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Development of Alba High Speed Alloy

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Abstract

Aluminium Bahrain has developed in-house an alloy called "ALBA HIGH SPEED 6063.10", which is a variant of alloy AA 6063. The driving force behind this has been the ever standing requirement of extruders to attain progressively higher extrusion speeds, thereby boosting productivity. Small and controlled amounts of Mn and Mg additions to alloy AA 6063 were found to help in improving extrusion speeds and reduce die pick-up thereby improving the surface appearance. The reason was attributed to improved beta to alpha phase transformation rates at the microstructure level. This was achieved by having tight control of Mn addition to reduce the band from 0 % - 0.10 % in normal AA6063 alloy to 0.03% – 0.06 % in 6063.10. In addition controlling the Mg addition to 0.45 % – 0.51 % in the new alloy, assisted in better distribution of Mg_2Si precipitates in the matrix during the cooling process, post soaking at 580 °C.

Introduction

Aluminium Bahrain (Alba) is a primary aluminium smelter located in the Kingdom of Bahrain. It has a capacity of about 860,000 mt per annum.
The Casthouse-3 of Aluminium Bahrain (Alba) produces billets (about 340,000 mt per annum) in the following alloy groups:

- 6005 (Al-Si-Mg) Typical use: Extruded shapes and tubing for commercial application requiring strength greater than AA6063.
- 6060 (Al-Si-Mg) Typical use: Architectural application.
- 6063 (Al-Si-Mg) Typical use: Architectural extrusion, door & windows.
- 6061 (Al-Si-Mg-Cu-Cr) Typical use: Trucks, pipelines, and other structure applications where strength, weldability, and corrosion resistance are needed.
- 6082 (Al-Si-Mg) Typical use: Extruded shapes and tubing for commercial applications requiring strength greater than AA6063.

Alba uses direct chill (DC) MaxiCast™ Airslip billet casting technology for manufacture of billets. This method uses enhanced cooling technology feature.
Alba produces billets in the following sizes and in the following configuration in terms of log densities as shown in Table1.

Serial No.	Diameter (mm)	Diameter (Inch)	No. Of logs / Cast
1	152.4	6	128
2	177.8	7	108
3	203	8	84
4	216	8.5	68
5	228.6	9	68
6	254	10	54

Table 1: Alba billets sizes and configuration

Background

In 2008 some of our customers in the GCC were exploring possibility of extruding our products at higher speeds. In this process, they had encountered some tearing problems that had hindered their efforts. This was investigated by a team of specialists who attributed this effect to the quantum of transformation of beta AlFeSi (plate like monoclinic) phase to alpha AlFeSi (rounded cubic) intermetallic phase, during homogenization [1].

An extensive literature study was undertaken which revealed that small amounts of Mn addition (0.03% - 0.06% by wt) significantly increased the transformation rate from beta to alpha phase and thereby improved extrudability. [1, 2] The exact addition rate of Mn was arrived at, through trial and error.
Subsequently Alba High Speed AHS 6063.10 was developed after extensive trials at some of our customers' end.
Soon after development of this alloy, Alba had conducted technical workshops across the GCC and Middle East to launch the product to a wide customer base. The response was overwhelming and since then, several customers have readily accepted this alloy in lieu of the conventional 6063, which improved their extrusion speeds and productivities by an average of 30 %.

Metal preparation and condition

Alba's liquid aluminium metal is treated to minimize hydrogen gas and oxide levels prior to casting into billets by air pressurized (DC) MaxiCast™ Airslip casting. This process is designed to produce high quality billet with consistent extrusion properties.

After casting and inspection, ALBA billets are homogenized to 580 °C for two hours to achieve a uniform metallurgical structure with more than 95% β to α transformation. Homogenizing ensures that billets conform to the extrudability requirements with the end product developing maximum mechanical properties consistent with the composition of the alloy and the specified temper.

Features of AHS 6063.10

AHS 6063.10 alloy is a medium strength alloy with excellent extrudability and anodizing characteristics. The alloy can achieve minimum - T5 and – T6 properties specified for 6063 alloy.

Application of AHS 6063.10

Alloy 6063.10 can be used in application requiring medium strength levels. Typical uses include architectural, building, kitchen suite sections and general purpose extrusions.

Physical properties of AHS 6063.10

Physical properties are given in Table 2 below.

