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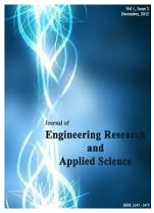

Detection, Analysis and Development of Faults in Cold Work Tool Steel Spinning Molds Used in Industrial Applications

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Abstract

Cold work tool steel DIN 1.2379 is used in press machines used in enterprises producing built-in cooktops, where the upper tables of the furnaces are pressed and cold shaped. During the production in the press machine, some errors were observed in the plastered kiln tables. In order to examine these errors, a number of researches were made on the damage mechanisms on the male and female die sets of the pressing machines and the faults on the quarry tables and on the die sets. DKP and INOX plastering sheet samples were pressed in molds. It was observed that these pressed sheet metal samples were not fully plastered in the determined areas and the errors occurred on the part due to this. The depths in the hotplates were measured in male and female molds with a measuring instrument caliper. After the measurement, it was determined that there was a 0.5 mm difference in the larger chamber of the male mold set than the hotplates. Thereupon, the molds were removed and sent to the CNC Machining Center in order to equalize this difference. Here, after the necessary chip removal and grinding was done, it was connected to the press bench again. After entering the values with appropriate parameters, the plastered sheets were examined. No ponding was observed in the plastered sheets. However, tears were observed at the edges of the sheet samples. AUTOFORM R7 finite element analysis program was used to detect the tears in order to prevent errors during production and to detect them beforehand. FLD diagrams were examined. In order to prevent tearing, polishing was applied to the areas with notch effect and Teflon roll film was used on both sheet metal samples before plastering. However, no ruptures were found and the results were obtained. Production continued where it left off.

Keywords: *Male Mold; Female Mold; Cold Work Tool Steel; Spinning*

1.Introduction

Cold work tool steels; It is known that they have high wear resistance, toughness, dimensional stability, homogeneous microstructure, resistance to abrasive-adhesive wear, fatigue damage starting from the surface of the tool part, and easy machinability in pre-annealed structure. Since cold work tool steels are not manufactured to be resistant to extreme temperatures, it has been determined that the operating temperature ranges vary between 210 -260 °C (Roberts, 1998). Many metallic components are known to be produced by cold forming metal sheet plates at room temperature. cold work moulds; It is known to be used in various metal forming processes such as pressing, punching, drilling and cutting of work metals. It has been determined that the core parts in the molds that form a direct contact interface with the work metals are made by using cold work tool steels. For this reason, it has been predicted that the appropriate selection and processing of cold work tools is important for the durability and service life of the molds (Mesquita, Rafael A., 2016). The wear between the tool steel and the workpiece is thought to be one of the most important factors limiting the useful life of the tool steel.

Factors affecting wear in a system can be listed as follows; properties of the main material (microstructure, surface hardness, heat treatment etc.), properties of the opposite material and ambient atmosphere such as temperature and humidity.

In addition to all these, it is thought that some properties of the materials depending on the service conditions (the type of loading exposed, etc.) have a great effect on the wear mechanism. Wear, which affects tool life, occurs through a variety of mechanisms. It has been determined that the most important wear types are abrasive and adhesive wear, which have been determined before. Ways to prevent wear; It is thought that using lubricants, increasing the surface hardness with various processes such as coatings, purifying the microstructure from inclusions and refining its various properties (Tastemür, D., and

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Süleyman Gündüz, 2021). Considering the working conditions of cold work tool steels used in metal spinning processes, it is thought that they are exposed to impact and shear forces together. Male and female die sets were examined, and as a result, dimensional difference was observed in the male die. As a result, different plastering DKP and INOX sheet metals were plastered and examined. The aim of the thesis studied; By visualizing the working conditions of metal forming processes in the industry, it is to determine the damage mechanism that will occur in this process and thus the factors that will trigger this damage mechanism.

2.Theoretical Method

2.1 Steel Norm 1.2379 Work Team

When we consider the type of steel here as heat treatment, since 1.2379 work tool steels contain austenite phase and carbide structure at solid temperature ranges, decomposition of the carbide structure never occurs despite all applied heat treatments. It has a 15% weight carbide structure that has been heat treated and its hardness level is in the range of 230-250 Brinell hardness.

The toughness and carbide structure content here presents many difficulties in machining steel material at this stage. Therefore, the machinability of such steel materials is increased by adding 0.16% S. Here, the presence of sulfur in heat treatments has no effect. Cooling in the oil environment, the hot work tool is cleaned by the collapse of the layer that appears on the surface, thus providing a suitable surface. Materials that are hardened by cooling-heating processes applied in a suitable atmosphere maintain their surface roughness. During the heating process of the steel material at 1030˚C, the carbide dissolves and becomes enriched in terms of austenite phase, carbon ratio, chromium ratio and molybdenum ratio.

Hardened tool steel contains 13-16% of the austenite phase and there is usually no problem for the austenite phase. However, if small size differences are important in the life of the mold material, a strengthening process is required. It is applied through heat treatments following multiple cooling processes reaching -75˚C It is important not to apply too much heating in the heat treatments applied to the press molds, if it is heated too much, it increases the residual austenite number in the body. As can be seen here, D2 type steels can be hardened with small changes in size (Topbaş, 1998).

