International Journal of Innovative Engineering Applications

Journal homepage: https://dergipark.org.tr/ijiea

INVESTIGATION OF PRESS BRAKE PUNCHES AND DIES PRODUCED BY CASTING METHOD AND FROM MANGANESE STEEL MATERIAL IN TERMS OF MACHINABILITY

Oktay Adıyaman[*1]

[1]*Besiri Organized Industrial Zone Vocational School, Batman University, TR-72100, Batman, Turkey*

Abstract

Original scientific paper

Punches and dies employed in sheet metal "V" bending have been obtained generally from stock materials, AISI 4140 and EN C45 (Ck 45), in industrial applications through machining. The fact that local and different manufacturing methods have been applied in manufacturing these punches and dies has gained great significance in terms of external dependency and economy. The purpose of this study is to manufacture punches and dies used in "V" bending process from manganese steel via cast method and compare the newly obtained molds with presently used molds in terms of machinability and surface roughness. In this study, the experimental samples from both AISI 4140 and manganese steel were machined at different cutting parameters (cutting speed, feed rate, depth of cut), hence they were compared by analyzing with regard to chip morphology, cutting tool edge wear and surface roughness. At the end of the study, it was concluded that the punches and dies manufactured from manganese steel produced in foundry and widely found are alternatives compared to available AISI 4140 steel molds in terms of machinability.

Keywords: *"V" bending, machinability, punches and dies, sheet metal, manganese steel.*

DÖKÜM YÖNTEMİ İLE MANGANLI ÇELİK MALZEMEDEN ÜRETİLEN ABKANT PRES ZIMBA VE DİŞİ KALIPLARIN İŞLENEBİLİRLİK YÖNÜNDEN İNCELENMESİ

Özet

Orjinal bilimsel makale

Sac metal bükmede kullanılan zımba ve dişi kalıplar endüstriyel uygulamalarda genellikle AISI 4140 ve EN C45 (Ck 45) kütük malzemelerden talaşlı imalat yöntemiyle elde edilmektedir. Bu kalıpların imalatında yerel ve farklı imalat yöntemlerinin uygulanması dışa bağımlılık ve ekonomiklik anlamında önem kazanmaktadır. Bu çalışmada amaç, döküm yöntemiyle manganlı çelikten "V" bükmede kullanılan zımba ve dişi kalıplarının imal edilerek elde edilen yeni kalıpların mevcut kalıplarla işlenebilirlik ve yüzey pürüzlülüğü yönüyle karşılaştırılmasıdır. Çalışmada hem AISI 4140 hem de manganlı çelikten deney numuneleri farklı kesme parametrelerinde (kesme hızı, ilerleme, talaş derinliği) işlenerek, talaş morfolojisi, kesici takım uç aşınması ve yüzey pürüzlülüğü yönünden analiz edilerek mukayese edilmiştir. Çalışma sonunda yerelde bulunan dökümhanelerde üretilebilen ve yaygın olarak bulunabilen manganlı çelikten üretilen zımba ve dişi kalıpların mevcut AISI4140 çelikten talaşlı imalat yöntemiyle üretilen kalıplara göre işlenebilirlik yönünden de alternatif olduğu sonucuna varılmıştır.

Anahtar Kelimeler: *"V" bükme, işlenebilirlik, zımba ve dişi kalıplar, sac metal, mangan çelikleri.*

1 Introduction

In sheet metal bending processes, press brake and in relation with this, punches and dies used in "V" binding processes are quite common [1] with many studies [2]. The performance properties of the employed punches and dies have become prominent; and the issues such as the examination of the production processes of these molds, their machinability, wear and deformation stabilities and production-cost factors have gained significance [3]. The punches and dies used in "V" bending are generally produced from AISI 4140 and EN C45 (Ck 45) steel. Hence, machining production method takes the first place. AISI 4140 steels are widely employed in many molds, machine parts and cutting tools. AISI 4140 steel comprises about 10% of raw material in machining production processes. These steels have high hardenability property due to the alloy elements they contain [4]. AISI 4140 steels build a hard martensitic structure after tempering is done to harden them due to the Cr and Mo alloy element content; and as a result of this, they provide mechanical properties such

* Corresponding author.

E-mail address: oktay.adiyaman@batman.edu.tr (O. Adıyaman)

Received 27 June 2022; Received in revised form 25 September 2022; Accepted 08 October 2022

 Doi: https://doi.org/10.46460/ijiea.1136221

as resistance, ductility and toughness properties at the same time. Because of this property, this type of steel is widely used [5]. One of the most important disadvantages of these steels is that they have quite brittle structures [6]. Therefore, it is necessary to choose the temperament temperature very carefully [7,8,9].

Steels with high manganese are known for their high hardening and toughness properties. High manganese steels are produced due to their excellent properties such as tensile strength, ductility and wear resistance; and they are used in the fields which are under the effects of high wear and impact [10]. Manganese steels are engineering materials widely used owing to the properties they have such as high work hardening, high wear resistance, toughness and ductility. The most important disadvantage of high manganese steels is that their machinability is quite difficult. The most significant property of these steels is that their structures change into austenitic martensitic and they harden when they are exposed to cold deformation under mechanical effects [11]. Sulphur, eliminating hot brittleness of these manganese steels, has a binding and carbide generator effect [10,12]. The fact that alternative steels to AISI 4140 and EN C45 (Ck 45) steels employed widely in “V” bending punches and dies are to be developed and that less cost processes are to be improved for machining methods and production appear to be problems that should be solved. It is necessary that the problem be compared in such aspects as especially machinability and applicability by trying different materials.

When the studies carried out are examined, it is seen that the subjects can be categorized [13]. We can study these categories under the main headings of modelling, sheet metal properties and measuring methods, adaptive bending, part placement, bending order, collision detection, tolerance verification and loading with robot [13]. It is seen that there appear three different bending zones during bending process. This is the first zone which appears due to inner radius of punch, and the layer starting from the point occurred with only elastic deformation and formed with variable radius, and the layer occurring after spring back not displaying any permanent deformations [14-16]. Spring back takes place widely on many materials with different parameters [17-21].

When these studies are examined, few studies have been encountered in investigating the materials used in “V” bending punches and dies. In the study where the effects of alloy elements employed in sheet metal form molds (body shell and front side panel) were examined [22], the mechanical properties of molds produced from eutectic and around eutectic (sub-eutectic and supra-eutectic) Bi-Sn alloys used in sheet metal bending were investigated. In order to determine the mechanical properties of the molds with this alloy material, hardness, tensile and compression tests were applied to the molds. It was observed that the compressive strength of the alloys decreased with Bi ratio and a maximum compressive strength value was obtained in the supra-eutectic alloys with a Bi ratio of 51% [22].

