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Motorised System for Loading and Unloading of Press Dies in Press Machine

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Abstract: The paper describes the use of a plate heat exchanger in transferring heat between two fluids. It explains that the design of a plate heat exchanger involves multiple heat transfer plates held together by a fixed plate and a loose pressure plate. These plates have a gasket arrangement that creates separate channel systems for the primary and secondary media, allowing for counter-current flow and effective heat transfer. To manufacture the corrugated plates, the text mentions the use of Hydraulic Press Machines with different capacities depending on the plate dimensions. The process involves changing heavy press dies, which is time-consuming and decreases overall plant efficiency. To address this issue, a proposed solution is to semi-automate the loading and unloading of press dies. A mechanical system is designed, comprising a table with rollers and linear motion guideways. The system utilizes a Ball screw mechanism powered by a servo motor and driven by a Worm Gearbox. The orientation of the motor, perpendicular to the line of motion, saves space and provides more working space on the workshop floor. In summary, the proposed solution aims to increase efficiency and safety by implementing a mechanical system for loading and unloading press dies in plate heat exchanger manufacturing, incorporating a Ball screw mechanism, servo motor, and Worm Gearbox.
Keywords: Solidworks, FEA, Press Die Machine, Ballscrew

I. INTRODUCTION

The job of loading and unloading the press die is done manually with the help of a crane which is a tedious task. Moreover, the crane is not sufficient to insert the die completely into the press machine. This consumes excessive time, physical work and contributes to the idle time of the plant thereby reducing its productivity.
A dedicated sturdy mechanism needs to be developed for loading and unloading of these dies in the press machine with minimum human interference and is time efficient. To overcome these problems, a mechanism is required to accelerate the die changing process. A motorized die loading and unloading mechanism using a Ball Screw, worm and worm wheel gearbox, rollers and linear motion guideways is adopted for this purpose. The solution aims to reduce the time required for this process with minimum effort and ensuring the safety of workers.
The precise loading and unloading of the die are ensured to reduce the damage. By studying the various methods of performing the task of loading and unloading of dies, selection of the best mechanism is promoted. The designing of the parts and assembly of the system is accomplished using SOLIDWORKS. While the analysis and simulation were performed using ANSYS. The results were then compared and verified, and the necessary improvisations were implemented before proceeding for manufacturing.

A. Problem Statement

Design and analyse a mechanism to carry out the tedious task of loading and unloading dies with the help of a ballscrew mechanism accompanied with linear motion guideways. the problem statement revolves around improving the efficiency of die loading and unloading processes, minimizing manual handling risks, reducing die damage, and enhancing overall productivity and cost effectiveness

B. Objective

1) To design and develop a press tool changing attachment with minimum material, minimum overall cost, and significant strength.
2) To reduce total idle time of press machine while die changing operation to 1 hour or less.
3) To load dies in the range of 2 to 15 tonnes for a stroke distance of 2.5m with minimal human interference.

C. Scope

The proposed solution will focus on significantly reducing the time required for loading and unloading dies during changeovers. The objective is to minimize downtime and increase the overall efficiency of the plant. The automated system will aim to protect the integrity of the dies during the loading and unloading process.The scope of the project will include integration of the automated system with the existing press machine setup.

