduced during the Covid-19 period. Our research has underlined the importance of innovation activities during and after the Covid-19 pandemic, suggesting that particular attention should be paid to the restoration of the infrastructure and business environment.

Finally, some limitations should be considered. First, only the year 2020 was considered in this study. Therefore, future studies should focus on the analysis of new data, which will be available in the next year to provide more information on the effects of Covid-19 pandemic on the performance of innovation systems. In addition, given the small size of the sample, caution must be taken when interpreting the results. Future studies should also consider the effects of the actions taken by the governments of emerging countries. Additional data collection would help to estimate these effects.

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THE IMPORTANCE OF FOREIGN OWNERSHIP FOR THE CREATION OF INNOVATIONS: AN INTERESTING EXPERIENCE OF CENTRAL EUROPE REGIONS

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Abstract - Current research on innovation in catching-up Central and Eastern European (CEE) countries has clearly confirmed that these countries are associated with problems such as lower trust between cooperating partners, insufficient infrastructure, lack of funding and thus lower innovation performance, for example compared to more developed countries (typically countries from Western Europe). The application of innovative models and patterns of behaviour of Western states therefore proved to be insufficient, mainly due to the above-summarized problems and unpreparedness of individual actors within CEE countries. The arrival of foreign owners of firms in CEE countries seems to be one of the possible ways to achieve changes that could accelerate the process of catching up with more developed countries. This could be caused mainly by breaking old structures and bringing new experience, knowledge, and managerial practices, but also financial resources. This study aims therefore to analyse the influence of foreign ownership on the innovation activities of firms within catching-up CEE countries. More specifically, we compare firms from Central Europe (Czech Republic, Slovakia, and Poland) and from Baltic States (Estonia, Latvia, and Lithuania). For this study, we are using the World Banks´ Enterprise Survey data from 2019 and information about, in total, 3,361 firms from six catching-up CEE countries. The results point out that there are significant differences between Central European countries and Baltic States, whereas foreign ownership seems to be a significant determinant of innovation primarily within Baltic States. On the contrary, this study revealed patterns of behaviour that are identical and key for both groups of countries. Especially, these are internal research and development, acquisition of external sources (knowledge or research and development), and participation in firm groups. These results significantly contribute to the "catching-up literature" dealing with firm innovation in Central and Eastern Europe, where there is still a lack of studies dealing with the issue of the effects of foreign ownership.

Keywords - Foreign Ownership; Catching-up Countries; Comparative Study; Central and Eastern European Countries.

I. INTRODUCTION

Thousands of current research studies discuss the topic of innovation, its impact on performance, sustainability, resilience, but also on processes, management, and many other contexts. In the research papers published in the last fifty years, it is possible to see the conclusions of the findings. The key findings are: innovation is the driving force behind corporate productivity (Stojčić and Hashi, 2014), but also a crucial determinant of competitiveness, regional development and growth (Acs et al., 2017).

Demircioglu, Audretsch & Slaper (2019) argues in their study that many scholars perceive innovation as a dependent variable (examining the factors that influence innovation) and the other group considers scholars to be an independent variable and focuses on examining the impact of innovations (outputs) on outcomes (business or regional development goals). The second group answers the questions of how innovations affect other economic processes, their efficiency, help achieve prosperity, wealth, etc. (Zhylinska et al., 2020).

There are many studies that agree that labor force, especially knowledge, talent, creativity, and the ability to be innovative are crucial determinants of innovation (Nakamura, 2000). This statement is also supported by Demircioglu, Audretsch & Slaper (2019) and they add that other sources of innovation need to be explored, as these are the determinants of different types of innovation, innovation activities and impact on innovation absorption.

Due to the availability and occurrence of various sources (drivers/factors/determinants) of innovation in space, there is seen a spatial dispersion of innovations (Davelaar & Nijkamp, 1997). This is a source of regional disparities and a source of public policy efforts to create an environment that contains the key drivers of innovation in the region they manage (Capello & Cerisola, 2021). Therefore, it is possible to see many studies that examine the same or similar factors and their impact on innovation in different regions (countries, continents) and get completely different results (for examples see more in Parrilli, Balavac & Radicic, 2020).

A specific group of countries are countries that seek catching-up neighbor countries that show higher economic growth (Prokop et al., 2021). Political representation as well as firms must create a pro-innovation environment (Del Brío et al., 2003). These processes are very lengthy and relatively inefficient. Therefore, in practice, domestic firms are looking for partners in foreign markets who become their co-owners or full owners. These mergers and acquisitions result in a change in the initial conditions, foreign-owned firms acquire other innovative factors, have access to new knowledge or can implement R&D activities to a greater extent (Kwon & Park, 2018; Prokop, Stejskal & Hudec, 2019). There is not much evidence of these strategic business behaviors. Therefore, this paper answers the question of whether foreign ownership spur the innovation of catching-up countries.