Obtaining “V” bending punches and dies from manganese steel through molding method and comparing it to stock AISI 4140 steel in terms of processing time and cost were assessed in previous relevant studies [23,24]. According to this, 89% processing time achievement was realized in manufacturing punches from manganese steel by means of molding method. The punches obtained through molding method in terms of waste compared to punches produced stock AISI 4140 raw steel were obtained as 16,5% and 89% respectively [24]. The comparison of the metal sheet surface contact zone wear during bending was conducted in another work [25]. In this study, it was established that the punches and dies produced from manganese steel exhibited better performance in terms of wear compared to the molds produced from AISI 4140.

In industrial sheet metal bending, it was observed that high waste amounts and high costs in labor, time and cutting edge costs occurred due to the use of machining methods to take the "V" bending punch and dies made of AISI 4140 and EN C45 (Ck 45) steel as stocks and bring them into the required form. In addition, the fact that these steels are produced by some certain countries creates a foreign-dependency. Considering the deficiency in the literature, it is necessary to try different regional and national raw material alternatives and casting etc. and investigate the applicability of manufacturing methods of these molds.

In this context, the aim of this study is to test the manganese steel as an alternative to the steel produced from AISI 4140 and EN C45 (Ck 45) steel in “V” bending punch and dies and to examine it in terms of machinability. It is also aimed to obtain these molds by casting in order to minimize the machining method. Studying the issue from this perspective will expand the field of future researches. It will shed light on the trials related to the use of steel types with different mixtures and different structures in this field. Minimizing machining will provide economy in waste and cost. Ensuring the use of local and national resources will reduce external dependency. Therefore, different alternatives should be created by using material types and production techniques that can be produced in our country. It is important to create an alternative material and production technique in sheet metal bending molds, and for this purpose, punch and dies should be manufactured by casting from manganese steel material and the issue should be analyzed in terms of machinability.

2 Material and Method

2.1 Preparing Samples for Mechanical Tests

“V” bending dies used in press brakes are produced in different sizes to be used in experimental studies. In the production of the models, 3 different punches and 2 different female mold models were selected from the catalogues of CKB Machine Mold Limited Company [26], which are mostly used in bending processes. These selected models were produced with casting method from manganese steel by giving 2 mm finishing allowance especially to the sheet metal bending contact and assembling (fixture) surfaces (Figure 1).

The comparison of the production time performance of the punches and female molds cast from manganese steel in Figure 1, and the punches and dies produced from stock AISI 4140 steel, was made in previous studies [23-25].

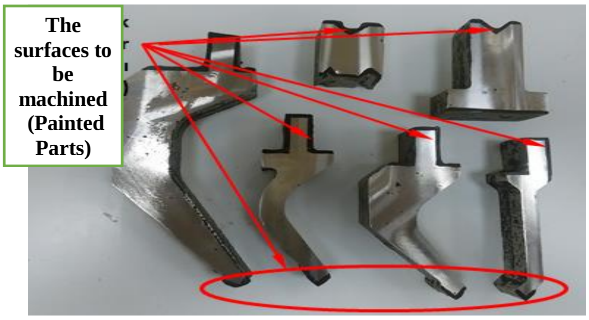

Figure 1. Produced casting punch and die simples.

In this study, test samples were obtained by casting method in order to perform both machinability and mechanical tests along with casting of punches and dies. AISI 4140 steels are obtained from existing steel stocks. The chemical properties of the cast manganese steel and AISI 4140 steels are given in Table 1

Table 1. Chemical analyses of used materials.

Chemical Analysis of Manganese Steel				
Element	**%**	**Element**	**%**	
Carbon (C)	1.375	Nickel (Ni)	0.104	
Phosphor (P)	0.047	Vanadium (V)	0.047	
Molybdenum(Mo)	0.261	Manganese (Mn)	17.59	
Cupper (Cu)	0.110	Chrome (Cr)	0.977	
Sillisium (Si)	0.356	Aluminum (Al)	0.013	
Sulfur (S)	0.005	Boron (B)	0.002	
Remaining Part Ferrum (Fe)				

Chemical Analysis of AISI 4140 Steel						
C	Mn	Si	Cr	S	P	Mo
0.41	0.83	0.21	0.9	0.027	0.027	0.18

2.2 Machinability Activities

Apart from the punches and mold models, 4 pieces of plates to be used in machinability processes were cast in the dimensions of 100x10x100 mm (Width x thickness x length).

Regarding the machinability tests, the ISO 8688-1 standard, which is the standard for machinability and the parameters for the determination of tool wear and tool life, was taken as reference in this step. All chip removal processes were performed on a 3-axis CNC milling machine. It is necessary that the width of cutting tool piece should be nearly 60-70% of the cutting effective diameter [28,28]. In the experimental studies, APMT1604PDSR-MM insert type belonging to Korloy Company and PC5300 series inserts belonging to this insert and a 30 mm diameter end milling were used for the use of these inserts (Figure 2).

In addition, test samples were prepared to be used in machinability applications. Since the end mill tool with a diameter of 50 mm was chosen to process the test samples, the piece width (W) was processed with the end mill with a width of 30 mm as 60% of the diameter (Figure 2).

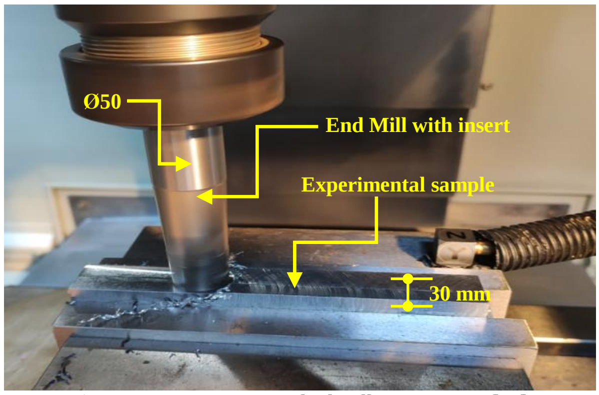

Figure 2. ISO 8688-1 standard milling operation [28].

For comparison with each other, test samples were obtained from both AISI 4140 steel and cast manganese steel materials.

2.3 Test Design

Within the context of machinability processes of the samples prepared for processing application, the machinability tests of the workpieces were performed with AISI 4140 steel and cast manages steel. In processing of experimental samples prepared for this purpose, three different cutting parameters and three different levels for each parameter were chosen. Cutting speed, feed rate and depth of cut were chosen as factors, and levels related to these factors were determined. These levels were obtained from cutting tool catalogue information of the firm web site [28].

As the cutting tool, Korloy branded APMT 1604PDSR-MM standard and PC5300 coded insert was used. Korloy 2014-2015 tool catalogue was used for the determination of machining method and cutting parameters. Considering that the selected inserts should be convenient for interrupted cutting and convenient for machining manganese steel with cast iron properties, the machining parameters were similarly selected from the same catalogues.

After all the evaluations, considering the cutting parameters in Table 2, L9 orthogonal array with 9 experiments was chosen according to the Taguchi experimental design as the most suitable design for the experimental study. For the experiments, a total of 18 tests were carried out, 9 of them were with AISI 4140 steel and 9 of them were with manganese steel samples that were cast.

