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The Extrusion Process Capability Improvement of AA5083 Al-Mg-Mn System

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---*ABSTRACT*---

In this study, it is aimed to improving the extrusion capability of AA5083 aluminium alloy with high magnesium (Mg). The thermo mechanical response of a magnesium alloy directly affected by extrusion parameters is highly complex. First of all, the casting experiments with chemical composition based on different rate of the magnesium (Mg) and chrome (Cr) were performed in this study. In the homogenization heat treatment, the billets have a 127 mm diameterwereheated at 480°C and 500°C with 480 and 600 minutes. The homogenized billets were subjected to shock cooling till reach room temperature. In the extrusion process, the investigation of the different parameters (billet and mold temperature, press speed (mm/s), press pressure (bar), press time (s) on the extrusion capability were performed. In the ageing parameters, 180°C and 200°C with 240 and 360 minutes were used. The mechanical properties were tested for all experiment results. Although the extrusion process principle is basically the same, the relationship between aluminium alloy specific to the major elements and deformation behaviour has changed significantly. There is no any surface defects and problem about that forming linearity in the low billet temperature and low extrusion speed.

Keywords: *AA5083,Aluminum Alloys, Extrusion Capability, Microstructure*

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I. INTRODUCTION

The thermal conductivity, non-flammable, inflammable properties of the aluminium alloy provide significant advantages as the engineering material. Aluminium is a relatively light metal with a specific density of 2.7 g/cm3 compared to metals such as steel, nickel, brass, and copper. AA 5083 aluminum alloy is widely used for many applications in automotive, marine and construction industries due to its high strength-to-weight ratio, excellent corrosion resistance, toughness and weldability [8].Magnesium (Mg) alloys are generally formed on the basis pressure casting which is used in the shaping of metal and metal alloys that are melting at low temperature and can be molded in metal molds. Although it's based on the theory that every material can allow extrusion deformation within certain limits despite its high content of Magnesium (Mg) and extrusion process parameters specific to major elements can be developed [1].Many theoretical and experimental studies have been focused on the mechanical properties of the AA5083 aluminium alloy.Auira et al. have studied homogenization process of the AA5083 between 350°C and 600°C.Auira et al. investigated intermetallic phases after the homogenization process. It has been obtained that the minimum intermetallic phases in the 520°C. In other words, it is easier to dissolve the intermetallic phases in the matrix at the points where 500°C is exceeded [2].Also it has been reported that optimal parameters of the homogenization process is 520°C and 8-10 hour by Dolic and Brodarac in the experimental studies [3].Recently many studies have been focused on the hardening mechanisms. The one of the proposed hardening mechanism is grain size refinement. It has been predicted that increased mechanical properties and corrosion resistance can be obtained that grain size refinement [4].Also the Al-Mg responsible for precipitation hardening can be significantly improved rapid solidification after plastic deformation process.Hot extrusion process can be combined with rapid solidificationfor obtaining of thealuminium profile with high mechanical properties [5].The high rate Magnesium (Mg) directly affect the forming process of the AA5083 because of its low forming capability.The studies have been carried out on the AA5083 predicted that the relationship between chemical composition of alloy and deformation remarkably show a change, although the extrusion process principle is basically the same.Also the experimental studies showed that the thermo mechanical response of the Magnesium alloy is affected by extrusion parameters.It has been accepted that all materials allow extrusion deformation within the certain limits and can be improved extrusion capability [6].The extrusion processthat dimensional change of solid material is performed by using high temperature and high pressure with a certain time.Aluminium extrusion process which is defined as a plastic strain method is affected by many parameters. The billet and mold temperature (^{0}C), extrusion speed (mm/s), press pressure (bar) and press time (s) have a critical role on the extrusion capability of the high strength aluminium alloy. These extrusion parameters are needed to adjust aluminium alloy series which has a different major element. Also the one of the most important point isthe material flow of the high strength aluminium alloy is controlled during extrusion process [7]. In plastic deformation method, the aluminium alloy seriesthat has a different chemical composition exhibit the different metal fluid characterization.Thus, the adjusting of the extrusion parameters specific to chemical composition especially major element is most important for efficiency the physical properties of the aluminium profile.

II. Experimental

2.1. Production Process

One of the most important process is determining of the chemical composition based on alloying criteria in the aluminium alloy production. Experimental casting of melting of the metal was performed in induction furnaces. The chemical composition was analyzed by using spectrometer. The chemical composition of 5083 aluminium alloy billet production is given Table 1.

Table 1. Chemical analysis of AA5083

Sample	Si %	Fe %	Cu %	Mn %	Mg %	Cr %	Zn %
1	0,35	0,25	0,04	0,55	4,10	0,15	0,20
2	0,35	0,26	0,05	0,56	4,08	0,20	0,20

It's aimed to investigation of the addition of magnesium (Mg) and chrome (Cr) in casting process for Al-Mg-Mn system. The experiment casting parameters are givenTable 2.