The remainder of this paper is structured as follows. First, the literature review focuses on innovation determinants and their impact, especially foreign ownership of the innovative firms. Second, characterization of research model and data is provided. This is followed by the analysis of data that results in conclusions.

II. RELATED LITERATURE

The study of Demircioglu, Audretsch & Slaper (2019) raises the question what the sources of innovation processes in firms are. They point to the results of a number of studies that conclude that resources are external (external environment of the firm and entities located in it - firms, customers, suppliers, networked firms, etc.) and internal (internal resources - employees, knowledge, knowledge flows and acquisitions, ability to realize the research, etc.). It is also possible to add colleges or universities, R&D organizations that move both outside and inside the firm (depending on the project or type of cooperation).

One of the main internal sources of innovation activities is, of course, expenditure on internal R&D. Sharma et al. (2016) or Zhang & Tang (2017) and many others confirm that sufficient internal funding allows the firm to create an R&D department that will support innovation capacity and significantly increase the potential for innovation. Financial resources are also a determinant of other non-financial innovation forces.

Internal resources include, above all, the firm ability to innovate, i.e. to have internal processes set up in an innovative way. According to Kraśnick et al. (2018) includes creativity, courage, flexibility, openness, and a focus on learning. These elements of an innovative firm culture include, above all, space for innovation, trust, openness and freedom. Some sources combine these elements into an innovation-oriented culture (De Tienne & Mallette, 2012). Creating such an innovative corporate culture must be part of the business strategy (Hacklin et al., 2018).

The second key determinant of innovation coming from the firm's internal resources is the employees and their ability to develop their potential. Both managers and other employees should develop an organizational culture leading to innovation, education, and actively respond to self-development training offers in the areas of strategic focus of the firm. It is important to point out the need for such education and training to be effective in order to achieve the intended result, i.e. innovation (Yang et al., 2019).

The second group of innovation forces are external resources. As with internal ones, external R&D expenditures should be highlighted (Love & Roper, 2002). These can be obtained both from external public grants and through cooperation with R&D organizations. Likewise, these funds can be obtained from cooperating organizations and potential future co-owners or owners who could enter the firm financially or intangible or fixed assets in the future (Medda, 2020).

As with internal forces, external knowledge and foreign technology are the important resource (Torres de Oliveira et al., 2022). It depends on the firm's ability to engage in cooperative projects so that it is acceptable for the partner to share and share knowledge or technology (Gagliardi, 2019). At present, these technologies are emphasized in the innovation of technological units aimed at sustainability (Korsakienė & Raišienė, 2022), higher environmental friendliness, and production efficiency (Prokop et al., 2021).

External intangible or fixed assets are a specific group of forces that come from both foreign firm and foreign cooperation. A number of studies (e.g. Bagna et al., 2021 or Hsiao et al., 2021) emphasize the high potential of these assets, but at the same time underline the limited mobile capacity of fixed assets, thus creating spatial differences between regions.

These studies often emphasize the need to examine the internal and external sources of innovation in the regions and to carry out comparative studies that can analyze the sources that are tied to the region and are ubiquitous. They significantly affect the innovative capacity of localized firms, but at the same time they open opportunities for cooperating firms and firms migrating for local assets, which they consider to be a source of competitive advantage (Syromyatnikov et al., 2021).

III. METHODOLOGY

3.1 Data and variables

The World Bank conducts extensive research (standardized survey) into the business environment in many countries around the world. It focuses on selected elements of the business environment such as infrastructure, science and research, financial resources, but also competitiveness, performance, or the ability to produce innovations. The basic set for this research is the primary data from Enterprise

Survey 2019 (ES). The basic sample contains data from firms in the manufacturing industry and services.

The sample contains data from firms from Central and Eastern Europe (CEE) countries, concretely the Czech Republic, Slovakia, and Poland and within Baltic States - Estonia, Latvia, and Lithuania. In total, we analyze 3,361 firms from these countries.

The variables described in Table I were taken over for the research. For a more detailed description, the descriptions given by the questions from the EC questionnaire were accepted.