Property	Typical values
Density	2700 kg/m3
Modulus of thermal expansion	69.5 GPa
Coefficient of thermal expansion	23.4 x 10-6 / °C
Thermal Conductivity	209 W / (m.K)
Electrical Conductivity	32 MS/m
Approximate Melting Range	615°C to 650°C

Table 2: Typical physical properties (T5 temper)

Mechanical properties of AHS 6063.10

With appropriate extrusion and heat treatment practices, the following minimum and typical properties can be achieved as shown in Table in 2. The minimum properties are as specified in the Aluminium Association, USA for 6063 alloy.

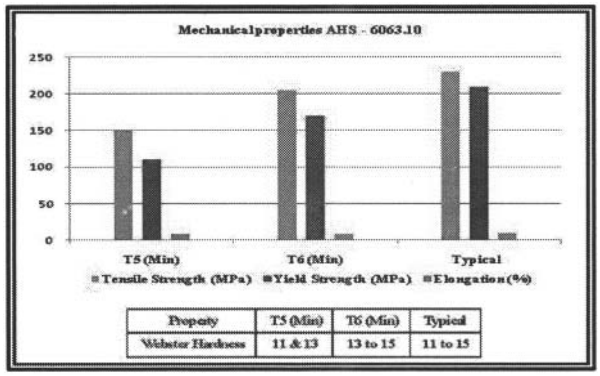

Figure 1: Mechanical properties of AHS alloy

Field Trials

Several Trials were conducted successfully and jointly with customers. The trial conducted at Al Taiseer KSA with 203 mm billets in alloy AHS (6063.10) is discussed in this paper and the result are shown in Table 4:

Methodology of trials

The methodology followed at the extruders for the development of optimum extrudability using the AHS 6063.10 alloy billet involved two key steps. Those are outlined below and it was decided that representatives from ALBA's technical team be present to work with the extruder to facilitate the development of optimum extrusion performance using the 6063.10 alloy billet.

Stepl. The AHS (6063.10) billets were extruded under the existing process conditions particularly in connection with temperatures (die, billet and exit) as well as extrusion speeds that were being used with the existing 6063 type conventional alloy. All extrusion process conditions as well as the resultant product quality particularly surface condition, recovery and aged (-T5) mechanical properties were recorded for analysis .If anodizing was done by the extruder, then samples from the anodized material were collected for review by the team involved in the optimization work.

Step2. Subsequent to a review of the existing process conditions and the resultant section product quality, dies were selected for the optimization work .This included two to three dies used for extrusion of solid profiles as well as two to three dies used for extrusion of hollow profiles. The dies selected were significant usage dies by the extruder and had a good die history recorded. The selected dies were ensured to be well nitrided and in a good condition of maintenance. The selected dies were then heated to the specified temperature for extrusion prior to being loaded to the press. The plan was to extrude the ALBA AHS 6063.10 alloy billet, around 10 billets on each die at progressively increasing extrusion speeds under closely monitored conditions of extrusion temperatures, particularly exit temperature, and speed measurements.

The target was to achieve up to a 50% speed increase on a given die without any deterioration in the as- extruded surface finish (pick- up or die lines) or the onset of tearing or speed cracking. The temperature control in the log or billet heater being used by the extruder was a key requirement in the achievement of the optimum extrusion performance using the AHS6063.10 alloy billet and this was a focus area for monitoring throughout the work.

Subsequent to the optimization of maximum acceptable extrusion speeds on the selected dies, the as-extruded material was aged under standard conditions of temperature & time and the mechanical properties. Hardness readings were taken to confirm that the material has been aged to the desired level. If anodizing is carried out then the material was anodized to clear and bronze colors, to again confirm that the required anodized quality level has been achieved.

Typical processing conditions

Preheating

Billets were preheated to a temperature in the range of 440 ^{0}C-480 ^{0}C to ensure good extrudability and mechanical properties. Difficult sections such as thin walled extrusions or hollows may requite higher billet preheat temperatures (~ 490 °C), while simple sections may be extruded with lower preheat temperatures (~ 430 °C).

Press Quenching

The cooling rate of the extrudate from exit temperature down to 250 °C should be in excess of 60 °C/min to achieve minimum mechanical properties. For thin sections (less than 3mm), a still air or fan air cooling should be adequate to achieve this cooling rate. For thicker sections (3 to 6 mm), vigorous fan cooling is usually required to achieve the minimum cooling rate. Water mist cooling may be required on thicker sections.

Straightening

Stretching to an elongation of about 0.5% is recommended for straightening while stretching beyond 1% elongation may result in orange peel finish on the extrudate.

Ageing Treatment

Various ageing times and temperatures can be used to obtain good mechanical properties. However a typical aging condition for 6063.10 alloy in production operation is 4 hours at a soak temperature of 185 ^{0}C+/ 5°C .