Table 2. Experiment casting parameters

Sample	Melting Temperature(°C)	Casting Speed (mm/s)	Cooling Water Temp. (°C)
1	685	137	19
2	688	137	19,5

The casting process was performed at low temperature because of the Magnesium (Mg) tend to oxidation. It was observed that the oxidation of the molten metal surface in the tapping launder. The experimental casting studies is given Figure 1.

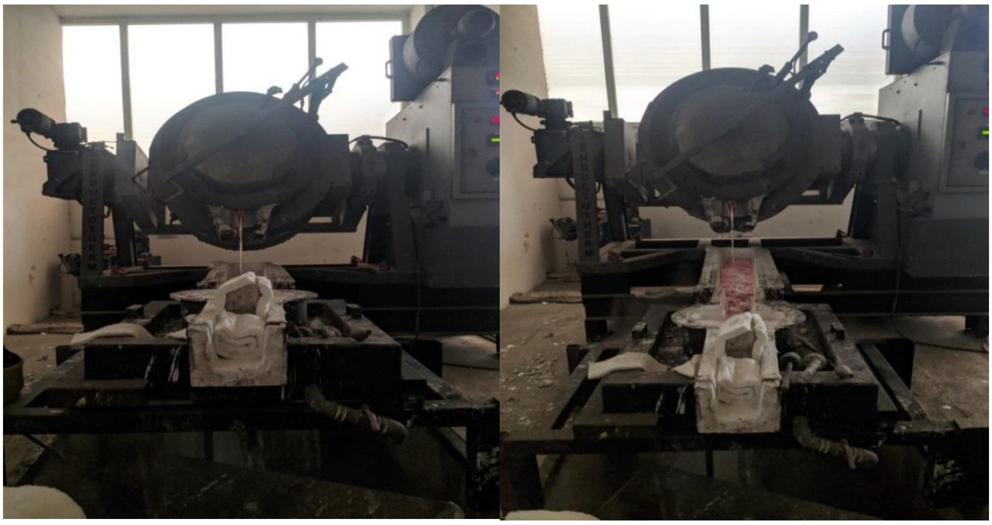

Figure 1. The casting process of AA5083 oninduction furnace.

Homogenization heat treatments were performed with different temperature and time. Table 3 shows homogenization parameters. Billet samples were cooled with a fan until they reached approximately 200 °C after homogenization. The water cooling process was carried outafter reaching 200 °C.

Table 3. Homogenization Heat Treatment

Sample	Temperature (^{0}C)	Time (hour)
1-2	480	8
1-2	480	10
1-2	500	8
1-2	500	10

The homogenization heat treatments were performed is given Table 3 for samples with 1 and 2 which have a different chemical composition. Totally 8 samples were homogenized by using parameters are given Table 4. The hardness value of samples has a different heat treatment were performed.The extrusion process was conducted for 1 and 2 samples with heat treatment 480°C and 8 hour. Extrusion process properties and parameters are given Table 4. The billet is heated about 480 ^{0}C. The preheating of aluminium billet allows to be easily formed aluminium and reduce of the press pressure.

Table 4. Extrusion Process Parameters

Sample	Press (Ton)	Billet Temperature (^{0}C)	Mold Temperature (^{0}C)	Press Speed (mm/s)
1	1400	480	450	1,7
2	1400	480	450	1,1

Table 5 shows the artificial ageing parameters was performed for AA5083 aluminium profiles. The artificial ageing parameters were only applied sample 2 because of extrusion failure of sample 1.

Table 5. Artificial AgeingParameters

Sample	Temperature (^{0}C)	Time (hour)
2	180	4
2	180	6
2	200	4
2	200	6

2.2. Metallographic Process

AA5083 sampleswere made ready for microstructure investigation by standard metallographic methods (mounting, grinding, and polishing) and then etching process was conducted to the samples by using 2% nital solution. Microstructure analysis were performed for all samples has a different chemical composition and heat treatment.

2.3. Mechanical Tests

Tensile test machine called ZwickRoell with 20 tons was used for tension test. Tensile strength, yield strength and the amount of % elongation were determined.

III. Results and Discussion

3.1. Microstructure Analysis

The microstructuresof homogenized samples1 and 2 with different homogenized parameters (480°C, 500°C with 8 and 10 hour) are given Figure 2, 3, 4 and 5.The grain boundary can be clearly that in the microstructure of homogenized sample with 480°C with 8 and 10 hour in Figure 2. It has thought that the part which in the grain boundaries increases the strength of the material.The other samples with different homogenized parameters exhibit nonhomogeneous structure also ambiguous grain boundary with reference to 480°C with 8 and 10 hour.