Dependent variable	
Firms´ innovation (INN)	During the last three years, has this establishment introduced new or improved products or services?
Independent variables – Internal sources	
New pro-innovative processes (PROC)	During the last three years, has this establishment introduced any new or improved process? These include methods of manufacturing products or offering services; logistics, delivery, or distribution methods for inputs, products, or services; or supporting activities for processes?
Training (TRAIN)	Over fiscal year, did this establishment have formal training programs for its permanent, full-time employees?
Internal R&D exp. (RRDIN)	Over the last three years, did this establishment spend on research and development activities within the establishment?
Strategy (STR)	Does this firm have formalized, written business strategy with clear key performance indicators?
Independent variables – External sources	
External knowledge (ROEK)	Over the last three years, did this establishment spend on the acquisition of external knowledge? This includes the purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other businesses or organizations.
External R&D exp. (RRDEX)	Over the last three years, did this establishment spend on research and development activities contracted with other firms?
Foreign technologies (TECH)	Does this establishment at present use technology licensed from a foreign-owned firm, excluding office software? Acquisition of external (foreign) technologies could help firms to reduce the costs and uncertainties related to expensive and risky innovations (Lee et al., 2007).
Ext. intangible assets (INTAS)	In fiscal year, did this establishment purchase or acquire any trademarks, copyrights, patents, licenses, service contracts, franchise agreements, or other intangible assets?
Ext. fixed assets (FIXAS)	In fiscal year, did this establishment purchase any new or used fixed assets, such as machinery, vehicles, equipment, land, or buildings, including expansion and renovations of existing structures?
Independent variables – Controls	
Domestic ownership (DOMOWN)	Domestic ownership including private domestic individuals, firms, or organizations
Foreign ownership FOROWN	If the respondent indicated that firm has not "domestic ownership", then firm is automatically considered that it has "foreign ownership".
Domestic markets (MARK)	Did this establishment sold its main product at domestic market?
Enterprise group (ENTGP)	Is this firm part of a business membership organization, trade association, guild, chamber of commerce, or other business support group?

Table I: Characteristics of variables.
Source: Enterprise Survey (2019)

3.2 Regression models for influence measuring of internal and external sources on firms´ innovation in CEE countries

At the beginning of our research process, we need to reveal the influence of internal and external sources on firms´ innovation. Because the input and output data are binary variables, the traditional and commonly used binary logistic regression analysis using the ordinary least squares (OLS) estimator was chosen.

On the other hand, external sources allow firms to gain access to additional competencies, skills, knowledge, and technologies and give rise to knowledge spillovers and inter-organizational knowledge transfers (Schuhmacher et al., 2018 and Medda (2020).

Generally, regression analyses are often used to reveal the direct effects of independent variables (determinants of innovation – internal and external sources) on the innovation performance of firms in Europe. The relationship between innovation (INN) output and its determinants (shown and specified in Table 3) could be defined as follows (Divisekera & Nguyen, 2018):

$$\mathrm{INN} = \beta_0 + \sum_{i=1}^{m} \beta_i X_i + \varepsilon \quad (1)$$

where INN is an innovation output, is x_i a vector of variables that influences the innovation output, β_i is a vector of corresponding coefficients and ε is an error term. Data quality testing was performed, and the data were tested for collinearity by using the Spearman correlation coefficient (rho). Results showed that the correlation between variables is significantly different from zero (rho ranges between $-1 \leq$ rho ≤ 1). We also tested independent variables for collinearity by using the Variance Inflation Factor (VIF). Multicollinearity was not found - all models had VIF < 5. All tests were performed in IBM SPSS.

In the first step, we created six regression models (one for each country) to reveal the influence of selected independent variables (shown in Table 1) on firms´ innovation outputs within CEE countries. To extend the body of knowledge on firms´ innovation, we also included control variables focused on firms´ ownership, markets, and participation in the enterprise group. In the second step, following the approach of Prokop et al. (2019), regression analyses of the aggregate datasets were performed. That enables us to obtain results that are significant for all countries in the sample, and with similar conditions for them. We subsequently created regression models for Central European countries (including the Czech Republic, Slovakia, and Poland), Baltic States (including Estonia, Latvia, and Lithuania), Central and Eastern European countries (including all selected countries mentioned above). Not all countries had the same number of elements in the file. Therefore, in the framework of methodological adjustments, the sample sizes were adjusted (reduced by random sampling in Poland) to be identical.

IV. EMPIRICAL RESULTS

Table II shows results for the Czech Republic, Slovakia and Poland (Central Europe countries) and Table III for Estonia, Latvia, and Lithuania (Baltic States). Within Central Europe countries, introduction of new processes was proven as a significant prerequisite for successful firms' innovation. As we showed above (Table I), it could include methods of manufacturing products or offering services, logistics, delivery, or distribution methods for inputs, products, or services, or supporting activities for processes. In the Czech Republic, internal knowledge sources predominate over external sources acquired by firms´ participation in business membership organization, trade association, guild, chamber of commerce, or other business support groups. Similar results were observed in the case of Slovakia. Both countries have undergone similar historical developments and it is obvious that they are still burdened by some forms of lock-in effects and probably by the Not Invented Here (NIH) syndrome. This syndrome manifests itself in the attitude of internal R&D employees who refuse external knowledge during inbound open innovation (Hannen et al., 2019). On the contrary, in Poland, firms are also significantly influenced by external knowledge flows (ROEK) and use some forms of fixed assets. Moreover, domestic ownership plays a significant role within Polish firms.