An example of steel mold with the norm of 1.2379 is given in Figure 1 below.

Figure 1. 1.2379 The appearance of the mold used in the normed industry

3. Mold Life

The life of tool steel molds; It can be called the number of materials it produces until it passes to manufacture the material and after each grinding process, the material cannot be manufactured. The manufacturing capacity of the tool steel mold is considered as the number of materials that the tool steel mold can manufacture from its final state to the unusable result. Therefore, the manufacturing capacity of each tool steel mold should vary according to the material type of the work material to be pressed. For example, the number of products that can be manufactured from a 0.20 carbon cold rolling heat-treated steel strip material of a given work tool steel mold is less than the number of products to be manufactured from brass raw material (Ataşimşek, S., 1977).

3.1. Causes of Wear Mechanism Affecting Mold Life

Wear conditions in tool steels can be caused by the following reasons.

• Small press empty area.
• If the size of the male mold is too high in the female mold.
• Working of the molds at a short distance from each other.
• Dimensions of the molds that are not proportional to the cross-sectional area.
• The edges of the male and female molds are not free from dirt, there is no straight grinding.
• Inappropriate hardness values of sets of male and female molds.
• The application trajectories of male or female molds are at a level that will increase the wear mechanism.
• Problems caused by assembling the die sets.
• Production of excess parts after sharpening of tool work steel molds.
• Physical negativities of the machines to which the press molds are attached.
• Defects of attachment of tool steel dies to the press table [34]

4. Material Method

In the experiments applied in our factory, the forms obtained by pressing 2 different sheet samples in 0.7 mm thick dkp sheet and chrome sheet, 1.2379 quality steel spinning molds were examined. Different sheet metal samples were tested in different prints. The differences between them were visually recorded. It was determined that these differences were caused by the quality of the sheets and the defect in the die set, and the die sets were sent to the processing center for necessary operations. The stages are supported with pictures.

4.1. Press Bench Used in Practice

The plastering works on the sample sheets were carried out on the work bench called 'HÜRSAN PRES'. (Fig. 2)

Figure 2. Hursan plastering machine view

The technical specifications of the press machine used in manufacturing are given in Table 1.

Table 1. Press machine specifications chart

MODEL	DCP 77/650
PRESSURE WEIGHT	19000 KG
PRESSURE FORCE	4000kN
ENGINE POWER	22 Kw
TRAY PRINTING CAPACITY	1400x1200
VOLTAGE	380 V
FREQUENCY	50 Hz
MAX. CURRENT	48 A
DESCENT SPEED (MİN. MAX.)	100 mm/sn
ASCENT SPEED (MİN. MAX.)	170 mm/sn
PRESSING SPEED (MİN. MAX)	10 mm/sn
MAX. STROKE	600 mm
MAX. PRESSURE	250 Bar
MAX. POWER	28 Kw
NOISE LEVEL	80 dB
TOTAL REACTION TIME	0.5
SAFETY DISTANCE	500 mm
PUMP	105

5.Conclusions

DC04 7114 quality DKP sheet sample was used as an alternative in the studies aimed at solving the damage occurred in the 304 quality INOX sheet used in the production of built-in cooktops. A total of 6 samples were prepared from DC04 7114 quality (spun) DKP sheet samples and 304 quality INOX sheet samples. 1.2379 cold work tool steel dies are connected to the press bench by means of suitable fasteners. Respectively, 3 pieces of 304 quality INOX sheet metal samples were placed on the female mold and the plastering images obtained were examined. As a result of the examination, ponding and cracks on the edges were observed in the furnace panels used in the factory.

With the same molds, this time, the pits and crack appearance on the product, which is obtained as a result of pressing 3 female molds from DC04 7114 quality (spunning) DKP sheet material, are less observed than the 304 quality INOX sheet sample. In this study, studies were carried out to prevent pitting and tearing in the corners of the hearth panels. Values related to press printing are given in Table 2.

Table 2. Press pressure measurement values charts

EXPERIMENT NO.	ARM PRESSURE	POT PRESSURE	UPPER LIMIT	POT LIMIT	PRESSING
1	75 bar	100 bar	230 mm	25 mm	80 mm
2	80 bar	105 bar	240 mm	30 mm	80 mm
3	90 bar	110 bar	250 mm	40 mm	80 mm

Form images of DC04 7114 quality DKP and 304 quality INOX sheet samples on the furnace panels according to the pressure values above are given in Figure 3 and Figure 4.

Figure 3. Form image of DC04 7114 quality DKP sheet material as a result of press printing

Figure 4. 304 quality INOX cooker panel press printing result form images

5.1. Mold Defect Analysis

DIN 1.2379 cold work tool steel male and female mold sets were checked with measuring tools on the heights. It has been observed that the depth in the area where the large pool is located in the section where the furnace pools are located in the male mold is 0.5 mm more than the other pools.

