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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Development of New Die Design in Towing Hook Production

Çeki Demiri Üretiminde Yeni Kalıp Tasarımı Geliştirilmesi

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Abstract

In this study, a new design has been developed for towing hook dies used in hot forging processes. For this objective, analysis studies were carried out with different process parameters and methods for new designs in dies for both hot forging process and product. After the analysis, the die designs were determined that produced the prototype products at the optimum speed, efficiency and quality. While designing a special die for hot forging operation, a new die design has been developed in which both processes can be performed using a single die with two stages, pre-shape and final shape. Compared to the dies studied for hook groups in the literature and our old dies currently being worked, it is aimed to eliminate the errors caused by the inability to calibrate the final shape such as early wear, short die life, burr residue formation. Such a technics specific to the part as specific to the towing hook was performed for the first time, and with the die design developed by comparing the results of analysis studies, field trials and prototype studies in the Q-Form simulation program, the production of towing hook at optimum efficiency was achieved.

Keywords: Towing hook, Hot Forging, Die Design, Q FORM, Wear

Öz

Bu çalışmada sıcak dövme işlemlerinde kullanılan çeki demiri kalıplarına yeni bir tasarım geliştirilmiştir. Bu amaçla hem sıcak dövme prosesine hem de ürüne dair kalıplardaki yeni tasarımlar için, farklı proses parametreleri ve yöntemlerle analiz çalışmaları yapılmıştır. Analizler sonrasında prototip imalatları yapılmış en optimum hızda, verimlilikte ve kalitede ürün sonucu veren kalıp dizaynları belirlenmiştir. Sıcak dövme operasyonuna özel kalıp tasarımı yapılırken ön şekil-son şekil olmak üzere iki aşamalı tek bir kalıp kullanılarak iki işlemin de gerçekleştirilebildiği yeni bir kalıp dizaynı geliştirilmiştir. Literatürde kanca grupları için çalışılan kalıplara ve mevcutta çalışılan eski kalıplarımıza kıyasla erken aşınma, kısa kalıp ömrü, sakal oluşumu gibi son şeklin kalibre edilememesinden doğan hataların giderilmesi amaçlanmıştır. Çeki demiri özelinde parçaya özel böyle bir uygulama ilk defa yapılmış, Q-Form simülasyon programında analiz çalışmaları, saha denemeleri ve prototip çalışmaları sonuçları kıyaslanarak geliştirilen kalıp dizaynıyla optimum verimde çeki demiri üretimi sağlanmıştır.

Anahtar Kelimeler: Çeki Demiri, Sıcak Dövme, Kalıp Dizaynı, Q FORM, Aşınma

I. INTRODUCTION

The tow hook is hidden under the rear bumper of the vehicles or visible in some off-road vehicles, offered as an option in new vehicles, at the rear of the vehicle; It is a metal part used for towing non-motorized vehicles such as caravans, boats or trailers. The principle of use of this part, as the name suggests, is the connection point used for towing the wheeled non-motorized (or motorized) vehicles that are desired to be towed. Although the drawbars, which are used to move open or closed cargo trailers and caravans that can carry various loads, and therefore to increase the carrying capacity of the passenger vehicle, are produced in different structures depending on the purpose of use in the world, but generally simpler and easier to produce are preferred in Turkey. Since different structures are required for tow hooks depending on the condition of the chassis or the lower part of the monocoque body and the spare wheel, production is made according to the vehicle model [1,2]. When the studies in the literature related to the subject are examined: carried out a study on the design improvements of the connection brackets, in which the suspension elements are mounted on the body, especially in the chassis areas of commercial vehicles [3]. In the proposed bracket designs; The gist is to reduce the weight and increase the strength of the parts. While making suggestions for design improvements; The changes that can be made in the geometric, topological and dimensional properties of the parts are emphasized. Studied the design improvement of the upper wishbone of a vehicle's front suspension system. After starting their research by performing the finite element analysis of the existing structure, they put forward various design suggestions and calculated the obtained recovery rates [3]. At first, static analyzes were carried out for the existing structure with 5 different loading conditions created by the ADAMS program. As a result of the analysis, weak areas in the structure were determined and unimportant areas were determined in terms of stresses where excess material could be removed.

