ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

Comparison of L-Shaped and Circular Punch Holder Mechanisms in Sheet Metal Dies Using Finite Element Analysis

Hilal Kir[1]; Yahya Işik[2]; Mustafa Yazar[3]

[1,2]Department of Mechanical Engineering, Faculty of Engineering, Bursa Uludag University, Bursa, Turkiye
[3]R&D Department, Şahinkul Machine and Spare Parts Manufacturing Co. Ltd., Bursa, Turkiye

Publication Date: 2025/12/19

Abstract: In this study, the mechanical performance of the widely used L-shaped punch holder mechanism and a newly developed circular punch holder mechanism for sheet metal forming dies was comparatively investigated. Finite Element Analysis (FEA) was performed using the Ansys software to evaluate the static structural behavior of both mechanisms under applied loads. The materials employed in the analyses were AISI 1050 steel, D2 tool steel, and grade 12.9 AISI 4140 bolts. According to the obtained Von-Mises stress and total deformation results, the circular punch holder exhibited lower stress (593 MPa) and deformation (5.94 mm) values compared to the L-shaped holder (617 MPa, 6.16 mm). The circular design, fastened with two M6 bolts, provided better structural stability than the L-type configuration using a single M8 bolt. Additionally, the new circular design allows the assembly of punches with various diameters, offers easier installation in narrow spaces, and ensures a cost advantage. As a result, the developed circular punch holder mechanism presents an innovative and practical solution that enhances production efficiency and contributes directly to industrial manufacturing applications.

Keywords: *Punch Holder Mechanism; Sheet Metal Forming Die; Finite Element Analysis.*

How to Cite: Hilal Kir; Yahya Işik; Mustafa Yazar (2025) Comparison of L-Shaped and Circular Punch Holder Mechanisms in Sheet Metal Dies Using Finite Element Analysis. *International Journal of Innovative Science and Research Technology*, 10(12), 941-952. https://doi.org/10.38124/ijisrt/25dec582

I. INTRODUCTION

The technological developments in the automotive industry contribute to the improvement of the properties of steel sheets used in production. Lightweight yet high-strength sheet materials are among the factors that increase tool wear, especially in sheet metal forming dies operating under high loads [1,2]. In sheet metal forming dies, tool wear is frequently observed due to the contact occurring between the workpiece and the cutting tools, friction, lubrication effects, and surface roughness [3]. In particular, during the cutting and punching operations of more ductile materials, the cutting punches undergo deformation in the direction of the hole as they separate from the elastic sheet material, and dragging and pulling behaviors occur on the punch surface during this process. In such cases, the proper selection of lubricant plays a critical role in increasing the punch tool life [4].

Various methods have been proposed to prevent tool wear. One of these methods is surface coating of forming punches [5, 6]. Among the factors causing tool wear in cutting punches, deformations resulting from the inability to achieve complete alignment due to very small die clearances in fine blanking processes also play a role [7]. During the cutting process, the holder mechanism that supports the cutting punch and ensures its strong operation may loosen over time at its connection points under the applied forces, leading to axial misalignments. This situation shortens tool life and causes decreases in production quality. When the studies in the literature are examined, Akyürek et al. investigated the effect of optimum punch–die clearance on tool wear [8]. Li and his colleagues, on the other hand, emphasized the difficulty of die design and developed a model that automatically assigns punch holder mechanisms for hole surfaces with different geometries on the sheet. In their study, the large number of punches on the die were automatically designed and modeled. The punches, designed together with punch holder mechanisms, also provided increased strength values during the cutting process [9]. Semaan and his colleagues aimed to increase the tool life of cutting punches in their study by evaluating the punch geometry and fastening methods they used with a finite element model, thereby improving the punch efficiency [10].

Increasing the strength of cutting punches and preventing axial misalignments caused by frictional forces required performing finite element analyses of the holder

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

mechanism to which the punch is fixed. For this purpose, based on one of the similar studies in the literature—specifically the evaluation of punch holder mechanisms by Semaan and colleagues [10]—the current design was examined. Punch holder mechanisms obtained from supplier companies were compared with the newly designed punch holder mechanisms developed by the company conducting the study. In particular, the effects of changing the number of bolts connecting the punch holder body and the punch holder, as well as the types of springs used in the mechanism, were examined in detail.

The original contribution of the study is the analysis of both the widely used L-shaped punch holder mechanisms in the literature and the evaluation of the design and performance of circular punch holders, which require less assembly space and allow the installation of punches with different diameters. The newly developed circular punch holders offer higher strength, cost advantages, and ease of use in narrow spaces compared to existing designs. This comprehensive approach aims to provide direct contributions to industrial applications and to introduce a new perspective to the literature.

II. MATERIALS AND METHODS

Sheet metal forming dies are classified as simple dies (in which only a single operation is performed), transfer dies, drawing dies, and progressive dies. One of the most commonly used processes in these die operations is the sheet metal punching process [11]. Punching operations are employed not only due to the geometrical requirements of the part but also to prevent the misalignment of sheet blanks within the die. Punches, which are essential components of sheet metal forming dies, can be mounted independently onto the die or can be fixed using a punch holder mechanism. The punch holder mechanism is shown in Figure 1.

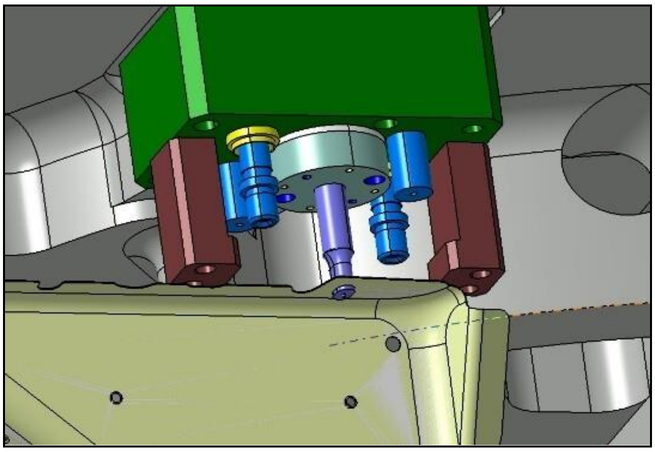

Fig 1 Punch Holder Mechanism Mounted on the Die.

Punch holder mechanisms consist of components such as the punch, punch holder, punch holder body, guide bushing, spring, and the crush plate used to absorb a portion of the load applied on the punch. Punch holders are generally mounted onto the die body. These mechanisms, which are mounted onto the die body, ensure that the punches remain fixed and operate safely during the sheet metal punching process under dynamic and static loads. The 3D model of the punch holder mechanism components is shown in Figure 2.

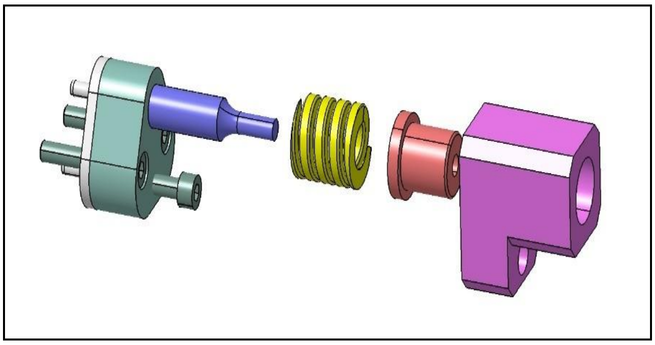

Fig 2 Components of the Punch Holder Mechanism.

Punch holders operate in a fixed position by being attached to the upper die. During the punching process, the punch holder mechanism, which is connected to the die using pins and bolts as shown in Figure 2, applies force to the guide bushing when it comes into contact with the sheet material, thereby causing the die spring to compress. As the die spring compresses, the punch tip advances through the sheet metal and creates the hole. When the process is completed and the press returns to its initial position, the punch holder returns to its pre-compression position as the applied pressure on the mechanism decreases. This process is repeated throughout the production cycle, and over time, it leads to failures in the punch holder mechanism.

- *Design of the Punch Holder Mechanism*

Sheet metal forming dies are production tools that consist of different die elements depending on the geometry of the sheet part and that withstand high forming forces. Among the various parameters considered in the design and manufacturing of these dies, one of the most common processes is the punching–cutting operation. The punch mechanisms used in these operations are generally purchased externally by die manufacturing companies and then mounted onto the die. In this study, it was observed that as a result of the forming operations, the connections between the punch holder body and the punch holder loosened due to the high forces and the wear occurring between the sheet material and the punch, which ultimately led to axial misalignments. To prevent these problems, the aim was to increase the strength of the punch mechanism under operating conditions and to produce punch holder mechanisms manufactured at lower cost as an alternative to the externally supplied ready-made punch holders.