Variables		Countries					
		Czech Republic		Slovakia		Poland	
		p-value	beta	p-value	beta	p-value	beta
Internal Sources	PROC	.096*	.478	.003***	1.661	.000***	2.015
	TRAIN	.096*	-.493	.763	.136	.186	.289
	RRDIN	.002***	.857	.611	.373	.008***	.933
	STR	.883	-.043	.066*	.919	.217	-.291
External Sources	ROEK	.405	.358	.595	.339	.008***	.906
	RRDEX	.139	.545	.423	-.658	.353	-.436
	TECH	.948	.025	.190	-.640	.944	.021
	INTAS	.106	.709	.441	-.599	.293	-.522
	FIXAS	.071*	.631	.762	.137	.000***	1.160
Control Var.	DOMOWN	.652	-.283	.256	1.042	.012**	1.119
	FOROWN	.732	-.228	.069*	1.806	.138	1.259
	MARK	.255	.348	.278	-.589	.175	-.381
	ENTGP	.049**	.549	.076*	.812	.323	.245
	Cox & Snell R	.161		.130		.186	
	Nagelkerke R	.215		.208		.290	

Table II: Regression models for the Czech Republic, Slovakia, and Poland – Central Europe countries.

Table III presents results for Baltic countries. In these countries, no predominant factors of innovation performance were identified and there are no significant similarities. Only in the case of orientation to domestic markets, we see similarities between Lithuania and Latvia. On the other hand, internal and external R&D expenditures seem to be significant determinants of firms´ innovation in Estonia.

Variables		Countries					
		Estonia		Latvia		Lithuania	
		p-value	beta	p-value	beta	p-value	beta
Internal Sources	PROC	.956	.026	.069*	.906	.984	-.011
	TRAIN	.617	-.234	.528	.336	.084*	.885
	RRDIN	.067*	.956	.742	.182	.181	1.084
	STR	.131	-.709	.803	-.109	.514	.354
External Sources	ROEK	.974	.019	.574	.275	.427	.477
	RRDEX	.020**	1.381	.422	.487	.394	.656
	TECH	.337	-.538	.629	.245	.087*	-1.268
	INTAS	.585	.688	.454	-.463	.345	1.218
	FIXAS	.162	-.705	.705	.202	.794	.132
Control Var.	DOMOWN	.580	-.390	.074*	1.127	.659	-.478
	FOROWN	.128	1.227	.063*	1.532	.788	.321
	MARK	.385	-.393	.010**	1.197	.047**	1.145
	ENTGP	.051*	.904	.130	.705	.341	.529
	Cox & Snell R	.231		.181		.195	
	Nagelkerke R	.308		.241		.268	

Table III: Regression models for Estonia, Latvia, and Lithuania – Baltic States

The results in Tables II and III show that traditional regression models may not always be suitable for finding the determinants of innovation and proposing appropriate ways to use them. To fix this limitation of proposed models, we continue through aggregate datasets for Central Europe countries, Baltic States and CEE countries. It could provide benchmarks for individual countries from these groups of states. Regression models for Central Europe countries, Baltic States and CEE countries

As it is shown in Table IV, data aggregation provided more significant results, specifically in the case of all CEE countries together. The new processes, internal R&D, acquisition of external knowledge and fixed assets were identified as significant factors in these countries. Furthermore, foreign ownership influences firms´ innovation creation more than domestic ownership. Participation in the groups of firms also significantly influenced innovation output. The same results were observed for the group of Central Europe countries. On the other hand, internal and external R&D expenditures, foreign ownership, domestic markets, and participation in the groups of enterprises are significant for firms in Baltic States.

Variables		Countries					
		CEE Countries		Central Europe		Baltic states	
		p-value	beta	p-value	beta	p-value	beta
Internal Sources	PROC	.000***	.972	.000***	1.237	.149	.377
	TRAIN	.386	.114	.559	.092	.447	.198
	RRDIN	.000***	.779	.000***	.743	.003***	.881
	STR	.269	-.148	.461	-.119	.522	-.161
External Sources	ROEK	.004***	.499	.004***	.660	.745	.094
	RRDEX	.471	.142	.583	-.139	.033**	.718
	TECH	.172	-.216	.393	-.164	.205	-.375
	INTAS	.597	.119	.965	.012	.498	.299
	FIXAS	.000***	.727	.000***	.913	.831	-.059
Control Var.	DOMOWN	.013**	.589	.017**	.734	.531	.250
	FOROWN	.002***	.898	.118	.606	.015**	1.155
	MARK	.948	-.009	.376	-.163	.044**	.500
	ENTGP	.000***	.477	.011**	.415	.023**	.580
	Cox & Snell R	.174		.173		.150	
	Nagelkerke R	.246		.254		.200	

Table IV. Regression models for CEE countries, Central Europe countries and Baltic States

The experimental results of regression analyses showed that the analysis of larger data sets (for example, by merging several countries together) can help to identify significant innovation determinants better. However, the explanatory power of these models is still low, and it is not possible to propose conclusions and implications that would lead to new findings. Therefore, by using the same datasets, we propose to use the artificial neural networks approach that could provide additional results and help to find specific paths to innovations.

V. CONCLUSIONS

The contribution of this study based on the results can be seen on two levels. The first is methodological - we have confirmed that when assessing the determinants of innovation performance, it is better to examine larger volumes of data - for example, to join countries into larger units or regions (in it is possible). If the results still have a weak significance, other methodological ways must be applied.