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With the design proposal they deem appropriate, they reduced the weight of the upper swing arm by 15%, while reducing the maximum stress value on the structure by 29%. Made new proposals on the design improvement of a motor bracket and supported these proposals with finite element analysis. The current design of the bracket they will be working on has received poor results from testing and analysis [4]. For this, they proposed design changes. With the design change they proposed, they reduced the weight of the part by 12% and increased the structural strength of the part by 50%. [5,6]. In this study; A new design has been developed for the towing hook dies used in hot forging processes by using the Solid Works 3D design program. For this purpose, analysis studies were carried out in Q-Form Forging Simulation Program with different process parameters and methods for new designs in die related to both the hot forging process and the product. After the analyses, the prototypes were manufactured and the die designs that gave the product result at the optimum speed, efficiency and quality were determined. While designing a special die for the hot forging operation, a new die design has been developed in which both processes can be performed by using a single die with two stages, the preform-final shape. Finally, prototype studies were carried out with the new design, and analysis studies with experimental results were confirmed by characterization studies.

II. MATERIALS AND METHODS

In this study, the whole process is handled in order to be able to manufacture with a much shorter operation time and therefore a higher number of units/hours compared to the existing ones in mass production. For this purpose, all innovative die designs that can be applied for tow hooks have been evaluated, considering the qualities of the existing production benches. The tow hook image is given in Figure 1. The operability of the dies designed using the Q-Form simulation program was tested according to the different process conditions that were predicted to be suitable as a result of the researches. In the experimental applications of the study, the designs verified in the simulation program and the process conditions were compared with the prototype studies and characterization studies were carried out.

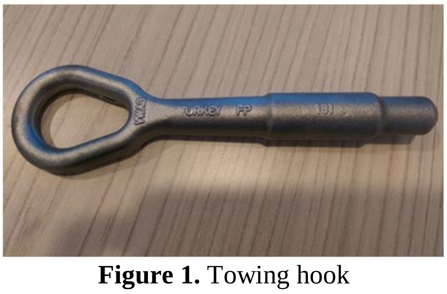

Figure 1. Towing hook

The study was generally carried out in two stages. In the first stage; new design studies, analyzes and process optimizations were made, and in the second stage; Experimental studies and prototype studies were carried out, testing and characterization studies were carried out. In Figure 2, the visual of the towing hooks produced as prototypes is given.

Figure 2. Prototype production towing hook

Value Stream Map (VSM) was prepared for the towing hook, which is the subject of the study, and when this VSM prepared was analyzed for process optimization, the need for increased productivity in forging and burr operations was determined. Studies have been carried out for alternative scenarios over alternative settlement geometries, which are predicted to be suitable in the VSM analysis. For towing hooks, activities that will increase efficiency focused on forging and burr operations in the production process, and then settlements were evaluated. Especially, alternative production parameters were tried and at the same time, alternative new designs of process dies were started. A new die design has been made instead of single forging dies used in forging operations, literature and general applications. This new design developed within the scope of the study; It is a two-stage die design as preform-final shape. Analysis results are given in Figure 3 for the work carried out before the final design.

Premature wear in the forging eyes of the dies, skull formation in burr cutting operations are common problems in the use of single forging dies. In order to remove the skull formations encountered during production, sanding operation should be added to the process. Operations such as extra sanding added while reaching the final product require extra labor and energy and increase the cost per unit. In the study; The analysis of the double forging die design as the preform-final shape was made. In these analyzes, it has been determined that the pre-shape die is worn, the skull formation is prevented by calibrating the part in the final shape die and the life of the final shape die is extended. Solid Works design program was used for the draft and final designs, then the designed dies were analyzed in the Q-Form Forging Simulation Program. An example screenshot from the analysis studies is given in Figure 4. The analysis results were interpreted and the most suitable die design for mass production was decided. The raw material sections to be used during the design studies were also determined. The die designs made were tried on the production line, and after these trials, the bench to be used in the prototype studies for the appropriate die design was selected according to the process requirements by testing the required forging forces.