In sheet metal forming dies, the standard L-shaped punch holder mechanism and a newly designed circular punch holder—allowing punch assembly in smaller spaces and capable of being fastened with two or more metric bolts instead of a single mounting bolt—were developed. The designed punch holder mechanisms were modeled using Catia V5 software. The technical drawings of the modeled L-shaped and circular punch holder mechanisms are presented in Figure 3a and Figure 3b, respectively.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

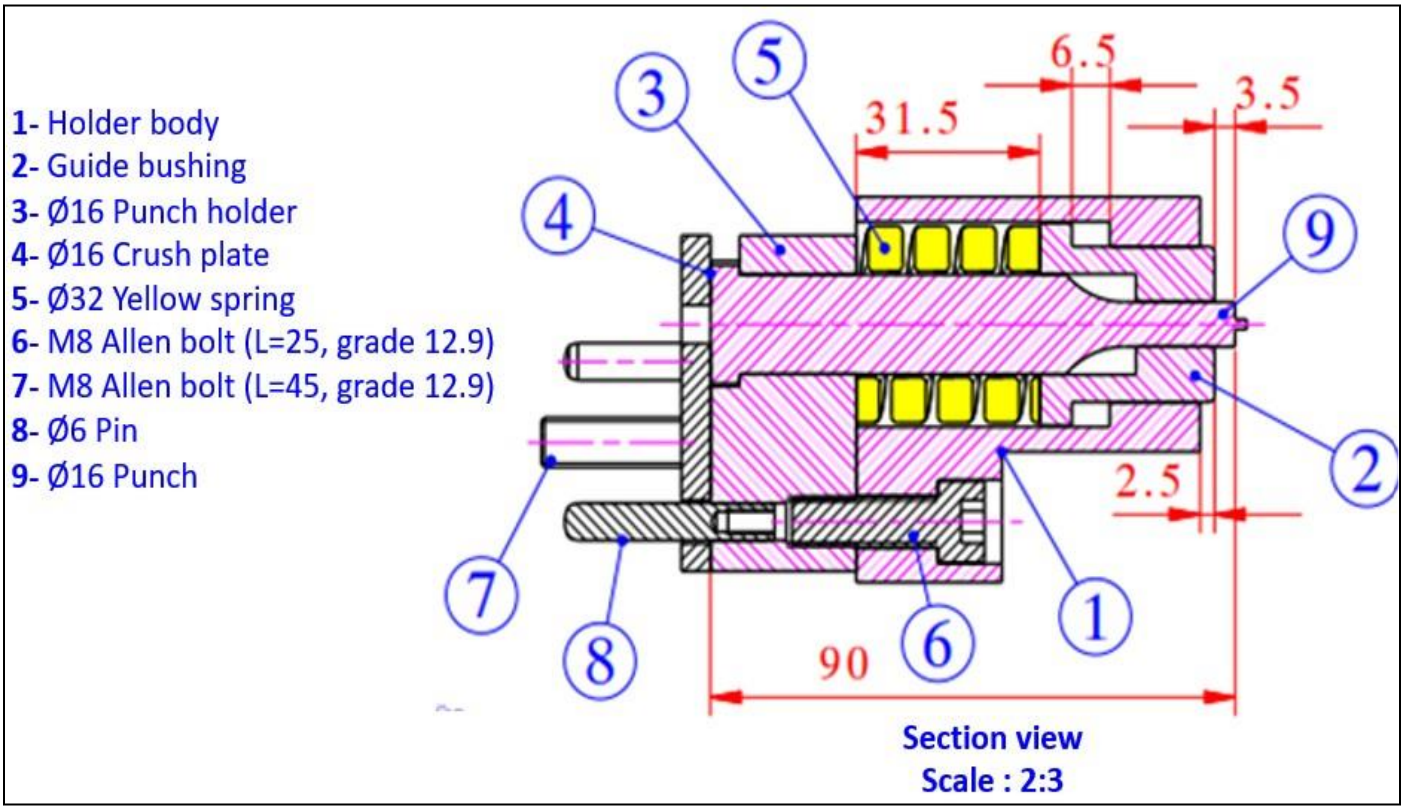

Fig 3a L-Shaped Punch Holder Mechanism.

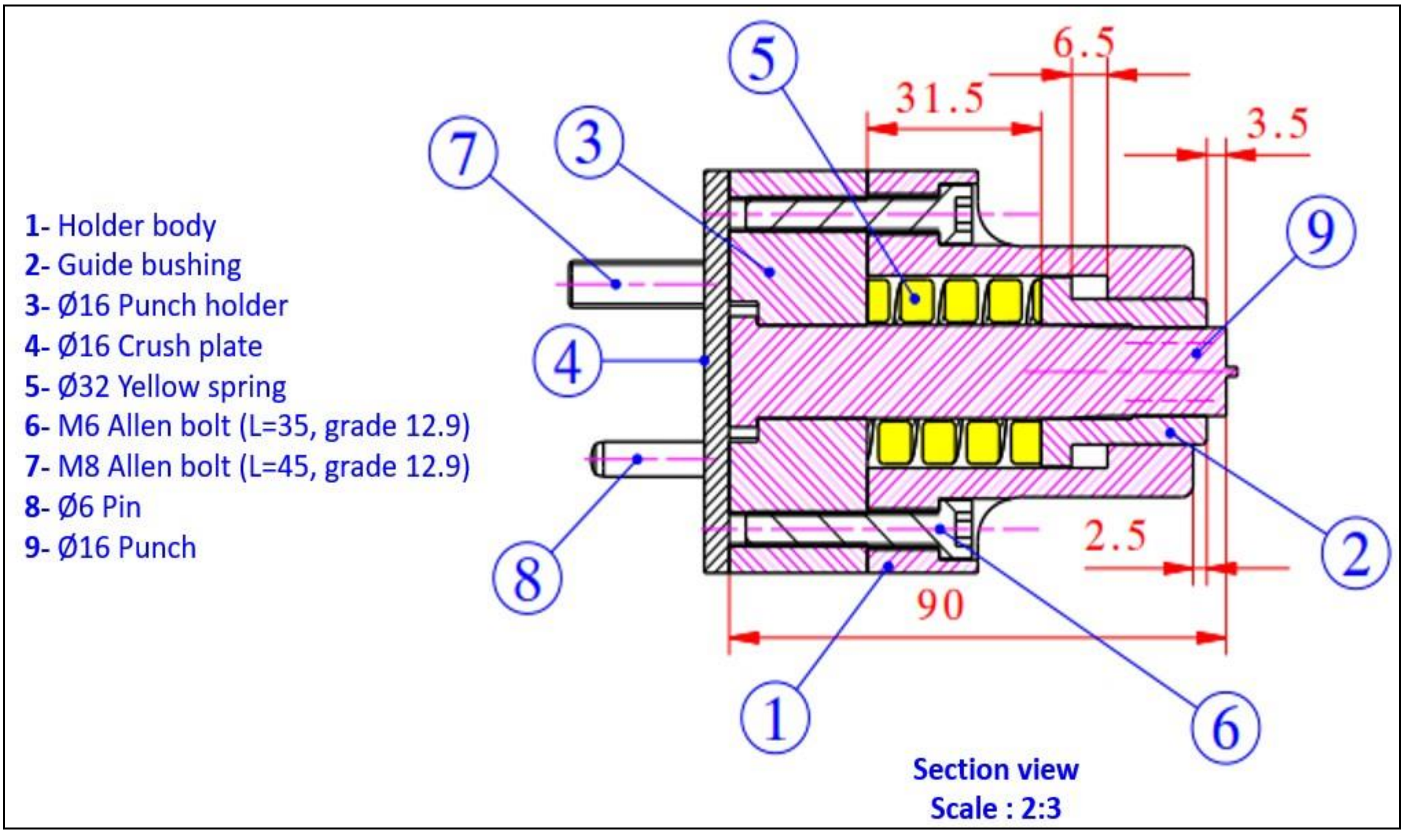

Fig 3b Circular Punch Holder Mechanism.

In the designed punch holder mechanisms, AISI 1050 material was selected for the punch holder, punch holder body, and guide bushing. This material has a hardness value of 54–56 HRC. The Allen bolts used in the mechanism were selected with a grade 12.9 quality standard. Finite element analyses were conducted to evaluate the performance of the models on the die after the design stage was completed.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

➢ *Finite Element Analysis of the Punch Holder Mechanism*

For the finite element analyses of the punch holder mechanism, the "Static Structural" module in the Ansys software was used. The forces applied to the punch holder mechanism are transferred to the yellow die spring through the guide bushing in the mechanism, and the guide bushing compresses the spring, ensuring the contact of the punch with the sheet material. The metric bolts used in the punch holder mechanism connect the punch holder and the holder body to each other.

In the analysis study, D2 tool steel was selected from the Ansys material library for the die cutting punch, while AISI 1050 steel was used for the other components of the punch mechanism. For the metric bolts, AISI 4140 steel with a grade 12.9 quality standard was selected, and the yield and tensile strengths of the material were defined in accordance with the quality standard. Table 1 presents the mechanical properties of the materials.

Table 1 Mechanical Properties of the Punch Holder Mechanism Materials

Material Name	Yield Strength (MPa)	Tensile Strength (MPa)	Poisson's Ratio
AISI 1050 Steel	362.80	633.90	0.29
D2 Tool Steel	2066.0	2290.0	0.29
AISI 4140 (Grade 12.9)	1100.0	1200.0	0.29

During the cutting process, the forces applied to the punch holder mechanism were simulated in the finite element analysis. In the finite element analyses, the metric bolts were modeled as solid bodies. To increase computational efficiency and to reduce the effect of contact pressure on the analysis model, the bolt threads were not modeled. By neglecting the bolt and nut thread interaction between the bolt and its mating component, this connection was defined in the simulation as "bolt thread" [12]. The bolt thread connections for the M8 and M6 bolts are shown in Figure 4a and Figure 4b, respectively.

