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Studying the Impact Force of Steel Wheel on the Elastic Half-Space by Dynamic Response Analysis

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Abstract:- For the purpose of realising the impact force on an elastic half-space wheel made of steel, a dynamic response analysis is established in terms of finite element analysis. Moreover, the finite element analysis is used for quantifying the maximum impact force in addition to detecting the value of the elastic modulus of the wheel. The research objective is to analyse the maximum acceleration of the wheel throughout the impact force process. However, the main affecting factors are the elastic modulus symbolled by (E), impact height symbolled by (h), as well as ratio of the Poisson symbolled by (σ) for the half-space, based on Palmgren empirical equation. In terms of the finite element method the impact force process is simulated at several Poisson's ratios and elastic modulus on the same wheel at several impact heights. Later, a diagram termed MAP, and the fitting equations of the correlation between the affecting factors and maximum acceleration are acquired. The simulation outcomes demonstrate that once the steel wheel influences an elastic half-space, a nonlinear quadratic relationship is obtained between the impact height, elastic modulus, and maximum acceleration of the wheel and elastic half-space. However, the half-space Poisson's ratio shows a slight impact reflected into the maximum wheel acceleration. Nevertheless, the error that is occurred between the interpolation, theoretic, as well simulation values was around 25%, which satisfies the engineering conditions. As a result, it is able to be applied in the dynamic process calculation for the impact force process that the wheel enforces on an elastic half-space. Moreover, the maximum acceleration of the wheel is linked to the major affecting factors throughout the influence force process. The elastic modulus and impact force of the elastic half-space additionally be predicted corresponding to the obtained fitting relationship.

***Keywords**:- Steel wheel; Palmgren, elastic half-space; Poisson's ratio; impact height; elastic modulus; and maximum acceleration..*

I. INTRODUCTION

In engineering field, the collisional influence between movable objects represents a major problem, and the analysis of the force impact process has continually been a frequently considered and complicated topic in the dynamics field (Zhai, Han, Chen, Ling, &Zhu, 2019). Within engineering, the steel wheel can be described as a component formed in a cylindrical shape. The influence between the plane and the steel wheel is a characteristic reflection of the reality of the influence between the plane and the cylinder. Typically, the plane structure, in reality, is represented using multi-layer structures, that are regarded as a corresponding structure to an elastic half-space (Brach, 2007).

The acceleration indicator is an essential parameter, since it is straightforward to measure within the analysis of the dynamic response, in addition, can completely reflect the dynamic parameters analysis. For instance, impact duration as well as force at the impact procedure (Wang, Nagayama, & Su, 2019). Thus, the analysis proceeding the variations of acceleration indicator once the steel wheel enforces force on the plane is of important implication in investigating the moving object's response throughout force impacting and quantifying the dynamic modulus and impacting force of elastic plane (Makhlouf & Aliofkhazraei, 2015). A characteristic, which is nonlinear strong is considered as one of the factors that impact the process that is influenced by several factors such as the shape of the structure, the initial conditions as well as material characteristics (Jin, Li, & Zhang, 2014).

As a result, a comprehensive theoretical approach to impact dynamics analysis has still not been established (Brunton, Budišić, Kaiser, & Kutz, 2021). For the purpose of investigating the force impact process, first Newton offered a kinematic recovery coefficient towards illustrating the variation within the velocity earlier collision process. Then, after the collision process between two objects (Khulief, 2013). Moreover, Poisson offered the recovery coefficient of the dynamic collision from the point of view of the momentum (Flores, 2021). Various researchers investigated the recovery coefficient of the collision process from the viewpoint of energy (Dragna, Pandrea, & Stănescu, 2021). Various Chinese researchers performed examinations

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of collision dynamics, in addition, to evaluating the appropriate requirements of the three collision coefficients in conjunction with the impact process accuracy of collision (Shen, Sun, Fan, Huang, & He, 2022; Ni, et al., 2021).

Various researchers applied kinematic recovery coefficient in order to assess the dynamic impact of rockfall on the ground. A study has indicated that the recovery coefficient of collision can clearly illustrate the change in an object's motion prior to and after exposing to a collision force, however, it cannot illustrate the dynamic parameters change for instant acceleration and force throughout the collision.The investigation of the impact process in terms of dynamic response concentrates on the contact mechanics area. The fundamental principle of the collision impact among elastomers was suggested by Hertz (Zeng, Huang, Wang, Guo, & Ye, 2021). According to Hertz's contact foreign mechanics, and domestic researchers performed various analyses on the impact dynamics among two spheres or plane and sphere or cylinder, thus, achieving a precise theoretical explanation (Zhu, et al., 2022; Tarodiya & Levy, 2021).

Nevertheless, it is not easy in the line contact analysis between plane and cylinder, as well as there still is no convenient and accurate solution obtainable (Tagliafierro, Domínguez, Crespo, & Göteman, 2022). Various research offered a nonlinear characteristics model in terms of the correlation between strain and impact according to the Hertz contact hypothesis, which is typically employed to examine the dynamic impact response between plane and cylinder (Chu, et al., 2022; Corral, Moreno, García, & Castejón, 2021; Abruzzo, Beghini, & Santus, 2022).

Nevertheless, the implicit formula implemented in the hypothesis becomes complicated to be employed in engineering applications. In order to provide its availability, several researchers offered experimental equations that implement display formulas, and the Palmgren equation is the highly and commonly recommended one (Invernizzi, Montagnoli, & Carpinteri, 2022). Even if the Palmgren experimental equation carry high-level of the computational precision, it is primarily applied for the dynamics impact process between a plane and a solid cylinder. However, the wheel made of steel is a familiar cylindrical shield structure in the field of engineering (Barroso, Pan, & Merino, 2022).