II. LITERATURE REVIEW

This paper presents a numerical investigation of die loading in extrusion-based additive manufacturing, with a focus on understanding the effects of different process parameters on die loading and identifying strategies to minimize its impact. The article "Numerical Investigation of Die Loading in Extrusion-Based Additive Manufacturing" presents a numerical study on the die loading behavior in the extrusion-based additive manufacturing process. The authors propose a finite element model to simulate the die loading process and investigate the effects of various parameters, such as the die geometry, material properties, and process conditions. The results show that the die loading behavior is highly sensitive to these parameters and can significantly affect the quality and accuracy of the printed parts. The study provides insights into the die loading mechanism and offers guidance for optimizing the process parameters to improve the performance of extrusion-based additive manufacturing[1]. This paper presents the design and development of a pneumatic die loading mechanism for sheet metal forming that is intended to reduce operator fatigue and increase productivity. The mechanism uses pneumatic cylinders to load and unload the die, and it is capable of handling dies up to 200 kg. This paper presents an automated die loading and unloading system for metal stamping that is designed to improve productivity and reduce operator workload. The system uses a hydraulic mechanism to load and unload the die, and it is capable of handling dies up to 1000 kg. The article "Design and Development of a Pneumatic Die Loading Mechanism for Sheet Metal Forming" describes the design and development of a pneumatic mechanism for loading and unloading dies in sheet metal forming. The authors propose a new design that uses pneumatic cylinders to lift and lower the dies, which offers several advantages over traditional mechanical systems, such as improved speed, accuracy, and safety. The article presents a detailed description of the design and construction of the mechanism, as well as the results of tests conducted to evaluate its performance. The study concludes that the pneumatic die loading mechanism is a viable and effective alternative to traditional mechanical systems for sheet metal forming applications[2].This paper has presented work on hydraulic scissors lift which is developed to lift upto 300 kg load at a height of around one meter. This mechanism is specially designed for loading and unloading press tool dies by considering press machine shop where installation of Gantry cranes and use of forklift is not convenient. A simple attachment is also provided for pulling the die from bolster plate to the scissor lift platform. This whole arrangement is mounted on AGV. The objective of the present work is to design and develop a press tool changing attachment with minimum material, minimum overall cost and significant strength. Design calculations must not be exceeded standards, allowable maximum deflection and stresses. To analyze and validate manual calculations, solid modeling and computer simulations are involved using CATIA v5 R19 and Hypermesh 11.0 softwares. The research highlights to reduce total idle time of press machine while die changing operation results in increased production rate. Number of trials are taken on the same model in press machine shop. Total time required for changing and remounting the die is reduced by approximately half an hour compared to existing method of press tool changing. The design of a die for an industrial part involves creating a tool or mold that can shape raw materials, such as metal or plastic, into a specific shape or form. The design process typically starts with analyzing the part's geometry, material properties, and production requirements. The die design involves selecting appropriate materials, determining the die's shape and size, and choosing manufacturing methods that can produce the die accurately and costeffectively. The design may also involve considerations such as required tolerances, the type of press or machine that will be used to stamp or form the part, and necessary maintenance procedures. The goal of die design is to create a tool that can efficiently produce parts that meet required specifications, while minimizing waste, defects, and production costs[3]. The article "Design and Development of Press Tool Changing Attachment on Automated Guided Vehicle" presents a new design for a press tool changing attachment that can be mounted on an automated guided vehicle (AGV) for use in a press shop. The authors propose a modular design that allows for quick and easy tool changing, which can improve the efficiency and flexibility of the press shop. The article presents a detailed description of the design and construction of the attachment, as well as the results of tests conducted to evaluate its performance. The study concludes that the press tool changing attachment on an AGV is a viable and effective solution for improving the performance of press shops[4]. The article "Dynamic properties analysis of ball screw feed system based on improved hybrid model" presents an improved hybrid model that analyzes the dynamic properties of a ball screw feed system used for precision positioning in industrial applications.