Table 2. Machinability parameters and levels.

Factors	**Unit**	**Level 1**	**Level 2**	**Level 3**
Cutting Speed (A)	m/min	75	100	125
Feed Rate (B)	mm/rev	0.1	0.15	0.2
Depth of Cut(C)	mm	0.5	1	1.5

L9 test design of 18 test designs carried out and test distribution of this test is shown in Table 3. As a result of machinability processes, surface roughness measurements of all machined surfaces were conducted.

Table 3. Taguchi L9 orthogonal test design.

ExpNo	Variables	Cutting Speed (A)	Feed Rate (B)	Depth of Cut (C)
1	A1B1C1	1	1	1
2	A1B2C2	1	2	2
3	A1B3C3	1	3	3
4	A2B1C2	2	1	2
5	A2B2C3	2	2	3
6	A2B3C1	2	3	1
7	A3B1C3	3	1	3
8	A3B2C1	3	2	1
9	A3B3C2	3	3	2

In the measurements, it is aimed to compare the surface roughness of AISI 4140 and manganese steel surfaces and to determine the difference. Measurement specifications for surface roughness measurements are shown in Table 4.

Table 4. Surface roughness measurement parameters.

	Device brand and Model	SRT-6210
	Measurement Method	Gauss
	Measurement Unit	Ra
	Measurement speed	0.25 Vt:0.135 mm/s

In each of the AISI 4140 steel and manganese steel samples machined according to the experimental design in Table 3, a Ra value was measured in the front, middle and back regions perpendicular to the machining direction. In addition, 3 measurements in the front, middle and back regions were measured in the direction parallel to the machining direction (Figure 4). The arithmetic mean of 3 values in each region was taken and recorded. The surface roughness tests were carried out according to the norms specified in TS 971. In surface roughness measurement, the value of cutting speed (λc) was taken as 2,5 according to ISO standard of the device.

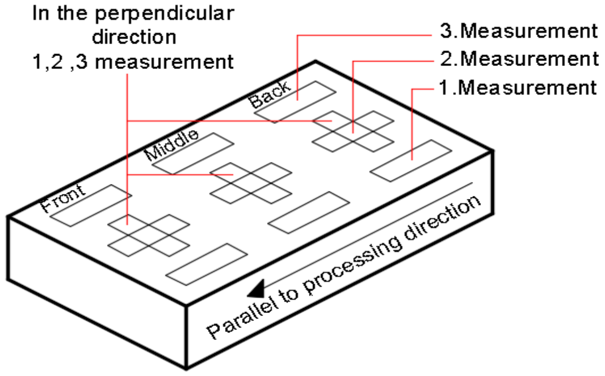

Figure 4. Structures on the chip.

3 Results and Discussion

3.1 Chip Morphology and Tool Wear

According to L9 orthogonal test design and test data given in Table 2 and 3, the chips obtained from the machinability processes of AISI 4140 steel and manganese steel samples (Figure 3) made for the analysis of the machined parts and the images of the insert of the cutters performing each operation were examined under the SEM microscope. 200X and 500X SEM images of all chips were obtained. The machinability analyzes were evaluated based on the chip forms obtained and the damage on the cutting edge. The chip SEM image used in the evaluations and its definitions are shown in Figure 3.

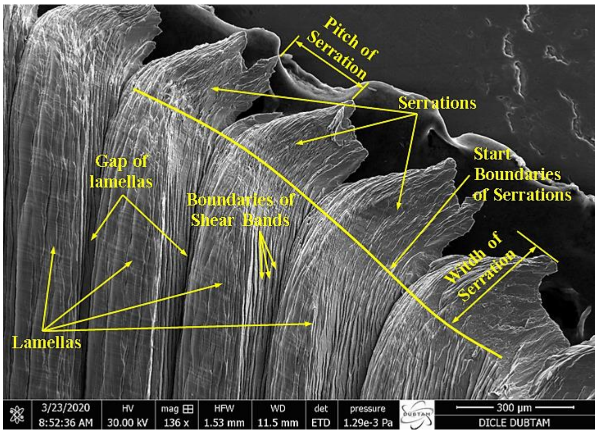

Figure 3. Structures on the chip.

When the chip types of both methods are examined, in the process of not only AISI 4140 steel but also manganese steel, serrated type chips were observed to occur (Figure 4).

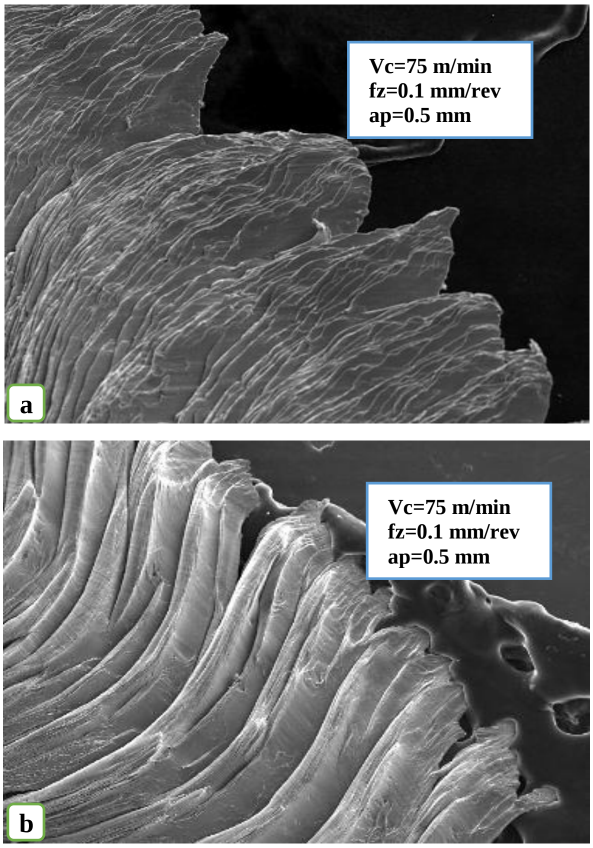

Figure 4. Serrated type chips obtained as a result of processing a) AISI 4140 b) Manganese steel.

The formation of serrated chips causes fluctuations in cutting forces, accelerates tool wear and reduces the quality of the machined surface [30,31]. For this reason, when we look at the surface roughness, it is seen that there are deteriorations in the surface roughness due to serrated chips. In addition, the adiabatic slip band, which is formed without any damage to the primary deformation zone, is considered the main cause of serrated chip formation [31,32]. Serrated chips are generally obtained in the machining of hard materials and the serration ratios may vary according to the tool geometry. (Figure 5).

