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MICROSTRUCTURE AND MICROHARDNESS ANALYSIS OF EXTRUDED ALUMINIUM ALLOY AA6063

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ABSTRACT

The experimental procedure and image analysis for the microstructure and microhardness analysis of aluminum AA 6063 is given. The analysis includes the change of grain size and microhardness in thermo-mechanical history of extrusion. The grain sizes and microhardness are calculated at three different stages of extrusion which are as-cast billet, as-extruded and as-hardened. The whole plan is carried out in three steps. In first step extrusion trials are carried out on AA 6063, in second step grain sizes are calculated and in third step the microhardness are calculated. Optical microscopy and image analysis with Dexel Imaging is conducted to calculate the grain size of AA 6063. For the microhardness calculation Vickers Hardness Tester with Quntimate Imagetech software are used. To study the change in grain size and microhardness, the percentage reduction in grain size and percentage increase in microhardness was presented here. The results of the analysis are given and discuss.

Keywords: *Extrusion, Optical Microscopy, Microstructure and Microhardness.*

1. Introduction

Aluminium is one of the most important and widely used metals in the construction, transportation, electrical sector and packaging. The analysis of microstructure of aluminium extrusion process has become more important in recent years. In extrusion process the mechanical properties of the extruded profile depend on the change in microstructure during the production cycle from casting billet to hardening of extruded. Predicting the mechanical properties of product after heating, extrusion and quenching are very important rather than performing the cost and time expenditure extrusion experiment and characterization. Coarse intermetallics precipitation, precipitate free zones (PFZ), grain size distribution and coarsening are some examples of problems related to crystal alloy metallurgical evolution that could lead to poor product proprieties at the end of the production sequence [1]. In this study the material which is investigated is Aluminium alloy 6063 commonly referred as an architectural alloy. It is a medium strength alloy and normally used in intricate extrusions. It has high corrosion resistance, good surface finish, readily suited to welding and can be easily anodized. Temperature is the most influencing factor in the development of the microstructure. To improve the mechanical properties of extruded product fine grain size is one of the key requirements. How the grain size changes in complete extrusion cycles, i.e. from casts billet to the age hardening is presented.

2. Experimental Investigation

The experimental alloy is used in the form of billet provided by Sudarshan Alluminium India Ltd. located in Miraj. Table 1 shows the chemical composition of experimental as-cast and as-extruded aluminum alloy AA6063.

Table 1. Chemical composition of experimental alloy AA6063 (weight %)

Element	% Present
Si	0.37-0.4
Fe	0-0.32
Cu	0-0.1
Mn	0-0.1
Mg	0.44-0.47
Zn	0-0.1
Ti	0-0.1
Cr	0.1 max
Al	Balance

The extrusion experiments are carried out on 600MT Hydromech press available at Sudarshan Aluminium India Ltd. located in Miraj MIDC. The direct chill cast logs were used for the extrusion of AA6063. Then the log is cut into billets of required size, which is heated to achieve the required temperature. Then heated billet is placed in a container having temperature 450°C using the loader and then billet was

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pushed to heated die by applying pressure with the help of ram to the other end of the billet. The extruded profile is air quenched with the help of fans. The process is continuous so after extruded is out they are cut in to require length. After that the extruded profiles are age hardened at 220°C for 6 hrs. and finally air cooled to room temperature. Table 2 shows the Parameter of extrusion trials.

Table 2. Parameters of extrusion trials

Trial	Extrusion Ratio	Die Temp (°C)	Billet Temp (°C)	Container Temp (°C)	Ram Speed (mm/s)
1	14	450	480	450	9
2	14	470	500	450	9
3	14	500	530	450	9

3. Results for Microstructure

To analyze the microstructure of extruded aluminum grain size is measured in different steps. The sample is taken from the as-cast billet and extruded profile before and after hardening for analysis. This sample are analyzed under the optical microscope after polishing and etching, then images of microstructure is captured and grain size are calculated by Dexel metallography imaging software available in mechanical department Walchand college of engineering Sangli.

