POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)
URL: http://dergipark.org.tr/politeknik

A comparative study on wear and machinability behaviors of AM20, AJ21 and AS21 magnesium alloys

AM20, AJ21 ve AS21 magnezyum alaşımlarının aşınma ve işlenebilirlik davranışları üzerine karşılaştırmalı bir çalışma

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To cite to this article: Akyüz B., "A comparative study on wear and machinability behaviors of AM20, AJ21 and AS21 magnesium alloys", ***Journal of Polytechnic***, 26(1): 243-248, (2023).

Bu makaleye şu şekilde atıfta bulunabilirsiniz: Akyüz B., "A comparative study on wear and machinability behaviors of AM20, AJ21 and AS21 magnesium alloys", ***Politeknik Dergisi***, 26(1): 243-248, (2023).

Erişim linki (To link to this article): http://dergipark.org.tr/politeknik/archive

DOI: **10.2339/politeknik.784416**

A Comparative Study on Wear and Machinability Behaviors of AM20, AJ21 and AS21 Magnesium Alloys

Highlights

- *This paper is a comparative study on mechanical properties, wear resistance and machinability behaviors of AM20, AJ21 and AS21 (Mg-2Al-X) cast magnesium alloys.*
- *The effects of the changing in third alloy component (x:0.5 Mn, 1 Sr and 1 Si, and constant 9 Al, wt.%) in these alloys on microstructure (intermetallic phases), mechanical properties, wear resistance and machinability (cutting force, surface roughness, FBU and also chip formation) were comparatively analyzed.*
- *The highest mechanical properties and wear resistance were in AS21 alloy and the highest machinability were in AM20 alloy.*
- *The machinability of the alloys were increase with increasing cutting speed.*
- *The highest surface qualit were in AJ21 alloy.*

Graphical Abstract

In this study, the Magnesium alloys used (AM20, AJ21 AND AS21) were first melted in atmosphere controlled melting furnaces (under CO_2+SF_6), and then cast into metal moulds (seen on Figure).

Figure. The AM20, AJ21 and AS21 cast magnesium alloys used in the experimental study

Aim

The effects of the changing in third alloy component (x:0.5 Mn, 1 Sr and 1 Si, and constant 9 Al, wt.%) in the AM20, AJ21 and AS21 (Mg-2Al-X) cast magnesium alloys on mechanical and wear properties and machinability were comparatively analyzed.

Design & Methodology

In this experimental study, the casting Magnesium alloys (AM20, AJ21 and AS21) used, were first melted in atmosphere controlled melting furnaces (under CO_2+SF_6), and then cast into metal moulds. After that mechanical, wear and machinability tests were carried out on the alloys.

Originality

Considering that among the alloys used in the experiment, only the 3 rd alloy component (i.e. 0.5 Mn, 1 Sr and 1 Si and 2 Al constant in all alloys, wt.%) changes, In these alloys, the effect of changes in alloy components on microstructure changes and the effects of these changes on the machinability (cutting force, surface roughness, flank build up-FBU and chip formation etc.) are investigated. In this context, this is an authentic study that fills an important place in the literature.

Findings

The intermetallic phases seen in the microstructure with the effect of the components forming the alloy in AM20, AJ21 and AS21 alloys have an effect of increasing the mechanical properties of the alloy. In particular, it can be said that the intermetallic phase (Mg_2Si) in the AS21 alloy is the most effective in improving the mechanical properties of the alloy (compared to the others).

Conclusion

The highest mechanical properties and wear resistance were in AS21 alloy and the highest machinability was in AM20 alloy. The machinability of the alloys was increase with increasing cutting speed.

Declaration of Ethical Standards

The author of this article declares that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

A Comparative Study on Wear and Machinability Behaviors of AM20, AJ21 and AS21 Magnesium Alloys

Araştırma Makalesi / Research Article

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(Geliş/Received : 24.08.2020 ; Kabul/Accepted : 08.11.2021 ; Erken Görünüm/Early View : 15.08.2021)

ABSTRACT

This paper is a comparative study on mechanical properties, wear resistance and machinability behaviors of AM20, AJ21 and AS21 (Mg-2Al-X) cast magnesium alloys. The effects of the changing in third alloy component (x:0.5 Mn, 1 Sr and 1 Si, and constant 2 Al, wt.%) in these alloys on microstructure (intermetallic phases), mechanical and wear properties and machinability (cutting force, surface roughness, FBU and also chip formation) were comparatively analyzed. The highest mechanical properties and wear resistance were in AS21 (i.e. 49.2 hardness and 181.5 MPa UTS) alloy and the highest machinability were in AM20 (cutting force 35.6N) alloy. The machinability of the alloys were increase with increasing cutting speed.