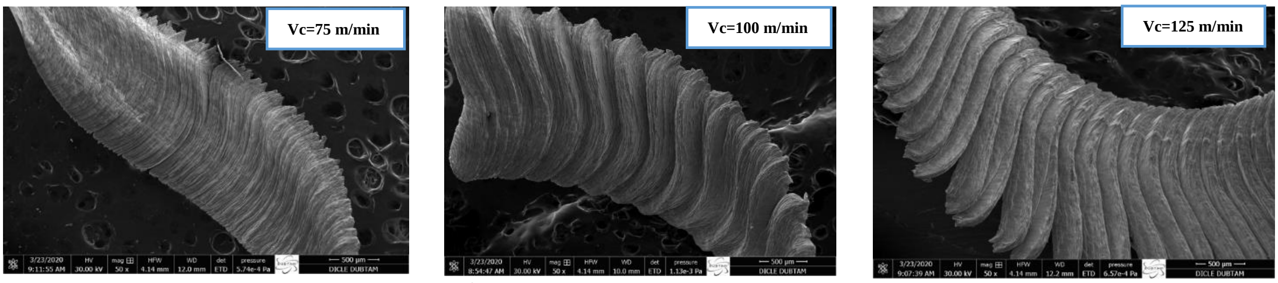

Figure 5. Chips forming related with cutting speed increase in AISI 4140.

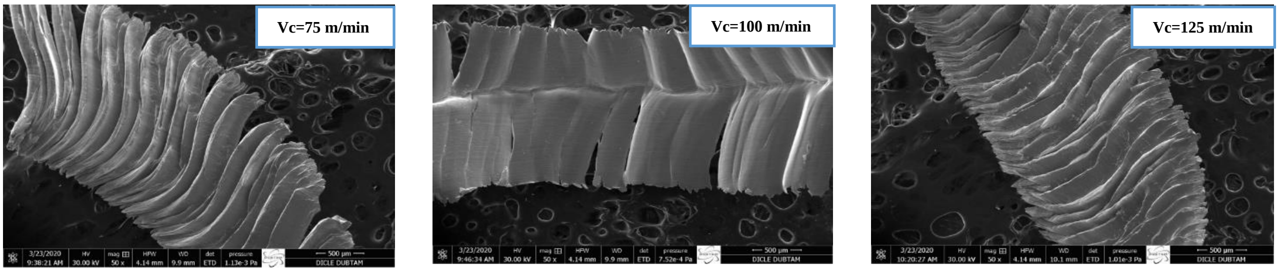

Figure 6. Chips forming related with cutting speed increase in manganese steel.

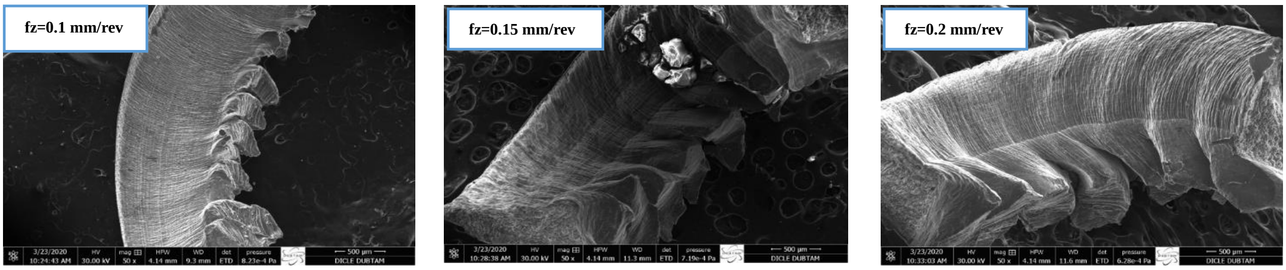

Figure 7. Chips formed related with feed rate increase in AISI 4140.

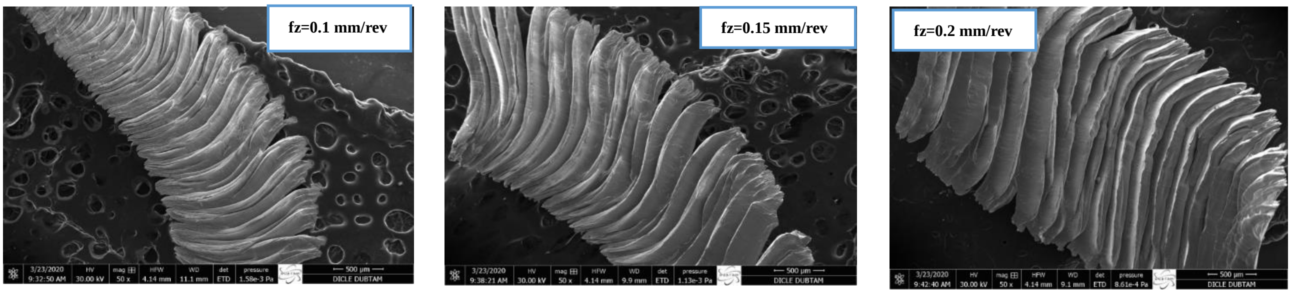

Figure 8. Chips formed related with feed rate increase in manganese steel.

When Figure 5 is examined, it is seen that with the increase in cutting speed, the lamellas in the chips become less frequent and the serration pitches increase in parallel. It is also seen that the width of the serrations also deepens in the same way. The chips obtained in the machining of manganese steel are shown in Figure 6.

When Figure 6 is examined, it is seen that the width of the serration decreases in manganese steel, but the gaps between the lamellas increase more than that of AISI 4140. However, when looking at AISI 4140 steel, it is seen that the gaps between the lamellas increase with the increase in cutting speed, whereas the gaps between the lamellas decrease with the increase in cutting speed in manganese steel.

When the chips obtained depending on the feed rate are examined, the chip shapes of AISI 4140 steel are seen in Figure 7, and the chip shapes of manganese steel are seen in Figure 8.

When Figures 7 and 8 are examined together, a serrated chip type and a continuous chip type are formed in AISI 4140 steel, whereas a chip type with a shorter serration width is formed in manganese steel. In addition, while the amount of feed rate increases, the serration pitches of AISI 4140 steel increase, while the gaps between the lamellas increase in manganese steel. We are of the opinion that these cavities, which we call deformation cracks, are formed as a result of the hardness given by the high manganese content in the material and the hardening of the grain boundaries in the microstructure, and this is also helped by the carbide structures at the grain boundaries. In AISI 4140 steel, it is observed that the width of the serration increases significantly with the increase in feed rate, while the width of the serration is seen very little in manganese steels. For this reason, there is no opinion about the width of the serration.

In order to make a comparison between AISI 4140 steel and manganese steel in terms of machinability, tool wear was also investigated. SEM analyzes of the cutting edges used in 9 machining of AISI 4140 and manganese steel materials carried out according to the parameters in Table 5 were made; and tool wear was compared. In the analysis, both AISI 4140 and manganese steel materials behaved similarly at low cutting speeds and almost no wear was observed (Figure 9).