3.1 As-cast billet AA6063

Three samples are taken from the center of the billet, middle of the radius of the billet and outer of the billet respectively for the microstructure study. The Fig 1 shows position of three samples taken from the billet. Optical images of sample taken at 100x magnification are shown in the Fig.2. The average grain size of the as - cast billet of AA6063 was 40 μm. As seen from the microstructure the as-cast AA 6063 have equiaxed grains.

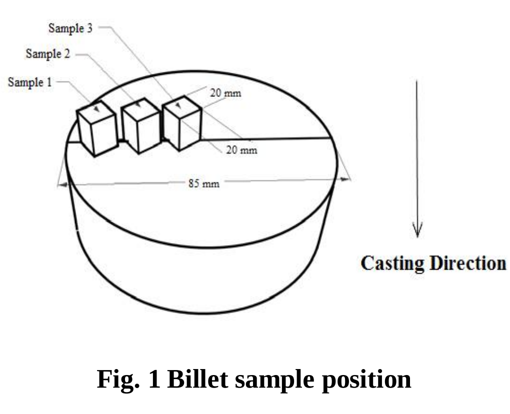
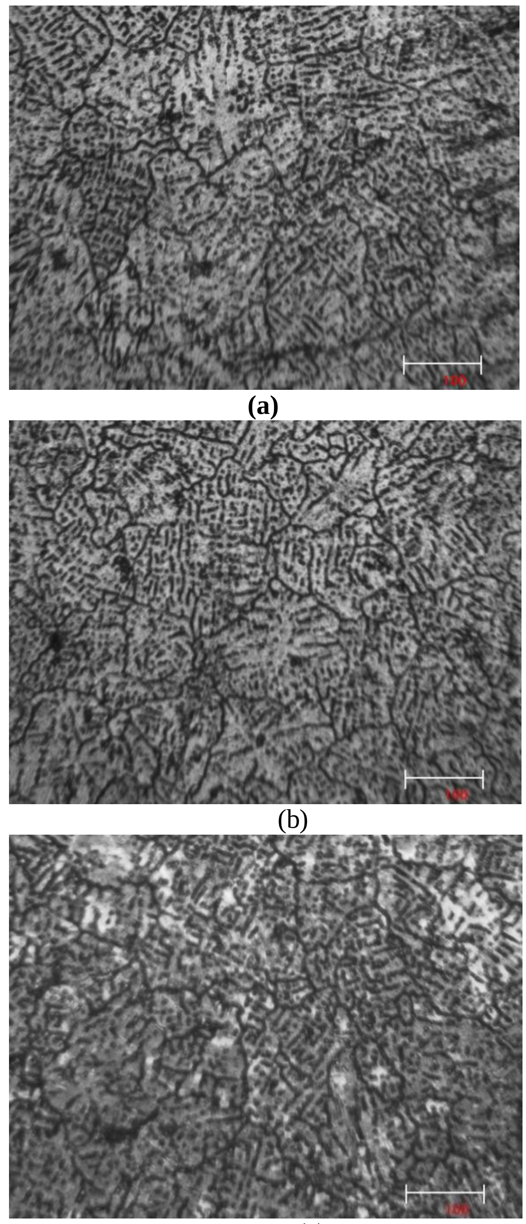


Fig. 1 Billet sample position



(a)

(b)

(c)

Fig. 2 Microstructure As-Cast Billet AA 6063 at 100X (a) Sample 1 (b) Sample 2 (c) Sample 3

3.2 As-extruded AA6063

Optical microstructure images are taken from the extruded sample before and after age hardening. Fig. 3 and 4 shows the microstructure of extruded before and after hardening respectively. As seen from the result the grain size of AA6063 decreases after the extrusion process and again decreases when age hardening of the sample was carried out. Therefore, in the extrusion process as the AA 6063 goes to harden extruded from cast billet grain size is becoming finer and finer. The

Table 3 shows the average grain size of AA 6063 of each trial.