Extrusion Conditions

The temperature of the container should be set at least 30 °C below the billet temperature to ensure the billet skin is retained in the butt. The billet preheat temperature and extrusion speed should be controlled so that the exit temperature is maintained in the range of 500 ^{0}C to 550 ^{0}C .Typical extrusion speeds for this alloy are in the range of 20 to 50 m/min for solid profiles and 15 to 40 m/min for hollow profiles.

Die Preheating

For extrusion of solid and hollow sections the dies were heated to around. 450 °C .Dies should not be overheated or held for long times in die oven.

Results of Trials

Samples were sent to external Lab. (SECAT) for evaluation of microstructure before doing field trials at customer end. The mount consisted of three homogenized billet [3]. The summary of SECAT's report is shown in Table 3:

1. Homogenization was good with only traces of Mg_2Si seen indicating that Mg and Si have been retained in solid solution, refer to Figure 3.
    a. The liquation depth was 90μm; it was low and acceptable, refer to Figure 2.
    b. The Beta to Alpha conversion was good and greater than 98%; Intermetallic particles were fragmented.
    c. The intermetallic particles were relatively small and consistent in size with thickness <1 μm and length 0.5-10 μm.
2. In general, billet microstructure was good with no problems expected during the extrusion process. Extrudability was expected to be good. This was based on practical guidelines from the following:
    a. The very low levels of Mg_2Si
    b. The intermetallic particles were in the form of rounded or small rod like particles with samples showing excellent particle break up and Beta to Alpha conversion.

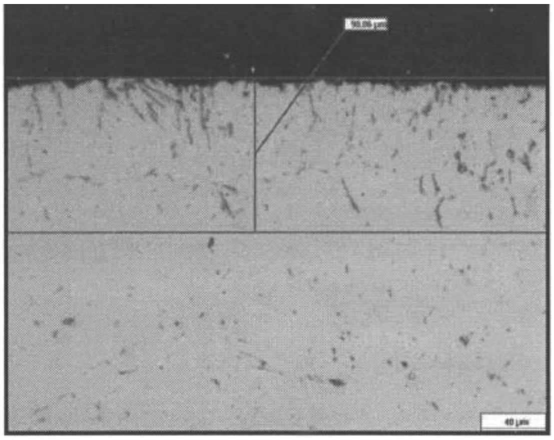

Figure 2: Optical microphotograph of alloy AHS (6063.10) sample showing liquation depth

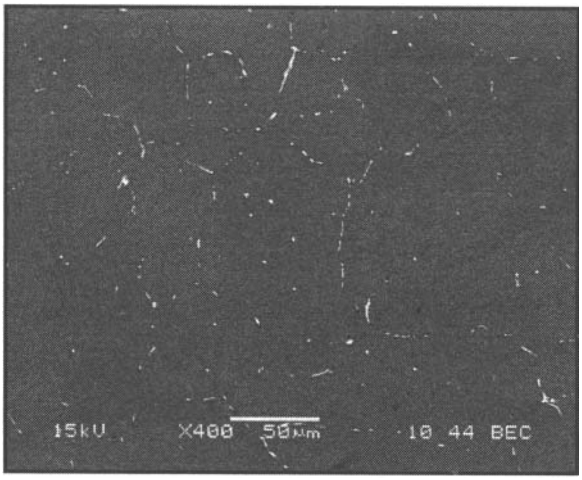

Figure 3: SEM images of particle structure alloy AHS 6063.10

Table of Summary of evaluation Alba Billet alloy AHS (6063.10) analysis results **[3]**

β to α (%)			Compound Size (µm)	
C entre	Middle	Edge	Thickness	Length
>98	>98	>98	< 1	0.5~10
Mg2Si <1µm			Liquation Depth (µm)	Over Heated
C entre	Middle	Edge	90	none
trace	trace	trace		

`Table 3: Summary of field trial of alloy AHS (6063.10) analysis results at Al Taiseer extrusion company KSA.