Keywords: Machinability, wear resistance, AM20, AJ21, AS21 series magnesium alloys, cutting force, surface roughness, mechanical properties, flank build-up (FBU), intermetallic phase.

AM20, AJ21 ve AS21 Magnezyum Alaşımlarının Aşınma ve İşlenebilirlik Davranışları Üzerine Karşılaştırmalı Bir Çalışma

ÖZ

Bu makale, AM20, AJ21 ve AS21 (Mg-2Al-X) döküm magnezyum alaşımlarının mekanik özellikleri, aşınma direnci ve işlenebilirlik davranışları üzerine karşılaştırmalı bir çalışmadır. Bu alaşımlardaki üçüncü alaşım bileşenindeki (x; 0,5 Mn, 1 Sr ve 1 Si ve sabit 2 Al, ağırlıkça %) değişimin mikroyapı (intermetalik fazlar), mekanik ve aşınma özellikleri ve işlenebilirlik üzerindeki etkileri karşılaştırmalı olarak analiz edilmiştir. Bu alaşımların mikroyapısında bulunan intermetalik fazların sertlik, mukavemet, aşınma direnci ve işlenebilirlik özellikleri (kesme kuvveti, yüzey pürüzlülüğü, talaş yığılması-FBU ve ayrıca talaş oluşumu) üzerinde etkisi olduğu görülmüştür. En yüksek mekanik özellikler ve aşınma direnci AS21 (49.2 sertlik ve 181.5 MPa UTS) alaşımındaydı ve en yüksek işlenebilirlik AM20 (kesme kuvveti 35.6N) alaşımındaydı. Alaşımların işlenebilirliği artan kesme hızı ile artmıştır.

Anahtar Kelimeler: İşlenebilirlik, aşınma direnci, AM20, AJ21, AS21 serisi magnezyum alaşımları, kesme kuvveti, yüzey pürüzlülüğü, mekanik özellikler, talaş yığılması (FBU), intermetalik faz.

1. INTRODUCTION

Today, magnesium alloys have many areas of use. Automotive, transport, aerospace and electronics sectors may be mentioned among the most important of these [1-7]. Having properties such as low density, high strength, high wear and creep resistance, as well as being among the lightest building metals, having mechanical properties can be improved and being castable, these alloys have important features that enable them to find new areas of use every day [7-24].

Because of their light weight (low density), magnesium alloys play an important role in achieving fuel economy and emissions (CO_2, SO_X, and NO_X vb.) especially in the automotive and aerospace sectors [2,4,5]. Furthermore, due to their biodegradability, magnesium alloys are used in many other fields, particularly in the medical areas, communication-telecommunications and the manufacturing of various electronic devices [4-6]. Magnesium alloys are also important as environmentally-friendly building metals of the 21st century (low density and recycling).

In this context, a wide range of researches on magnesium alloys are currently being performed. Of these alloys, AZ31, AZ91, AS21, AS41, AM20, AM60, AJ21, AJ51, AJ52, AJ62 and ZK60 etc. alloys may be mentioned as the primary ones. When the studies on magnesium alloys are examined, it is observed that they focus on subjects such as the development of mechanical properties (i.e. hardness, strength, fatigue, wear and creep resistance, corrosion etc.) as well as formability and machinability of magnesium alloys [1-24].

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In the study, the microstructure, mechanical behaviors and wear resistance as well as machinability properties of AM20, AJ21 and AS21 cast magnesium alloys, which are very important in many fields, especially in automotive and aerospace sectors, have been examined comparatively. In these alloys, the effect of changes in alloy components on microstructure changes and the effects of these changes on the machinability (cutting force, surface roughness, flank build up (FBU) and chip formation etc.) are investigated/discussed. In this context, this is an authentic study that fills an important place in the literature.