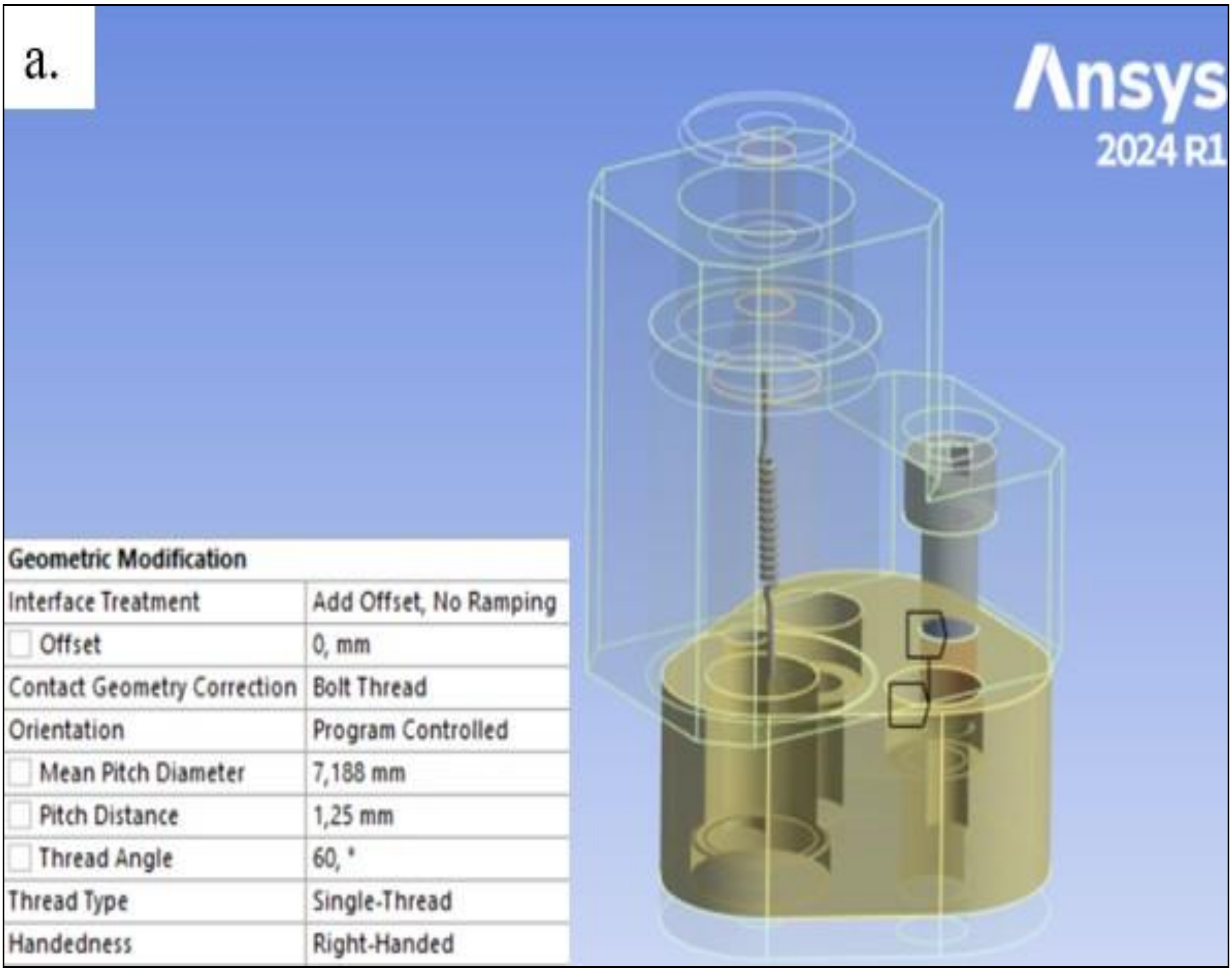

Fig 4a. M8 Bolt Thread Contact Structures

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

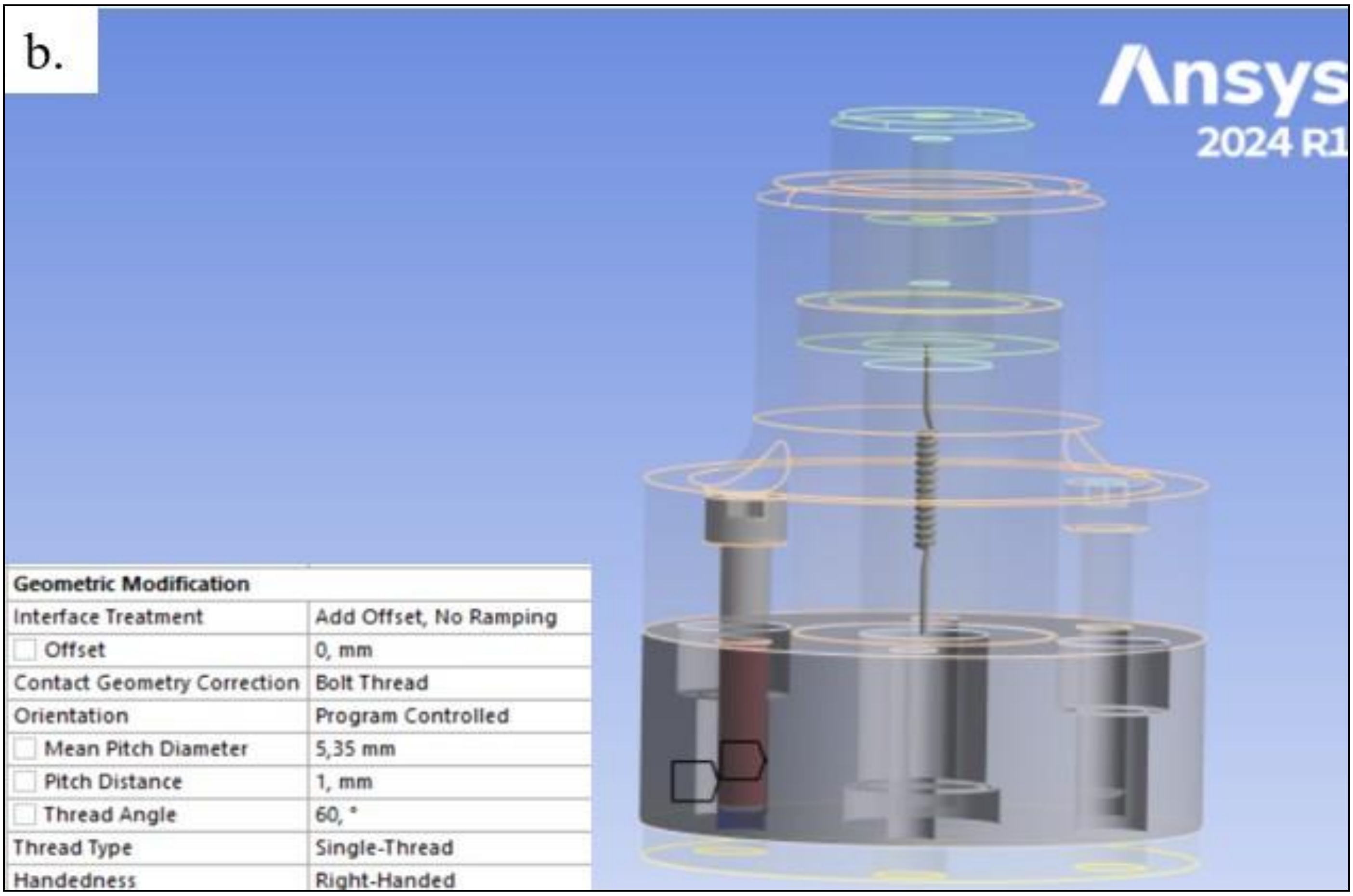

Fig 4b. M6 Bolt Thread Contact Structures

The metric bolts that connect the components of the mechanism to each other are subjected to pre-tension using a torque wrench. This applied pre-tension compresses the connected components under a force, generating friction on the contact surfaces and preventing the parts from sliding over one another [13,14]. In this study, the pre-tension forces corresponding to the torque values were applied to the bolt shank [15]. Bolt pre-tension forces are calculated depending on numerous parameters. In this study, however, in order to standardize the pre-tension forces, they were selected based on the friction coefficients (μ) given in the tables of the machine elements book by Babalık and Çavdar [16]. The pre-tension values applied to the M6 and M8 bolts are presented in Table 2.

Table 2 Assembly Pre-Tension Force FMF_MFM (N) for Grade 12.9 Bolts [16]

Size	**Grade**	**Assembly Pre-tension Force F_M[N] μ= 0,12**
M6	12.9	16100
M8	12.9	29500

A friction coefficient of 0.12 was assigned between the mechanism components to ensure a realistic simulation of contact interactions within the finite element analyses. In the L-shaped punch holder and the circular punch holder mechanisms, the contact between the crush plates and the punch holder was defined as "bonded." These two die components are connected to each other by bolt and pin fasteners. However, to optimize the analysis time, the fasteners were not physically modeled; instead, they were idealized.