The reason for this difference is the regional abrasions that occur on the surface of the male mold as a result of the production in high quantities and the form on the surface prevents the elongation of the material for plastering during the plastering of the part, and for this reason, pitting has occurred in the specified area of the mold.

After these form images were obtained, the die sets were removed from the press machine and sent to the processing center. It was connected to the machine in the machining center and 0.5 mm chip removal was performed. The desired form was obtained in the sheet material. The image of the die sets going to the machining center is given in Figure 5.

Figure 5. Connecting the male mold to the CNC lathe in the machining center

After the machining of the male mold, stress-relieving heat treatment was applied in order to prevent residual stresses and distortions in the structure, and then it was left to cool in the furnace environment for 1 day. The micro-structures before and after heat treatment are given in Figure 6 below.

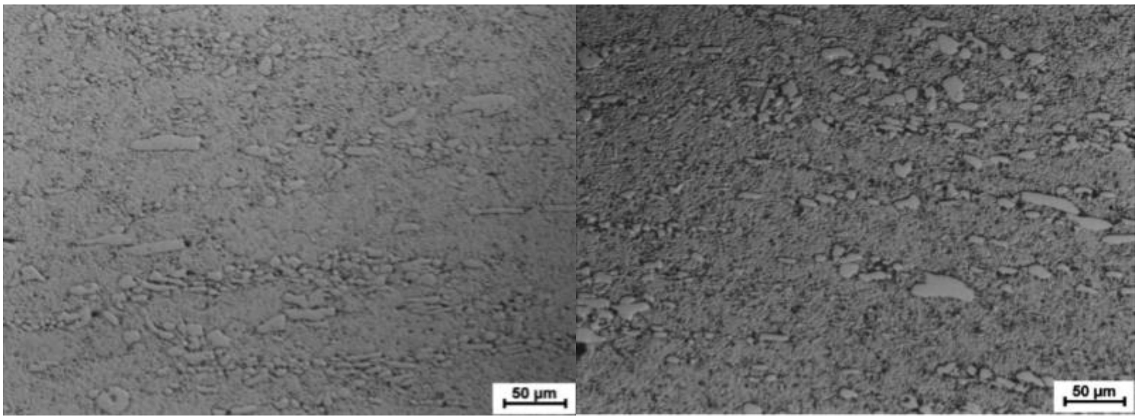

Figure 6. Internal structure formed before and after heat treatment

The production of built-in hob panels is primarily sized to press sheet metal parts. After the sheet metal parts are sized, they are plastered after they are placed on the workbench. Afterwards, the excesses formed on the edges of the sheet metal parts coming out of the plastering are entered into the cutting molds for the perimeter cuts and the perimeter cuts are performed.

5.2 Analysis Works

Before starting the experimental studies, analyzes are made in order to predict the accumulation of stresses that may occur during pressing, the determination of the damage mechanisms that may be encountered, and the necessary actions. Using the analysis programs we use in the finite element method provides a great advantage in terms of time and cost in this sense. Analysis studies were carried out with the help of the AUTOFORM R7 program used in the finite element method and supported by the form images with the Ansys program. Figure 7 shows the deformation images showing the pitting area and the simulation images of the torn area on the upper panel of the furnace where 304 quality INOX sheet sample is desired to be produced. Following are the precautions to be taken afterwards.