2. MATERIAL AND METHOD

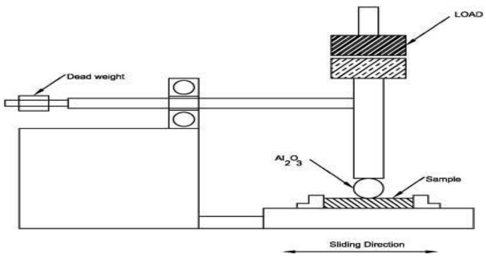
The AM20, AJ21 and AS21 cast magnesium alloys (0.5 Mn, 1 Sr and 1 Si, respectively, and constantly 2 Al, wt. %) used (the compositions seen on Tablo 1).

In this study, Mg alloys used were first melted in atmosphere controlled melting furnaces (under CO_2+SF_6), and then cast into metal moulds. Ünal [10,16] and Akyüz [6,13,15] described the casting or manufacturing process of these magnesium alloys in their previous studies. In addition, the previous studies of the author describe the details for the procedures as well as the sample standards for the test (namely the polishing, etching solutions & etching process, machining tests and tensile tests of the microstructure samples) [5,8]. Each sample was subjected to microstructure (Nikon Eclipse LV150) analyses and XRD analyses (Panalytical-Empyrean). Tensile tests (Shimadzu AGS-J 10 kN) and hardness tests (Shimadzu HMV-2) were performed (on each sample at seven measurements in all tests). Samples were subjected to wear tests (details decribed in previous studies by the author [13]) (Tribotester TM Clich, Figure 1a). The compositions of the alloys (Optical Emission Spectrometry-Spectrolab M8) and experimental setup are seen on Table 1 and Figure 1, respectively.

Table 1. The alloys on which the study is performed

Alloys	Al	Mn	Sr	Si	Zn	Fe	Mg
AM20	2.14	0.5	-	-	0.1	0.02	Rest
AJ21	2.18	-	1.12	-	0.1	0.02	Rest
AS21	2.20	-	-	1.18	0.1	0.02	Rest

("A", "M", "J" and "S", refers to the Al, Mn, Sr and Si content of the alloy, respectively, wt. %.)



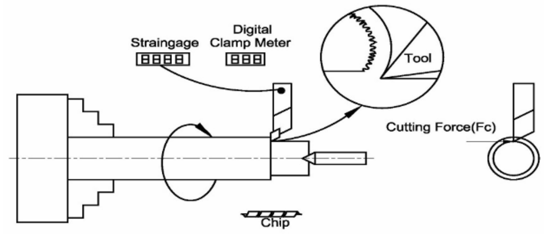


Figure 1. Experiment setup used in this study (a) wear testing device and (b) measurements of cutting force with strain-gage.

The machinability tests of the experimental study are carried out on CNC lathe (DMG CTX-Alpha300, PCD CCGT 120408 FL K10 tool, Orthogonal and Dry Cutting). These tests were performed at three different cutting speeds (chip section constant, chip depth- *a*:1 mm, feed-*f*:0.1 mm rev^{-1}). Cutting forces and surface roughness values obtained during turning/machining of test samples were obtained. In addition, Flank Build-Up (FBU), tool wear and chip formation have been examined in terms of alloy components and machining parameters. The values of the cutting force were determined through the creation of a mechanism with the aid of strain-gauge (as given in Figure 1b), and also surface roughness was determined by Time-TR200.

3. RESULTS AND DISCUSSION

3.1. Microstructure and XRD

Figure 2 and Figure 3 presents the microstructure images obtained from (optical microscopy) OM and XRD pattern of magnesium alloys from AM20, AJ21 and AS21 series. It is observed that the microstructure of these alloys consist of *α*-Mg and intermetallic phase (Al_8Mn_5 in AM20, Al_4Sr in AJ21 and Mg_2Si in AS21), as presented in Figure 2. It is easy to discriminate the intermetallic phase and *α*-Mg grain (grain size seen on the scale) from the matrix under OM (Figure 2).

In the literature, it is stated that the intermetallic phases formed/seen in microstructure change according to alloy composition, cooling rate, cooling conditions and cooling medium [3-24]. In the alloys, intermetallic phase began to be seen in the microstructure (Al_8Mn_5 in AM20, Al_4Sr in AJ21 and Mg_2Si in AS21) (Figure 2). Microstructure images and XRD pattern are consistent with the literature [3-24].