In finite element analyses, one of the essential parameters for evaluating the model's accuracy is the mesh process. The mesh operation, which discretizes the geometry into network structures, directly affects computational stability and accuracy [17]. When determining the mesh structure, mesh quality and analysis time are important factors. In this analysis study, different mesh structures and mesh counts were tested, and the model that provided higher mesh quality was selected. The mesh size of the models was set to 2 mm. In the L-shaped punch holder model, the punch holder and the M8 bolts were meshed using "Tetrahedrons," while the other components were meshed using the "MultiZone" method. Similarly, in the circular punch holder mechanism, the punch holder, holder body, and M6 bolts were meshed using "Tetrahedrons," whereas the other components were modeled using the "MultiZone" mesh structure.

The mechanical behavior and load transfer mechanisms of the punch holder mechanism during the punching operation on the sheet metal were examined in detail. The

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

punch holder mechanism is expected to perform a linear movement along the sheet surface under the applied 3 mm pressing displacement. To achieve this movement, a force of 161.6 kg (≈ 1585 N) must be applied to compress the spring-loaded pressing element by 3 mm. In the conducted analysis, the yellow die spring, which was compressed by a maximum of 6.5 mm, had a load coefficient of 528.2 N/mm.

In the finite element analyses, the maximum compression force of 3500 N was applied to the die, and a pressing force of 1585 N was applied for the operation with a 3 mm cutting length. Since finite element spring analyses are a complex process and have the potential to increase analysis time, the yellow die spring in the punch holder mechanism was modeled as a "Spring" element in the Ansys software. The "Spring" model of the die spring for the L-shaped and circular punch holder mechanisms is shown in Figure 5a and Figure 5b, respectively.

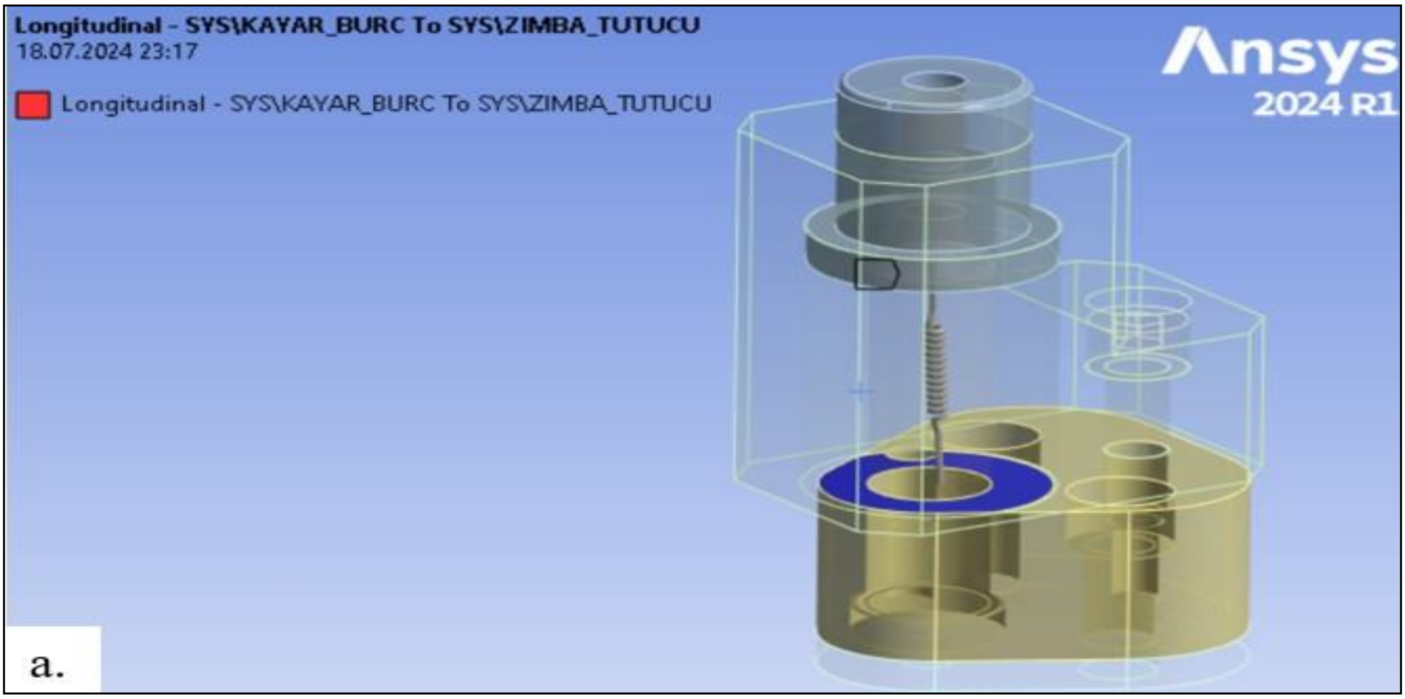

Fig 5a. Spring Contact of the L-Shaped Punch Holder Mechanism

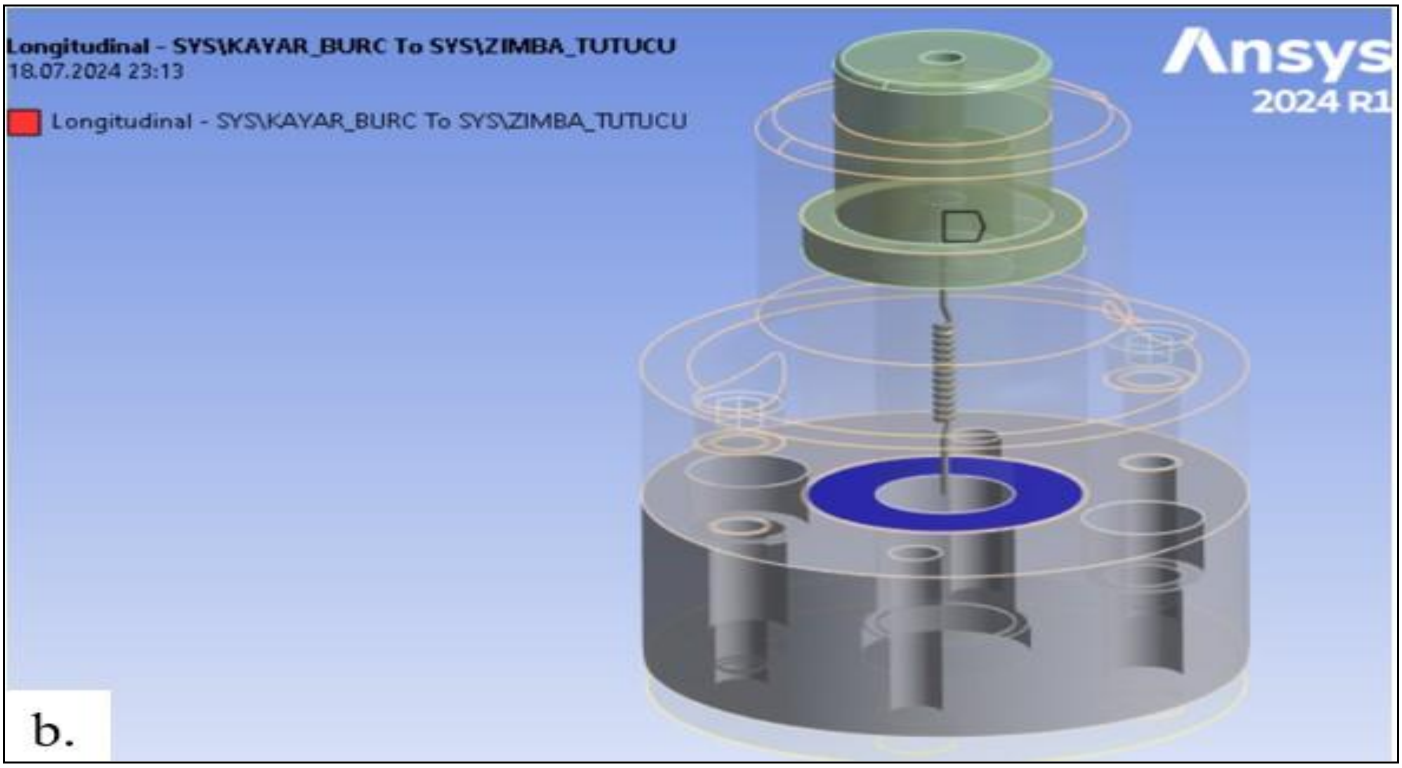

Fig 5b. Spring Contact of the Circular Punch Holder Mechanism

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

Within the scope of the study, the boundary parameters for the die spring analysis were examined in detail, and finite element analyses were performed for two different force values. To increase the efficiency of the analyses, the mechanism was fixed from the bottom surface of the crush plate. The boundary conditions of the L-shaped punch holder mechanism are shown in Figure 6, and those of the circular punch holder mechanism are shown in Figure 7.