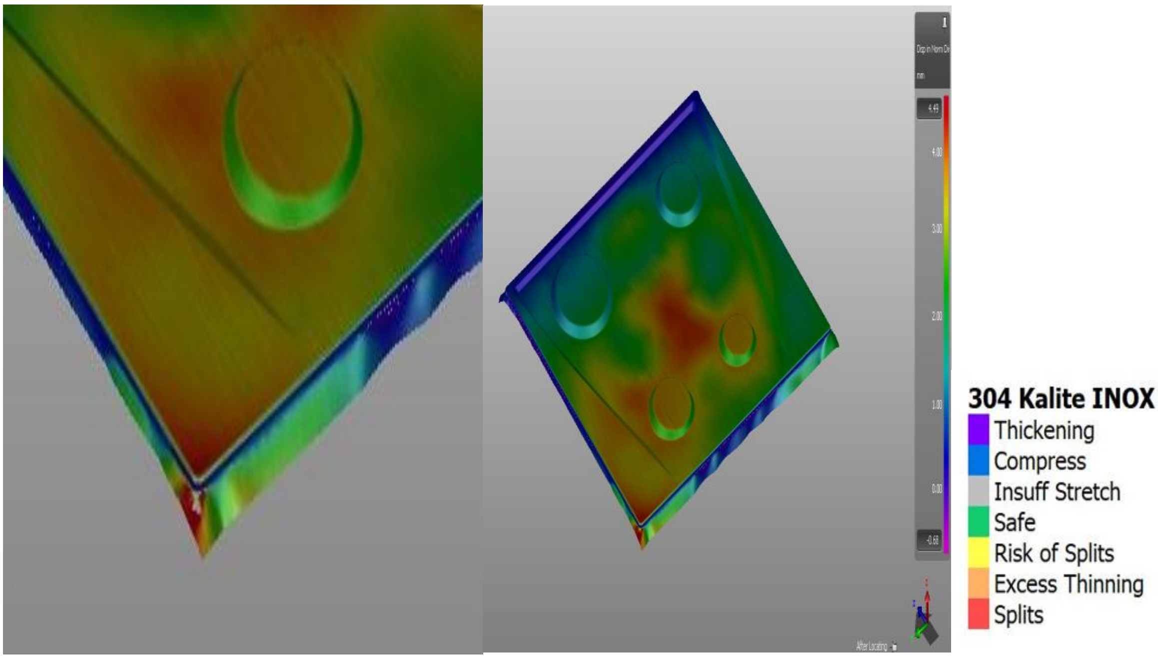

Figure 7. Simulation images of the ruptured region and the ponding region

Measures to be taken in order to eliminate the errors;

a) Elimination of depth differences by machining

b) Use of mold lubricant spray and lubricating film roll in order to ensure a healthy plastering

c) Applying stress relief heat treatment to relieve residual stresses in the mold

d) Improvement of Sample Sheet geometry

With these methods, it is aimed to prevent tearing and ponding.

5.3 Manufacturing Process

5.3.1. Manufacturing With 304 Quality Sheet Metal

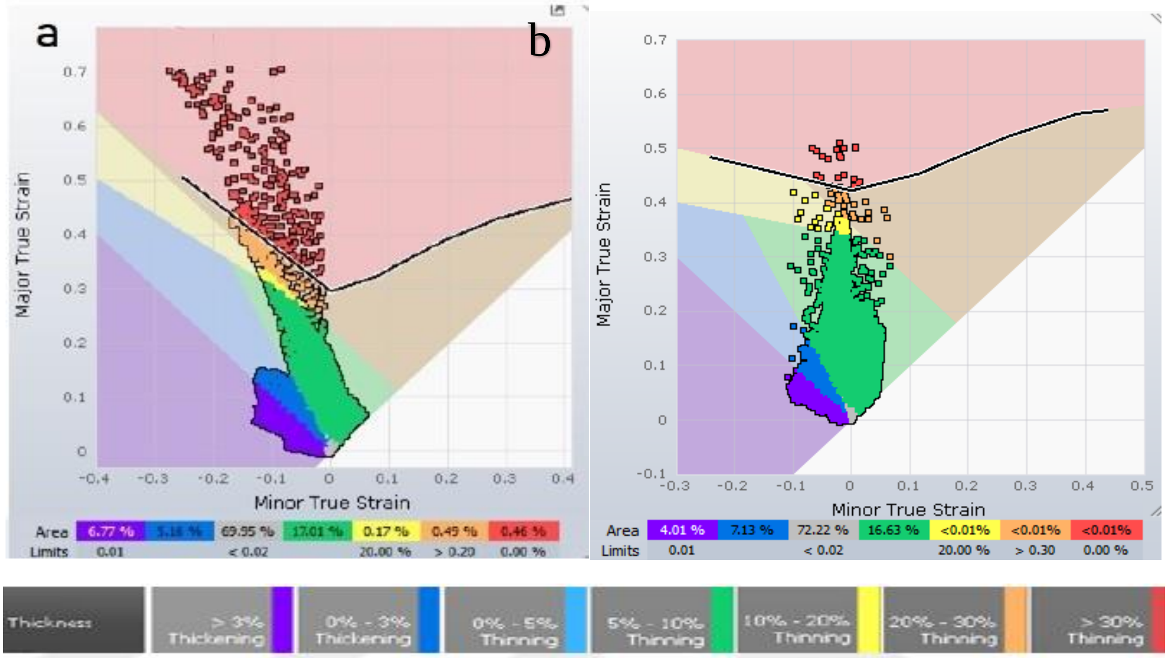

Figure 8. a:304 quality INOX sheet faulty geometry FLD diagram, b:304 quality INOX sheet tear-reduced repaired geometry FLD diagram

By removing 0.5mm excess sawdust from the male mold, ponding on the furnace panel was not observed. A tear occurred in the faulty geometry of the 304 quality INOX sheet sample. In order to prevent tearing, geometry improvement was made by making 10 mm rounding corners on the corners of the sheet metal sample. Tearing is reduced by 40% (Fig. 8) With the results, the occurrence of pitting and tearing was predicted. In order to eliminate this pitting and tearing, it was aimed to prevent this problem by adding additional materials during the manufacturing process. First of all, plastering was realized with the last geometry in the mold during the manufacturing process (Figure 9).

As a result, tearing occurred in each product in the regions shown in the simulation output in Figure 7.

There are three factors in the formation of the tearing mechanism. The elongation ability, friction factor and notch factor due to the quality of the sheet material. When we look at three factors here, a number of ways have been used to eliminate the notch effect, primarily because it saves time and is more economical in the manufacturing process. Here, the notch effect has been removed by polishing the tear zone along the region shown in Figure 9 while the sheet is in the template state.