The second level of the contribution is the identification of innovation determinants applied in selected European countries. We contribute to the recognition that foreign ownership is a crucial determinant only in some countries of the researched region (Baltic states). This can be explained by similar historical developments. Another group of key determinants is expected, internal research and development and the acquisition of external sources of knowledge have the highest importance.

Topics for future research are seen mainly in the research of the synergistic effect of individual innovation determinants and the observation of subsequent patterns of behavior of economic entities. This study has limitations especially in significance of the results, which depends on the quality of the input data.

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HYBRIDIZED QPSO FOR ELECTROMAGNETIC DESIGN PROBLEMS USINGDE TECHNIQUE WITH DYNAMICPARAMETERS

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Abstract - The quantum particle swarm optimization (QPSO) method of swarm intelligence has successfully resolved several electromagnetic inverse problems. The approach encounters local minima and lost diversity in the final stages of optimization. To address this kind of problem, a new hybridization method is presented in this paper that integrates QPSO with differential evolution (DE). The proposed HQPSODE introduces additional capabilities, such as the non-linear adaptive control parameter, crossover, and DE selection strategy are introduced to the smart QPSO approach to enhance the exploration. According to experiment results, the hybrid HQPSODE strategy has a search accuracy and convergence advantage over other optimization techniques.

Keywords - Smart Particle, Hybridization, QPSO, DE, Energy Storage Device (SMES)

I. INTRODUCTION

Optimization problems are frequent, impulsive, and related to every real-world field, including electromagnetic, digital computers, power engineering, telecommunications, control systems, robotics, and signal processing, in the study of engineering and artificial intelligence. The optimization designing has received significant research attention over the last two decades. As a result, to solve optimization problems, a more effective global searching capability is necessary. Researchers have developed several optimization algorithms, such as the non-dominating sorting genetic algorithm (NSGA) using Pareto optimal fronts[1], the self-adaptive penalty approach genetic algorithm [2], the artificial bee colony[3][4] [5], and the cuckoo search [6], for the best possible solutions to optimization problems. Particle swarm optimization(PSO), on the other hand, has grown in popularity over the past ten years because it provides better results for optimization problems[7] [8]. Numerous researchers have developed a vast spectrum of compatible and comprehensive evolutionary intelligence optimization algorithms to address objective functions that are challenging to deal with using structured approaches [9]. PSO has drawn the attention of several researchers worldwide, who have created a significant number of enhanced versions of the fundamental PSO and verified them using various optimization problems [10]. Researchers have recently introduced several improved PSOs, including terminal crossover, steering-based PSO, human behavior-based PSO[11], position-transitional PSO[12], and hybrid whale PSO[13].
Although PSO is simple to use and effective in solving many objective functions, it may encounter local minima when addressing complex multimodal problems. To overcome this problem, Sun et al. developed the quantum-behaved version of PSO (QPSO) in 2004, which is based on wave function characterization of particle solution candidate rather than the velocity and position of each particle using the time-dependent Schrodinger equation [14].

$$i\hbar\psi\left(x_{ij}^{(t)}\right)=\frac{-\hbar}{2m}\frac{d^2\psi\left(x_{ij}^{(t)}\right)}{d(x_{ij}^{(t)})^2}+V\left(x_{ij}^{(t)}\right)\psi\left(x_{ij}^{(t)}\right) \quad (1)$$

Following that, the position function obtained by the Monte Carlo stochastic model is as follows,

$$x_{ij}^{(t+1)} = \begin{cases} p_{ij}^{(t)} + \beta * \left|M_{best}^{(t)} - x_{ij}^{(t)}\right| * \log\left(\frac{1}{u_{ij}^{(t)}}\right), & if\ u_{ij}^{(t)} \geq 0.5 \\ p_{ij}^{(t)} - \beta * \left|M_{best}^{(t)} - x_{ij}^{(t)}\right| * \log\left(\frac{1}{u_{ij}^{(t)}}\right), & otherwise \end{cases} \quad (2)$$

Whereβ is contraction expansion coefficient.
Recent years have seen a rise in interest in studies on hybrid systems in swarm intelligence to address more complex and challenging problems. Quantum particle swarm optimization (QPSO) and other evolutionary optimization techniques have recently benefited from more effective modifications due to recent developments in machine learning and artificial intelligence (AI). Using a hybridized Gaussian QPSO with cuckoo search. Nirmal et al. solve first and second-order differential equations by transforming them into unconstrained optimization problems [15]. In [16], author modified basic QPSO with enhanced strategy for global optimization of electromagnetic devices.In this paper author uses a model hybridized QPSO with DE and validates it with several benchmark functions and an electromagnetic TEAM problem 22. The remaining sections of the paper are

structured as follows. The author includes literature on PSO, conventional QPSO, and hybridized QPSO algorithms in the introduction section. Section 2 explains the proposed hybridized algorithm. Section 3 presents experimental results and analyses. In Section 4, a numerical application is given. Finally, section 5 presents the conclusion.