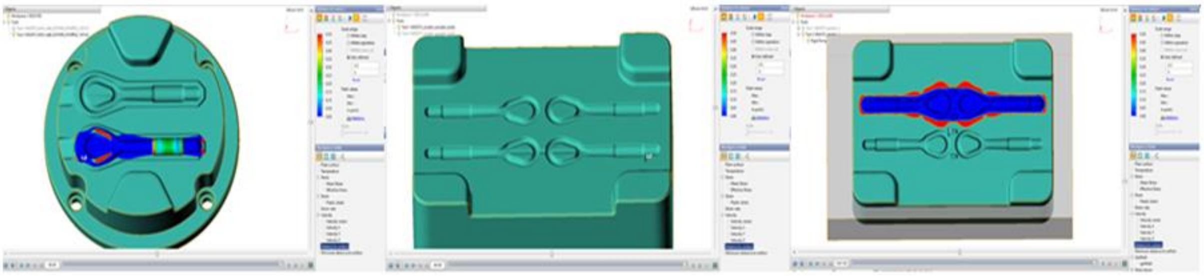

Figure 3. Different die designs [a)single die design b) first double die design c) new die design]

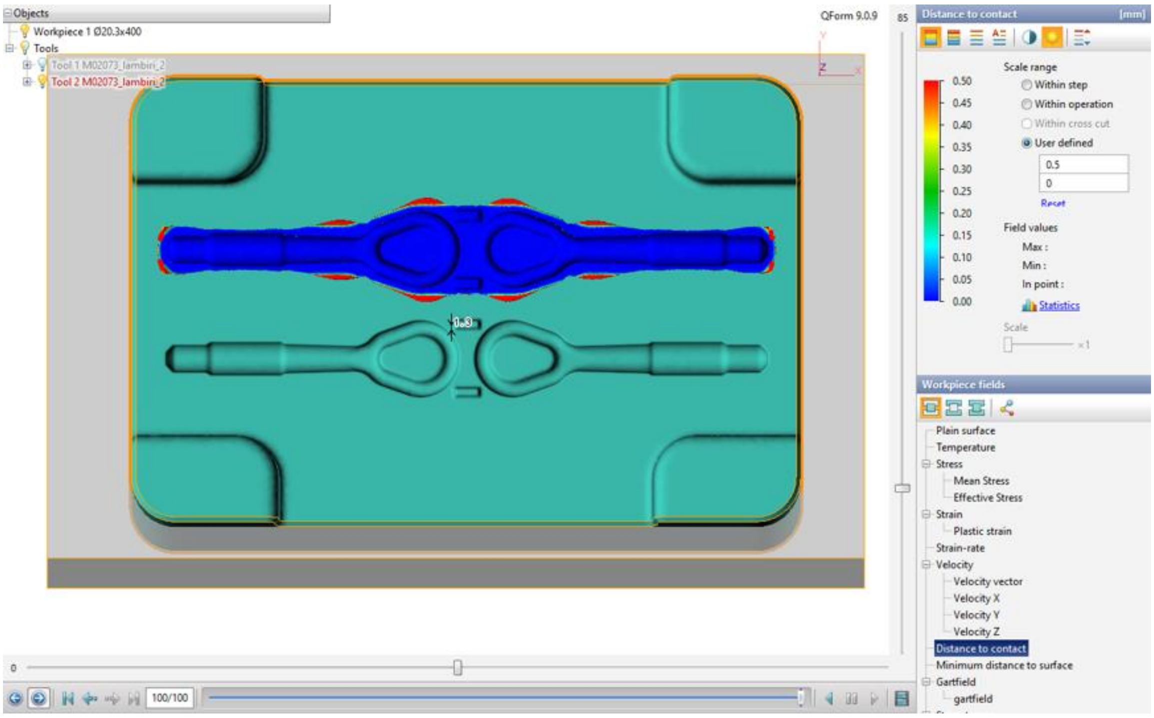

Figure 4. Q-Form analysis studies for new design

Forging dies and hot burr dies were designed for the designs that were decided to manufacture prototypes. Another important issue in the study is the start-up activities of the hot deburring operation. In the literature and general applications, cold deburring is preferred in the production process flows of the towing hook. In our study, hot deburring was included in the process instead of cold deburring in order to increase the process efficiency. Figure 5 shows the image taken during the prototype forging trials.