Until now, no proof is available to demonstrate that the dynamic impact force between elastic half-space and steel wheel can be resolved by utilising this equation. This paper offered a simulation analysis model of a wheel made of steel affecting the elastic half-space as a plane structure by implementing a finite element analysis process. According to the Palmgren equation, the major affecting factors influencing the dynamic process of the wheel steel affect the elastic half-space, typically defined also the steel wheel acceleration is considered as the supported (dependent) variable, founding the correlation between several affecting factors and the steel wheel acceleration.

II. LITERATURE REVIEW

Several investigations have been carried out based on the analysis of the mathematical model of dynamic response, considering the impact force on a rigid structure such as a wheel made of structural steel or another material with tensile strength. Dynamic response surveys have also been used to determine the effect of a dynamic force on a rigid structure, particularly on a specific contact part, using computer-aided analytical design (CAD) software.

In (Bogdevicius, Zygiene, Bureika, & Dailydka, 2016) simplified technique is provided to determine the force of the wheel's impact vertically with the interaction between the rail and the flat. The presented technique confirmed its ability to use it to determine the contact force at its maximum level, as well as its distribution across the length of contact between the rail and the affected wheel. It was discovered that the vertical exposed force relies on both wheel and rail geometrical parameters, vehicle speed and the rail deviation angle. Based on the simulation findings, it was revealing the influence of the wheel geometrical factors, vehicle speed to maximum limit of contact force along with its distribution within the contact area.

According to (Steenbergen & Metrikine, 2007), this study proposed a typical beam model based on an elastic-half space, which is assumed to be a modular design and is used to study and explain a slab-railway system for loading a moving train. The power of the probe lies on the effect of describing the half-space plane and beam interface on the moving response in terms of the circumferential path. This research has three traditional methods, the first traditional method and the second simplified. In the first method, it was proposed that traction, which is uniformly distributed under the beam cross section, while half-space plane and beam continuity are required along the midline of the beam. In relation to the second method, all stresses are still considered in the design and are uniformly distributed over the beam, while the average displacement in terms of half-space the distance under the beam and the beam displacement require continuity. While the third method is considered the standard method in terms of contact mechanics.

As proposed in (Bian, Gu, & Murray, 2013), a finite element analysis (FEA) was carried out on a three-dimensional model to study the effect analysis driven by the flat wheel by means of the FEA package integrated in the ANSYS software. It was discovered that the existence of a flat wheel significantly boosts the dynamic force on the sleeper and rail. Moreover, it was observed that the flat wheel size was increased monotonically increase.

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III. METHODOLOGY

➢ *Determining Method of the Main Affecting Factors*

The main steps to specify the affecting factors of the dynamic impact response are simplifying the concerning model, then determining the major affecting factors, in terms of the next assumptions:

- *The elastic modulus of the wheel made of steel varies considerably from the plane structure (elastic half-space), therefore the wheel made of steel is considered as the fixed body.*
- *Small strain is considered within the dynamic impact process, which is confirmed by the elastic half-space.*
- *No horizontal forces, just the vertical force is distributed on the contact part, within the dynamic impact process.*
- *Choosing a smooth contact surface, not including frictional force. Figure 1 shows the dynamic impact model:*

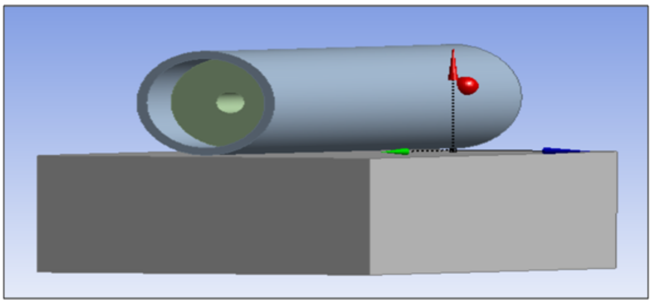

Fig 1 Steel Wheel Diagram.

Based on the stated assumptions, the maximum value of the contact force is uniformly distributed among the tessellation line, in addition to its amount can be resolved by the Hertz principle and Palmgreng experimental equation. However, once the cylinder enforces effect on the elastic half-space, the correlation between the deformation and the impact force can be expressed as in Eq.1:

$$F = K\varepsilon^n \quad \text{Eq.1}$$

Where the term F denotes the impact force in N, the term ε denotes the elastic half-space deformation in m; the term denotes the cylinder nonlinear index, which is 10/9 according to the Palmgren elastic contact model; and the term K denotes the contact equivalent stiffness, which typically is contingent on the contact body shape and material. Based on the Hertz contact principle and Palmgren contact model, thus, the contact equivalent stiffness (K) can be expressed using Eq.2:

$$K = \frac{\pi}{(2 \times 3.81)^n} \frac{E \times 10^{-6}}{1-\sigma^2} (1000\,L)^{(\frac{8}{9})} \quad \text{Eq.2}$$

Where the term E denotes the elastic modulus of the material, in MPa; the term σ denotes the elastic half-space Poisson's ratio, and the term L denotes the elastic line contact length, in mm. Therefore, the maximum impact once the cylinder affects the plane (elastic half-space) can be expressed using Eq.3: E=2500 MPa

$$F_m = K\left[1000(n+1)\frac{m_l}{K}gh\right]^{(\frac{n}{n+1})} \quad \text{Eq.3}$$

Where the term Fm denotes the maximum impact, the term h denotes the wheel impact height in mm; the term ml denotes the cylinder mass in kg. Based on Newton's Second Law, the maximum acceleration (am) once the cylinder affects the plane can be expressed using Eq.4:

$$a_m = \frac{F_m}{m_l} = \frac{K}{m_l}\left[(n+1)\frac{m_l}{K}gh\right]^{(\frac{n}{n+1})} \quad \text{Eq.4}$$

According to Eq.4, within the process, once the cylinder affects the plane, the dynamic impact response is linked to the cylinder dimensions impact height (h), length (L), and mass (m), in addition to (E) and (σ) of the material the elastic modulus and Poisson's ratio, respectively. This paper aims to analyse the correlation between the dynamic response change and the elastic half-space change of the concerned teel wheel including the correlation between the impact height change, steel wheel response, and the elastic modulus. Therefore, the steel wheel dimensions, particularly the mass (m) and length (L) are adjusted to fixed values

.