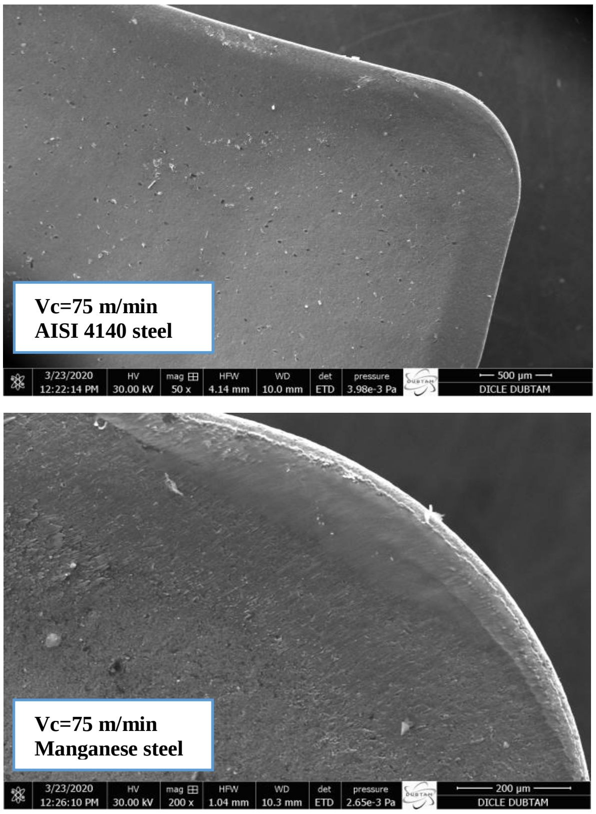

Figure 9. Cutting edge wears at low cutting speed.

It was observed that although tool wear is low in cases where the cutting speed and feed rate values are low, the wear increases more at high cutting speeds and high feed rate values (Figure 10).

When Figure 10 is examined, no wear was observed on the flank surface of the insert tool at a feed rate of 0.15 mm/rev in both AISI 4140 and manganese steel, but some wear was observed on the rake surface. However, as the feed rate was increased, it was observed that the cutting edge wear increased even more. No crater wear etc. in both steel types of cutting tools was encountered. When all the tools were examined, it was observed that the wear in manganese steel processing was slightly higher than that of AISI 4140 steel. However, considering the gain in the processing time and waste amount of the parts, which were widely explained in previous studies on the subject, the gain obtained in the processing of manganese steel punches and dies with the casting method and the amount of wear on the cutting tool were found to be a tolerable factor. In this respect, it was concluded that the disadvantage of manganese steel punches and dies can be kept to a minimum in terms of machinability of manganese steels.

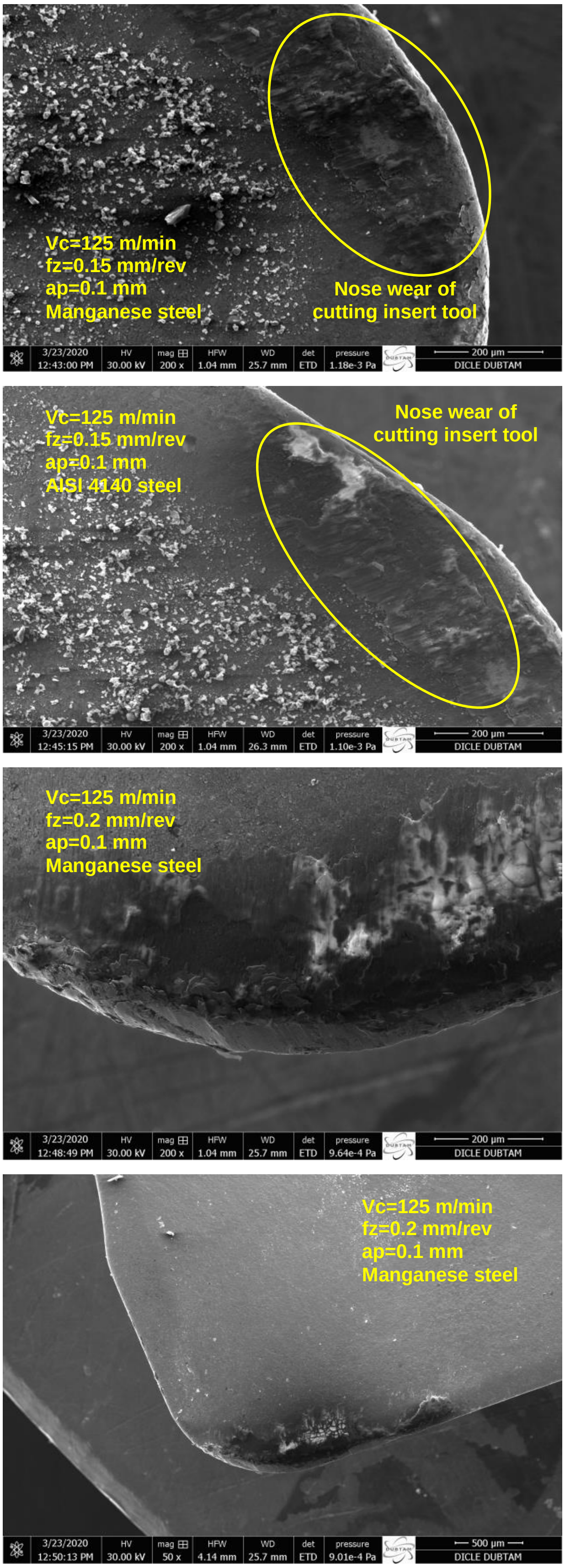

Figure 10. Cutting edge wears at high cutting speeds.

3.2 Surface Roughness

After the comparison of AISI 4140 steel and manganese steel in terms of machinability, the surface roughness of the machined samples were measured and compared. The surface roughness values of the machined AISI 4140 and manganese steel are given in Table 5 and 6, respectively.

The graph of the surface roughness of work piece samples formed in machining of AISI 4140 in Table 5 is seen in Figure 11 and the graph of the surface roughness of work piece samples formed in machining of manganese steel in Table 6 is seen in Figure 12.

Table 5. The surface roughness values of the machined AISI 4140.

No	Parallel to machining direction									Perpendicular to machining direction		
	Front			Middle			Back			Front	Middle	Back
	Measure 1	Measure2	Measure3	Measure 1	Measure2	Measure3	Measure 1	Measure2	Measure3			
1	1.21	1.13	0.745	1.135	1.005	0.67	1.065	0.915	0.98	0.975	0.835	1.105
2	1.255	1.095	0.85	1.32	1.055	0.845	1.235	1.145	0.705	0.87	1	0.89
3	2.16	1.74	1.21	2.24	1.84	1.72	2.42	2.02	1.54	1.15	1.07	0.94
4	0.69	0.85	0.385	0.795	0.875	0.562	0.605	0.79	0.48	0.765	0.88	0.77
5	1.17	1.59	1.25	1.47	1.235	1.275	1.62	1.32	1.51	0.885	1.145	0.905
6	1.97	1.64	1.31	1.9	1.73	1.15	2.03	1.65	1.25	1.095	1.3	1.3
7	0.62	0.73	0.266	0.572	0.585	0.288	0.705	0.71	0.202	0.91	0.68	0.705
8	1.56	1.34	0.965	1.56	1.3	1.005	1.59	1.38	0.845	0.865	0.785	0.935
9	2.3	1.42	1.3	1.93	1.5	1.08	1.68	1.34	0.955	0.9	1.03	0.925

Table 6. The surface roughness values of the machined manganese steel.