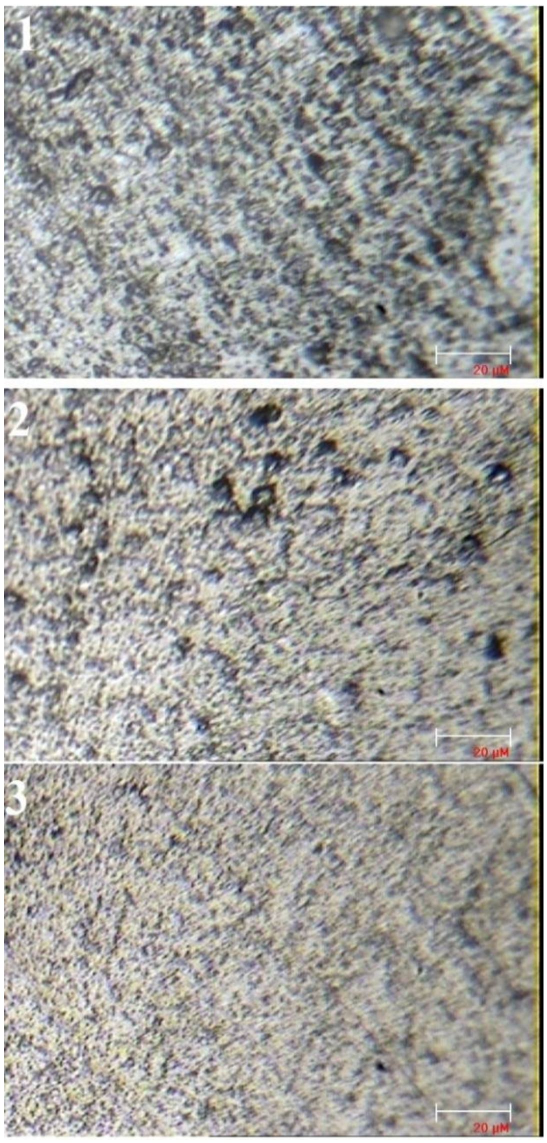


Fig. 3 Microstructure of AA6063 as-extruded before hardening

Another important microstructure characteristic is grain shape. As seen from figure 4 the grains of AA 6063 becomes elongated after extrusion. Therefore in as-extruded before hardening aluminum alloy AA 6063 has equiaxed and elongated grains. The figure 5 shows the equiaxed grains. During the hardening process recrystallization of grains occurs and elongated grains were recrystallizing to equiaxed grains. Therefore in as-hardened aluminum alloy AA 6063 has the equiaxed grains.