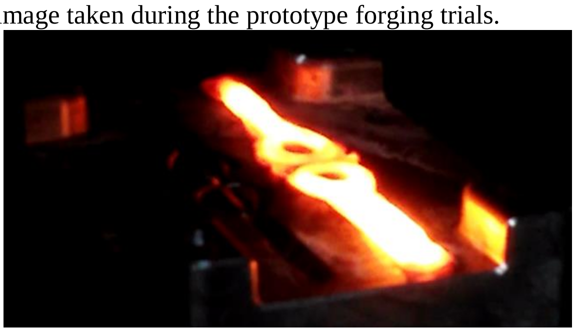

Figure 5. Forging trials

The hot burr die is designed according to the burr geometry that will come out after the forging operation. One of the biggest advantages of this application is that the sandblasting operation applied to the cooling parts after forging is eliminated if hot deburring is done. However, the disadvantages of hot deburring operations; It is not an easy-to-apply process, difficulties are encountered during the application in mass production, burr protrusions remain on the burr line on the part when the part cools, and the part shrinks more than expected. In Figure 6, the image of the prototype forging parts produced within the scope of the study without burr operation is shown.

Figure 6. Prototype forging part

Within the scope of this study, many design and analysis studies have been carried out, and the production process of towing hook has been handled as a whole, and process efficiency has been improved with the principle of maximum number of minimum hours in optimum conditions that can be adapted to mass production. The sanding operation was also eliminated through to the skull formation, which will be prevented from commissioning the new hot burr mold designed in this study. Thus, through to these improvement and development activities in operations, two operations (sandblasting and sanding) in the flow of general applications have been eliminated. Characterization studies were carried out for the products obtained at the end of the prototype studies. Within the scope of characterization studies; tensile, hardness tests and microstructure analyze were carried out.

III. RESULTS AND DISCUSSION

In this study, an innovative die was designed for the towing hook made of 41Cr4 steel to increase production efficiency and extend the life of the die. Forging forming processes were analyzed through the finite element analysis method, and the behavior of the material and the die during production was examined. The forging process was carried out in line with the parameters determined by the design, analysis and simulations. Within the scope of the study, each step of the towing hook forging process is planned. Simulation studies have been performed for the new die design in Q-Form, which is working with the finite element analysis principle [7,8]. Characterization studies were carried out, tensile and hardness tests were carried out. Table 1 and figure 7 give values and graphs for yield tests.

Table 1. Yield test values

Name	Max Stress	Initial Diameter	Initial Length
Pass/Fail	1050, 1200		
Units	N/mm2	mm	mm
M02073-247-1	1194.66	12.000	60.000
M02073-247-2	1111.65	12.000	60.000

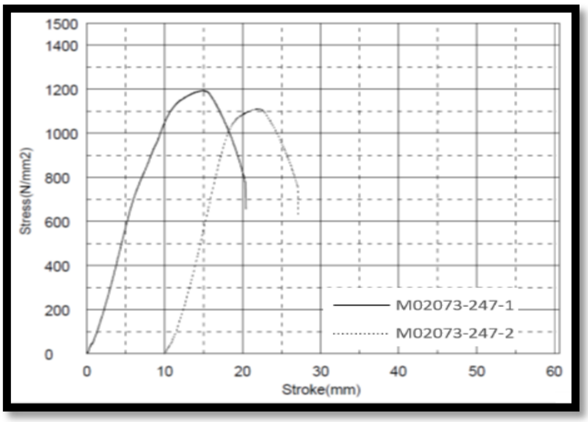

Figure 7. Yield test graph

Within the scope of the study, microstructure examination was carried out. Microstructure analysis images are given in Figures 8. The surface characteristics of prototypes produced with new die design based on micro structure analysis results remain within EN 10083-1 e standards. There are no formations in the micro structure that will play a negative role in mechanical properties [9,11].