The proposed model takes into account the interaction between the mechanical components of the system and is used to investigate the system's natural frequencies, vibration modes, and damping characteristics. The article also presents experimental results that validate the accuracy of the proposed model. The study concludes that the improved hybrid model can be used to optimize the design and control of ball screw feed systems, leading to improved performance and reliability in precision positioning applications. Behavior and assists in optimizing its performance for precision positioning and motion control applications[5]. The article "Development of a Motorized Die Loading System for a High-Speed Press" describes the development and testing of a motorized die loading system that can be used in high-speed press operations. The authors propose a design that uses a motorized cart to transport the dies to and from the press, which can improve the efficiency and safety of the die loading process. The article presents a detailed description of the design and construction of the system, as well as the results of tests conducted to evaluate its performance. The study concludes that the motorized die loading system is a viable and effective alternative to traditional manual systems for high-speed press operations[6]. The article "Automated Die Loading and Unloading System for Metal Stamping" describes the design and development of an automated system for loading and unloading dies in metal stamping operations. This paper presents a new die loading method for sheet metal forming processes that involves the use of a spring-back compensation mechanism to improve dimensional accuracy and reduce tool wear. The authors propose a modular design that can be customized to fit different press sizes and die configurations, which can improve the efficiency and flexibility of the stamping process. The article presents a detailed description of the design and construction of the system, as well as the results of tests conducted to evaluate its performance. The study concludes that the automated die loading and unloading system is a viable and effective solution for improving the productivity and safety of metal stamping operations[7].The article "Finite Element Analysis of Progressive Die Loading for Sheet Metal Forming" presents a finite element analysis (FEA) study on the progressive die loading process in sheet metal forming. The authors propose an FEA model that can simulate the die loading behavior and investigate the effects of various parameters, such as the die geometry and material properties. This paper presents a finite element analysis of the progressive die loading process used in sheet metal forming, with a focus on identifying the factors that influence die loading and their effects on the final product. The results show that the die loading behavior is highly sensitive to these parameters and can significantly affect the quality and accuracy of the formed parts. The study provides insights into the progressive die loading mechanism and offers guidance for optimizing the process parameters to improve the performance of sheet metal forming processes[8]. The article "Analysis of Power Screw Using 'Ansys'" presents a finite element analysis (FEA) study on the behavior of a power screw under various loading conditions. The authors propose an FEA model in ANSYS that can simulate the mechanical behavior of the screw and investigate the effects of various parameters, such as the pitch, lead, and friction coefficients. The results show that the model can accurately predict the stress distribution and deformation of the screw and can be used to optimize the design parameters for maximum strength and durability The study concludes that ANSYS is a powerful tool for analyzing the behavior of power screws and can help to improve their performance and reliability in industrial applications[9]. The article "Development of a New Mechanical Die Loading System for HighSpeed Stamping" describes the design and development of a new mechanical system for loading and unloading dies in high-speed stamping operations. The authors propose a modular design that can be customized to fit different press sizes and die configurations, which can improve the efficiency and flexibility of the stamping process. The article presents a detailed description of the design and construction of the system, as well as the results of tests conducted to evaluate its performance. The study concludes that the new mechanical die loading system is a viable and effective solution for improving the productivity and safety of highspeed stamping operations[10]. The article "Influence of die guidance systems on the angular deflection of press slide and die under eccentric loading" investigates the effect of die guidance systems on the angular deflection of press slides and dies under eccentric loading. The authors propose a finite element analysis (FEA) model that can simulate the behavior of the press and die system, and investigate the effects of various parameters such as the die guidance system, eccentricity, and material properties. The results show that the choice of die guidance system can significantly affect the angular deflection of the press slide and die, which can lead to increased wear and tear and reduced productivity. The study concludes that proper selection and optimization of the die guidance system is important for improving the performance and reliability of press operations[11].

III. METHODOLOGY

A. Ballscrew

Ball screws, also called a ball bearing screws, recirculating ball screws, etc., consist of a screw spindle and a nut integrated with balls and the balls' return mechanism, return tubes or return caps. Ball screws are the most common type of screws used in industrial machinery and precision machines. The primary function of a ball screw is to convert rotary motion to linear motion or torque to thrust, and vice versa, with the features of high accuracy, reversibility and efficiency.

There are many benefits in using ballcrews, such as high efficiency and reversibility, backlash elimination, high stiffness, high lead accuracy, and many other advantages. Compared with the contact thread lead screws as shown in ,a ballscrew adds balls between the nut and spindle. The sliding friction of the conventional screw is thus replaced by the rolling motion of the balls

B. Linear Motion Guideways

A linear guideway allows a type of linear motion that utilizes rolling elements such as balls or rollers. By using re- circulating rolling elements between the rail and the block, a linear guideway can achieve high precision linear motion. Compared to a traditional slide, the coefficient of friction for a linear guideway is only 1/50. Because of the restraint effect between the rails and the blocks, linear guideways can take up loads in both the up/down and the left/right directions. With these features, linear guideways can greatly enhance moving accuracy, especially, when accompanied with precise ball screws.

C. Servo Motor

A servomotor acts like a rotary actuator that is mainly used to change electrical input into mechanical acceleration. This motor works based on servomechanism wherever the position feedback is utilized for controlling the speed & the final location of the motor. Servo motors turn & get a certain angle based on the applied input. Servo motors are small in size, but they are very energy efficient.