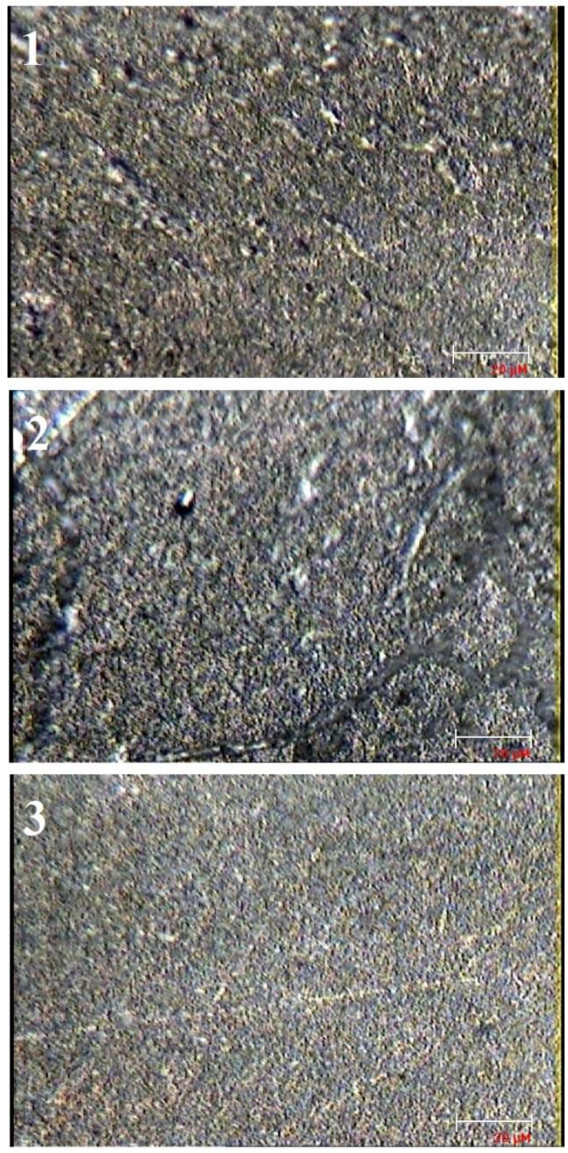


Fig. 4 Microstructure of AA6063 as-extruded after hardening

Table 3: Average grain size of extruded AA 6063

Trial	ASTM Grain Size No.		Grain Size (μm)	
	Before Hardening	After Hardening	Before Hardening	After Hardening
1	11.29	13.29	6.4	3.2
2	11.38	12.95	6.2	3.6
3	11.03	14.37	7.0	2.2

3.3 Percentage reduction of grain size

To study the grain size evolution the percentage reduction of grain size was calculated. The percentage reduction of grain size in the extrusion and hardening is calculated from the billet grain size. Table 4 shows the percentage reduction of grain size in as-extruded before and after hardening.

Table 4. Percentage reduction of grain size

Trial	**Average Grain Size** (µm)			**% Reduction of Grain size**	
	Billet	Extruded	Hardened	Extruded	Hardened
1	40	6.4	3.2	84.0	92.0
2	40	6.2	3.6	84.5	91.0
3	40	7	2.2	82.5	94.5

The percentage reductions in grain size of the extruded before hardening were found out to be 82 to 84%. After hardening the percentage reduction of grain size were 91 to 95%. After hardening the reduction of grain size was more than that of before hardening. During extrusion thermal and mechanical stresses are applied on the extruded, due to which the grain size is decreased. During the hardening of the extruded recrystallization of grains occurs and the grain size is again decreased.

4. Results for Microhardness

Five Vickers hardness tests were performed for each sample one center and four corners. The Fig. 5 shows the position of indentation. The 100 gm. load is used to make the indentation in Vickers Hardness test. For image analysis of indentation Quntimet Imagetech software was used.

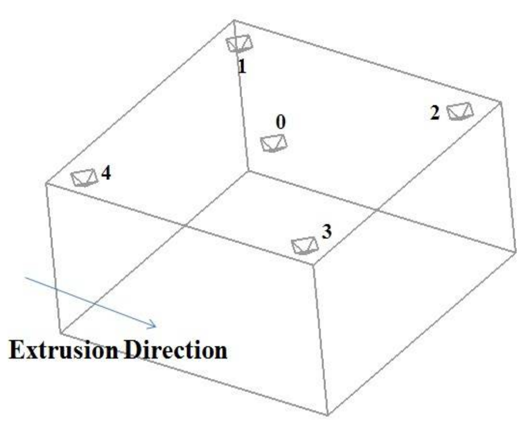


Fig. 5 Position of indentation for microhardness test

4.1 As-cast billet AA6063

For the microhardness test also three samples are taken from the center of the billet, middle of the radius of the billet and outer of the billet respectively. From each sample five microhardness values are calculated using image analysis software. The average value of microhardness was found out to be 44 VHN.

4.2 As-extruded AA6063

For microhardness test one sample is taken from each extruded before and after hardening. The average microhardness of as-extruded before and after hardening samples is shown in the Table 5.

Table 5. The microhardness of as-extruded AA6063

Trial	**Average Microhardness** (VHN)	
	Before Hardening	After hardening
1	49.02	53.25
2	44.46	52.43
3	46.24	52.01

4.3 Percentage increase of microhardness

To study the change in microhardness the percentage increase of microhardness is calculated. The percentage increase of microhardness in the extrusion and hardening is calculated from the billet microhardness. Table 6 shows the percentage reduction of grain size in as-extruded before and after hardening.