No	Parallel to machining direction									Perpendicular to machining direction		
	Front			Middle			Back			Front	Middle	Back
	Measure 1	Measure2	Measure3	Measure 1	Measure2	Measure3	Measure 1	Measure2	Measure3			
1	0.835	0.82	0.615	1.24	1.24	0.835	1.205	1.195	0.84	0.715	0.835	1.085
2	1.46	1.15	0.985	1.31	0.99	0.915	1.185	1.115	0.805	1.07	1.02	0.93
3	2.15	1.78	1.69	2.1	1.74	1.57	2.25	1.91	1.46	1.03	1.2	1.11
4	0.84	0.89	0.615	0.84	0.715	0.43	0.77	0.71	0.542	0.795	0.855	0.83
5	1.45	1.05	0.875	1.29	1.005	0.715	1.3	0.955	0.885	0.745	0.94	0.975
6	2.09	1.77	1.34	1.8	1.51	1.37	1.38	1.34	1.185	0.945	1.25	1.46
7	0.825	1.245	0.48	0.69	0.92	0.492	0.7	0.995	0.462	0.915	1.01	1.205
8	1.245	1.195	0.725	1.06	1.04	0.86	1.3	1.14	0.805	0.785	0.785	1.08
9	1.29	1.53	0.995	1.9	1.275	1.235	1.73	1.34	0.97	1.12	1.09	0.93

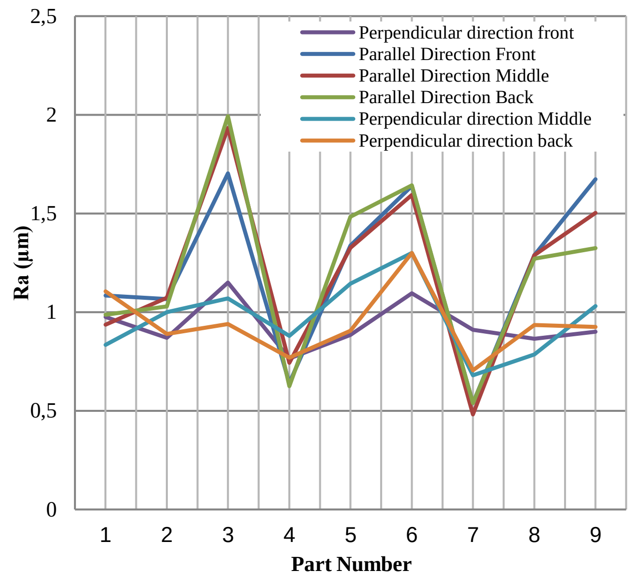

Figure 11. Surface roughness in machining AISI 4140 steel.

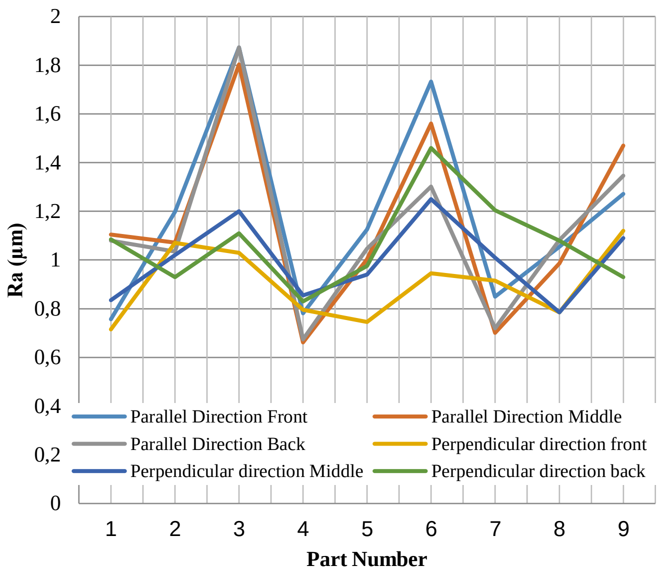

Figure 12. Surface roughness in machining manganese steel.

When the graph in Figure 11 is examined, it can be seen that the highest Ra values were obtained in the 3, 6 and 9 parts with the highest feed rate values. It is a well-known case that the feed rate has the greatest effect on Ra. In addition, in measurements made in the direction parallel to the feed rate, the Ra value was always higher than the measurements made in the direction perpendicular to the feed rate at all cutting speeds, feed rates and depths of cut. It is thought that this is related to the surface form formed, and while measuring Ra from the machined surface in machining parallel to the direction of progress, the more indented form on the surface produces Ra values at higher values.

The graph of the surface roughness of work piece samples formed in machining of manganese steel in Table 6 is seen in Figure 12.

When Figure 12 is examined, it is seen that the highest Ra values were obtained in pieces 3,6 and 9, where the feed rate was maximum. However, it is seen that lower Ra values were obtained in all Ra values compared to AISI 4140 steel. In manganese steel, higher Ra values were obtained in the perpendicular direction to the machining direction, as in AISI 4140 steel. When the graphics in both Figure 11 and Figure 12 are examined, it is seen that there appeared an increase in Ra values as the cutting speeds increased. This is also seen in the literature studies. Aslan [33] and Özler [34] stated in their study that the surface roughness increased later with the increase of cutting speed although it decreased a little before. The reason for the increase in Ra value was shown to increase with the increase in cutting speed and the increase in cutting forces and tool vibration [34]. With the increase in cutting speeds, frictions at the tool-chip interface increase and Ra values increase accordingly. If the temperature and friction at the interface are high, there will be BUE (Built up Edge) between the tool rake surfaces. These form a built-up edge shape. Fractures in the built-up edge can pass to the chip and the workpiece. Thus, it causes deterioration in both the tool and the workpiece [35,36]. In the studies, it was recommended to use M20 quality cutting edges for processing high manganese steels [36]. In addition, it has been stated that the increase in cutting forces and the increase in tool vibration are the reasons for the increase in the surface roughness with the increase in feed rate [35,36].

When the graphs in Figure 11 and 12 are examined, it is observed that relatively lower Ra values were obtained in lower depth of cut values as in the experiments 1, 6 and 8. It has been determined that the depth of cut has had the least effect on Ra parallel to this in the studies carried out [36]. When all these results are considered, it is observed that in Ra measurements we obtained in experiment samples that the most effective value was feed rate, then cutting speed and the least effective one was depth of cut.

In the Taguchi test design, first of all, the efficiency of all parameters on Ra and the ideal conditions for the minimum Ra value were determined. The signal-to-noise ratio response table for obtaining the ideal values of cutting parameters in AISI 4140 and manganese steel machining to provide the smallest Ra value is given in Table 7.