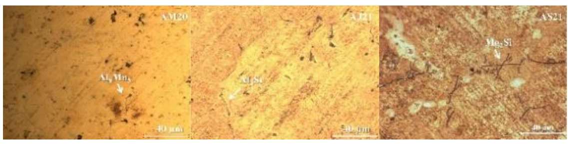


Figure 2. AM20, AJ21 and AS21 alloys Optical Micrographs (50x).

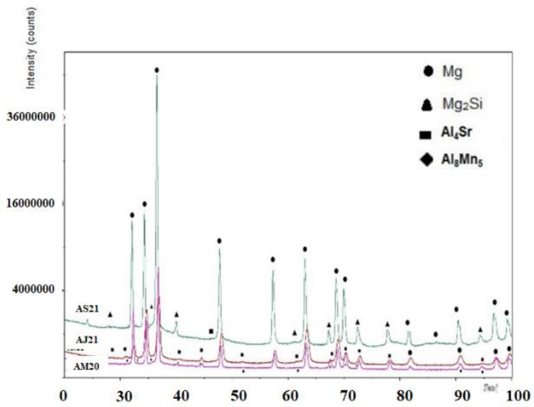


Figure 3. XRD pattern of the alloys

3.2. Mechanical and Wear Behaviors

The data obtained from the mechanical tests (hardness and tensile tests) and wear tests of the alloys are presented in graphs (Figures 4-6). Examining the sample hardness data (HV_{10}), the highest hardness was in AS21 (~20% the highest, 49.2N) (40.8N in AM20 and 44.4N in AJ21) (Figure 4). It can be said that the intermetallic phase (Mg_2Si) in AS21 is the most effective in increasing hardness of the alloys (Al_4Sr in AJ21 and Al_8Mn_5 in AM20) (Figure 4).

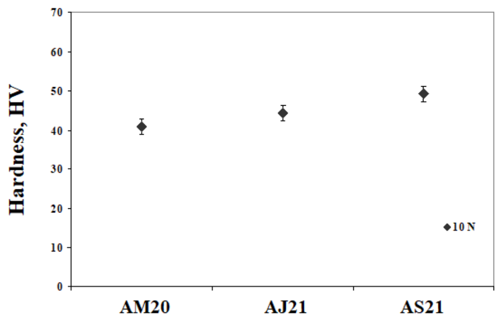


Figure 4. Hardness HV of AM20, AJ21 and AS21 magnesium alloys.

Tensile test data (UTS, YS and El% values) of AM20, AJ21 and AS21 alloys (UTS; 124.7 MPa, 138.6 MPa, 181.5MPa, and YS; 72.7 MPa, 78.6MPa, 94.1MPa, and EL%; 6.1, 5.8, 4.9, respectively) can be seen in Figure 5a-b. The bigest UTS and YS were obtained in AS21, while the lowest UTS and YS were obtained in AM20 alloy (Figure 5a). The lowest EI% was observed in AS21 alloy (Figure 5b). According to this, it can be said that the Mg_2Si intermetallic phase in AS21 alloy is more effective in the increase of UTS and YS (compared to other alloys), on the other hand, it has an effect of decreasing the El%.

Wear tests results are seen on Figure 6. The highest wear resistance was observed in the AS21 alloy (Figure 6a). The wear resistance of AS21 was found to be higher than AJ21 (~12%) and AM20 (~29%) (Figure 6a). There was no significant difference observed in the friction coefficients of the alloys (Figure 6b). According to this, it can be said that the Mg_2Si intermetallic phase in the AS21 alloy is more effective in increasing wear resistance.

According to mechanical and wear tests results in the experimental study, the intermetallic phases seen in the microstructure forming the alloy in AM20, AJ21 and AS21 alloys have an effect of increasing the the hardness, strength and wear resistance of the alloy. In particular, it can be said that, in AS21, the intermetallic phase (Mg_2Si) is effective in improving the mechanical properties of the alloy.

