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Research article

A study on stamping of airliner's tail connector part through FEM simulation

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Abstract

Airliner's parts are very critical and should be manufactured properly without any defects, because every fault may lead to irreparable happening. Therefore, the manufacturing of the parts of airliners is very significant. One of the production methods for manufacturing these parts is die press metal forming (stamping). This process which is a kind of sheet metal forming process, in recent years has become one of the most widely used methods in the field of manufacturing industrial parts with complex geometry. Therefore, studying the effective factors in the proper execution of the process helps to achieve high-quality products and optimal geometry. To analyze the behavior of materials during the die press forming process, the FEM simulation procedure should be applied. In this study, manufacturing (stamping) of a part related to the tail of the 8-person capacity airliner, is investigated through FEM simulation. The FEM simulation is performed via ABAQUS software. Due to the importance of the weight of airliners, their parts are usually made of aluminum alloys. In this project, Al6061 is designated for the mentioned part. The results of the simulation show that the designed dies are suitable and the forming process is completely performed.

Keywords: Stamping, ABAQUS, Aerospace industry, FEM simulation, Press die design.

1- Introduction

As important light-weight structure material, aluminium alloys have been widely used in automotive and aerospace industries. In the last years, the manufacturing of parts with high strength and good dimensional accuracy has become the main objective in industrial applications. Within the available aluminium alloys, the 6xxx series has attract the interest of the industrial designers due to the high yield strength and ultimate tensile strength they present. However, the formability of these alloys in as-received industrial condition is very poor at room temperature and various studies are being carried out to develop efficient warm and cold forming processes to form them industrially using heated tools [1]. Sheet metals are widely applied in the automotive, ship-building and aerospace industries. In many cases, due to their poor plasticity at room temperature, defects are easily created in the forming process, such as wrinkling, cracking, poor forming accuracy, and spring-back. Studies have shown that material properties, processing techniques, and friction are the main factors which affect the formability and the quality of the parts [2-4]. Stamping includes a variety of sheet-metal forming manufacturing processes, such as punching using a machine press or stamping press, blanking, embossing, bending, flanging, and coining. The process is usually carried out on sheet metal, but can also be used on other materials, such as polystyrene. Depending on part complexity, the number of stations in the die can be determined. Stamping is usually done on cold metal sheet. Applying different deburring methods is very common for stamped parts [5-9]. Among multiple aluminium alloys, 6061 aluminium alloy is one of materials which are widely applied in the automobile and aerospace industry [10-13]. Therefore, predicting the possible defects in die and products is a significant parameter to reduce the costs. FEM simulation is a common solution to predict the accuracy of a forming process and obtaining the required parameters (e.g. blank holder force) [14]. Bruschi et al. conducted a survey about testing and modelling of metals response when subjected to sheet forming operations. They focused both on the modelling of hardening behaviour and yield criteria and on the description of the sheet metal formability limits [15]. Atxaga et al. in 2022, proposed the use of the hot stamping process that provides ready to use parts for the obtention of aircraft components as an alternative manufacturing technology to e.g. machined parts [16]. In addition, Yan et al. combined the two techniques, electromagnetic hydraulic forming (EMHF), to obtain a new high-strain-rate forming method, which was investigated through experimental and simulation studies [17]. Zhang et al. proposed a novel inflatable mandrel assisted hot-pressing process for manufacturing channel-section CFRP-aluminium hybrid profiles [18]. Moreover, Deng et al. studied a warm forming process using dies to apply force and heat the blank simultaneously for aluminium sheets [19]. Hua et al. improved forming efficiency by proposing a novel forming technique for heat-treatable aluminium alloys, termed pre-aged hardening warm forming (PHF) process [20]. Jia et al. studied the formability of aluminium (Al)-copper (Cu) composite foils in micro deep drawing [21]. Bueno et al. worked on the impact of the use of hydraulic presses against the use of mechanical presses [22]. Attar et al. studied the bottleneck by proposing a strategy for the creation of early stage manufacturing design guidelines for the common limiting design requirement of deep corners. In their study, aluminium alloys formed under both cold, and elevated temperature working conditions. [23]. Kandasamy et al. presented the Finite Element (FE) simulation of the flow of aluminium alloy A357 through different Equal Channel Angular Pressing (ECAP) dies. Their simulation involved creating a material model using user subroutines in ABAQUS to numerically analyse the flow behaviour of the material [24]. ECAP is common method for grain refinement of metals [25-27].