➢ *Materials and Finite Element Analysis Model*

Based on the stated assumptions, a model of the finite element analysis is set up using Ansys software, as shown in Figure 2. In the developed model, the steel wheel length is adjusted at 0.6 m as the material density is adjusted at 7.8 µkg/mm^3.

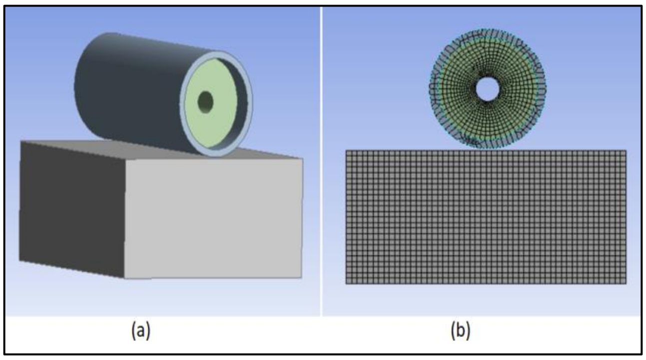

Fig 2 The Wheel Model a) the Finite Element Analysis Model, and b) the Meshing Model.

The conducted calculation indicates that the wheel mass in kg is 81.1, whereas the Poisson's ratio parameter is 0.3, as well as the elastic modulus value, is 310 GPa. The elastic half-space size is 6×3×3 m as well as it assumes symmetry limitations to symmetric parts and fixed limitations to bottom parts and other sides. However, the elastic half-space density of is 2.4 µkg/mm^3, and both Poisson's ratio parameter and elastic modulus are adjusted as independent quantities. The elastic modulus range is between the values 500-8500 MPa, whereas the range values of the Poisson's ratio parameter are between 0.2-0.4 (Bogdevicius, Zygiene, Bureika, & Dailydka, 2016).

To simulate the concerned model in terms of Ansys software, hexahedron integral element within 8 nodes and quadratic tetrahedron integral element of 10 nodes will be selected. Based on the stated assumptions model of the finite element analysis of the impact force, the direction is adjusted vertically downward, without large deformation, taking into consideration the conducted calculation. In order to ensure that the model simulation is without an hourglass problem, the total energy during the process is zero. According to the selection of the quadratic tetrahedron integral element of 10 nodes, the accuracy will be enhanced, and at the same time, the required calculation that will be considerably increased.

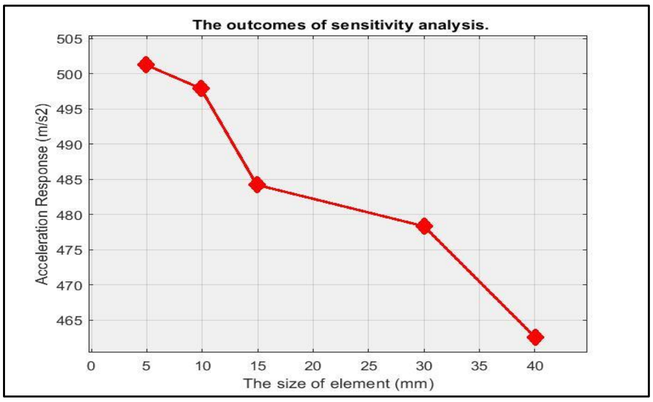

Fig 3 The Outcomes of Sensitivity Analysis.

For the purpose of determining the appropriate size of the mesh, the sensitivity testing is conducted on the FEA model. The value of the plane elastic modulus is adjusted at 6500 MPa whereas the value of Poisson's ratio parameter is preserved fixed value of 0.3. According to the simulation, the size of the grid is set at 0.04, 0.03, 0.015, 0.01, and 0.005 m, respectively.

The outcomes of the sensitivity analysis are demonstrated in Figure 3. In accordance with Figure 3, it could be observed that as the size of the grid is smaller than 0.01 m, the acceleration response is deaccelerated. Thus, once the grid size became 0.005 m, the calculation convergence is achieved. At the same time, to confirm the convergence condition greater time to solve is required.

When, the grid is adjusted at the Z direction, far away about 0.03 m from the elastic half-space outermost to 0.005 m within the middle, whereas the X and Y directions are adjusted to 0.015 m. The simulation outcomes are similar, but the required calculation time shows a considerable decrease of about 28%. As a result, the model is subdivided into meshes as indicated in Figure 2(b).

IV. RESULTS AND DISCUSSION

➢ *FEA Model Validation*

The value of the plane elastic modulus is adjusted at 6500 MPa whereas the value of Poisson's ratio parameter is preserved fixed at 0.3, in order to validate the FEA rationality. The force impact process is solved at different impact hight of 0.01, 0.02, and 0.03 m respectively. The stress nephogram is shown in Figure 4, once the steel wheel height falls to 0.03m. As observed according to Figure 4, once the wheel impacts the elastic half-space, the contact force is uniformly distributed among the tessellation line, as well as it just shows a slight increase at the rim of the wheel. Furthermore, the contact stress reveals elliptical distribution in the contact width, according to the line in the Hertz contact hypothesis. Since the steel wheel was considered a rigid body, the dynamic impact response at the total points at the wheel body is similar once the steel wheel affects the plane of elastic half-space.

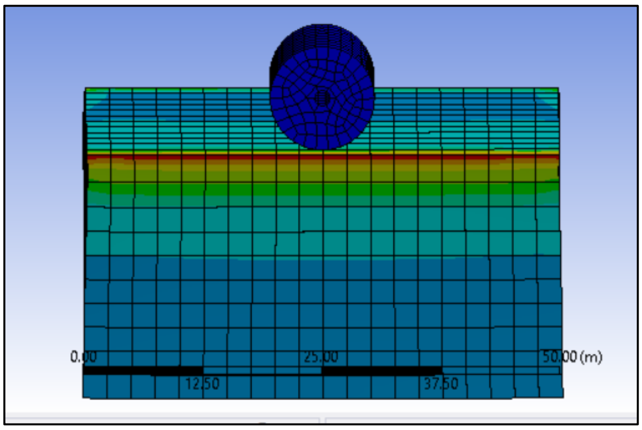

Fig 4 Stress Nephogram.