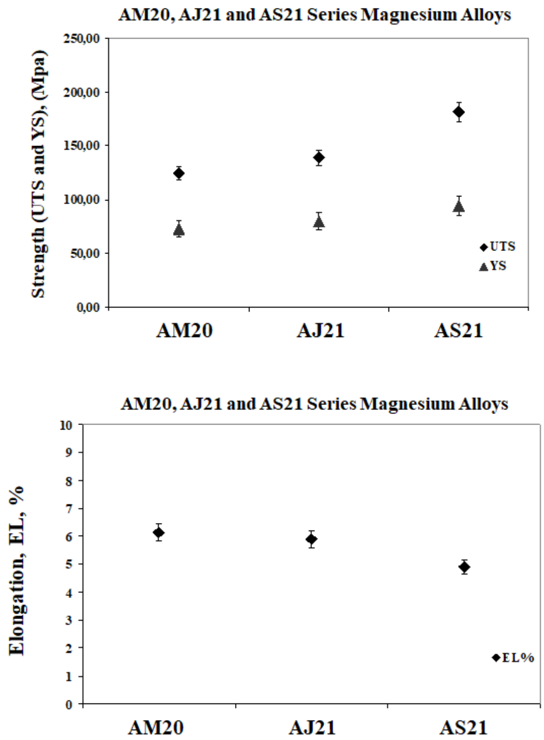


Figure 5. AM20, AJ21 and AS21 magnesium alloys (a) UTS, YS and (b) EL%.

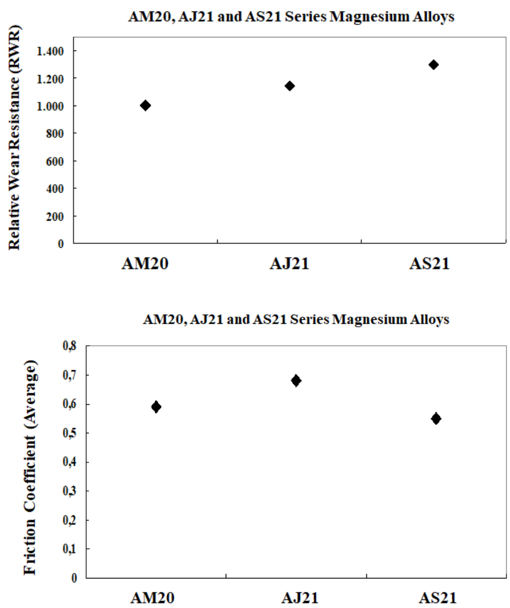


Figure 6. AM20, AJ21 and AS21 magnesium alloys, a) wear resistance b) average friction coefficient.

3.3. Machining Behaviors

Machinability test results (cutting forces and surface roughness) of the alloys are presented as graphs (Figure 7a-b). In the experiment, the lowest cutting forces are measured in the AM20 alloy and the highest cutting forces are measured in the AJ21 alloy (Figure 7a). It has been observed that the cutting forces of the alloys also increase due to the increase of the cutting speed (Figure 7a). The cutting force data generated during the machining of the alloys were 33.9N at AM20, 55.9N at AJ21 and 41.9N at AS21 at the smallest cutting speed (56 m/min). As the cutting speed was increased (168 m/min), the forces occurred as 35.6N, 62.3N and 46N (Figure 7a).

In the study, the highest surface roughness were seen on AM20 alloy and the lowest were obtained in the AJ21 alloy (Figure 7b). According to this, the highest surface quality was observed in the AJ21 alloy (with the effect of Al4Sr) (Figure 7b). In addition, the surface quality increased depending on the increase of cutting speed of the alloys (Figure 7b) (except AS21). In AS21 alloy, the intermetallic phase (Mg_2Si) increased the surface roughness value as the cutting speed of the alloy increased (Figure 7b). From this point, it can be said that intermetallic phases have an effect on the magnitude of cutting forces and surface roughness of the alloys.

According to the study, it can be said that the increase in cutting forces due to the change in alloy composition and the increase in cutting speed causes dislocation deposit in the chip and cutting tip interface, resulting in an increase in the cutting forces [5,7,13,15,19,25-32]. In AJ21, it can be said that the higher cutting forces have a larger effect in increasing the cutting forces of the Al_4Sr intermetallic phase, thereby reducing the machinability of the alloy. On the other hand, it can be said that this intermetallic phase (Al_4Sr) has an effect of decreasing the surface roughness values resulting from the machining of AJ21 alloy, and thus the surface quality of the alloy increases.