Table 7. Response tablo for signal to noise ratios for Ra.

AISI 4140 Steel			
Level	**Cutting Speed (m/min)**	**Feed Rate (mm/rev)**	**Depth of Cut (mm)**
1	-2.0392	3.1891	-2.0951
2	-1.2190	-1.9183	0.4651
3	0.2788	-4.2501	-1.3494
Delta	2.3180	7.4392	2.5603
Rank	3	1	2
Manganese Steel			
Level	**Cutting Speed (m/min)**	**Feed Rate (mm/rev)**	**Depth of Cut (mm)**
1	-2.1399	1.8746	-1.2134
2	0.2469	-0.4589	0.1809
3	-0.1339	-3.4425	-0.9943
Delta	2.3867	5.3171	1.3944
Rank			
Smaller is better			

When Table 7 values are examined, it is seen that the ideal parameters for the Ra values obtained as a result of the machining of both steel types are obtained under the conditions where the cutting speed is 125 m/min, the feed rate is 0.10 mm/rev and the cutting depth is 1 mm for AISI 4140 steel. In manganese steel, it is seen that the ideal conditions are obtained under conditions where the cutting speed is 100 m/min, the feed rate is 0.10 mm/rev, and the cutting depth is 1 mm. The graph of the signal-to-noise ratios for these conditions is shown in Figure 13 and Figure 14. When Figures 13 and 14 are examined, it has been determined that the most effective parameter on Ra in the machining of AISI 4140 and manganese steels is the feed rate.

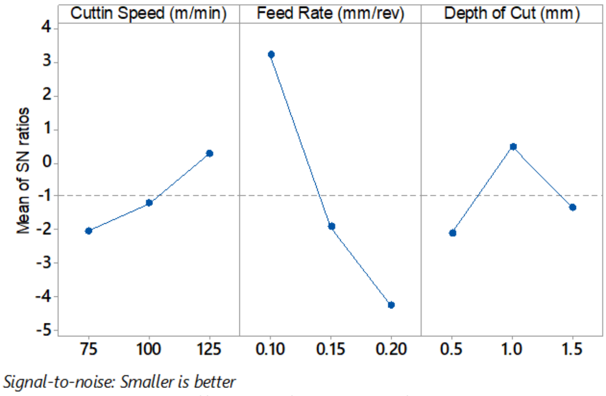

Figure 13. Main effects plot for SN ratios for AISI 4140 steel.

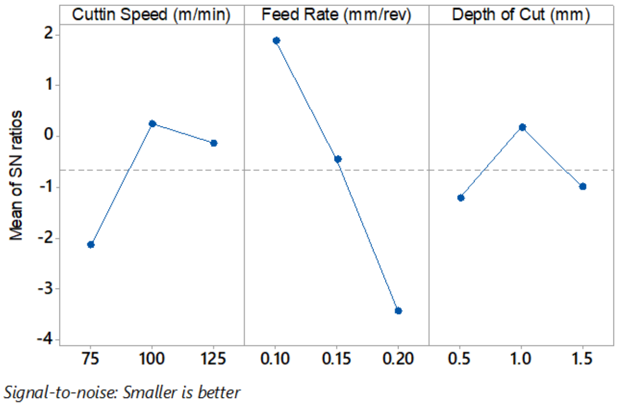

Figure 14. Main effects plot for SN ratios for manganese steel.

4 Conclusion

In this study, which was conducted in terms of machinability and surface roughness, the comparison of punches and dies made of manganese steel, which can be produced with the casting method, which can be applied in almost all casting workshops in our country, compared to the punch and dies produced by the machining method from AISI 4140 steel, widely used in the industry, the following results are obtained and can be summarized as follows:

- The most important disadvantage of punch and dies obtained by casting from manganese steel is the difficulty of machinability. However, with the minimum waste obtained by casting, only the mounting places of the punches and the sheet metal bending contact surfaces are cast with a margin, thus minimum processing time is obtained. In addition, it has been seen that this disadvantageous situation can be minimized by choosing the appropriate cutting parameters and cutting edge types in the machinability tests.

- No crater wear etc. of the cutting tools in both steel types was found. When all the tools were examined, it was observed that the wear in manganese steel processing was slightly higher than that of AISI 4140 steel.
- AISI 4140 and manganese steel materials behaved similarly at low cutting speeds and almost no wear was observed in these materials.
- While serrated chip type and continuous chip type were formed in AISI 4140 steel, chip type with shorter serration width was formed in manganese steel.
- The surface roughness of the samples produced by casting from manganese steel in the machinability tests turned out to be lower than that of AISI 4140 steels.
- In the machining of AISI 4140 steels, a chip form with a more serrated structure without inter-lamellar gaps was obtained, while in manganese steel, chips with less serration width and inter-lamellar gaps were obtained.
- Longer length punches and dies from manganese steel should be produced by casting method and additional studies should be carried out.
- It has been determined that the most effective parameter on Ra in the machining of AISI 4140 and manganese steels is feed rate. The ideal parameters for the Ra values obtained as a result of the machining of both steel types are obtained under the conditions where the cutting speed is 125 m/min, the feed rate is 0.10 mm/rev and the cutting depth is 1 mm for AISI 4140 steel. For manganese steel, these values are determined as cutting speed is 100 m/min, the feed rate is 0.10 mm/rev, and the cutting depth is 1 mm.

All these results show us that the punch and dies produced by casting from manganese steel are a good alternative compared to AISI 4140 steel, and the production of press brake punches and dies made of manganese steel with this casting method will create an alternative for reducing the foreign dependency of our country.

Acknowledgements

We would like to thank Batman University Scientific Research Projects Unit (Project no: BTUBAP-2018-TEK-1) for their financial support. We commemorate Associate Professor Zülküf DEMİR, who contributed and contributed to all scientific studies and passed away in 2019 due to COVID.

Declaration

This study does not require ethics committee approval.

References

[1] Basmaci, G., & Sayin, L. (2019). Experimental Investigation of the Springback Amount of Copper Sheet Plates Forming By "V" Bending Method. *Uluslararası Teknolojik Bilimler Dergisi*, 11(3), 147-154.

[2] Ozek, C. & Akkelek, H. (2021). Investigation of Deep Drawability of Rectangular Shaped Cups in Deep Drawing Dies. *International Journal of Innovative Engineering Applications*, 5(2), 187-194. DOI: 10.46460/ijiea.1006144

[3] Kam, M. (2016). *Experimental analyses of the Dynamic Behaviors of Cryogenically processed Shafts.* (Doctoral Dissertation, Düzce University).

[4] Uzkut, M., & Özdemir, İ. (2001). Investigation of the effect of changing heating speeds applied to different steels on mechanical properties. *Dokuz Eylül University Engineering Faculty Journal of Science and Engineering*, 3(3), 65-74.