In this study, feasibility of manufacturing of a part of the airliner's tail by stamping method is investigated via FEM simulation. In order to obtain the forming parameters including the press force, material thickness reduction and the maximum stress and strain, the process is simulated by ABAQUS software and then the maximum tensile stress, thickness reduction, and formability are obtained through these simulations.

2- Materials and methods

In this study, feasibility of manufacturing the of a part of an airliners' tail by stamping process is investigated via FEM simulation. For 3D-modelling of the die, the dimensions of the part are required. Therefore, the airliner's part was digitized through a 3D scanner, and the cloud points was extracted. Afterward, the 3D model was prepared through the Shape Design module of Catia software. The airliner's part is demonstrated in Fig. 1. This simulation should be performed in two steps. The first step is to punch the central hole of the part and the second step is to form the peripheral edges.

Fig. 1 Airliner' part

2-1- Material properties

Aluminium alloy will become the most competitive lightweight material because of its rich resources and good properties of small density, high specific strength and strong corrosion resistance. 6xxx aluminium alloy including A6016 as a kind of lightweight material and heat treatable alloy is widely used in the airliner's body panels and structural applications [28].

The physical and mechanical properties of A6016 using in the Property module of ABAQUS is introduced in Table 1, and its chemical composition is stated in Table 2.

Table 1: Physical and mechanical properties of the A6061

Properties	Value
Density (1000 kg/m3)	2.70
Heat transfer coefficient (W/m-K)	167
Electrical resistance coefficient (ohm-m)	3.99×10^{-8}
Melting point (°C)	651
Expansion coefficient (10^{-6}/K)	23.2
Elasticity module(GPa)	73.1
Poisson ratio	0.33
Yield strength (MPa)	310

Table 2: The chemical composition of A6061

Rem.	Ti	Fe	Mg	Cr	Ni	Zn	Si	Cu
Al	0.014%	0.6%	0.8%	0.04%	0.011%	0.25%	0.4%	0.4%

2.2. Simulation parameters

In this study the simulations are performed in ABAQUS software version 2019. The initial model is designed via Catia software. The initial part imported in the Part module is 3D and formable and on the other hand, the die, punch and blank holder are solid and non-formable. Fig. 2 shows the assembly of punch, die and blank holder to form the first step (central hole) of the process, which are imported in the Assemble modules of ABAQUS.