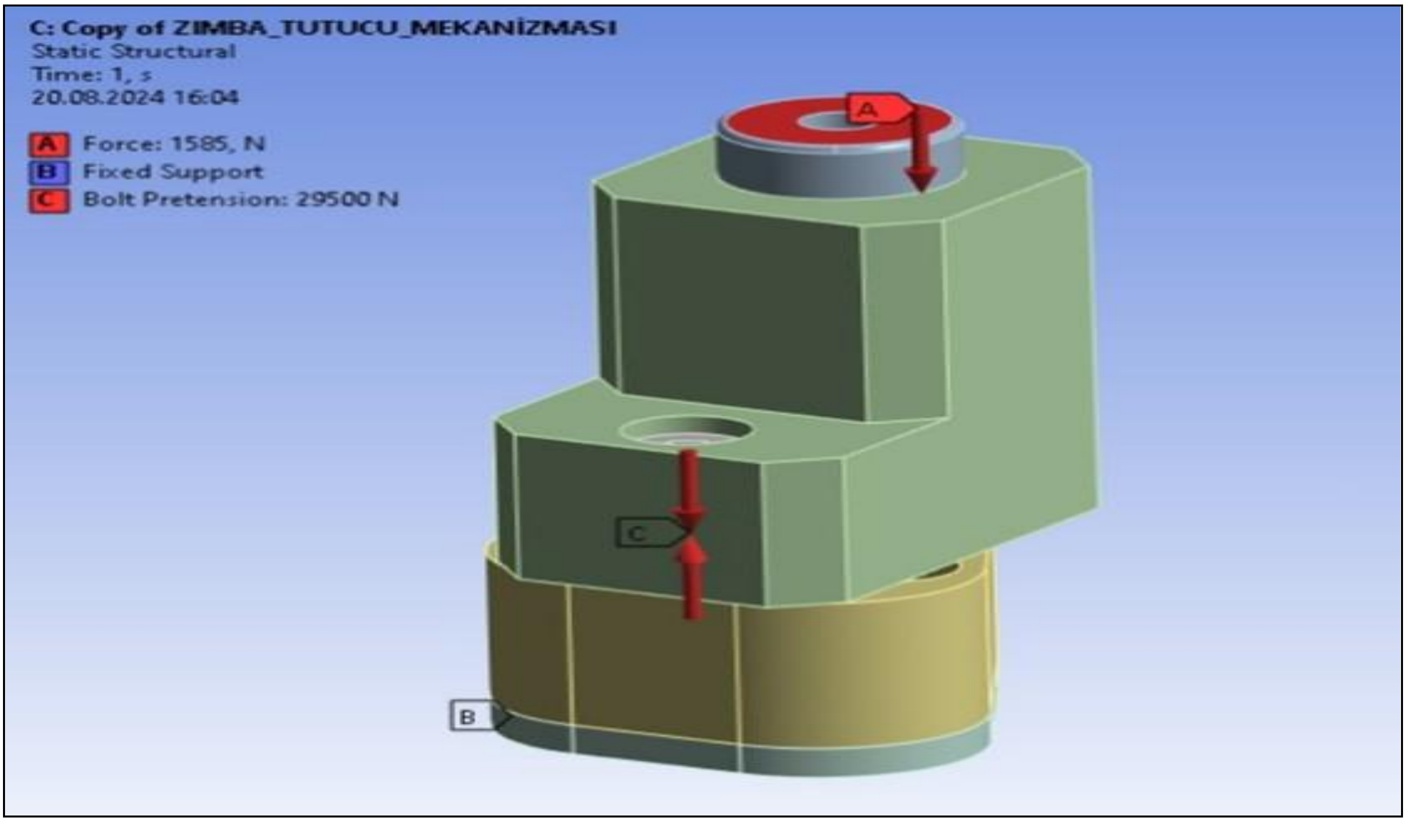

Fig 6 Boundary Conditions of the L-Shaped Punch Holder

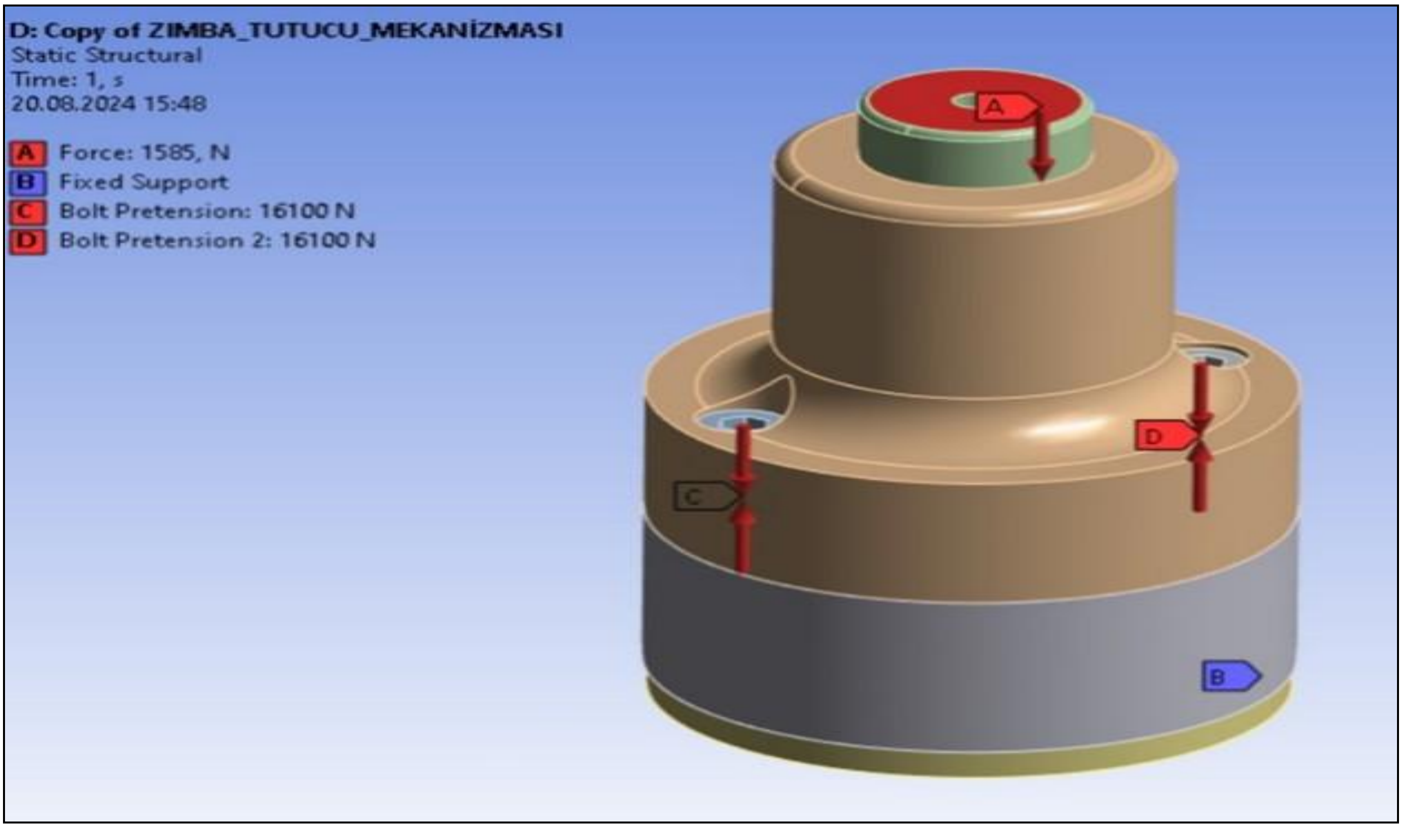

Fig 7 Boundary Conditions of the Circular Punch Holder

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

In the finite element analysis models, the contact of the punch holder mechanisms with the sheet metal and the movement of the guide bushing depending on the spring compression after this contact were examined. At the end of this process, the sheet metal punching operation is completed as the punching tool becomes free. When the punching operation is completed and the die separates from the sheet metal, the compression force on the die spring disappears, and the guide bushing returns to its initial position. This process was successfully simulated with the finite element analysis model, as shown in Figures 8 and 9.