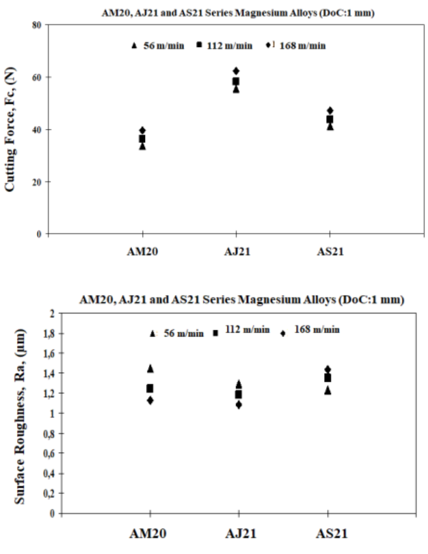


Figure 7. AM20, AJ21 and AS21 alloys, a) cutting forces (*Fc*) and b) the surface roughness (*Ra*) (V_c: 56, 112, 168 m min^{-1}, *a*:1 mm, *f*:0.10 mm rev^{-1}).

The Flank build-up (FBU), tool wear and chip formation can be seen in Figure 8 and Figure 9. Here, FBU as well as wear and chip formation with the effect of alloy components and cutting parameters can be mentioned (Figure 8). It was observed that FBU and wear occurs on a larger surface on the cutting surface where AJ21 alloy is machined (Figure 8). In addition, it was seen that the chips formed in the alloy of AS21 had a tighter helical shape and long (Figure 9). During the processing of the experiment samples, as a result of the effect of the alloy compositions and cutting parameters, it may be argued that FBU and wear occur at the cutting tool tip due to the dry adhesion and temperature rise between the cutter and the sample surface. It is known from the literature that there is a temperature increase at the cutting tool tip as a result of not using coolant during machining owing to the combustion of Mg alloys and the effect of dry adhesion [5-15, 25-32]. In addition, it has been reported in the previous studies that dislocation deposit on the cutting surface caused by dry adhesion on the cutting tool tip increases the cutting forces in the machining of magnesium alloys [6,8,13,15].

According to the results of this study, it can be concluded that the intermetallic phases (Al_8Mn_4 in AM20, Al_4Sr in AJ21 and Mg_2Si in AS21) that started to form in the microstructure of magnesium alloys have an effect on the magnitude of cutting forces, surface quality, FBU as well as wear on the cutting tool tip and the chip morphology (Figures 7-9).

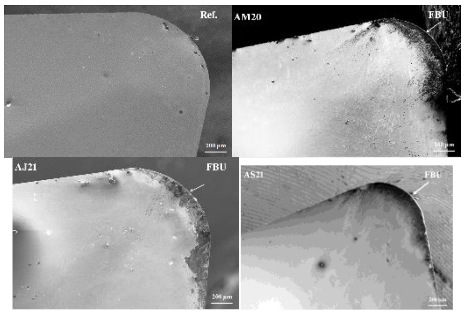


Figure 8. SEM image of AM20, AJ21 and AS21 magnesium alloys (V_c: 168 m min^{-1}, *a*: 1mm, *f*: 0.10 mm rev^{-1}).

Figure 9. AM20, AJ21 and AS21 alloys Chips (V_c: 168 m min^{-1}, *a*:1mm, *f*:0.10 mm rev^{-1}).

The data gathered from this section (and examinations related to microstructure from previous sections) and the results of the mechanical tests are supported by each other. Data, microstructure images and experimental results achieved from this study were in line with the literature [3-27].