Customer Feedback

The objectives listed earlier were achieved from the trials conducted at customer's end. The development and implementation of the new ALBA HIGH SPEED (AHS) 6063.10 alloy billet was progressed as a result of the visit made. Approximately 10.5 % relative speed increase was achieved on the selected dies (Hollow & Solid) sections being extruded at the time of the trial using the AHS6063.10 alloy billet. **[4]**

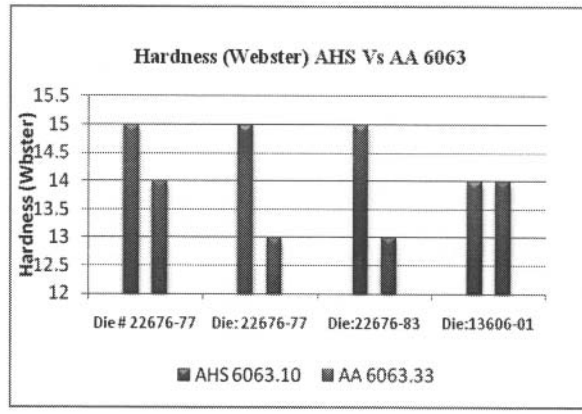

Figure 4: Extrusion Speed AHS Vs AA6063.33

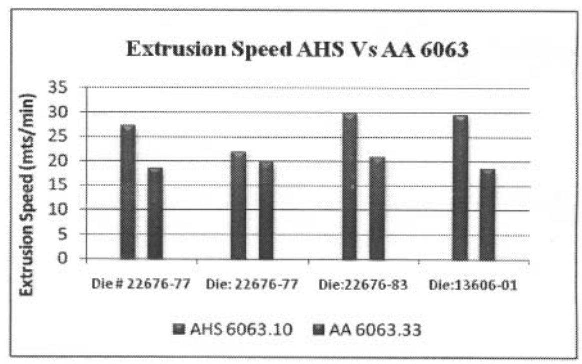

Figure 5: Hardness (Webster) AHS 6063.10 Vs AA6063.33

1. The break through pressure increase in ALBA AHS (6063.10) as compared to AA6063 shows evidence of a "stronger alloy".
2. Even the running pressure which is measured after 100 mm of Extrusion shows / support comment # 1.
3. The surface finish appearance during Extrusion / weld joint inspection shows less metal pick up, meaning better flow of metal.
4. This result shows the evidence that ALBA AHS (6063.10) was stronger by approx 10.5 % when compared to AA6063

Parameters	Die #: 22676-77	
	AHS 6063.10	6063.33
Press #	4	4
Billet temp °C	470	470
Wall thickness of profile mm	0.5	0.5
Extrusion speed mts/min	27.2	18.5
Surface finish	V. Good	Good
Ageing Cycle °C -hrs	200 - 4.50	200 - 4.50
Webster reading(Hardness)	15	14
UTS Kg/mm2	24.25	23.8
Parameters	Die #: 24855-17	
	AHS 6063.10	6063.33
Press #	4	4
Billet temp °C	470	470
Wall thickness of profile mm	0.75	0.75
Extrusion speed mts/min	21.8	19.8
Surface finish	V. Good	Good
Ageing Cycle °C -hrs	200 - 4.50	200 - 4.50
Webster reading(Hardness)	15	13
UTS Kg/mm2	N/P	N/P

Parameters	Die #: 22676-77	
	AHS 6063.10	6063.33
Press #	4	4
Billet temp °C	470	470
Wall thickness of profile mm	0.5	0.5
Extrusion speed mts/min	27.2	18.5
Surface finish	V. Good	Good
Ageing Cycle °C -hrs	200 - 4.50	200 - 4.50
Webster reading(Hardness)	15	14
UTS Kg/mm2	24.25	23.8
Parameters	Die #: 24855-17	
	AHS 6063.10	6063.33
Press #	4	4
Billet temp °C	470	470
Wall thickness of profile mm	0.75	0.75
Extrusion speed mts/min	21.8	19.8
Surface finish	V. Good	Good
Ageing Cycle °C -hrs	200 - 4.50	200 - 4.50
Webster reading(Hardness)	15	13
UTS Kg/mm2	N/P	N/P

Conclusion

As is evident, the development of alloy AHS 6063.10 has helped the extruders to enhance their extrusion productivity along with improvement in strength.

The technical team at Alba has also shown that by working closely with the extruder and monitoring the key extrusion parameters of billet and exit temperature on the press the process can be adjusted to obtain extrusion speed increases of up to approx 30 % over the previous AA6063 type alloy when run on the same die

This improvement in the extrusion speed, hence productivity, at the extruders is obtained while maintaining a good surface finish on the extruded product for subsequent surface finishing by either anodizing or powder coating. Mechanical properties after standard ageing cycle are also well above the minimum values specified for AA6063 alloy in the –T5 temper and with appropriate cooling of extruded section on the press above the mechanical properties specified for –T6 temper .

This development at Alba has therefore contributed significantly to overall optimization of performance for the extrusion industry and into the billets markets that Alba supplies.

References

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