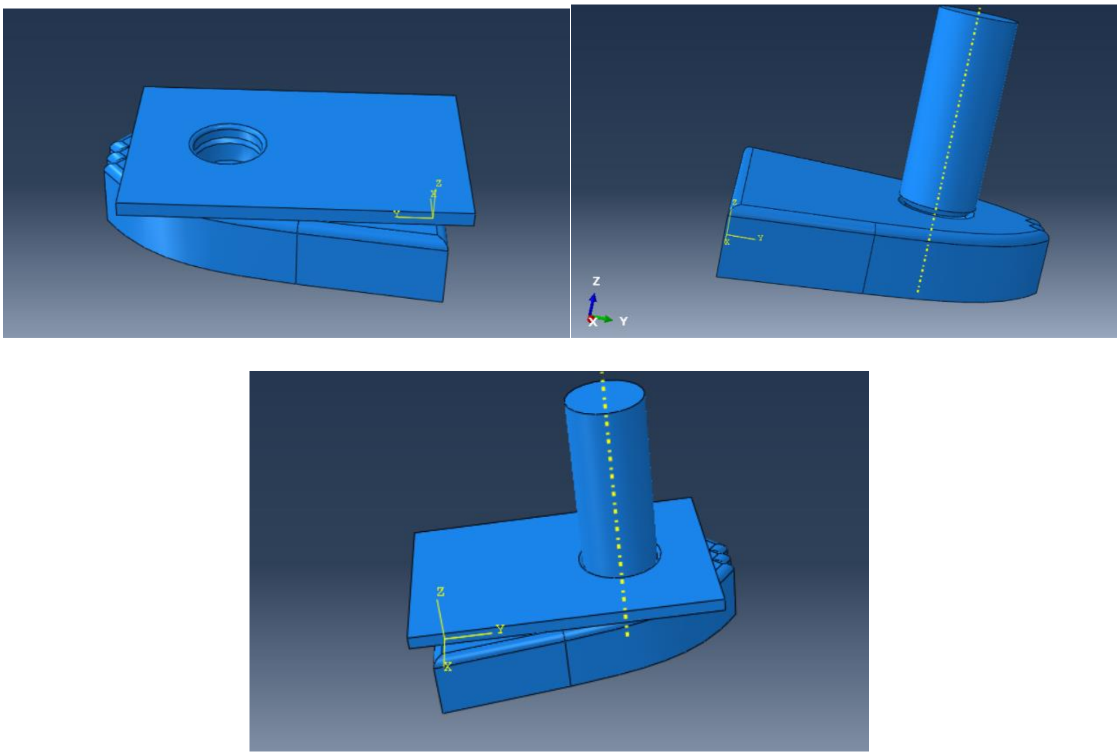

Fig. 2 Assembly of parts in first step

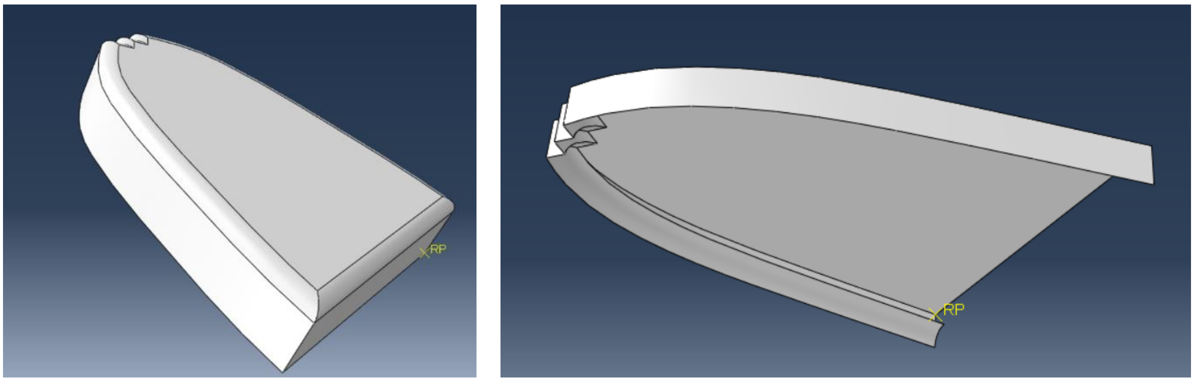

Fig. 3 The 3D model of the Punch and die to form the peripheral edges

In the second step, the edge of the part is formed. The two halve of the stamping die was design and modelling in Catia which is demonstrated in Fig. 3.

In the Properties modules of ABAQUS The Young's modulus is imported as 73 GPa and the Poisson's ratio, 0.3. For the plastic behaviour of the aluminium A6061 which is imported in the Properties module of ABAQUS the strain-stress relation is demonstrated in Fig. 4. The global mesh size is selected equal to 0.2 mm (with the minimum size control equals to 0.1 mm) and S4R (4-node doubly curved thin shell, reduced integration, hourglass control, finite membrane strains) is designated as mesh

	Yield Stress	Plastic Strain
1	305000000	0
2	309000000	0.001125
3	320000000	0.013996
4	331000000	0.118731
5	340000000	0.281615
6	350000000	0.481607
7	360000000	0.78642
8	370000000	1.1894

Fig. 4 strain-stress relation imported in Properties module

element type. Fig. 5 shows the meshed parts at the first step of forming and Fig. 6 shows the assembly of parts at the second step of forming. The Dynamic explicit solver is selected at the Step module to solve the problem and to perform the simulation. In the Interaction module, general contact is defined to match the related points of the part and die and the Coefficient of Friction (COF) is defined 0.3.