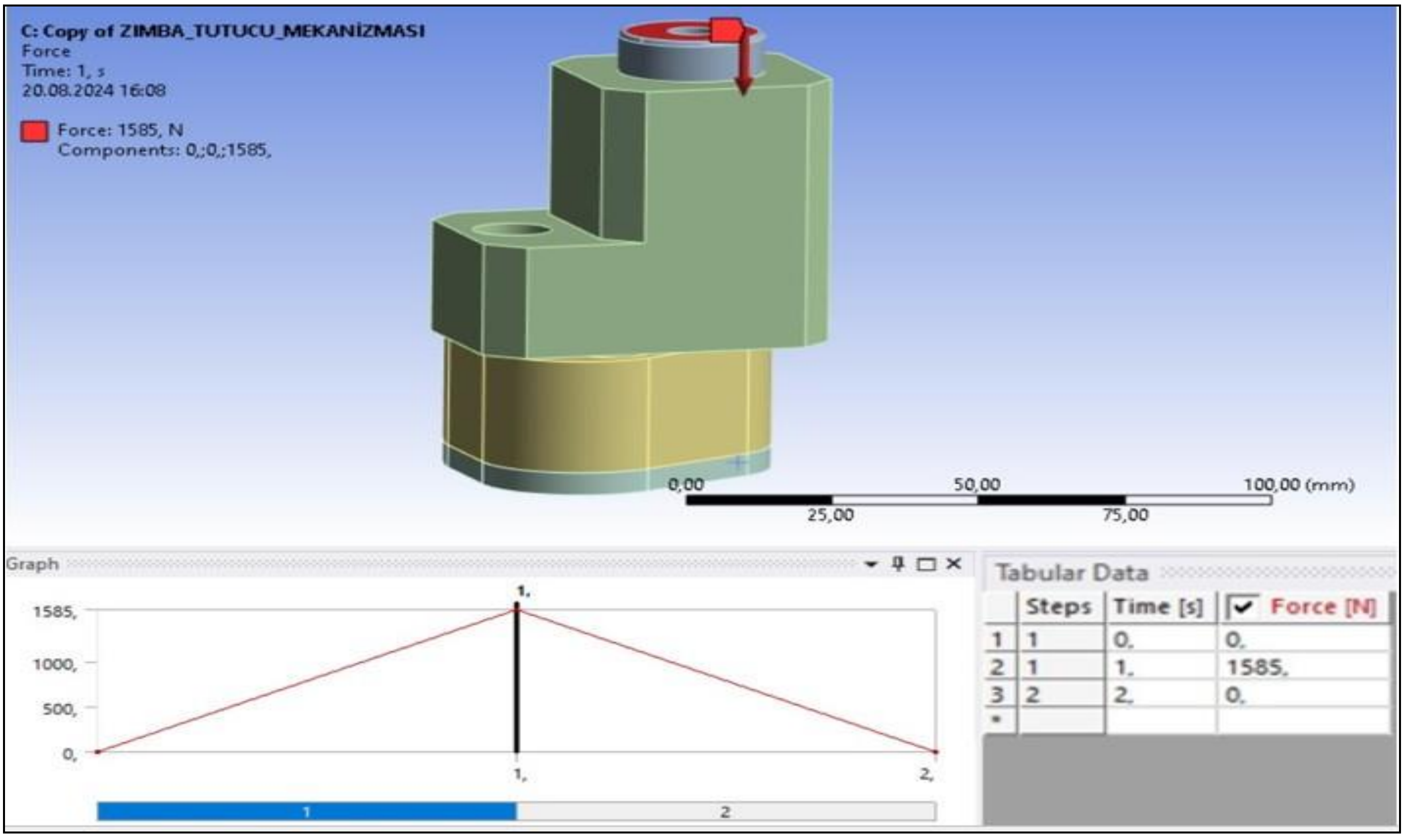

Fig 8 Operating Mechanism of the L-Shaped Punch Holder

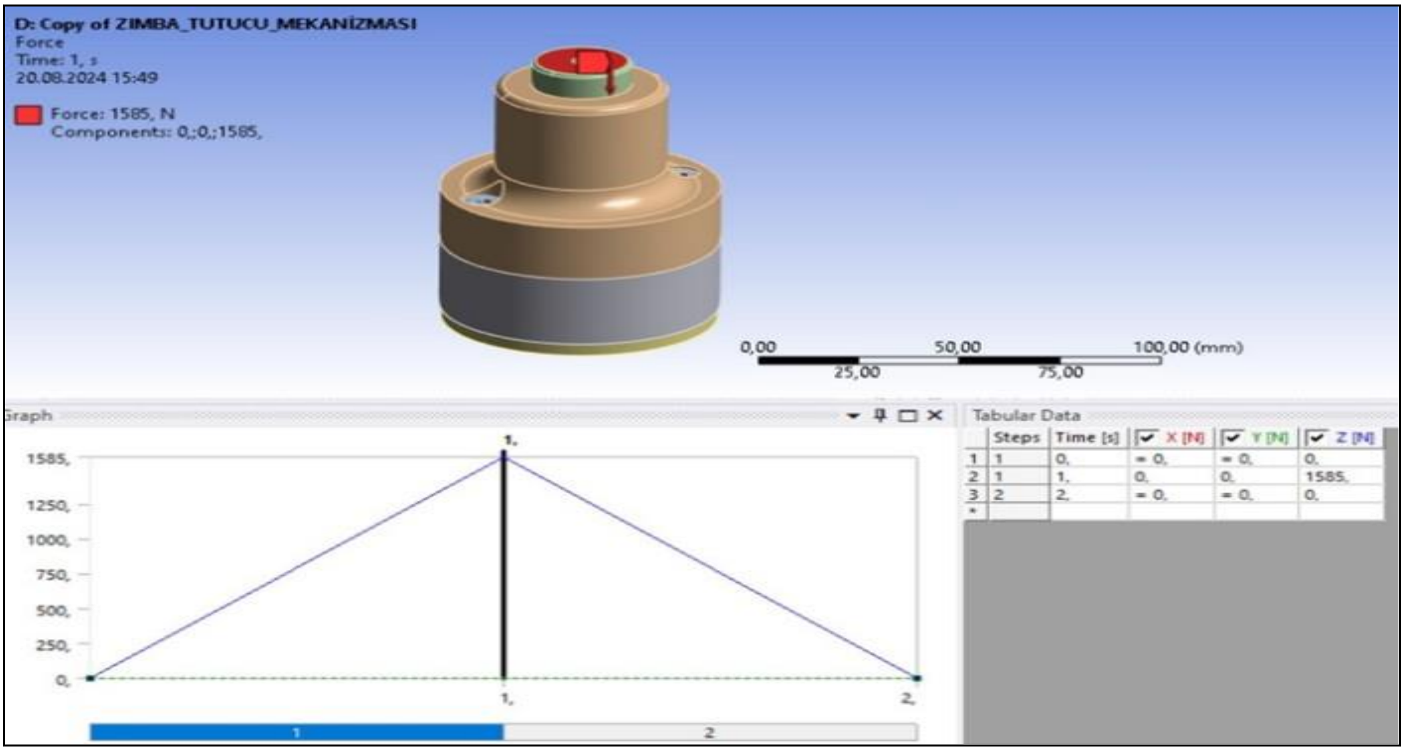

Fig 9 Operating Mechanism of the Circular Punch Holder

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

III. RESULTS AND DISCUSSION

This study aimed to compare the standard L-shaped punch holder mechanism with the newly designed circular punch holder mechanism using the finite element analysis method and to evaluate these mechanisms based on their total deformation and Von-Mises stress values. The main purpose of the analyses is to determine the advantages and disadvantages of the newly designed circular punch holder mechanism compared to the existing L-shaped punch holder.

The yellow die spring is compressed by a maximum of 6.5 mm. In the analysis studies, the total deformation of the die spring for the L-shaped punch mechanism was found to be 6.16 mm. The total deformation analysis results of the L-shaped punch holder are presented in Figure 10. For the circular punch holder mechanism, a maximum deformation of 5.94 mm was obtained. In the study, analyses were performed by changing the mesh values, and as the number of mesh elements increased, it was determined that the circular punch holder mechanism compressed the die spring by an average of 6.30 mm. However, changing the mesh size for the L-shaped punch mechanism did not have an effect on the compression amount, and the mesh size of 2 mm was evaluated as the optimum value for this analysis. Figure 11 shows the maximum deformation analysis of the circular punch holder mechanism.

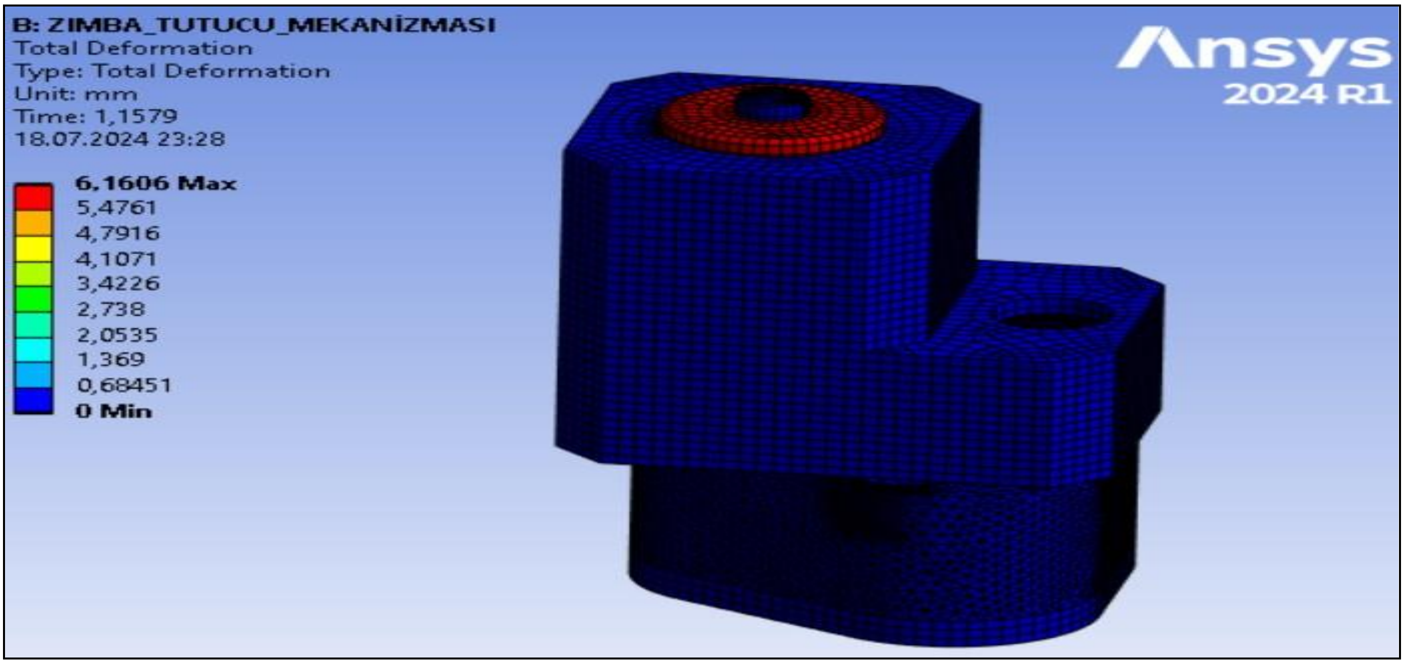

Fig 10 Deformation Analysis of the L-Shaped Punch Mechanism Under a Pressing Force of 1585 N