4. CONCLUSIONS

In summary, this experimental study was finalized with the following conclusions:

- In the study, the intermetallic phases (Al_8Mn_5 in AM20, Al_4Sr in AJ21 and Mg_2Si in AS21) started to form at grain boundaries depending on alloy composition.
- The mechanical properties of AS21 were observed to be higher. In AS21 alloy, the intermetallic phase (Mg_2Si) is more effective in increasing wear resistance, hardness and strength (UTS and YS).
- It was observed that the machinability of the AM20 alloy was highest (and its cutting forces were lowest) and the AJ21 alloy was lowest (and its cutting forces were highest) (Figure 7a). Considering that, among the alloys, only the 3rd alloy component changes, it can be concluded that the changes in the microstructure (intermetallic phases), have a positive effect on the mechanical, wear and machinability behaviors of the alloys depending on the third alloy component. In this study, it can be said that the Al_4Sr intermetallic phase (AJ21) is effective in the formation of the greatest cutting force.
- In AM20, AJ21 and AS21 alloys, it can be said that the intermetallic phases formed with the effect of alloy components cause cutting forces to increase as the cutting speed increases due to dislocation build-up (Figure 7a) and FBU (Figure 8). In addition, it was observed that these phases also had an effect in increasing the surface quality of the alloys (except Mg_2Si in AS21).

ACKNOWLEDGEMENTS

The author would like to thanks to Bilecik Şeyh Edebali University for support (2018-02.BŞEÜ.03-03, 2016-02.BŞEÜ.03-02 and 2013-02.BİL.03-01).

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in their studies do not require ethical committee approval and/or legal-specific permission.

AUTHORS' CONTRIBUTIONS

Birol AKYÜZ: This study were performed by author.

CONFLICT OF INTEREST

There is no conflict of interest.

REFERENCES

[1] King J. F. "Development of practical high temperature magnesium casting alloys", ***Magnesium alloys and their applications***, 14-22, (2000).

[2] Schuman S. and Friedrich H.E., "Automotive Applications in Europe", ***Magnesium Technology, Metallurgy, Design Data, Applications*** (Edited by H.E.Friedrich and B.L. Mordike), Springer-Verlag Berlin Heidelberg, Germany, 499-682, (2006).

[3] Zhang P., "Creep behavior of the die-cast Mg–Al alloy AS21", ***Scripta Materialia***, 52(4), 277-282, (2005).

[4] Kunst M., Fischersworring-Bunk A., L'Esperance G., Plamondon P. and Glatzel U., "Microstructure and dislocation analysis after creep deformation of die-cast Mg–Al–Sr (AJ) alloy", ***Materials Science and Engineering: A***, 510, 387-392, (2009).

[5] Tönshoff H. K., Denkena B., Winkler R J. and Podolsky C., "Machining, Magnesium Technology, Metallurgy, Design Data, Applications", (Ed. H. E. Friedrich and B. L.Mordike), ***Springer-Verlag Berlin Heidelberg***, 398, (2006).

[6] Akyüz B., "Influence of aluminum content on the machinability of AS series cast Mg alloys", ***Trans. Nonferrous Met. Soc.***, 24, 3452−3458, (2014).

[7] King J. F., "Technology of Magnesium and Magnesium Alloys, Magnesium Technology (Edited by H.E. Friedrich and B.L.Mordike) ***Springer-Verlag Berlin Heidelberg***, (2006).

[8] Tomac N., Tønnesen K. and Mikac T., "Study of Influence of Aluminum Content on Machinability of Magnesium Alloys", ***Strojarstvo: časopis za teoriju i praksu u strojarstvu***, 50 (6), 363 – 367, (2008).

[9] Tönshoff H.K., Friemuth T., Winkler J. and Podolsky C., "Improving the Characteristics of Magnesium Workpieces by Burnishing Operations", ***Magnesium Alloys and their Applications***, (Edited by K. U. Kainer), 406, (2006).

[10] Ünal M., "***An Investigation of Casting Properties of Magnesium Alloys***", Gazi University, Institute of Science And Technology, Ph.D. Thesis, (2008).

[11] Evangelista E., Gariboldi E., Lohne O. and Spigarelli S., "High-temperature behaviour of as die-cast and heat treated Mg–Al–Si AS21X magnesium alloy", ***Materials Science and Engineering: A,*** 387, 41-45, (2004).

[12] Ma G.R., Li X.L., Xiao L. and Li Q.F., "Effect of holding temperature on microstructure of an AS91 alloy during semisolid isothermal heat treatment", ***Journal of Alloys and Compounds***, 496, 577–581, (2010).

[13] Akyüz B., "Comparison of the machinability and wear properties of magnesium alloys", ***The International Journal of Advanced Manufacturing Technology***, *75*(9-12), 1735-1742, (2014).