D. Gearbox

Gearbox allows for the adaptation of power sources to meet specific operational needs. By changing gear ratios, the speed can be increased or decreased to optimize performance, productivity, and energy efficiency. It is also helpful in changing the direction of transmission.

E. Rollers

Rolling bearings support and guide, with minimal friction, rotating or oscillating machine elements – such as shafts, axles or wheels and transfer loads between machine components.Rolling bearings provide high precision and low friction and therefore enable high rotational speeds while reducing noise, heat, energy consumption and wear. They are cost- effective and exchangeable machine elements that typically follow national or international dimension standards.Rollers are installed over the die table to ensure smooth flow of the die while loading and unloading

F. Frame

Cast iron was selected as the material for the table frame due to its outstanding qualities such as high strength, rigidity, and excellent damping properties. These attributes are crucial in ensuring the stability and performance of the entire assembly.

IV. MATHEMATICAL MODELLING

Given
Mass = 15000kg
Maximum speed (Vmax) = 1 m/s
Acceleration time = 1
Guide surface resistance = 50N
Mass of pushing mechanism = m2 = 50 kg
Preload = 5000 N
Rated rpm of motor = 2000 rpm

$$\text{Selection of lead} = \frac{\max speed * 1000 * 60}{rated\ rpm}$$

$$= \frac{1 * 1000 * 60}{2000}$$

$$= 30\ \text{mm}$$

Minor diameter $(d_m) = major\ diameter - 2(thread\ depth)$

Thread depth = 0.5 * pitch
= 0.5*10 = 5mm

Minor diameter $(d_m) = 55 - 2(5)$ = 45mm

End cap type large nut which are suitable for fast feed is chosen (FSC-50-30K4) As it is a high speed transfer equipment and no impact load is present.

Basic load rating-

$$C_a = 58kN$$

$$C_{oa} = 117.5\ kN$$

Rigidity K = 629kN/μm

For nut,

Outside diameter = 75 mm

D1 = flange diameter = 110 mm

Overall length = 130mm

Calculating service lifetime on basis of nominal life:

Nominal life =22.06154889 $* 10^9$ revolutions

Average revolution per minute = 1600 min^{-1}

$$L_h = \frac{L\_10m}{N_m}$$

$$L_h = 22971.668\ hrs$$

Efficiency of the ball screw:
= (output power ÷ input power) * 100 (nm= mechanical efficiency = 0.40)
= ((axial load * speed * load) ÷ 2 π * 1000) ÷ ((axial load * speed) ÷ 367 *nm)
= (30 * nm * 367) ÷ (2 π * 1000)
= (30 * 0.40 * 367) ÷ (2 π * 1000) = 71 %

*Driven torque = mta = (F * P) ÷ (2000 π * n) { n = 0.9 }*
*= (15050 * 30)) ÷ (2000 π * 0.9)*
= 79.89 Nm
*Driven power = Pa = (mta * n) ÷ 9550*
*= (79.89 * 16) ÷ 9550*
= 0.1337 kW
As assuming velocity with which the mechanism moves v = 3 m/min
v = πdn ÷ 1000
*(3 * 1000) ÷ (55 * π) = n = 16 RPM*
Therefore, final RPM of the system = 16 RPM
from the catalogue, the Gearbox selected is - Bonfiglioli W 75 – L1 – UF1 – 125 – B3 and a servo motor of 0.18kW power and 2000 rpm is selected for the purpose.

For rollers ,
douter = 62 mm
We know that load of 1kg = 9.81 N
Number of rollers required = 28
*Thus, Total load = 9.81 *15000 = 147150 N*
Load per roller = Total load / Number of rollers =5255.36 N (Axial Load)
Bearing Life (L10) L10= 60n L10h 106 (Considering bearing life of 8000 hours for machines used for short and intermittent capacity) = 60(200(considered))8000 106
= 96 million rev
Dyanamic Load Capacity (C): C = P(L10)
0.3 = 5255.36(96)0.3*
=20667.3N
As equivalent of roller bearing load = 5.255 KN Dynamic load capacity = 20.667 KN
Bearing support unit
From the catalogue, the most suitable bearing support unit is BK 50
d1 = 50mm Bore depth A = 9mm h = 48 mm M6 H1 = 70 mm weight = 2.40 kg T = 35mm

V. CAD DEVELOPMENT

The CAD model of each component was designed using SOLIDWORKS Software. The dimensions for the same were calculated in detail in the previous chapter. After the development of all the components, the complete assembly was prepared using the appropriate relations among all the components.