By the assumption of, that the top part of the steel wheel, particularly the top centre is regeared as the test point, and the impact height is adjusted at 0.01, 0.02, and 0.03 m, with varying elastic modulus between the values 2500 and 6500 MPa, with fixed Poisson's ratio parameter at 0.3, the acceleration, stress, in addition to velocity response is acquired, as in Figure 5, Figure 6, and Figure 8. Figure 5 demonstrates the velocity response through the dynamic impact process. As observed, once the wheel falls to several hight at the same time affects the elastic half-space, in terms of different Poisson's ratio and elastic modulus values; the velocity response shows that it is only influenced by the height with a slight impact of both Poisson's ratio and elastic modulus variation. Based on the kinematic definition of the recovery coefficient termed by the letter e, as expressed in Eq.5, the findings have been confirmed in Table 1.

$$e = \frac{v_t}{v_0} \qquad \text{Eq.5}$$

Figure 6 indicates the curve of the dynamic impact response once the wheel made of steel affects the half-space. Corresponding to Figure 6, through the impact force process, a huge influence has been exposed due to the elastic modulus on the dynamic impact force, which reveals that as the value of elastic modulus increases, the impact force increases as well. Furthermore, elastic modulus influenced the impact interval, that is, as the value of elastic modulus increases, the shorter interval. However, Poisson's ratio has a slight influence on the dynamic impact force and time.

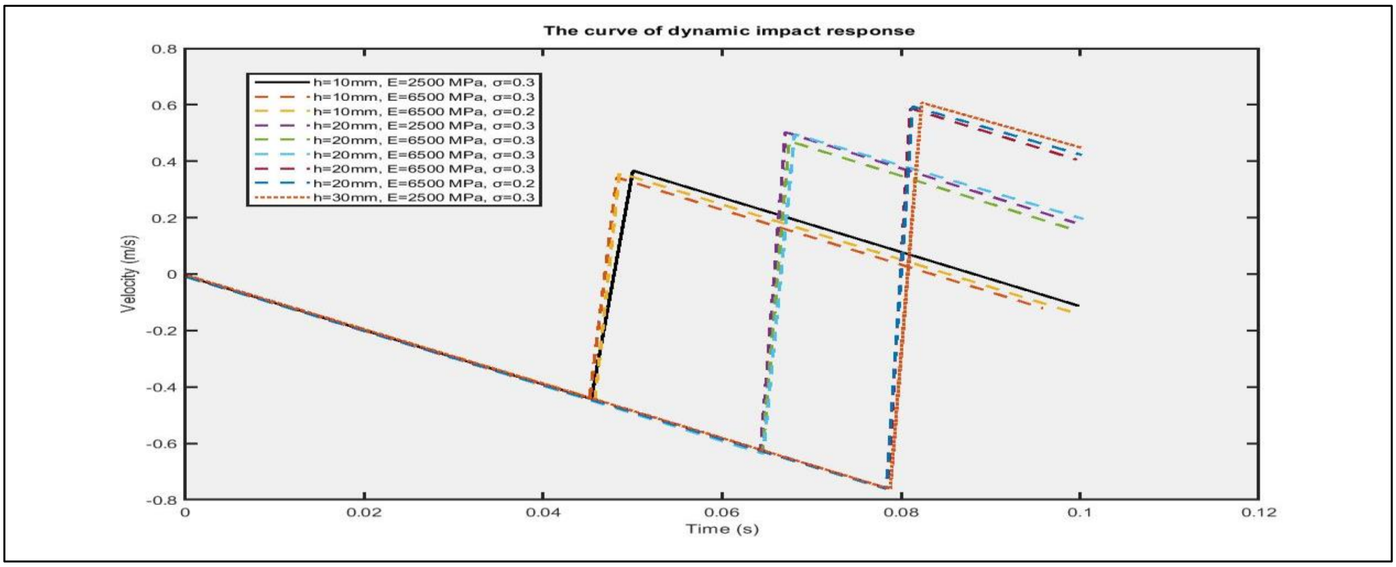

Fig 5 The Curve of Dynamic Impact Response.

Figure 6 reveals the curve of the maximum acceleration response, in terms of the steel wheel within the dynamic impact process. As observed, a huge influence has been exposed due to the elastic modulus on the acceleration response, which reveals that as the value of elastic modulus increases, the acceleration response increases as well. Similarly, Poisson's ratio has a slight influence on the dynamic impact force and time.