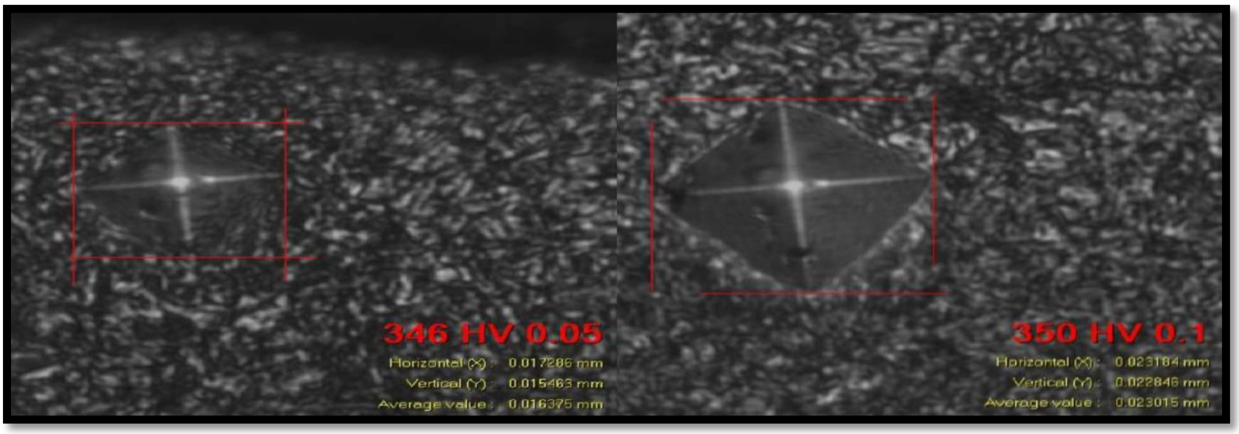

Figure 8. Microstructure and Hardness 346 HV0.05 @ 0.02 mm & 350 HV0.1 @ 0.03 mm below the surface (500x)

Modified design based on the thickness of the burr in the die and forged simulations with Q-form. The design based on the different burr thicknesses results in an optimal burr thickness of 1.3 [9,10]. The design with a burr thickness of 1 mm is called A. The design with a burr thickness of 1.3 mm is called B. The design with a burr thickness of 1.5 mm is called C. The analysis images for these designs are also given in Figure 9.

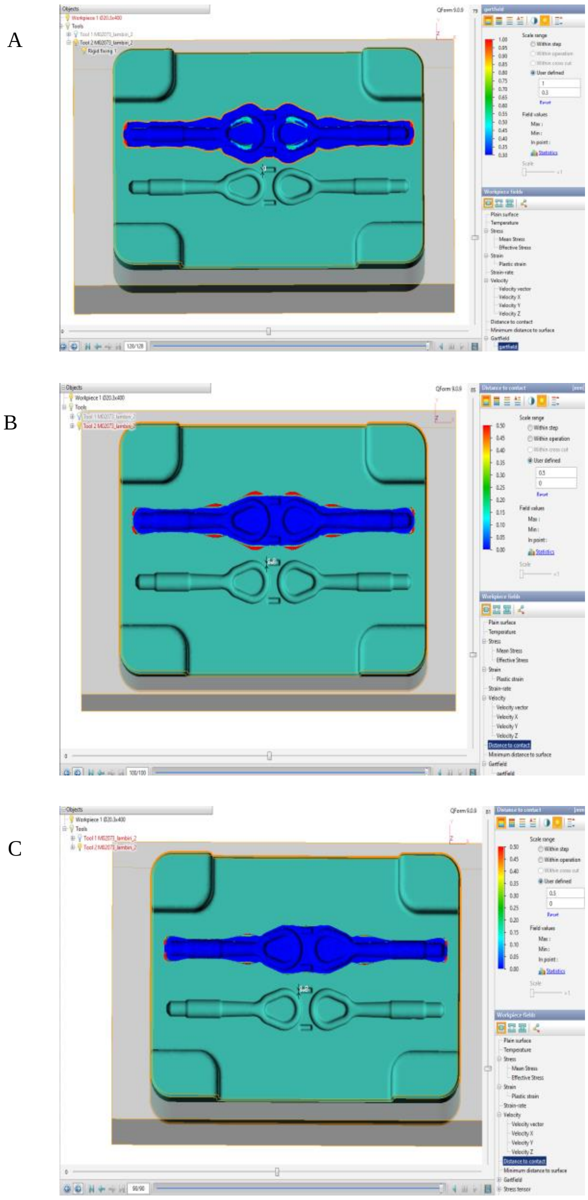

Figure 9. Burr thickness analysis for new die design

Die design optimization has started in the risk assessment phase after the burr thickness in relation to the desired product. The Q-Form analysis program for die design of the relevant product is looking at the risks for surface flow analysis such as; not filling, plication, scale formation etc. [9]. The analysis works performed in Figure 10 are given. Analysis with a burr thickness of 1, 1.3, 1.5 respectively is called A, B, C.