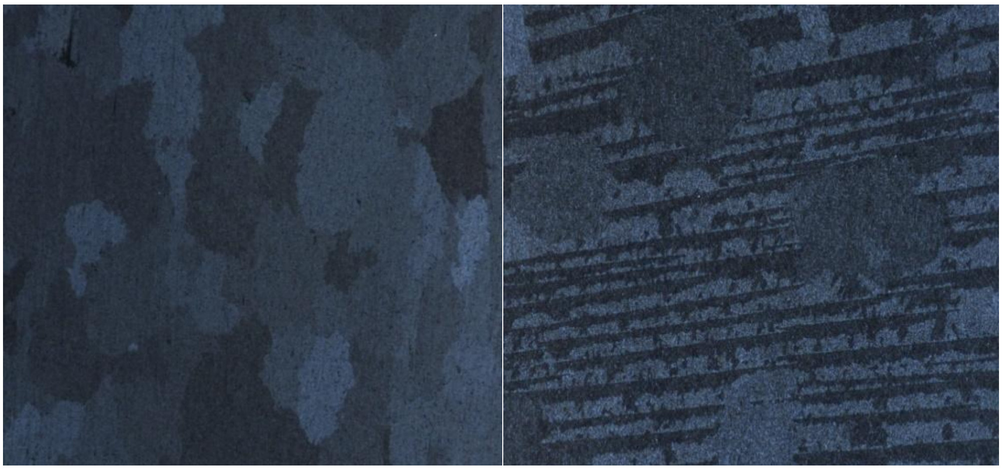

Figure 2. The microstructure of homogenized sample 2 with 480 °C (left) with 8 hour and 480°C (right) with10 hour

Figure 3. The microstructure of homogenized sample 2 with 500 °C (left) with 8 hour and 500 °C (right) with 10 hour

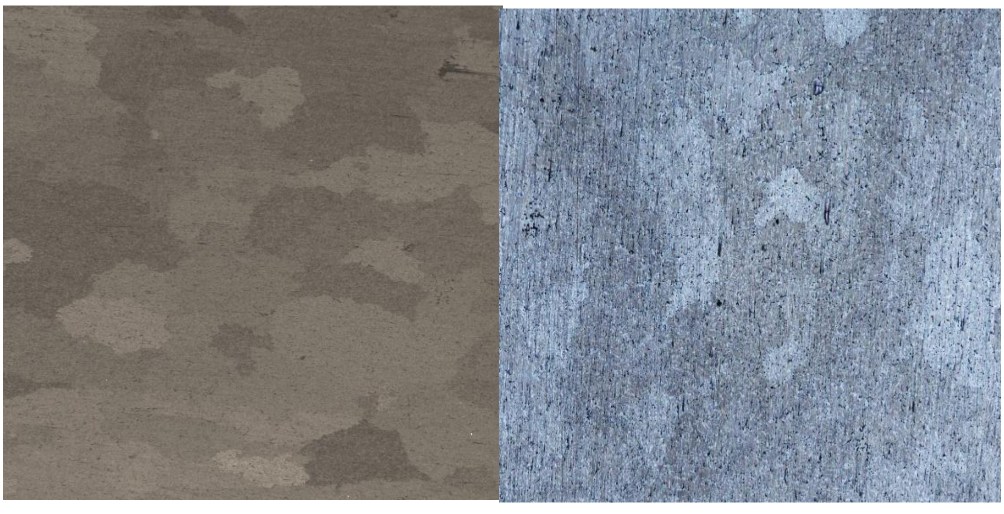

Figure 4. The microstructure of homogenized sample 1 with 480 °C (left) with 8 hour and 480 °C (right) with 10 hour