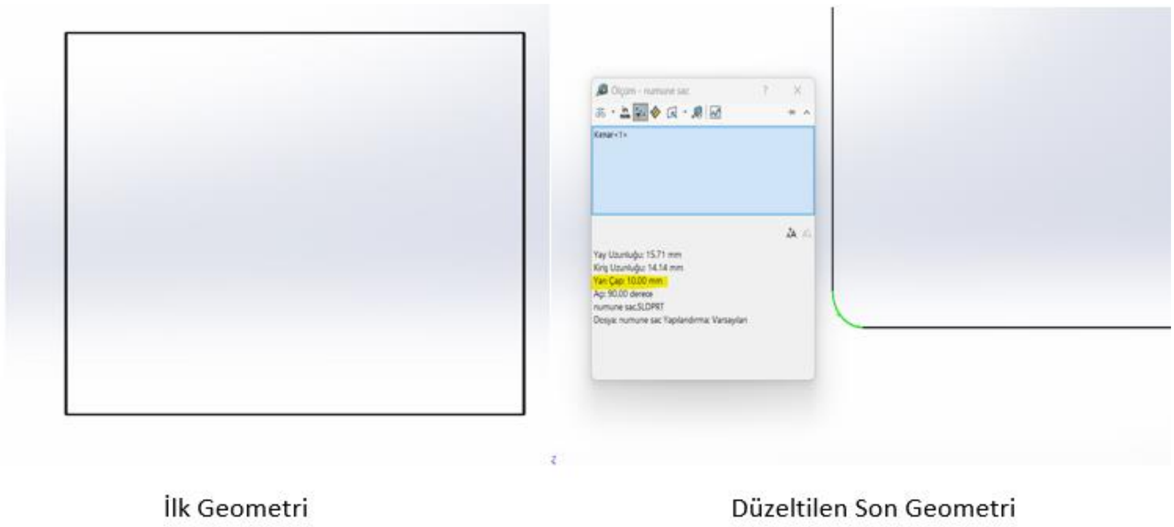

Figure 9. First and final corrected geometry view produced in the mold

By enlarging the corner radii in the sheet metal sample, the stresses at the corners were greatly reduced thanks to the variable radii (Figure 10).

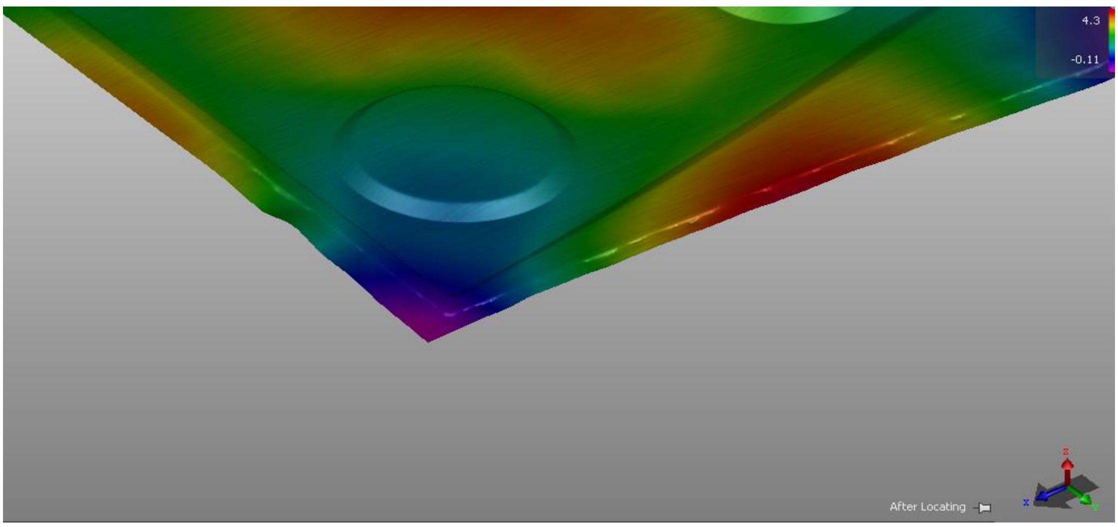

Figure 10. Stress-reduced simulation view with corrected geometry

After the geometry correction, the tearing phenomenon was greatly reduced due to the reduction of stresses, but it was not completely prevented. For this reason, studies have been carried out in order to completely eliminate the tearing by performing a number of additional operations. By removing the excess in the male mold, pitting is prevented and in addition, the tearing is reduced by 55% with the change in geometry. (Fig. 8) With the results, the occurrence of pitting and tearing was predicted. In order to eliminate this pitting and tearing, it was aimed to prevent this problem by adding additional materials during the manufacturing process.

First of all, plastering was realized with the last geometry in the mold during the manufacturing process (Figure 9). As a result, tearing occurred in the regions shown in the AUTOFORM output in Figure 7 in each product. There are three factors in the formation of the tearing mechanism. The elongation ability, friction factor and notch factor due to the quality of the sheet material. When we look at three factors here, a number of ways have been used to eliminate the notch effect, primarily because it saves time and is more economical in the manufacturing process. Here, the notch effect has been removed by polishing the tear zone along the region shown in Figure 9 while the sheet is in the template state.