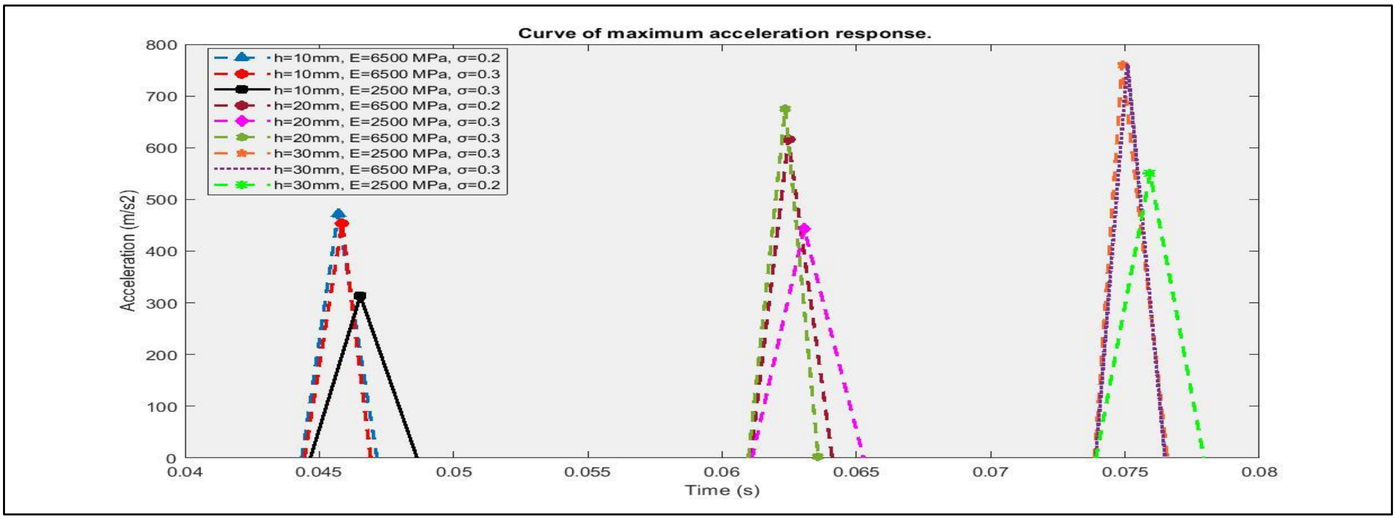

Fig 6 Curve of Maximum Acceleration Response.

A comparison was conducted between the simulated maximum acceleration, as well as velocity responses, and between the calculated impact force and acceleration as in Eq.3 and Eq.4. The plane (elastic half-space) within the process in terms of several Poisson's ratios and elastic modulus is influenced by the similar falling level of the steel wheel structure with various impact heights. The kinematic recovery coefficient earlier the impact and after it is about 0.66. Thus, it could be discovered that both elastic half-space material and impact height do not show any influence on the kinematic recovery coefficient within the impact force system.

According to Eq.3, the resulting error is 10% between the calculation and simulation findings of the maximum impact force. According to Eq.4, the resulting error is about 20% between the calculation and simulation findings of the maximum acceleration response. Thus, it satisfies the engineering conditions. Consequently, it is able to be employed in the dynamic process calculation of the impact

force process, in terms of the wheel enforcing an impact on an elastic half-space

- *Acceleration Response due to the Influence of Poisson's Ratio Change*

To study the steel wheel response in terms of the Poisson's ratio change, the impact force process is conducted using Ansys simulation, when the value of the plane elastic modulus is adjusted at 500, 2500, 4500, 6500, 8500 MPa, whereas the value of Poisson's ratio preserved fixed at 0.2, 0.25, 0.3, 0.35, 0.4, as well as the impact height is adjusted at 0.01 and 0.03 m, respectively.

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Figure 7 indicates the simulation outcome of maximum acceleration change in terms of the impact height was adjusted at 0.01 and 0.03 m, respectively, whereas the Poisson’s ratio varies between the values of 0.2 to 0.4 in conjunction with various elastic modulus values.

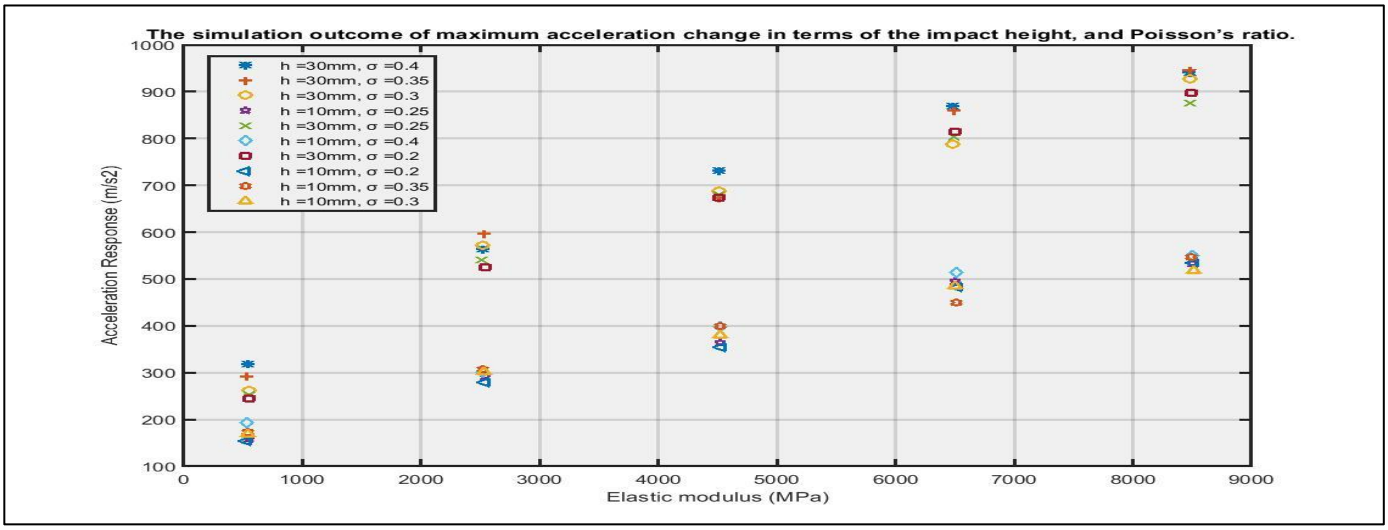

Fig 7 The Simulation Outcome of Maximum Acceleration Change in Terms of the Impact Height, and Poisson’s Ratio.

According to Figure 7, it could be observed that when the plane (elastic half-space) adjusted within the range of Poisson’s ratio between 0.2-0.4 and the constant elastic modulus 4 is affected by the similar falling level of the wheel at the identical height, however, the maximum acceleration shows the slight change. Therefore, Poisson’s ratio change shows a slight impact on the maximum acceleration exposed on the wheel.

Figure 8 indicates the simulation outcome of impact duration change in terms of the impact height was adjusted at 0.01 and 0.03 m, respectively, whereas the Poisson’s ratio varies between the values of 0.2 to 0.4 in conjunction with various elastic modulus values.