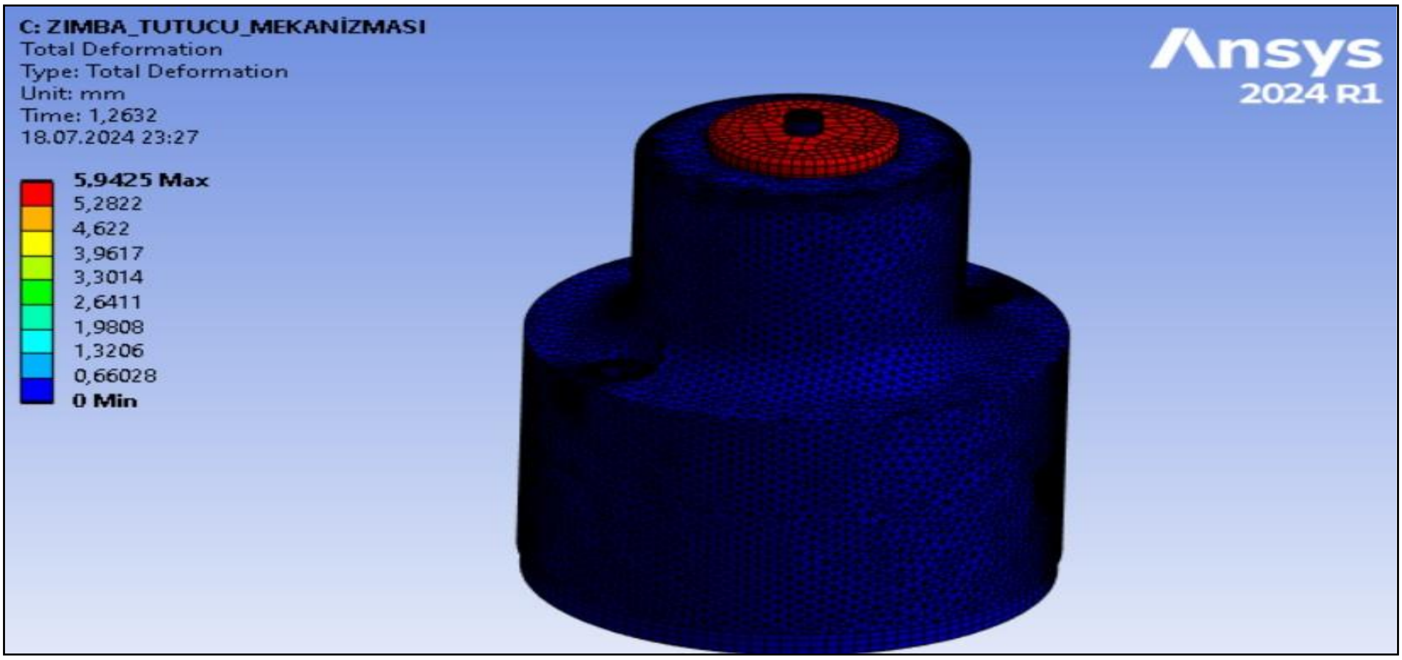

Fig 11 Deformation Analysis of the Circular Punch Mechanism Under a Pressing Force of 1585 N

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

In the comparison of the Von-Mises stress values, the maximum stress value of the L-shaped punch holder mechanism was found to be 617.69 MPa, as presented in the Von-Mises stress analysis of the L-shaped punch in Figure 12. The maximum Von-Mises stress value of the circular punch holder mechanism, shown in Figure 13, is 593.29 MPa.