After polishing, a tear occurred at the corner of the sheet sample, but the tear size was greatly reduced (Fig. 11).

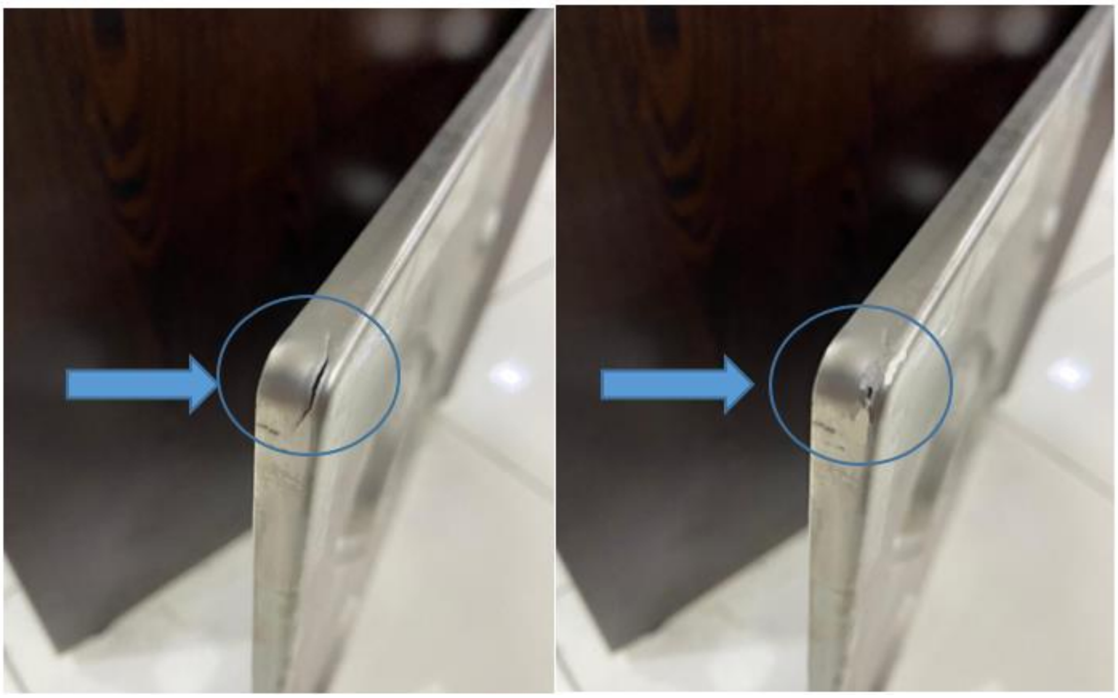

Figure 11. a. Production with unpolished DC04 7114 quality sheet b. Production with polished DC04 7114 quality sheet metal

A tear was observed in every stove panel produced during manufacturing. After the machining of the male mold geometry differences, ponding and pitting were not observed on the panel. In order to prevent the tears, we sprayed the mold lubricant spray on the female and male mold surfaces, eliminating the tensions and frictions that may occur in the sheet metal. In addition, mold lubricant (PTFE) Teflon roll film was used. No tearing was observed after the mold lubricant spray and mold lubricant (PTFE) Teflon film.After the ponding on the quarry top was prevented by the chip removal method of the geometric differences in the male mold, the polishing process was carried out on the torn areas of the 304 quality INOX sheet due to the notch effect. But this process alone was not enough. It did happen, albeit to a lesser degree, than with ripped polishing in the corners. In addition, a mold lubricant (PTFE) Teflon film was used to completely prevent tearing. After using this (PTFE) Teflon film, tearing was completely avoided. No tears were found in the last products manufactured (Figure 12).