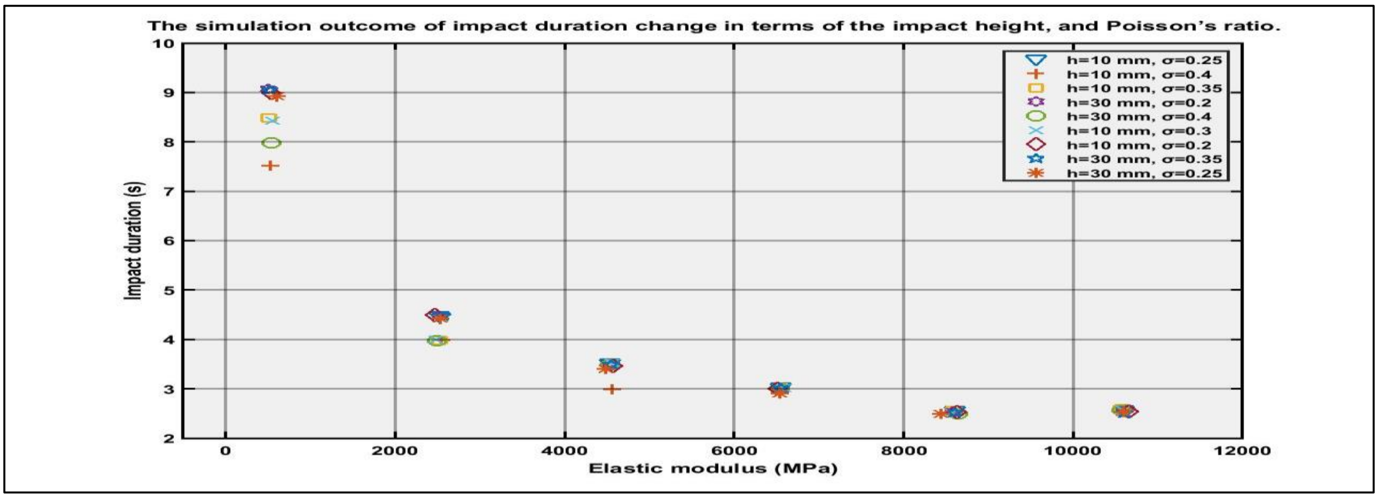

Fig 8 The Simulation Outcome of Impact Duration Change in Terms of the Impact Height, and Poisson’s Ratio.

Based on Figure 8, it could be concluded that when the plane (elastic half-space) adjusted within the range of Poisson’s ratio parameter between 0.2 to 0.4 and the constant elastic modulus is less than 2500 MPa shows a significant influence on the impact duration affected by the similar falling level of the wheel at the identical height, however, the maximum acceleration shows a slight change. Therefore, Poisson's ratio change shows a slight impact on the maximum acceleration of the wheel. Nevertheless, when the constant elastic modulus is larger than 2500 MPa, the change within Poisson's ratio shows no influence on the impact duration.

➢ *Acceleration Response due to the Influence of Elastic Modulus Change*

To study the steel wheel response in terms of the elastic modulus change, the impact force process is conducted using ANSYS simulation, when the value of the plane elastic modulus is adjusted at 500-14500 MPa, whereas the Poisson’s ratio parameter preserved fixed at 0.3, as well as the impact height is adjusted at 0.01 and 0.04 m,

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respectively. Figure 8 reveals the simulation outcome of maximum acceleration change in terms of various elastic modulus values.

As observed, as the elastic modulus increases the maximum acceleration increases as well when the elastic half-space plane is affected by the wheel within a similar height, which expresses the nonlinear quadratic relationship. The fitting relation curves, between the elastic modulus and maximum acceleration, within various impact heights, is demonstrated in both fit curve of height 0.01 and 0.04 m. According to the relations, it could be discovered that the R-squared value is greater than 0.95, hence, the fitting relation curves show a high level of accuracy.

- *Acceleration Response due to the Influence of Impact Height Change*

For the purpose of discovering the steel wheel response in terms of the impact height change, the impact force process is conducted using ANSYS simulation, when the value of the plane elastic modulus is adjusted at 500-14500 MPa, whereas the Poisson's ratio parameter preserved fixed at 0.3, as well as the impact height is adjusted at 0.01 and 0.04 m, respectively. Figure 9 reveals the simulation outcome of maximum acceleration change in terms of various impact height values.