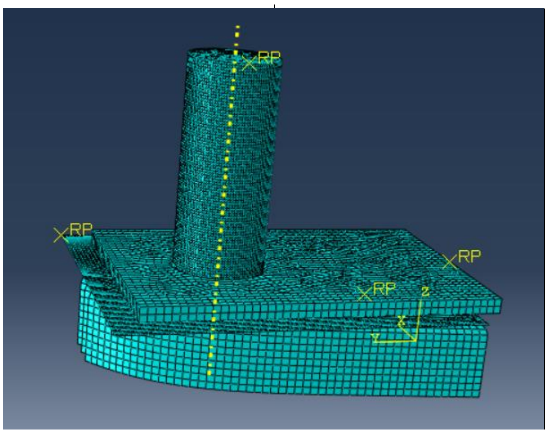

Fig. 5 Meshed Parts at the first step of forming

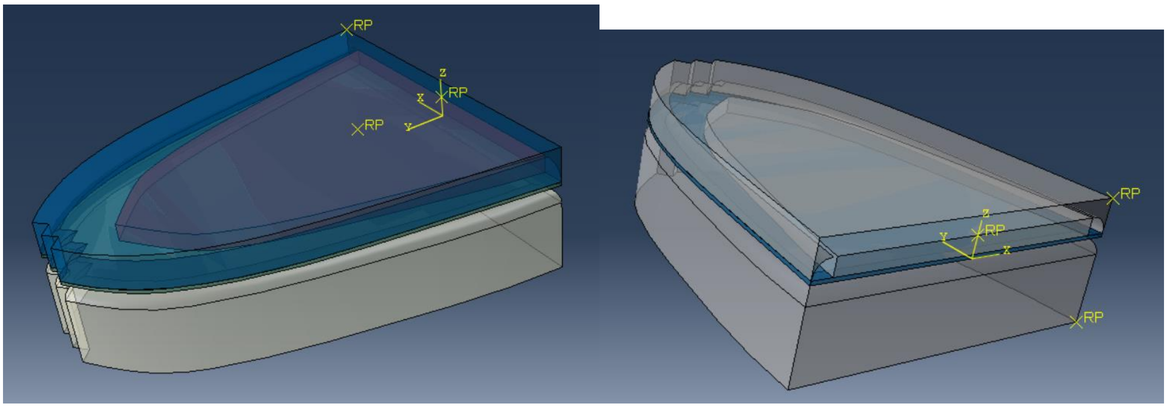

Fig. 6 Assembly of parts at the second step of forming.

3- Results & Discussion

In this study, feasibility of manufacturing the of a part of an airliners' tail by stamping process is investigated via FEM simulation. In the followings, the results of the simulation are presented. Fig. 7 shows the Von Mises stress imposed on the sheet metal at the first step for forming the hole. As it is shown in Fig. 7, the maximum stress was obtained 370MPa which is higher than yield stress of the Al alloy. Fig. 8 shows the points of the part which were entered to the plastic mode. The points around the hole, obviously are in plastic mode.

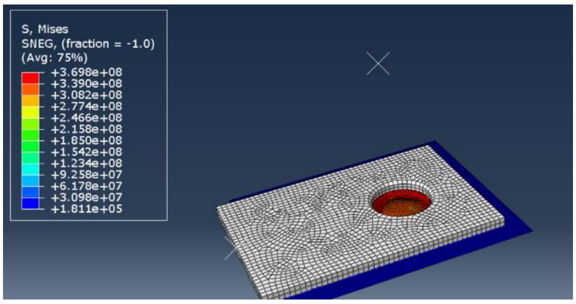

Fig. 7 Stress around the hole in the first step

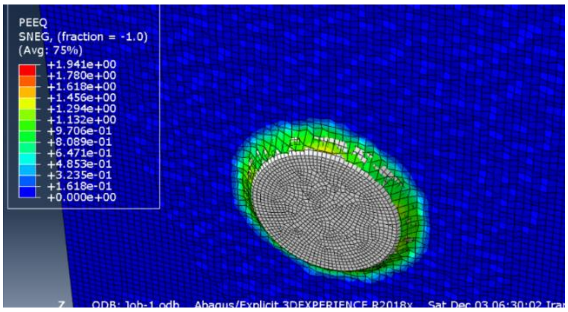

Fig. 8 Plastic points around the hole at the first step

Fig. 9 shows the formed part at the second step and the Von Mises stress occurred in the part. As it is shown in Fig. 9, the maximum stress was obtained 370 MPa at the second step. The simulation presents that the forming process was performed perfectly and the sheet metal is completely fill the die and the edges perfectly are formed. Fig. 10 demonstrates the plastic points in the second step. As it is shown, the edges of the part are in plastic mode. Finally, in Fig. 11, the convergence of the result (stress) by increasing the numbers of mesh elements has been demonstrated. According to this figure, with the 1000 mesh elements, the stress equals 326 MPa. And accordingly, by more increase in mesh elements, the result is converged to 370 MPa.