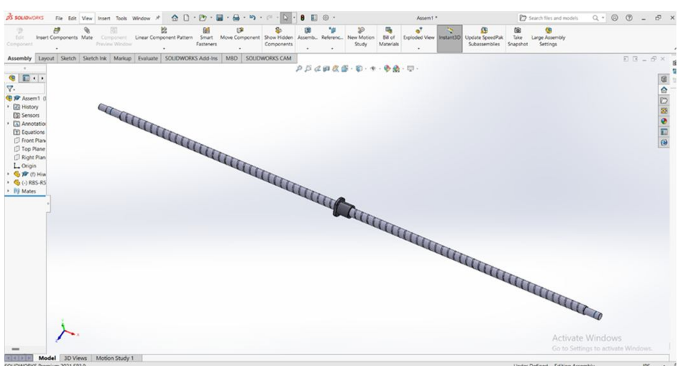

Fig 5.1: CAD model of ballscrew

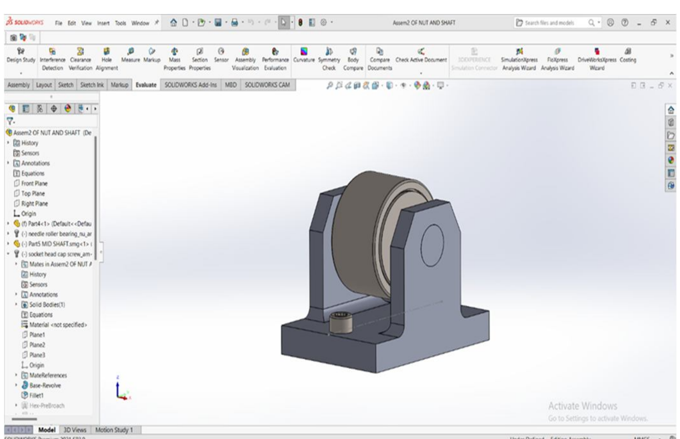

Fig 5.2 : CAD model of Roller

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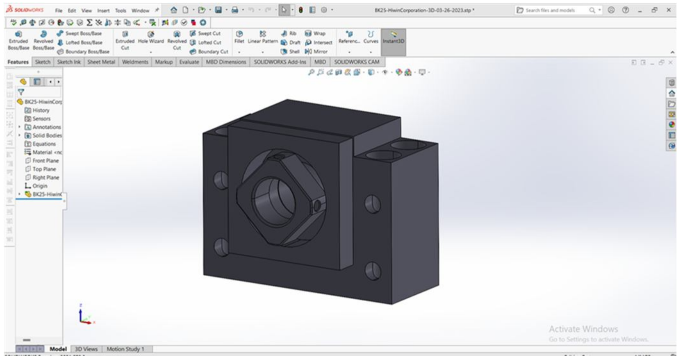