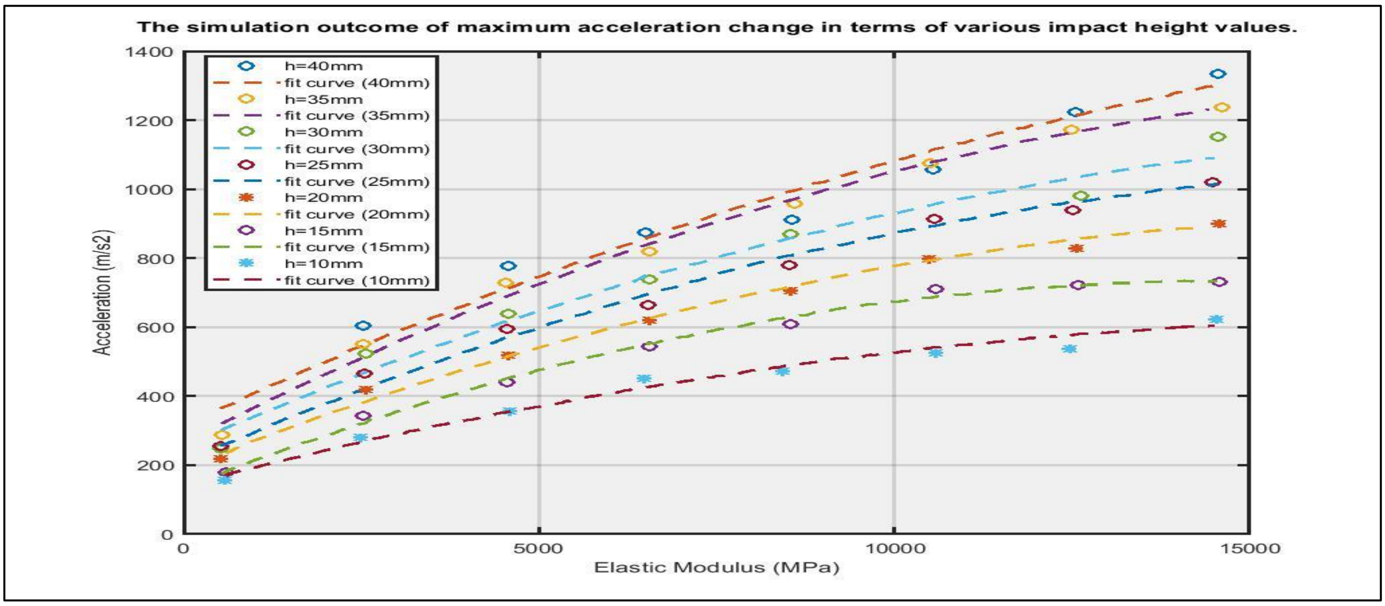

Fig 9 The Simulation Outcome of Maximum Acceleration Change in Terms of Various Impact Height Values.

The relationship of the maximum acceleration regarding the impact height change has been studied in this paper, as illustrated in Figure 10.

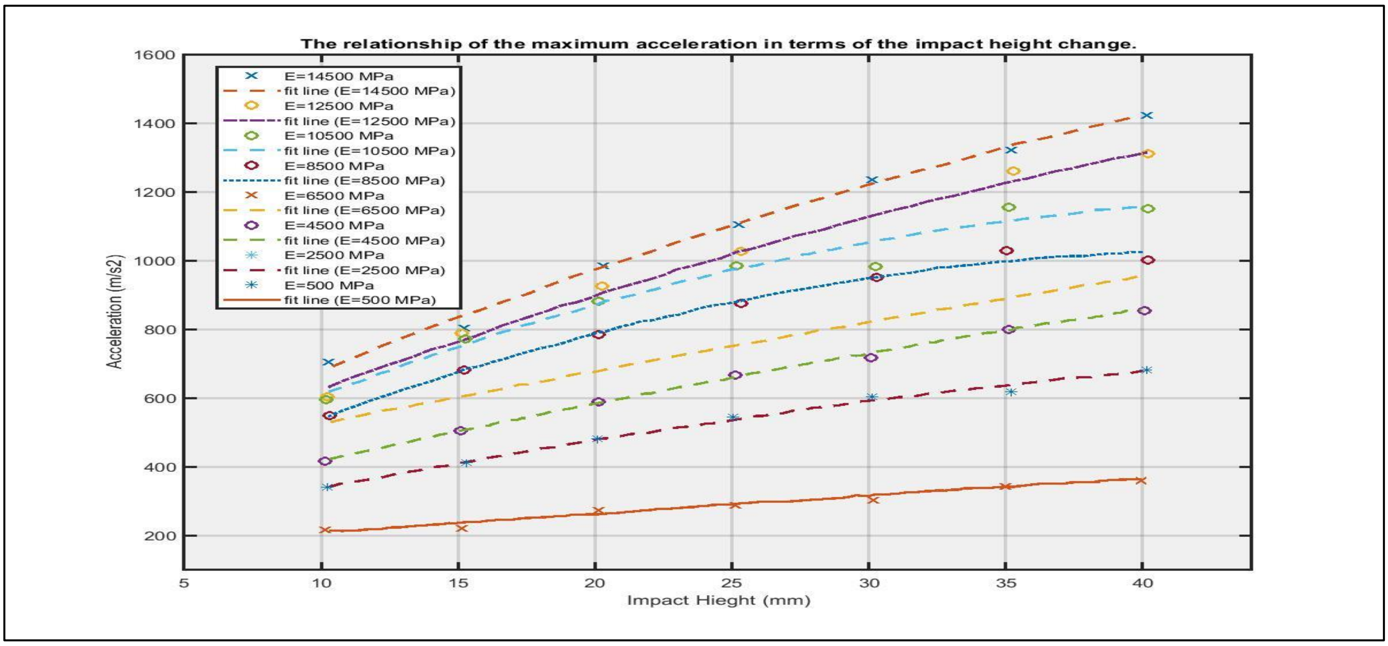

Fig 10 The Relationship of the Maximum Acceleration in Terms of the Impact Height Change.

According to Figure 10, it could be observed that when the elastic modulus is kept fixed, the relationship between the impact height and maximum acceleration is proportional.

Thus, as the impact height increases the maximum acceleration increases as well when the elastic half-space plane is affected by the wheel within a similar height, which expresses the nonlinear quadratic relationship. The fitting relation curves, between the impact height and maximum acceleration, within various impact heights are demonstrated as both fit curves of elastic modulus at 500 and 14500 MPa. According to the relations, it could be discovered that the R-squared value is greater than 0.95, hence, the fitting relation curves show a high level of accuracy.

- *Acceleration Response due to the Influence of Various Impacting Factors Change*

To examine the influence of diverse impacting factors on a dependent variable, the steel wheel acceleration response, several factors were adjusted as an independent factors such as wheel impact height, and the plane elastic modulus. In addition, the MAP diagram is shown in Figure 11, which indicates the correlation between diverse impacting factors and the maximum acceleration.