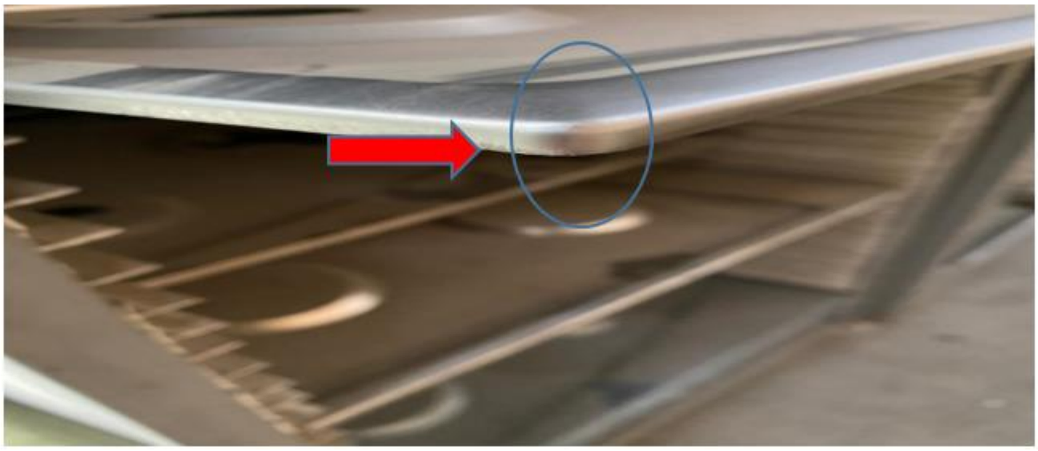

Figure 12. Stove top plate manufactured seamless

In order to prevent tearing, welding and polishing processes were applied to the torn area to prevent the torn area. However, these methods are economically very expensive. Therefore, these methods have been preferred since they are less costly in terms of polishing and mold lubricant (PTFE) Teflon film production on areas with notch effect. Alternatively, DC04 7114 quality DKP sheet sample was pressed. Likewise, rupture occurred. However, less tearing was observed compared to the other sheet metal sample (Figure 12)

5.3.2. Manufacturing with DC04 7114 Quality DKP Sheet Metal

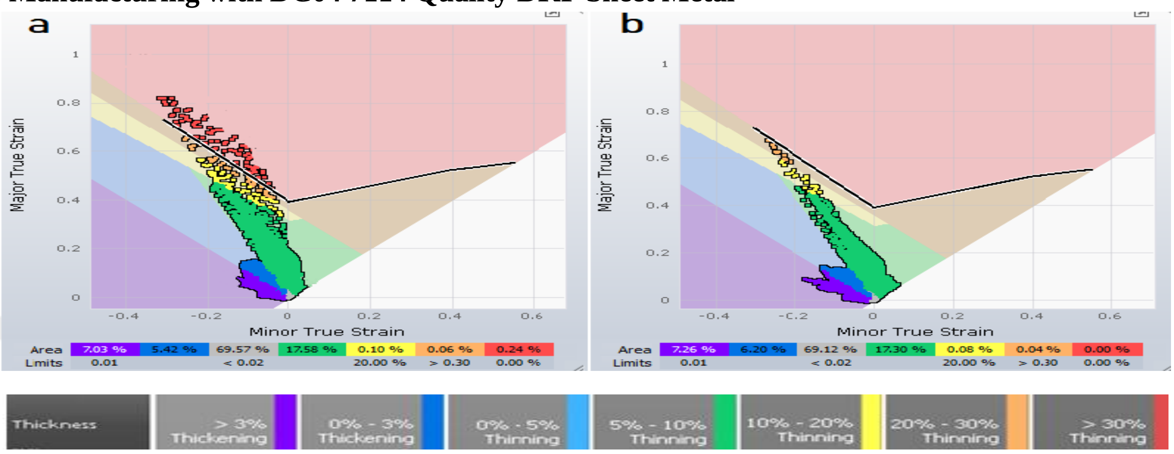

Figure 13. a. DC04 7114 Quality DKP sheet cannot be produced geometry FLD diagram b. DC04 7114 Quality DKP sheet metal torn blocked geometry FLD diagram

According to the result of the analysis of DC04 7114 Quality DKP sheet sample (Figure 13), tearing occurs, but the tearing rate is lower than the other sheet sample. The tearing that occurs in the sheet metal samples produced (Figure 14) is also given.

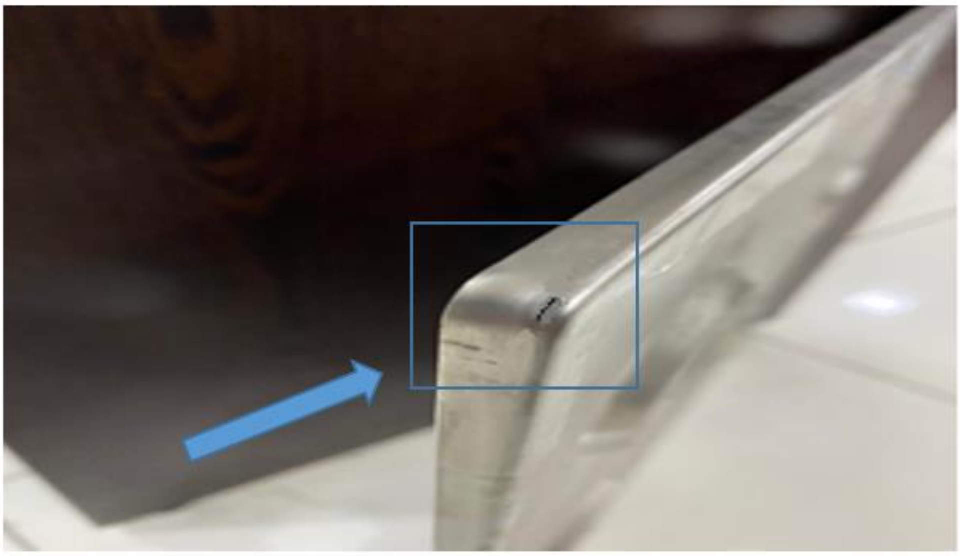

Figure 14. DC04 7114 Quality DKP sheet sample tearing appearance

5.3.3. Polishing Process

The polishing process was applied to the DC04 7114 quality DKP material, which had less tearing than the other sample. No tearing was observed in the sheet metal sample that was plastered after the application. (Figure 15)

Figure 15. Polished 304 Quality INOX seamless form

The notch factor was prevented in the samples. In order to prevent friction, which is another effect, tearing was prevented in a very economical way by using mold lubricant and Teflon roll film. The micro-structure image of the region where the tear occurred and the micro images of the region where the tear did not occur (Figure 16) of the DC04 7114 quality DKP sheet sample are given.