Fig 5.3: CAD model of bearing support unit

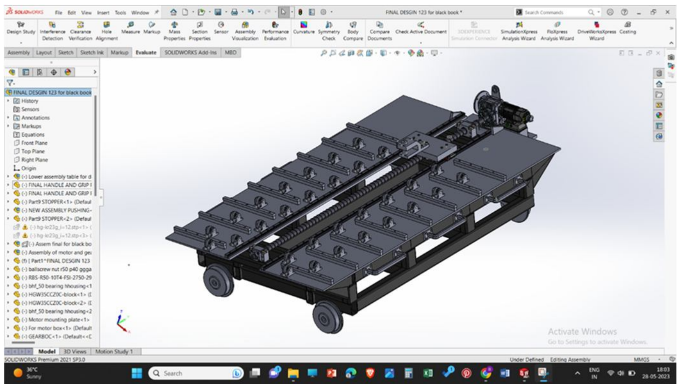

Fig 5.4: CAD model of the assembly

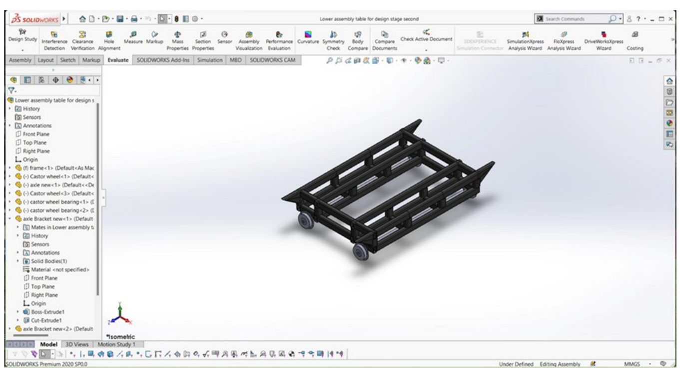

Fig 5.5: Frame

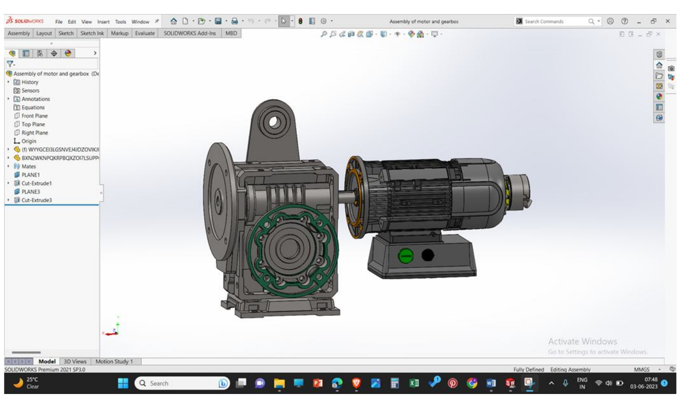

Fig 5.6: Gearbox and motor

VI. EXPERIMENTAL VALIDATION

The CAD models developed were analysed using Ansys software. The total deformations and equivalent shear stress is studied under the section.