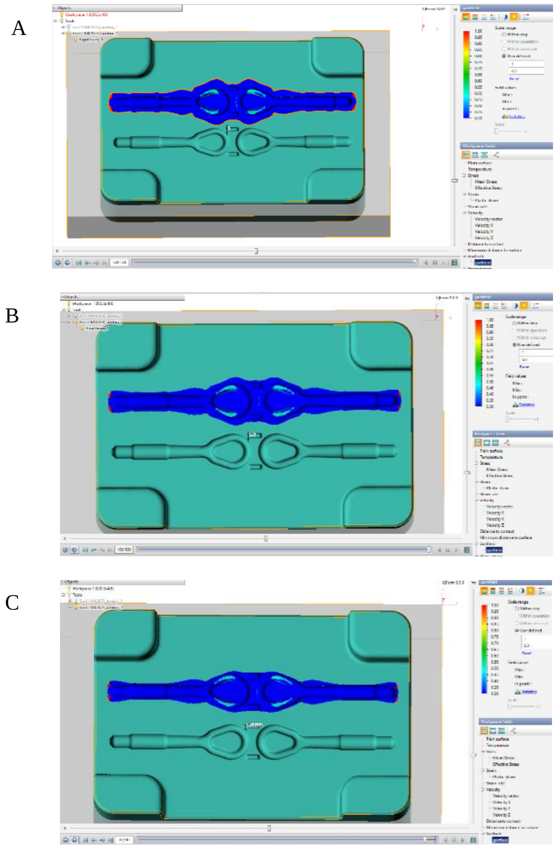

Figure 10. Surface flow analysis

Analysis has been performed to determine the press capacities and determine the tonnage values for the product to be manufactured. The design that correspond to the required press capacity and has a homogeneous burr line has been finalized after these analyzes. Different analyzes were carried out with these parameters to produce the optimal die in the hot forging operation, which varies depending on die stress, material strength, die material selection, raw material flow rate, die temperature, lubricant used and operating temperature. In this study, the design was revised as a result of the above-mentioned analyzes and different die designs were studied. Prototype studies were made with our new double forging die and the required efficiency was achieved.

IV. CONCLUSION

The achievements obtained as a result of this study are given below:

- In the analyzes made during the new die design, the non-filling part was primarily studied. After the analysis, 1.3 burr thickness was determined as the optimum value according to 1 and 1.5. In 1, the desired part could not be obtained, and the problem of not filling in the die was observed. In 1.5 compared to 1.3, the forging press increased due to the presence of more burrs, which is expected to shorten the life of the die and cause it to fracture in the long run.

- As a result of the risk assessments for the new die design, when the surface flow analyzes are compared, it has been determined that the design with a burr thickness of 1.3 mm is the most suitable design. Analyzing burr thicknesses 1 and 1.5, it is seen that they have surface flows that will cause undesirable part defects such as layering, non-filling, folding, etc. In addition, it has been observed that the new design, which prevents errors such as skull formation, layering, and non-filling, with a smaller diameter and less load in the die, increases the die life and part quality when compared to a single forging die.
- In the analysis phase of the new design, the analyzes were completed in order to determine the process values such as press power, raw material diameter, die temperature, raw material temperature, which were determined when the tonnage values were analyzed for the prototype production after the surface flow. Production conditions and analyzes were compared during production and it was observed that the obtained part had the desired microstructure and hardness values. When the parts made with a single forging die are compared with the parts obtained as a result of the new die design, it has been seen as a result of quantitative and qualitative analyzes that they meet the EN 10083-1 standard and the desired qualitative features. With the new die design, more efficient and longer die life parts can be produced.
- The quality problem caused by skull formation, which occurs in the production of towing hook, has been prevented by a new design study.
- With the changes made in the design, the weight of the raw material used has been reduced and raw material savings have been achieved. In the pre-work situation, while 1 piece was produced in a single press in the forging press benches, 2 pieces were started to be produced in a single press with the studies carried out. In this way, labor, time and energy savings have also been achieved.
- In general applications, as the number of parts produced in a single press has been doubled with the work carried out, a 50% increase in die life has been achieved.
- In the general applications made before the study; The heated raw materials were formed into parts by forging, then cooled and deburred by the cold deburring method. During these operations, scale formation was observed on the towing hook surface. The hot deburring process was started without cooling the part, and the deburring process was carried out without allowing scale formation. In this way, scale formation is prevented. The necessity of sandblasting the parts brought by cold deburring is eliminated.

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