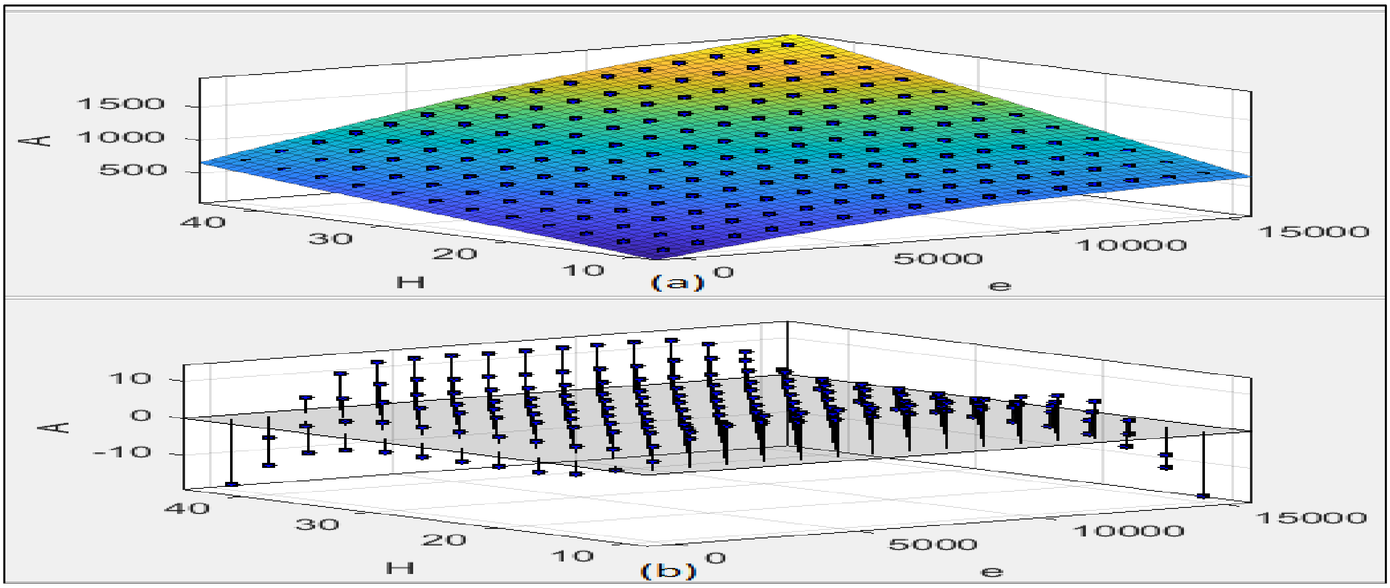

Fig 11 The Correlation between Diverse Impacting Factors and the Maximum Acceleration.

Figure 11(a) reveals the MAP diagram of the correlation between diverse impacting factors and the maximum acceleration, and Figure 11(b) reveals a residual plot regarding the fitting rational curves. According to Figure 11(a), it could be observed that the points illustrated depend on the impact height and elastic modulus in terms of the horizontal axis whereas the values of residual are represented in the vertical axis, which is without outliers. As noticed, the points scattered in a random manner upward and downward all around the plane along with a zero residual value. Consequently, the previous discovery indicates that the simulation fitting values are fairly fitted taking into consideration the regression surface. Eq.6 expresses the fitting relationship:

$$A = -30.36 + 0.05878E + 16.66h - 2.372 \times 10^{-6} + 0.001262Eh^2 \qquad \text{Eq.6}$$

To confirm the accuracy level of the fitting findings, four dissimilar elastic modulus values, and four dissimilar impact heights are selected randomly, for the purpose of conducting calculation and simulation analysis.

Based on the obtained results and the aforementioned equations from Eq.1 until Eq.4, it could be demonstrated that the theoretical findings are higher compared to the simulation and interpolation findings, within an error of about 25%. Nevertheless, the engineering condition is met. Therefore, it is confirmed its ability to be applied in the dynamic process calculation of a specific steel wheel, within a length of 0.6 m and mass of 81.1 kg, affecting the plane (elastic half-space).

V. CONCLUSION

In this paper, the impact force on an elastic half-space wheel made of steel, and the dynamic response analysis were determined in terms of finite element analysis. Based on the Palmgren elastic contact model and the Hertz contact hypothesis, it was proved that the most affecting factors, in the dynamic response are the elastic modulus, impact height, as well as Poisson's ratio regarding the half-space plane. The impacting forces was applied in terms of the impact height adjusted at 0.01, 0.02, and 0.03 m, with varying elastic modulus between the values 2500 and 6500 MPa, with fixed Poisson's ratio at 0.3.

The findings indicated that the recovery coefficient at every single process was consistent. Moreover, the resulting error between the theoretical and calculation findings regarding the maximum impact force according to Eq.3 is lower than 10%. Whereas the resulting error between the theoretical and calculation findings regarding the maximum acceleration according to Eq.4 is lower than 20%.

Furthermore, the impact force process was conducted using simulation, when the value of the plane elastic modulus was adjusted at 500, 2500, 4500, 6500, and 8500 MPa, whereas the value of Poisson's ratio was kept fixed at 0.2, 0.25, 0.3, 0.35, 0.4, as well as the impact height is adjusted at 0.01 and 0.03 m, respectively. As a result, the simulation findings demonstrated that when the plane (elastic half-space) regulated between the range of Poisson's ratio from 0.2 to 0.4 and the constant elastic modulus was influenced by the similar falling level of the wheel at the identical height, however, the maximum acceleration shows the slight change. Therefore, Poisson's ratio change shows a slight impact on the maximum acceleration of the wheel, whereas a considerable effect on the impact duration.

For the purpose of finding out the response of the steel wheel in terms of the change of the impact height, the impact force operation is performed using Ansys simulation, when the value of the level elastic modulus is set at 500-14500 MPa, while the value of the Poisson ratio is kept constant at 0.3, and also the impact height is adjusted at 0.01 and 0.04 meters, respectively. The simulation findings, as the elastic modulus increases the maximum acceleration increases as well, when the elastic half-space plane is affected by the wheel within a similar height, which expresses the nonlinear quadratic relationship.

According to the simulation findings regarding several impacting factors simultaneously, it was shown that the theoretical results are higher compared to the simulation and interpolation results, within an error of about 25%. However, the geometrical condition was met. Consequently, the finite element analysis (FEA) model is demonstrated to be acceptable, and the acquired simulation findings have the ability to be applied in the dynamic process calculation of a specific steel wheel, within a length of 0.6 m and mass of 81.1kg, affecting the plane

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