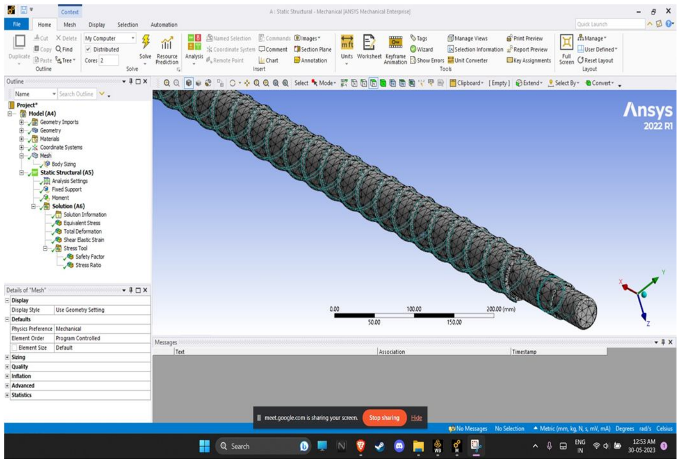

Fig 6.1 Meshing of ballscrew

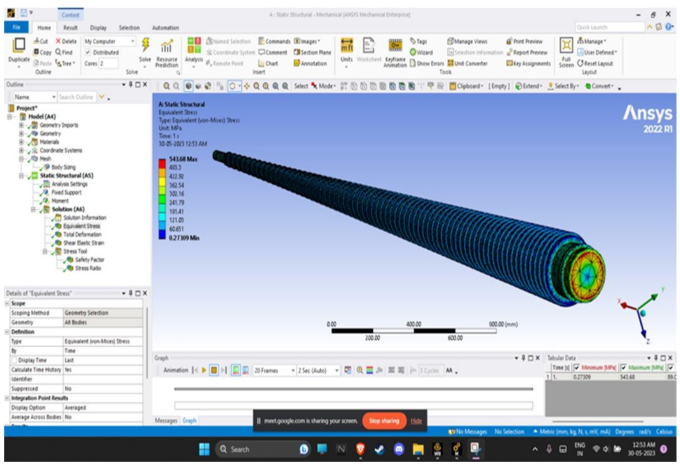

Fig 6.2 Deformation in ballscrew

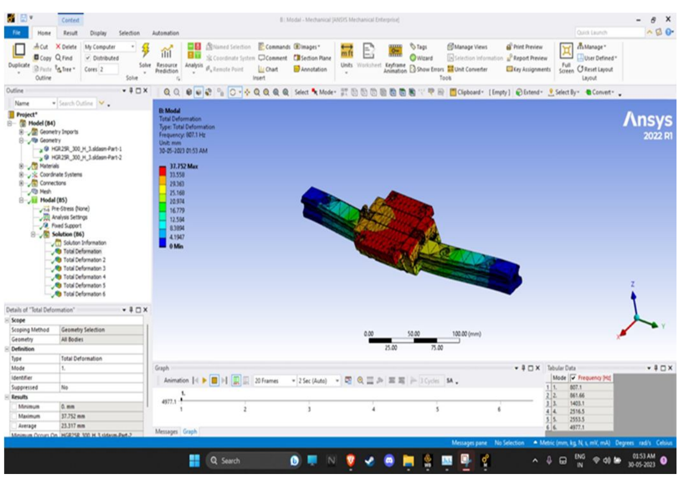

Fig 6.3 Deformation in LM guideways

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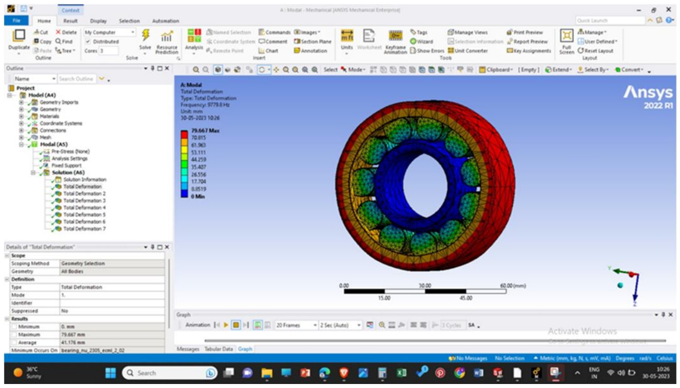