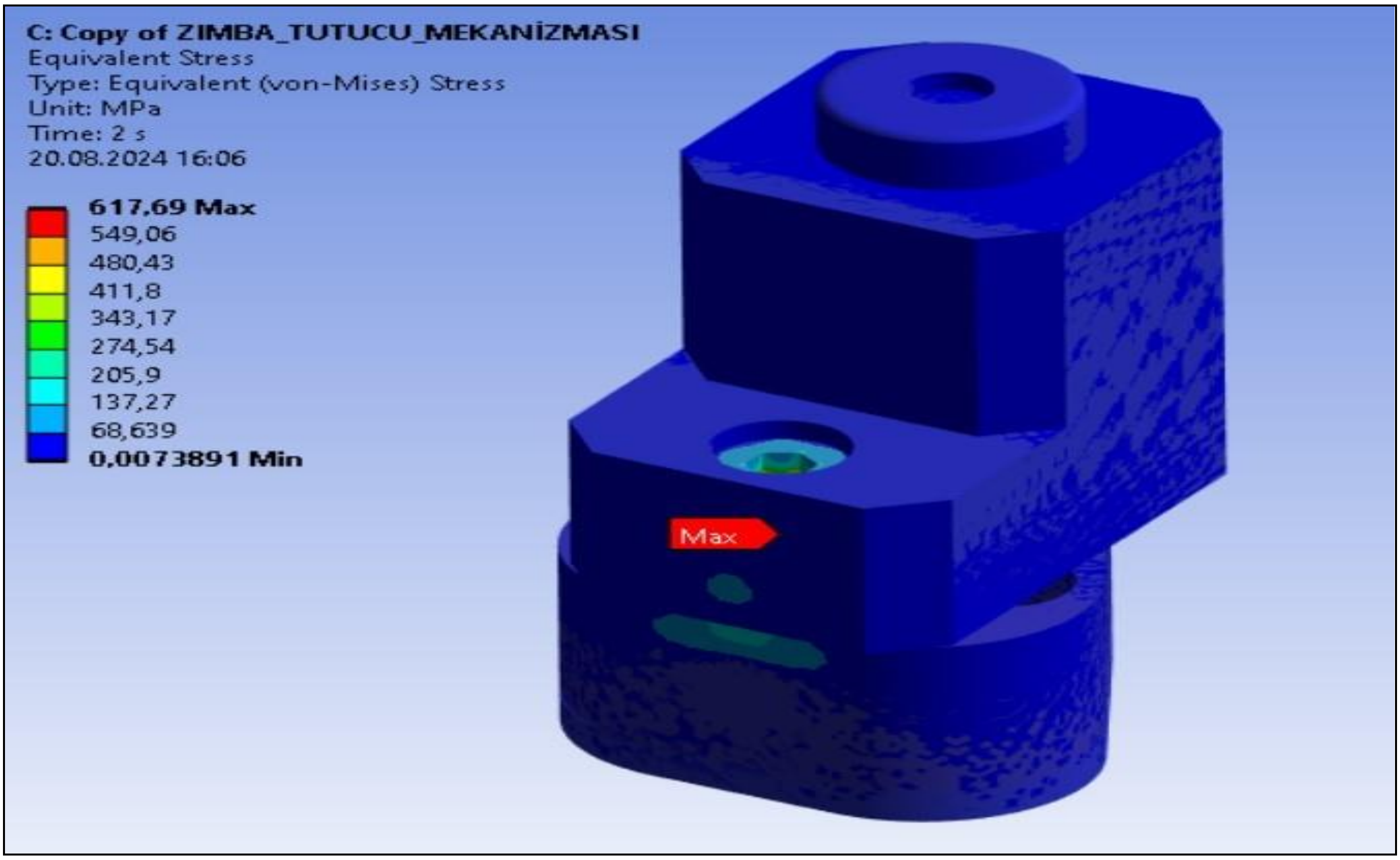

Fig 12 Von-Mises Analysis of the L-Shaped Punch Holder

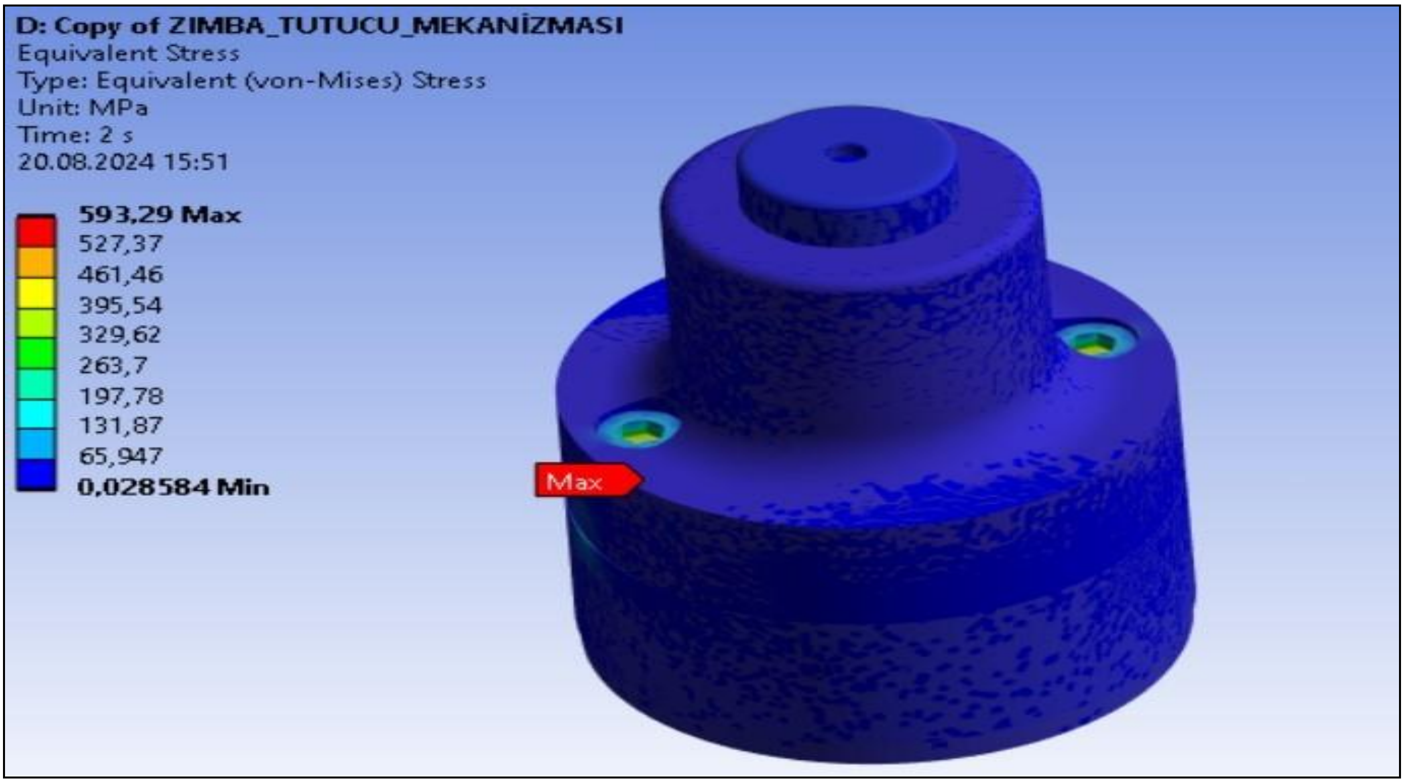

Fig 13 Von-Mises Analysis of the Circular Punch Holder

For both punch holder mechanisms, it was determined that the highest Von-Mises values on the punch holders occurred at the initial surfaces of the bolt threads. The Von-Mises analysis results are presented in Table 3.

Table 3 Von-Mises Analysis of the Punch Mechanism

Punch Mechanism Geometry	Punching Force (N)	Von-Mises Stress Analysis (MPa)
L-shaped	1585	617.69
Circular	1585	593.29

The analysis results show that both punch holder mechanisms exhibit stress values below their yield strength. This indicates that the punch holders can be used safely in punching processes. The higher deformation and stress values of the L-shaped punch holder mechanism compared to the circular punch holder suggest that this may create a disadvantage for the structural stability of the mechanism.

IV. CONCLUSIONS

In addition to innovative technologies, efforts are being made to improve existing manufacturing processes in order to increase production efficiency. In this study, punch holder mechanisms, which are widely used in sheet metal dies, were examined. Die components connected to punch holder mechanisms are used in the punching of sheet metal. During this process, punch holder mechanisms mounted on the die may become damaged over time due to bolt loosening under high forces and their inability to withstand the required strength values. Different geometries of punch holder mechanisms are used during punching processes. In this study, circular punch holder mechanisms were designed as an alternative to the widely used L-shaped punch holder mechanisms in the die manufacturing industry, and the necessary strength analyses were performed prior to the production process. In the analysis study:

- It was observed that the L-shaped punch holders exhibited higher Von-Mises stress values compared to the circular punch holders, and this was attributed to the use of a single M8 bolt as the die mounting element. In the circular punch holder mechanism, two M6 bolts were used for assembly, which resulted in achieving higher strength.

- Unlike other punch holder mechanisms, a yellow die spring was preferred as the compression spring. The strength values of the yellow die springs indicate that the mechanism can exhibit long-lasting performance under higher pressing forces.

- The circular punch holders provided higher strength with two bolts compared to the L-shaped punch holder mechanism, and allowed punches with different diameters to be easily mounted onto the mechanism. This contributed to reducing both labor and material costs. Additionally, the circular geometric design offered an advantage for use in narrower spaces.

- It was concluded that the punch holder mechanisms obtained from supplier companies can also be manufactured in-house. This enables die mechanisms that are purchased at high costs to be produced at more affordable costs when integrated into existing production processes.

As a result, the study demonstrated that the circular punch holder mechanism offers superior performance compared to existing L-shaped designs and can provide a significant contribution to increasing production efficiency. These results were supported by the acceptance of the utility model application of the study, demonstrating its potential for industrial implementation.

ACKNOWLEDGMENT

This study was supported by Şahinkul Makine in frame of the projectcode of ARGE-2022-30 2201640000 as researchers, Scholarshipin this study was supported by TÜBİTAK BİDEB (Turkish Sci-entific and Technological Research Council, Scientist SupportDepartment) (Project No: 119C053).

REFERENCES

[1]. J. Bang, M. Kim, G. Bae, H.G. Kim, M.G. Lee, J. Song, (2022), "Efficient Wear Simulation Methodology for Predicting Nonlinear Wear Behavior of Tools in Sheet Metal Forming", Materials, 15(13), 4509, 2022.
[2]. J. Bang, M. Kim, G. Bae, J. Song, H.G. Kim, M.G. Lee, "Quantitative Evaluation of Tool Wear in Cold Stamping of Ultra-High-Strength Steel Sheets", Metals and Materials International, 29, pages 327-342, 2023.
[3]. V.D. Luiz, A.J.d. Santos, M.A. Câmara, & P.C.d.M. Rodrigues, "Influence of Different Contact Conditions on Friction Properties of AISI 430 Steel Sheet with Deep Drawing Quality". Coatings, 13(4), 771. 2023.
[4]. E. Vidales, N. Cuadrado, N., E. Garcia-Llamas, J.T. Garitano, I. Aseguinolaza, M. Carranza, M. Vilaseca, G. Ramirez, "Surface roughness analysis for improving punching tools performance of 5754 aluminium alloy", Wear, Volumes 524-525, 2023.
[5]. T. Trzepieciński, "Approaches for Preventing Tool Wear in Sheet Metal Forming Processes", Machines, 11(6), 616, 2023.
[6]. J. Bang, G. Bae, M. Kim, J. Song, M.G. Lee, H.G. Kim, "Characterization of Formed TRIP1180 Steel Sheet Surface After Stamping with PVD-Coated Tools", Metals and Materials International, volume 30, 425-440, 2024.
[7]. Q. Zheng, X. Zhuang, Z. Gao, M. Guan, Z. Ding, Y. Hong, Z. Zhao, "Investigation on wear-induced edge

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25dec582

passivation of fine-blanking punch", The International Journal of Advanced Manufacturing Technology, Volume 104, pages 4129-4141, 2019.

[8]. F. Akyürek, K. Yaman, Z. Tekiner, "An Experimental Work on Tool Wear Affected by Die Clearance and Punch Hardness", Arabian Journal for Science and Engineering, volume 42, pages 4683-4692, 2017.

[9]. G. Li, P. Yang, Z. Liang, S. Cui, "Intelligent design and group assembly of male and female dies for hole piercing of automotive stamping dies", The International Journal of Advanced Manufacturing Technology Article, Volume 103, pages 665-687, 2019.

[10]. M. Semaan, V. Castex, E.R. Arramendy, M. Paredes, "Improvement of the Method for Fixing a Punch in the Punch Holder", Applied Sciences, 11(22), 11013, 2021.

[11]. C. Canales, P. Bussetta, J.P. Ponthont, "On the numerical simulation of sheet metal blanking process", International Journal of Material Forming, Volume 10, 55-71, 2017.

[12]. J. Cao, & Z. Zhang, "Finite element analysis and mathematical characterization of contact pressure distribution in bolted joints", Journal of Mechanical Science and Technology, Volume 33, pages 4715-4725, 2019.

[13]. J.M. Mínguez & J. Vogwell, "Effect of torque tightening on the fatigue strength of bolted joints", Engineering Failure Analysis, 13(6), pages 1410-1421, 2006.

[14]. R. Yousaf, & N. Shafi, "Finite element analysis of double lap protruding head bolted joints in tension simulating aircraft joints," 2021 International Bhurban Conference on Applied Sciences and Technologies (IBCAST), Islamabad, Pakistan, pp. 105-110, 2021.

[15]. P.D. Jamadar, H.K. Wagh, G.R. Desale, K. Tripathi, "Finite element based Pretension analysis of threaded Fasteners with Experimental Investigation", International Journal of Innovations in Engineering and Technology (IJIET), 6 (4), pages 585-593, 2016.

[16]. Babalık, F.C. & Çavdar, K., Makine Elemanları ve Konstrüksiyon Örnekleri, 10.Baskı, Dora Basım Yayın Ltd. Şti. Bursa, 2021.

[17]. A. Nemade & A. Shikalgar, A. "The Mesh Quality significance in Finite Element Analysis", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 17(2), 44-48, 2020.