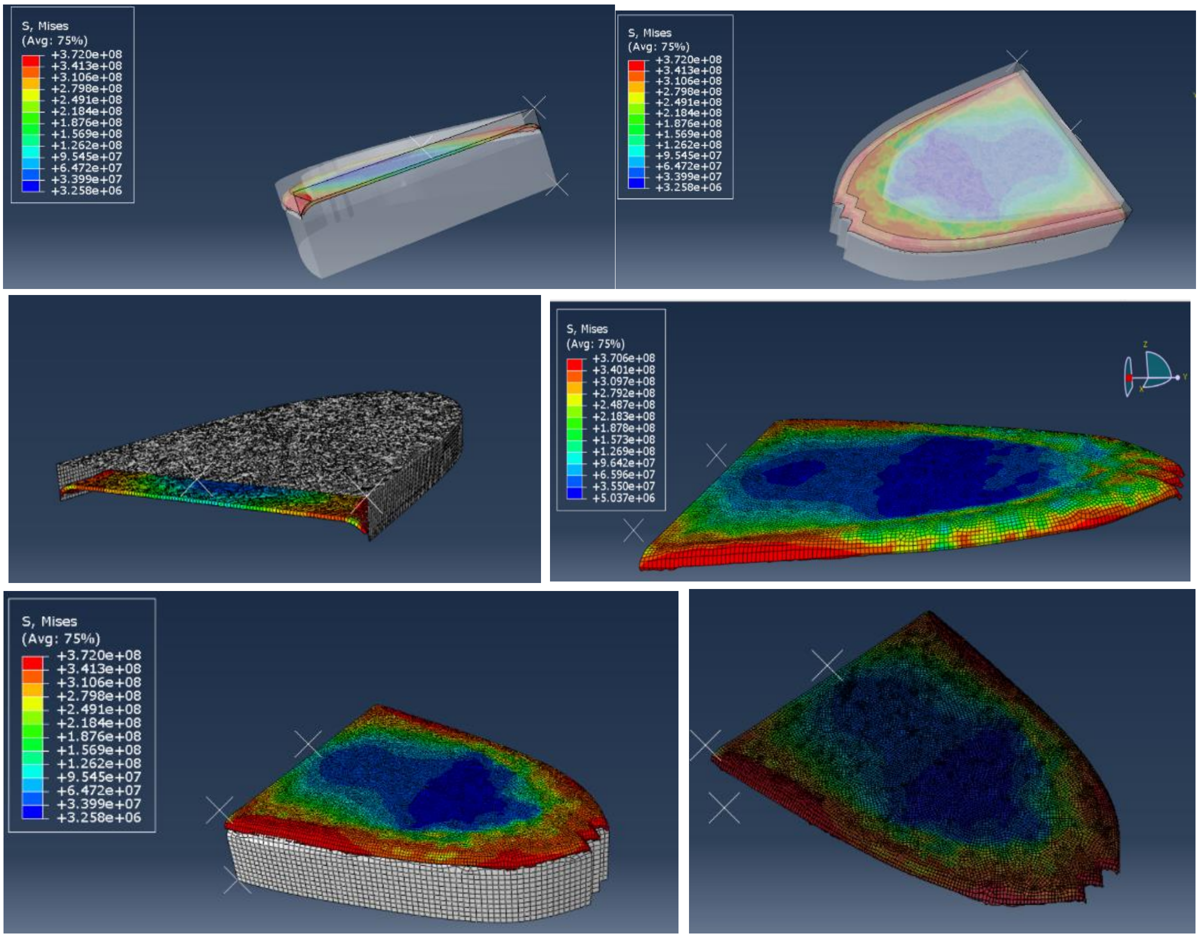

Fig. 9 Von Mises stress and formed part at the second step

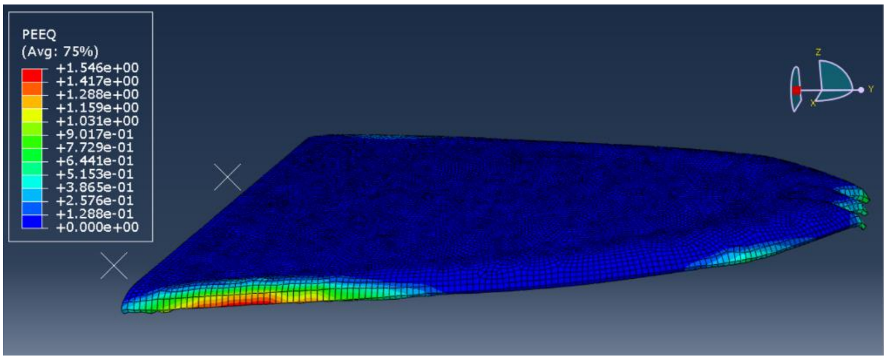

Fig. 10 Plastic points at the second step

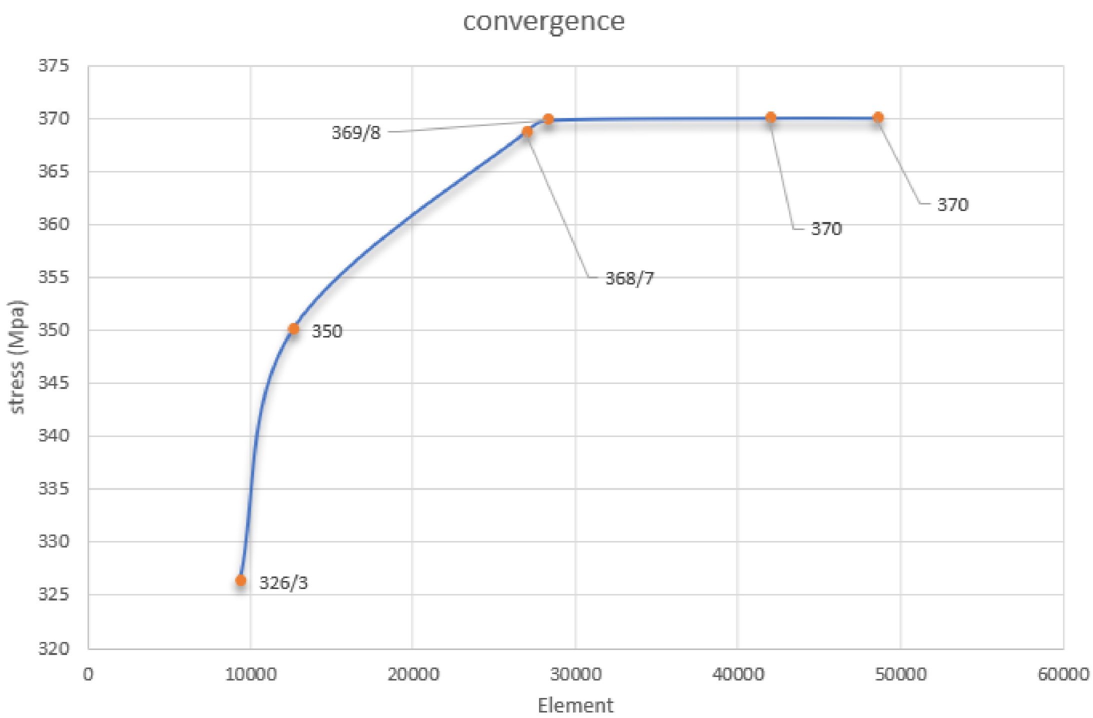

Fig. 11 Convergence of results (stress) by increasing the numbers of mesh

4- Conclusion

In this study, feasibility of manufacturing the of a part of an airliners' tail by stamping process is investigated via FEM simulation. In order to obtain the stamping parameters including material thickness reduction and the maximum stress and strain, the process is simulated by ABAQUS software and then the maximum tensile stress, thickness reduction, and formability are obtained through these simulations. In the followings, the results of the simulation are presented.

- The simulation presents that the forming process by the adjusted parameters is performed perfectly and the sheet metal is completely fill the die.
- According to the simulation, the punch, die and blank-holder are designed properly.
- The maximum stress was obtained 372MPa which occurred at the edges of the formed part.
- The maximum strain created around the hole at the first step of the

simulation was obtained 0.56. In addition, according to the results, the points around the hole, obviously are in the plastic mode.

- The thickness reduction around the hole (at the first step) is about 0.7mm and it is occurred only in some points.

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