Figure 16 DC04 7114 DKP sheet sample microstructure images

304 quality sheet metal sample micro-structure image of the region where the tear occurs and the images of the microstructure without tearing are included. (Figure 17)

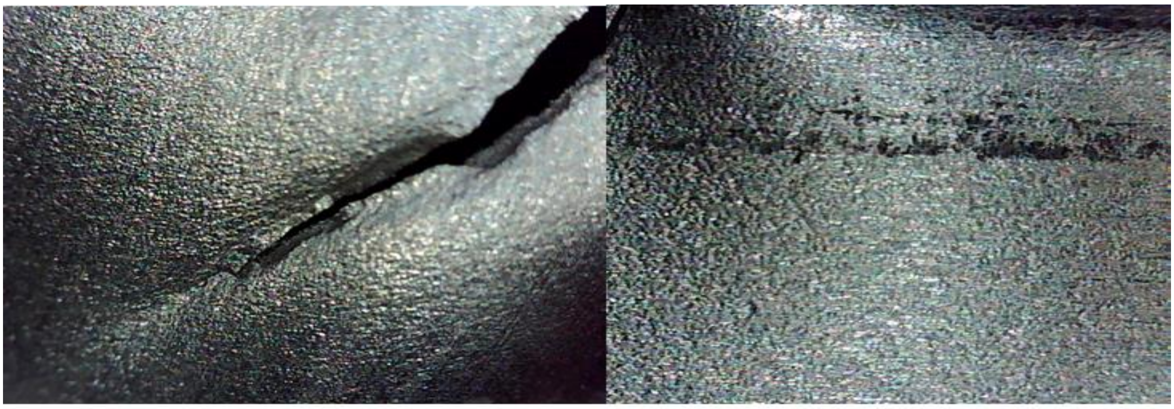

Figure 17. 304 quality INOX sheet sample microstructure images

6. Conclusions

In this study, studies and analyzes were carried out in order to eliminate the tears and pitting that occur during production in the stove panels produced in the sector that manufactures built-in cooktops.

• Using analysis programs to detect the damage mechanisms that may occur in the material in the sheet metal forming processes in the industry allows us to foresee the occurrence of the error. In the study, two different sheet metal samples were used to determine the areas where damage may occur due to tearing.

• It is possible to have the geometry of the mold materials in appropriate forms so that pitting does not occur in the spinning of sheet materials.

• It is thought that there may be elongation in the mold due to transport and displacement, and even residual stresses due to transport in the body.

• Physical measurements were made and measurements were made on the mold in the virtual environment, and it was determined that the large chamber of the furnace mold was 0.5 mm longer than the other chambers.

• In order to eliminate these differences, it was taken to the machining center and 0.5 mm chip removal was applied.

• In the plastering made with DC04 7114 quality DKP sheet materials, the stresses in the over-shaped areas were determined by analysis programs and it was observed that there were tears in the corners as a result of the plastering. In order to get rid of the notch effect on the corners, firstly, the corners were polished and the production was made by placing a mold lubricating Teflon roll film between the mold and the sheet metal and spraying it during production.

• In the spinning made with 304 quality INOX sheet materials, the stresses in the overshaped areas were determined by the finite element analysis program, and the tears as a result of the spinning were less common than the previous sheet sample. This small-sized tear is prevented by using a mold lubricating Teflon roll film.
• The factors affecting the forming ability of sheet metal samples in spinning production are the mechanical properties of the sheet material, the notch effect and the effect of friction on the surface.
• It is seen that the notch effects on the corners negatively affect the shaping ability of the material.
• It has been observed that the use of mold lubricating Teflon roll film during production between the mold and the sheet sample increases the forming ability of the sheet.
• The heat treatment applied to the mold helped to remove the residual stresses in the mold.
• Mold lubricant processes should be preferred in order to prevent tearing in terms of economy and cost.

Recommendations regarding the studies carried out are given below.
• In future studies, the geometry of the sheet metal samples can be improved by making corner rounding (radius) in order to reduce the notch effect. If the tearing damage and friction effect continue, the mechanical properties can be improved by applying heat treatment to the sheet metal sample.
• Detection of tearing damage can be predetermined before the sheet metal sample goes into production using analysis programs.
• Different lubricating materials can be used to prevent friction damage during sheet metal forming.
• The geometry of the molds must be in a form suitable for the geometry of the material to be plastered.
• In places where plastic deformation is excessive after plastering, the areas where the sheet starts to tear should be determined and appropriate actions should be taken.

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