Table 6. Percentage increase of microhardness

Trial	**Microhardness** (VHN)			**% Increase In Microhardness**	
	Billet	Extruded	Hardened	Extruded	Hardened
1	43.94	49.02	53.25	10.37	17.50
2	43.94	44.46	52.43	1.17	16.20
3	43.94	46.24	52.01	4.98	15.52

The average microhardness of as-cast billet were 44 VHN. During extrusion the grain size of extruded is decreased and the finer grains are formed. As the grains become fine the microhardness is increased. Therefore, the microhardness of extruded before and after hardening is increased. The microhardness of extruded before hardening were increased by 1 to 10%. After hardening the microhardness of extruded were increased by 15 to 18%. After hardening the percentage increased in microhardness of the extruded was more than that before hardening.

5. Conclusions

The development of microstructure during the whole manufacturing cycle of extrusion of commercial Aluminum alloy AA 6063 were investigated in as-cast, as-extruded and as-hardening state to understand the effect of process parameters on extruded microstructure. Microstructure characteristics study of AA 6063 includes the grain size evolution in each step of the extrusion process. The size of the grains is quantitatively measured using optical micrographs at 100x and 500x magnification. The average grain size is calculated using the Dexel Metallography Imaging software. It was observed that the grain size is decreasing after each thermo-mechanical process. The microhardness was also calculated with the help of Vickers Microhardness Tester.

The main conclusions observed are as follows.

i. In as-cast billet AA6063 the grain structure were found out to be equiaxed. After extrusion the grain structure was found out to be equiaxed and elongated. Then again in hardening the grain structure were found out to be equiaxed. It shows that the recrystallization occurs in the hardening process.
ii. The average grain size in as-cast billet AA6063 were 30-40µm and the average ASTM grain size were 6-7. In extrusion the grain size of AA6063 decreases from the as-cast billet AA6063 significantly 77-90% and again in hardening it decreases from as-extruded 42-69%.
iii. The microhardness in as-cast AA6063 was 44VHN. In extrusion it increases 1-27% and again increases in hardening 8-20% of the as-extruded.

Acknowledgement

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References

1. *Schikorraa M Donati L Tomesani L Tekkaya A E (2008), "Microstructure Analysis of Aluminium Extrusion: Prediction of Microstructure on AA6060 Alloy", Journal of materials processing technology, Vol.201, 156–162.*

2. *Warmuzek M (2004), "Metallographic Techniques for Alluminum and Its Alloys", Metallography and Microstructures, ASM Handbook, ASM International, Vol. 9, 711-751.*

3. *http://www.azom.com/article.aspx?ArticleID=2812 cited on 16 July 2014 15:23 IST.*

4. *Roy Woodward, "Aluminium Extrusion: Alloys, Shapes and Properties", TALAT Lecture 1302, Aluminium Federation, Birmingham.*

5. *YuanyuanGeng (2011), "Microstructure Evolution during Extrusion of AA3xxx Aluminium Alloys".*

6. *Schikorra M Donati L Tomesani L Tekkaya A E (2007), "Microstructure Analysis of Aluminium Extrusion: Grain Size Distribution in AA6060, AA6082 and AA7075 Alloys", Journal of Mechanical Science and Technology, Vol. 21, 1445-1451.*

7. *George Vander Voort, "Metallography and Microstructure of Aluminium and Alloys".*

8. *Lrivas A Munoz P Camero S Quintero-Sayago O (1999), "Effect of the Microstructure on the Mechanical Properties and Surface Finish of an Extruded AA-6063 Aluminium Alloy", ADV. MAT. SCI. & TECH. Vol. 2, 15-23.*

9. *http://www.gordonengland.co.uk/hardness/microhardness.htm cited on 10 November 2014 11:15 IST.*

10. *http://shodhganga.inflibnet.ac.in:8080/jspui/bitstream/10603/516/10/10_chapter%204.pdf cited on 10 November 2014 11:15 IST.*

11. *Abdel-Rahman M A AlaaAldeenAhmeda Emad Badawi A (2010), " Testing Natural Aging Effect on Properties of 6066 & 6063 Alloys using Vickers Hardness and Positron Annihilation Lifetime Techniques", Defect and Diffusion Forum, Vols. 303-304, 107-112.*

12. *De Silva G I P and Perera W C (2012), "Improvement of The Mechanical Properties of Aluminium 6063 T5 Extrudates By Varying The Aging Condition Cost-Effectively", SAITM Research Symposium on Engineering Advancements.*