[5] Avner, S.H. (1986). Introduction to Physical Metallurgy, *McGraw Hill Book Company, 2.ed., New York*, 315-336

[6] Oliveira, F. Hernandez, L., Berrios, J.A., Villalobos, C., Pertuz, A. and Cabrera, E.S.P., 2000, Corrosion-fatigue properties of a 4340 steel coated with Commonoy 88 alloy, applied by HVOF thermal spray, *Surface and Coatings Technology*, 140(2), 128-135.

[7] Charre, M. D. (2004). Microstructure of steel and cast irons, *(Trans. J.H. Davidson), Springer-Verlag Berlin Heidelberg New York*, p.417.

[8] Buytoz, S. (2004). *Investigation of mechanical behaviors of AISI 4340 steel after surface modification processes with nitruration and GTA welding method.* (Doctoral Dissertation, Firat University).

[9] Kesti, E. (2009). *Investigation of the effects of C-4140 steel on the temperament of environment of microstructure and mechanical properties.* (Doctoral Dissertation, Selcuk University).

[10] Tüfenk E. (2012). *Investigation of Austenitic Manganese Steels with Different Chemical Compositions after Heat treatment.* (Master's Dissertation, Ondokuz Mayıs University).

[11] Subramanyam, D. K. (2005). Austenitic Manganese Steels. ASM Handbook, Properties and Selection: Irons, Steels, and High Performance Alloys, *ASM Int., the United States of America*, Vol. 01, 1274-1302.

[12] Nejat S. (1995). High manganese austenitic steels and their sources. *Journal of Metal and Source*, 66, 36-41.

[13] Duflou, J., R., Vancza, J., Aerens, R. (2005). Computer Aided Process Planning for Sheet Metal Bending: A State of the Art, *Computers in Industry*, 56, 747–771.

[14] De Vin, L. J. (1994). Computer aided process planning for the bending of sheet metal components, *Doctoral Dissertation, Enschede the Netherlands*, ISBN 90-9007217-9.

[15] De Vin, L. J., Streppel, A.H., Kalsi, H. J. J., Singh, U.P. (1995). Sensitivity analysis for air bending, *Proceedings of the 3rd International Conference on Sheet Metal*, ISBN: 0-9527664-0 X, 221–230.

[16] De Vin, L. J., Streppel, A.H., Lutters, D. Kals, H.J.J. (1994). A process model for air bending in CAPP applications, *Proceedings of the 2nd International Conference on Sheet Metal*, ISBN: 1-85923-025-3, 17–28.

[17] Lutters, D., Streppel, A.H., Kals, H.J.J. (1997). Adaptive press brake control in air bending, *Proceedings of the 5th International Conference on Sheet Metal*, ISBN: 1- 85923-072-5, 471–480.

[18] Ötü, R., Demirci, H. İ. (2013)., Farklı Bükme Yöntemleri Uygulanarak V Bükme Kalıplarında AA 5754-O Sac Malzeme ile Elde Edilen Numunelerin Geri Esneme Miktarının Tespiti, *Makine Teknolojileri Elektronik Dergisi*, 10 (3), 27-42.

[19] Tekiner, Z., (2004). An experimental study on the examination of springback of sheet metals with several thicknesses and properties in bending dies, *Journal of Materials Processing Technology*, 145, 109–117.

[20] Özdemir, M., Gökmeşe, H., Dilipak, H., Yılmaz, V. (2104). Farklı ısıl işlemlerin 16Mo3 (1.5415) sac malzemenin ileri-geri esneme miktarına etkisinin deneysel ve mikroyapısal olarak incelenmesi, *Akademik Platform ISITES 2014 Sempozyumu* Karabük, (pp.148-155).

[21] Tekaslan, Ö., Şeker, U. 2009. "Pirinç sac malzemelerin geri esneme miktarlarının tespiti", *5. Uluslararası İleri Teknolojiler Sempozyumu (IATS'09)*.

[22] Durgun, I., Yigit, K., Aydin, H., & Bayram, A. (2017). "Investigation of Mechanical Properties of Bismuth and Stann Mold Alloys Employed in Metal Sheet Forming Molds", *Uludağ University Engineering Faculty Journal*, 22(3), Number 3, 11-20, DOI: 10.17482/uumfd.364084.

[23] Adıyaman, O., (2019). Investigation of Manufacturability of Sheet-Metal Punches Produced by Manganese Steel, *International Engineering and Science Symposium, 20-22 June, Siirt/Turkey*, (pp.794-811).

[24] Adıyaman, O. Kilic , M. Yakut, R. (2021). Investigation of time-production performance of punch and dies produced from manganese steel material by casting method, *International Symposium of Scientific Research and Innovative Studies, 22-25 February, Bandirma/Turkey,* (pp. 215-226).

[25] Adıyaman, O. Kilic, M. Yakut, R. (2021). Manganli çelikten döküm yöntemi ile üretilen bükme kaliplarinin aşinma daranişlarinin incelenmesi, *International Symposium On Engineering, Natural And Social Sciences, ISENS-21, 25-28 November 2021 Batman/Turkey*, (pp.110-117).

[26] CKB Makine Kalip. Retrieved June 24, 2022, from http://www.ckbmakina.com.tr/?products

[27] Sandvik Coromant. Retrieved June 24, 2022, from www.sandvik.coromant.com/tr, solutions for automotive components

[28] Korloy. Retrieved June 24, 2022, from www.korloy.com/tr/download/cata.do

[29] ISO Online Browsing Platform (OBP). Retrieved June 24, 2022, from www.iso.org/obp/ui/#iso:std:iso:8688:-1:ed-1:v1:en.do

[30] Ulutan, M., Çelik, O., Gasan, H., Er, Ü. (2010). Effect of Different Surface Treatment Methods on the Friction and Wear Behavior of AISI 4140 Steel, *Journal of Materials Science & Technology*,, 26(3), 251-257.

[31] Elbah, M., Yallese, M., Aouici, H., Mabrouiki, T. (2013). Comparative assessment of wiper and conventional ceramic tools on surface roughness in hard turning AISI 4140 steel, *Measurement*, 46, 3041–3056.

[32] Khrais, S.K., Lin Y. J. (2007). Wear mechanisms and tool performance of TiAlN PVD coated inserts during machining of AISI 4140 steel, *Wear*, 262, 64–69.

[33] Aslan, E., Camuşçu, N., Birgören, B. (2007). Design optimization of cutting parameters when turning hardened AISI 4140 steel (63 HRC) with Al2O3 + TiCN mixed ceramic tool, *Materials and Design*, 28, 1618–1622.

[34] Özler, L., Tosun, N., İnan, A. (2000). Investigation of Surface Roughness in Hot Machining of Austenitic Manganese Steel, *Turk J Engin Environ Sci*, 24, 287-296.

[35] Kıyak, M., Uysal, A., Çakır, O., Altan, E. (2012). Tool life in orthogonal turning of high manganese steel with rounded hard metal tools, *3 National Machining Symposium*, (pp. 496-502).

[36] Demir, B. (2004). Examination of double-phase steel producibility from Ç4140 steel", *Technology*, 4(1), 121-127.