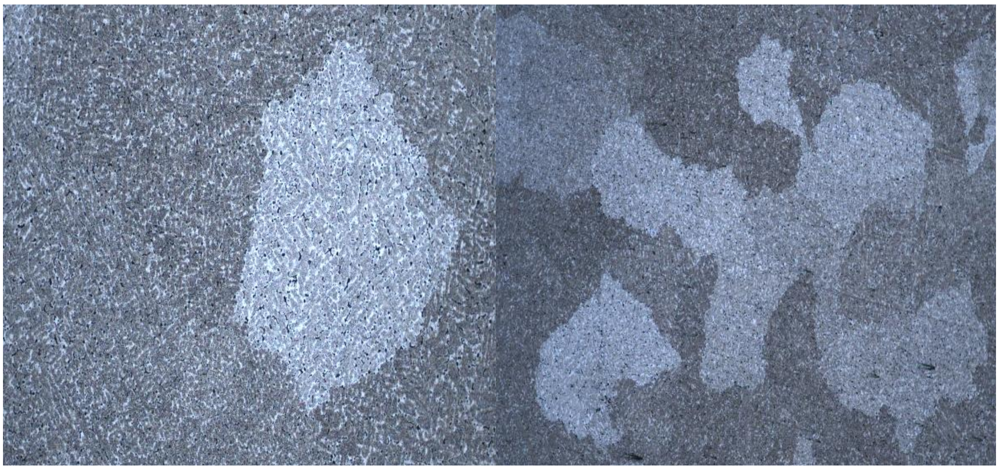

Figure 5. The microstructure of homogenized sample 1 with 500°C (left) with 8 hour and 500°C (right) with 10 hour

3.2. Extrusion Capability

It was observed that the surface defects and hot tearing for sample 1 in the extrusion process. It was predicted that the press speed has a important role in the extrusion capability for aluminium alloy which has a different range major element. The change of the dimensions of aluminium extrusion profile can be defined possible problems that arise from extrusion process parameters for more durable alloy. Also exit temperature of extrudate profile increases due to forming temperature and heat generated by friction. Thus all statuses can influence negatively extrusion process and aluminium surface quality. Figure 6 shows the aluminium profile of sample 1 and sample 2 were conducted different extrusion press speed (mm/s).

Figure 6. The extrusion process of sample 1 (left) and 2 (right)

The extrusion temperature arrives 500-520 °C by thermos mechanicaleffect which occur deformation that follows. The water cooling was applied aluminium profile for obtaining the rapid solidification. It was observed that the aluminium profile exit temperature reduce about from 427 °C to 356 °C in extrusion process. The exit temperature degree determines the microstructure, mechanical and surface quality of the aluminium profiles. Also the aluminium profile exit temperature directly affect the unrestrained oxidation. There is no any surface defects and hot tearing observed in low extrusion speed. Also it was obtained that the material flow controlling of the hollow profile is one of the most challenges point in the extrusion process. It has been predicted that same problem can be observed in the profile design with a complex geometry. Table 5 shows artificial ageing.

3.3. Mechanical Test Results

Table 6, Table 7 and Table 8 show the mechanical results of extrude AA5083 aluminium profiles with different artificial ageing parameters.

Table 6. Mechanical Results of AA5083

Artificial Ageing Parameters	**Mechanical Properties**		
Not Applied	**Yield Strength $R_{p0.2}$ (MPa)**	**Tensile Strength R_m (MPa)**	**Elongation (%)**
	145	297	17.8

Table 7. Mechanical Results of AA5083 with sample 1

Artificial Ageing Parameters		**Mechanical Properties**		
Temperature (C)	**Time (hour)**	**Yield Strength $R_{p0.2}$ (MPa)**	**Tensile Strength R_m (MPa)**	**Elongation (%)**
180	4	131	292	22.3
180	6	129	284	16.9
200	4	138	294	21.7
200	6	135	287	16.6

Table 8. Mechanical Results of AA5083with sample 2

Artificial Ageing Parameters		**Mechanical Properties**		
Temperature (C)	**Time (hour)**	**Yield Strength $R_{p0.2}$ (MPa)**	**Tensile Strength R_m (MPa)**	**Elongation (%)**
180	4	145	309	25.50
180	6	143	297	18.8
200	4	151	313	24.6
200	6	148	306	17.9

IV. Conclusion

This study is aimed at investigation of the extrusion capability of AA5083 which is Al-Mg-Mn system. The concentration of Cr based on 0.15 % and 0.20 % in experimental casting process, whenthe other elements in aluminium matrix was constant. The all billet samples which was refer to 1 and 2 number was applied different homogenization parameters with temperature and time. The hardness value of samples has a different heat treatment were measurements. According to results of the hardness of samples,It's decided that the billet which is length of 45 cm was applied heat treatment with 480 C and 8 hours for extrusion process.The extrusion parameters was determined with different extrusion speed (mm/s). Alsoit's observed that the extrusion speed has a critical role in the extrusion capability of durable aluminium alloy. Although the billetof sample 2 which has a more high Cr concentration was using, it was no observed that any surface defects such as hot cracks, surface tear, hot tearing with low extrusion speed. Although the billet of sample 1 which has a less Cr concentration was using, it was observed that surface defects with high extrusion speed in experiment studies. The artificial aging parameters was performed with 180-200 C and 4-6 hour for sample 1 and 2 and alsoaluminium profile not applied artificial ageing.The highest value of mechanical properties (R_m=313 MPa and $R_{p0.2}$ = 151MPa)was obtained for artificial ageing parameters with200 C and 4 hour for sample 2.

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