Fig 6.4: Deformation in rollers

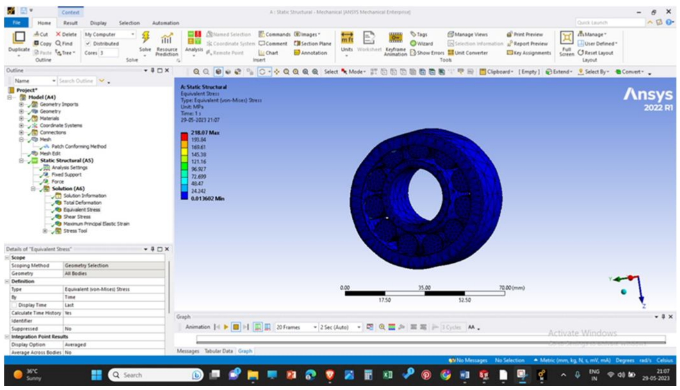

Fig 6.5 Equivalent Stress in Roller

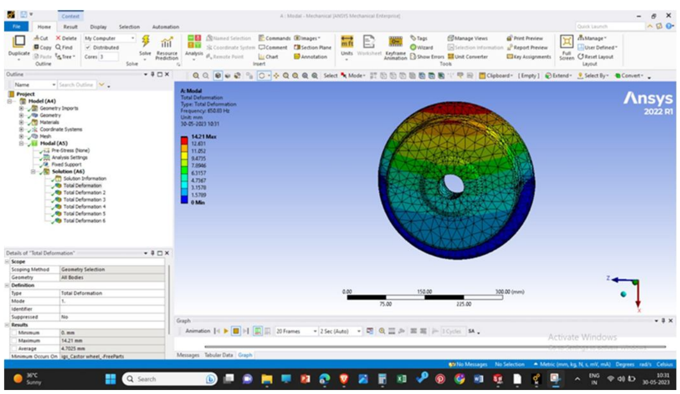

Fig 6.6: Deformation in Castor wheel

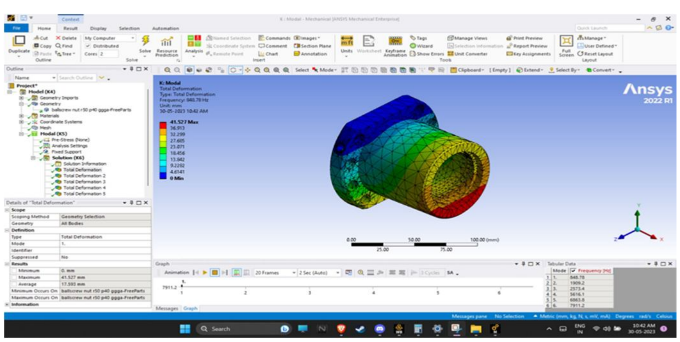

Fig 6.7: Deformation in nut

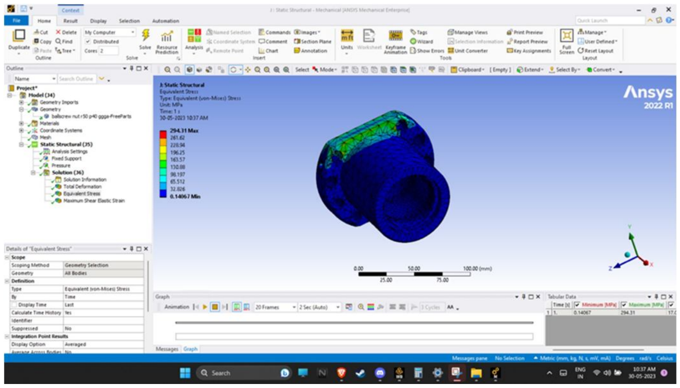

Fig 6.8: Equivalent stress in nut

VII. RESULTS

The following is the result table obtained after performing
Static Analysis on the components of the Assembly.
The calculated efficiency of the system is 52%.
Calculated efficiency of ball screw is 71%.
Time required is reduced by 80% to 85%.
That is, the same function is completed in 45 mins to 1 hour.
On implementing the proposed solution, the FMEA or t
he RPN is calculated to be 294.75

.

Component	Nodes	Elements	Total Deformation (mm)	Equivalent (Von-Mises) Stress(Max) (MPa)	Elastic Shear Strain
Ballscrew	162674	100262	2.3468	543.68	0.003374
Wheel	14057	8064	0.04698	92.03	0.001068
Roller	68851	37755	0.002086	218.07	0.005753
Axle	28253	15987	1.0684	137.27	NA
Nut	22911	12950	0.23571	294.31	0.0019271
LM guideways	46276	26519	0.37752	5.49	3.64e-5

Result Table For Static Analysis

The following is the result table obtained after performing Modal Analysis on the components of the Assembly

Component	Total Deformation (mm)	N1 (HZ)
Nut	41.527	848.78
Wheel	14.21	650
LM guideways	37.753	807.1
Axle	3.2452	73.827
Roller	80	9779.8

Result Table For Modal Analysis

VIII. CONCLUSION

In conclusion, the project focused on the design and validation of a press tool changing attachment using SolidWorks. The project successfully achieved its objectives, resulting in the following key outcomes:

Design Development: Multiple design concepts were generated and evaluated, leading to the selection of the most suitable design concept for further development. The 3D CAD model created using SolidWorks accurately represented the press tool changing attachment and its assembly.

Validation and Performance: Through structural analysis and simulations using SolidWorks Simulation, the design was validated for strength, stability, and performance. The results confirmed that the design met the required criteria and demonstrated its suitability for the intended application. Collaboration and Documentation: Effective collaboration with industry partners facilitated the manufacturing phase. The detailed design documentation, including engineering drawings, specifications, and assembly instructions, provided clear guidance for the industry to produce the press tool changing attachment. Continuous Improvement: Feedback from Company, including industry experts and Project Manager, was collected and incorporate into the design. Revisions and refinements were made to enhance the design, ensuring continuous improvement and optimization. The successful design and validation of the press tool changing attachment using SolidWorks provide the industry with an efficient and reliable solution. This project contributes to reducing idle time, improving productivity, and enhancing work efficiency

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