II. PROPOSED HQPSODE METHOD

The main objective of the proposed methodology is to determine the best fitness in all benchmark functions (unimodal, multimodal, and rotated) and for electromagnetic optimization problems. The conventional QPSO has good searching capabilities. However, it has limitations, such as a slow convergence rate and unexpected premature convergence without appropriate search space exploration. As discussed, the primary problems are low convergence speed and premature convergence.

A. Parameter updating strategy

To improve convergence speed and avoid premature convergence, we have improved exploration capability; an updated contraction expansion coefficient is demonstrated in this proposed strategy according to Eq (3),

$$\beta = \mathrm{rand}() * \mathrm{N}(\mu, \sigma^2) \qquad (3)$$

Where$\mathrm{rand}()$ is a random number and $\mathrm{N}(\mu, \sigma^2)$is a cumulative distribution function. Besides, with an updated version of β proposed algorithm also used a revised set of random numbers and phi with 0.5 offsets instead of pure random numbers as given below in eq (4) and eq (5),

$$\varphi = \mathrm{u} + \mathrm{n}_{\mathrm{offset}} \qquad (4)$$

$$\rho = \mathrm{u} + \mathrm{n}_{\mathrm{offset}} \qquad (5)$$

B. Hybridization mechanism

In this section, we discuss how to increase the searching capabilities of optimization problems by using the best particle nomination (smart particle) in the swarm. The new study of QPSODE uses an archive memory bank to store current and past position of particle for improved selection of the global best particle.

Previous work mainly focused on selecting the global best particle $\mathrm{G}_{\mathrm{best}}$ from the $\mathrm{P}_{\mathrm{best}}$ of the current iteration of the population. The mechanism is represented mathematically as follows:

$$\mathrm{P}_{\mathrm{best}\ \mathrm{i}}(\mathrm{t}) = \begin{cases} \mathrm{X}_{\mathrm{i}} & \text{if } \mathrm{f}(\mathrm{X}_{\mathrm{i}}(\mathrm{t})) < \mathrm{f}(\mathrm{P}_{\mathrm{X}_{\mathrm{i}-1}}(\mathrm{t})) \\ \mathrm{P}_{\mathrm{X}_{\mathrm{i}-1}}(\mathrm{t}) & \text{otherwise} \end{cases} \qquad (6)$$

Furthermore, with smart behavior, the researchers analyzed the hybridization phenomenon to balance global search and local search of solution candidates in the search space. We present QPSODE, a hybrid algorithm framework that combines DE's crossover and selection operators with QPSO.

In the search space, the initial population $\mathrm{X}_{\mathrm{initial}} = [\mathrm{x}_{\mathrm{i}}, \dots\dots, \mathrm{x}_{\mathrm{M}}]$(M stands for swarm size) is generated randomly.In crossover, each particle x_{i} (t) ($\mathrm{i} = 1, \dots\dots; \mathrm{N}$) is copied from v_{i} with the probability Cr $\in [0,1]$ (crossover rate), is taken 0.9 because it shows good response to higher dimension search problems where i is equals an index $\mathrm{J}_{\mathrm{rand}} \in [1, \mathrm{N}]$ chosen,

$$\mathrm{x}_{\mathrm{i}}(\mathrm{t}+1) = \begin{cases} \mathrm{v}(\mathrm{t})\mathrm{P}_{\mathrm{boltzman}} & \leq \mathrm{Cr} \text{ or } \mathrm{i} = \mathrm{i}_{\mathrm{rand}} \\ \mathrm{x}(\mathrm{t}) & \text{otherwise} \end{cases} \qquad (7)$$

III. RESULTS AND ANALYSIS

In this section of the paper, we will evaluate the QPSODE algorithm's performance using 6 well-known benchmark functions. Nonlinear unimodal includes the Sphere, simple and rotated Griewank, as well as simple Schwefel's 2.22 and shifted Schwefel's 1.2 functions listed in Table 1, all of these functions are minimization problems, with a minimum value of 0. These benchmark functions best objective function results reported in Table 2.

To analyze QPSODE's performance, we perform a numerical comparison against with those well-known and standard evolutionary algorithms in the optimization field, like QPSO presented by Jun Sun et al.[14], GQPSO by L. dos S. Coelho [17], and LI-QPSO presented by Shouyong Jiang et al. [18], SQPSO [19], as well as DE [20]. This work also examines the QPSO and DE performing independently in this work to determine QPSODE's efficacy. Figure 1 shows a graphic report of HQPSODE's performance. The experiment's results demonstrate that combining QPSO and DE improves performance and effectiveness while addressing various optimization problems. We may conclude that DE improves the QPSO's exploration and exploitation capability to meet the needs of electromagnetic problem optimization.