[14] Gil-Santos A., Moelans N., Hort N. and Van der Biest O., "Identification and description of intermetallic compounds in Mg–Si–Sr cast and heat-treated alloys", ***Journal of Alloys and Compounds***, 669, 123-133, (2016).

[15] Akyüz B., "Influence of Al content on machinability of AM series magnesium alloys", ***Kovove Materialy-Metallic Metarials,*** 56(5), 289-295, (2018).

[16] Ünal M., "Effects of solidification rate and Sb additions on microstructure and mechanical properties of as cast AM60 magnesium alloys", *International Journal of Cast Metals Research*, 27(2), 80-8, (2014).

[17] Faruk M., Özdemir A., Kainer K.U. and Hort N., "Influence of Ce addition on microstructure and mechanical properties of high pressure die cast AM50 magnesium alloy", ***Transactions of Nonferrous Metals Society of China***, 23(1), 66-72, (2013).

[18] Tsuchiya T., Watanabe K., Matsuda K., Kawabata T., Sakakibara K., Yamaguchi T., Saikawa S. and Ikeno S., "Effect of Al and Mn Contents on Microstructure in AM-

Series Magnesium Alloys", ***Advanced Materials Research***, 409, 379-382, (2012).

[19] Zhao N., Hou J. and Zhu S., "Chip ignition in research on high-speed face milling AM50A magnesium alloy", ***In: Mechanic Automation and Control Engineering (MACE),*** Second International Conference on. IEEE, 1102-1105, (2011).

[20] Kiełbus A., Rzychoń T. and Cibis R., "Microstructure of AM50 die casting magnesium alloy", ***Journal of Achievements in Materials and Manufacturing Engineering,*** 18(1-2), 135, (2006).

[21] Rudajevová A. and Lukáč P., "Comparison of the thermal properties of AM20 and AS21 magnesium alloys", ***Materials Science and Engineering: A,*** 397(1-2), 16-21, (2005).

[22] Kubásek J., Vojtěch D., and Martínek M., "Structural characteristics and elevated temperature mechanical properties of AJ62 Mg alloy", ***Material Characterization,*** 86, 270-282, (2013).

[23] L'espérance G., Plamondon P., Kunst M. and Fischersworring-Bunk A., "Characterization of intermetallics in Mg–Al–Sr AJ62 alloys", ***Intermetallics,*** 18, 1-7, (2010).

[24] Trojanová Z., Farkas G., Máthis K. and Lukáč P., "Hardening and Softening Processes in an AJ51 Magnesium Alloy Reinforced with Short Saffil Fibres", ***In Magnesium Technology***, Springer Cham., 435- 440, (2014).

[25] Tönshoff H.K. and Winkler J., "The Influence of Tool Cutting in Machining of Magnesium", ***Surface and Coating Technology***, 94-95, 610-616, (1997).

[26] Liu K., Li X.P. and Liang S.Y., "The mechanism of ductile chip formation in cutting of brittle materials", ***Int J Adv. Manuf. Technology,*** 33, 875-884, (2007).

[27] Zhao X.L., Tang Y., Deng W.J. and Zhang F.Y., "Effect of Tool Flank Wear on the Orthogonal Cutting Process", ***Key Engineering Materials***, 329, 705-710, (2007).

[28] Stephenson D. A. and Agapiou J. S. "***Metal cutting theory and practice***", 2nd edition, Danver, Taylor & Francis CRC press, USA, 371-550, (2016).

[29] Knight W. A. and Boothroyd, G., "***Fundamentals of metal machining and machine tools***", 3th edition, Danver, USA: Taylor & Francis CRC Press, 60-320, (2005).

[30] Kalpakjian S. and Schmid S.R., ***"Manufacturing Engineering and Technology***", 6th Edition, New York, USA: Pearson Prentice Hall., 553-658, (2010).

[31] Grover M. P., "***Principles of Modern Manufacturing",*** 4th Edition, Hoboken, USA: John Wiley & Sons Inc., 483-584, (2010).

[32] Black J. T. and Kohser, R.A., "***Materials & Processes in Manufacturing***", 10th Ed., USA: John Wiley & Sons Inc., 50-270, (2008)