Name	Benchmark Functions	Search Space	$f(x^*)$
Sphere	$f_1(x) = \sum_{i=1}^{n} x_i^2$	$[-100,100]^D$	0
Schwefel's 2.22	$f_2(x) = \sum_{i=1}^{n} \lvert x_i \rvert + \prod_{i=1}^{n} \lvert x_i \rvert$	$[-100,100]^D$	0
Rosenbrock	$f_3(x) = \sum_{i=1}^{n} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	$[-100,100]^D$	0
Griewank	$f_4(x) = \frac{1}{4000} \sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n} \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$	$[-100,100]^D$	0
Schwefel's Problem 1.2	$f_5(x) = \sum_{i=1}^{D} \left(\sum_{i=1}^{n} z_i\right)^2 + f_{bias_1}{}'$ $\mathbf{z} = \mathbf{x} - \mathbf{o}$ and $f_{bias_1} = -450$	$[-100,100]^D$	0
Griewank	$f_6(x) = \frac{1}{4000} \sum_{i=1}^{n} z_i^2 - \prod_{i=1}^{n} \cos\left(\frac{z_i}{\sqrt{i}}\right) + 1 + f_{bias_2}{}'$ $\mathbf{z} = \mathbf{x} - \mathbf{o}$ and $f_{bias_1} = -180$	$[-100,100]^D$	0

Table 1 Uni, Multi and Shifted Benchmark Functions

Algorithms	Sphere	Schwefel's 2.22	Rosenbrock	Griewank	Schwefel's Problem 1.2	Shifted Griewank
QPSO	-32.6	-7.82	0.75	-4.2	-7.48	-6.3
GQPSO	-14.4	-4.35	-2.42	-7.2	-3.2	-1.5
LIQPSO	-41.5	-5.02	-2.6	-5.3	-5.9	-3.1
SQPSO	-282.409	-37.12	-10.3333	-36.0437	-8.3842	-4.9681
DE	-13.623	-28.21	-1.33053	-27.9813	-2.27415	4.675412
HQPSODE	-481.587	-73.45	-38.2777	-72.9665	-11.1359	-6.29735

Table 2 Numerical Results of Best Objective Values for All Problems

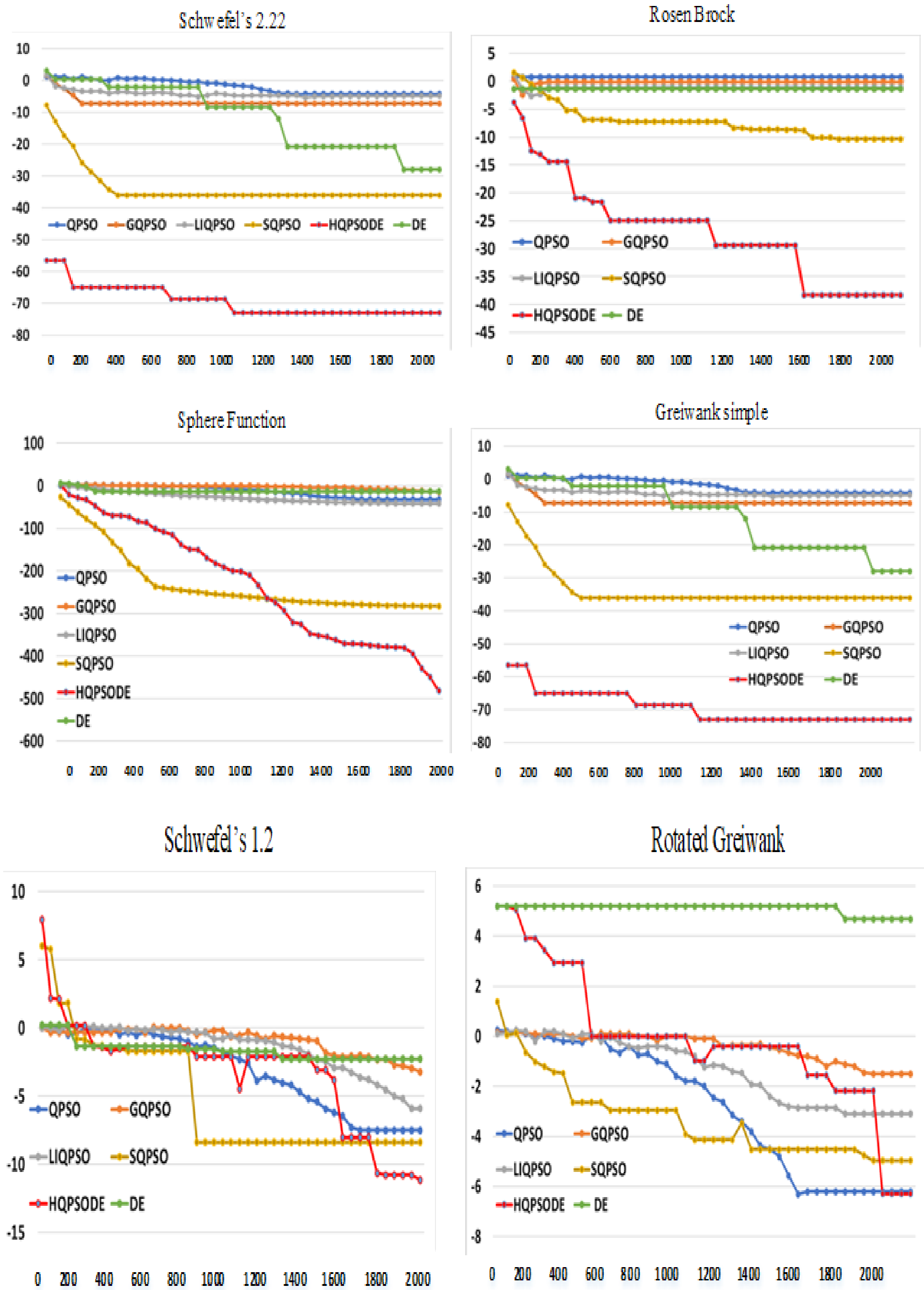

Figure1: The results of three different types of benchmark problems have been reported: shifting (Schwefel's Problem 1.2, Griewank), multimodal (Rosenbrock), and unimodal (Sphere, Schwefel's 2.22)

IV. NUMERICAL APPLICATION

An optimization algorithm is considered credible when it can solve many real-world problems. To validate the effectiveness of the proposed hybridized QPSODE, the superconducting magnetic energy storage (SMES) known as TEAM workshop problem 22 is chosen as a case study for engineering application, as shown in Fig. 2 [21].
This work aims to minimize the stray field outside external solenoids to improve safety.

$$\min f = \frac{B_{stray}^2}{B_{norm}^2} + \frac{|Energy - E_{ref}|}{E_{ref}} \quad (8)$$

where $|B_{max}|_{1,2} \leq 4.92T$ and B_{stray} are depicted in Eq. (9),

$$B_{stray}^2 = \frac{\sum_{i=1}^{22} |B_{stray,i}|^2}{22} \quad (9)$$

Moreover, when a magnetic field is created, the coil must be in quench condition to retain the physical state of coils and guarantee superconductivity within the solenoids. The current density is 22.5 A/mm2, so Bmaxshould be lower than 4.92 Tesla.

$$|J_i| \leq (-6.4|B_i + 56)(A/mm^2)(i = 1,2)$$

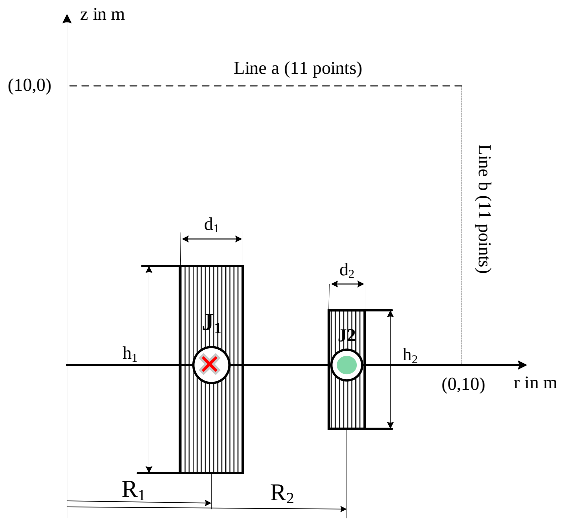

Figure 2: Schematic diagram of SMES optimization TEAM problem 22

Algorithm	R_2	$h_2/2$	d_2	OF
QPSO	3.0786	0.2414	0.3795	0.1077
GQPSO	3.1723	0.2319	0.3892	0.1222
LI-QPSO	3.0214	0.2732	0.3419	0.0959
SQPSO	3.0245	0.2561	0.2871	0.0278
DE	3.0214	0.2319	0.2892	0.0523
HQPSODE	3.0245	0.2561	0.2871	0.2777

Table 3 Performance Comparison of Different Optimal Algorithms on Team Problem 22

The experiment results shown in Table 3 show that HQPSODE is superior despite the fact that it converges quickly and performs more effectively compared to other techniques.

V. CONCLUSION

In this paper, to improve the reliability of the QPSO for electromagnetic optimization problems, HQPSODE using smart particle of SQPSO possesses several significant features: 1) smart particle, 2) memory archive. In order to improve the exploration, HQPSODE also adds new features as the non-linear adaptive control parameter, crossover, and DE selection strategy. The experimental data results show that this algorithm effectively improves global search ability and earlier convergence compared with other modified optimal QPSO algorithms. Moreover, the computational data verified its comprehensive application for multi-modal electromagnetic optimization problems.

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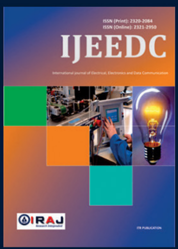

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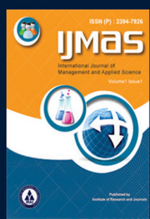

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