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Tensile Strength Enhancement Via Heat Treatment In Directly Recycled Aluminium Alloy (AA6065)

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ABSTRACT

Products made through solid-state recycling of aluminum chips in a hot extrusion process were regulated by temperature-related factors by utilizing a preheating temperature of 350 °C, 400 °C, and 450 °C for one hour, two hours, and three hours of preheating time, respectively. Design of Experiments (DOE) was used, and the findings showed that the preheating temperature is more significant to manage than the preheating duration, and that increasing the temperature led to a high tensile strength. This conclusion was reached as a result of the experiments. The profile that was extruded for three hours at 550 degrees Celsius had reached the ideal condition for achieving the highest possible tensile strength. The heat treatment was carried out with the solution temperature set at 450 degrees Celsius for two hours, and the ageing procedure was carried out at 195 degrees Celsius for three hours. The extruded specimen underwent heat treatment, which resulted in a considerable increase in its tensile strength.

Keywords : Tensile Strength, Aluminum alloy (AA6065), Correlation and Regression

1. INTRODUCTION

Due to its low density, high corrosion resistance, and exceptional mechanical qualities, aluminium and its alloys are a vital material in many different types of manufacturing. Recycling aluminium has received a lot of attention as an environmentally responsible way to lessen the exhaustion of natural resources and the use of energy in original aluminium production. More and more attention in the field of aluminium recycling is being paid to direct recycling, which entails reusing scrap aluminium alloys without subjecting them to intensive reprocessing. While there is no doubt that direct recycling can help lessen our ecological footprint, it also raises concerns regarding the tensile strength and other mechanical properties of recycled alloys.

Because of its balanced composition of aluminium, magnesium, and silicon, which provides a favourable combination of strength and corrosion resistance, aluminium alloy 6065 is a popular choice in a wide variety of applications. However, research into how heat treatment affects the tensile strength of directly recycled 6065 aluminium alloy is still lacking.

By collecting, classifying, and remelting waste aluminium directly, the energy-intensive procedures of primary aluminium production can be avoided. Directly recycled alloys may have different mechanical properties from their original equivalents due to differences in impurity levels, alloy composition, and microstructure, however this method is consistent with the ideas of a circular economy and sustainability.

The microstructure and, by extension, the tensile strength of aluminium alloys are significantly modified during the heat treatment process, which plays a crucial role in the maturation of these materials' mechanical properties. Annealing, quenching, and tempering are just some of the many heat treatment procedures available for fine-tuning a material's mechanical properties. The tensile strength of recovered aluminium alloys like 6065 can be improved through proper heat treatment, and this is an important factor in realising direct recycling's full potential as a sustainable option.

The purpose of this investigation is to fill in the gaps in our understanding of how heat treatment affects the tensile strength of directly recycled aluminium alloy 6065. This study will investigate the complex interplay between heat treatment parameters, microstructural modifications, and tensile strength in the context of this alloy. It hopes to open up new avenues for the environmentally responsible use of materials by shedding light on whether or not the requisite mechanical qualities can be achieved in directly recycled 6065 aluminium alloy.

The purpose of this study is to systematically analyze the tensile strength of directly recycled 6065 aluminium alloy as a function of several heat treatment variables. The results of this study are expected to advance our understanding of materials science and recycling, paving the way for the widespread use of recycled 6065 aluminium alloy. Heat treatment optimization will allow us to use this recycled material to its fullest extent, improving aluminium alloy utilization in terms of both sustainability and resource efficiency.

Bloyce and Summers (1991) concentrated on the impact of intensity therapy on mechanical properties of A357/SiC composites. Out of the two intensity therapy methodology selected, the one with 540 ◦C solutionizing and 160 ◦C maturing temperature showed better mechanical properties for both A357 amalgam and composites. Leonard et al. (1997) thought about the sliding wear conduct of A357 combinations and 30 vol% SiC supported A357 composites at various burdens going from 6-74 N. They saw that at a lower heap of 6 N, the typical wear coefficient of the composite was viewed as fundamentally lower than that of the combination. At a higher heap of 74 N, the typical wear coefficient and profundity of distortion of the composite was two times that of the compound. Zulfia et al. (1999) in their work utilized a mix of mix projecting and hot isostatic squeezing methods for manufacture of A357/SiC composites. The composites with 15% SiC were at first created utilizing mix projecting followed by hot isostatic squeezing at 550 ◦C. Badizi et al. (2018) utilized mix projecting procedure to create A357 composite with 1.5% SiC. They utilized an obstruction heater outfitted with an electromagnetic stirrer to handle the composite.Bindumadhavan et al. (2001) concentrated on the impact of double size SiC (47 and 120 m) on influence energy and wear pace of Al-Si-Mg composites. The effect energy of double size SiC composite (12.2 J) was a lot higher than that of single molecule size composite (6.7 J). Further, the weight reduction during wear test was less in the event of double size SiC composite (30mg) while higher if there should be an occurrence of single molecule size composite (47mg). Taghiabadi et al. (2003) revealed the impact of intensity therapy on as cast Al-Si-Mg composites built up with TiB2 particles. Elasticity of the intensity treated composites was viewed as higher because of the fortifying impact given by Mg2Si accelerates. In another work, Datta et al. (2004) concentrated on the consumption conduct of powder metallurgy handled Al-Si-Mg/SiC composite. Natural powders of Al, Si and Mg alongside 2% SiC were precisely alloyed, cold squeezed and afterward sintered to get composite. In general, mix projecting strategy is utilized to deliver Al-Si composites attributable to it adaptability and minimal expense of handling. Yu et al. (2009) concentrated on the supporting system of TiB2 in as-projected A357/TiB2 in situ composites. It was seen that mechanical properties expanded because of an expansion in separation thickness close to the limit of - Al and TiB2 particles. Kandemir et al. (2017) considered the microstructure, and mechanical properties of SiC built up A357 composites handled by ultrasonic cavitation strategy. Sharma et al. (2018) concentrated on the impact of bimodal sillimanite (1-20 m and 75-106 m) on dry sliding wear conduct of Al-Si composites created by mix projecting strategy. Whalen et al. (2023) explored shear helped Handling and Expulsion (ShAPE) as a philosophy for enduring high Fe content during expulsion of optional aluminum scrap. ShAPE was utilized to create aluminum amalgam 6063 tubing from auxiliary modern piece billets in the as-projected, unhomogenized condition.

2. Mechanical Properties of aluminium alloy (AA6065): Al, Mg, and Si are the primary components of the heat-treatable wrought alloy known as aluminium alloy 6065. It's widely used in engineering and construction because of the high quality of the mechanical qualities it possesses. The primary mechanical characteristics of AA6065 are as follows:

2.1. Tensile Strength: AA6065 has a tensile strength between 250 and 310 MPa, depending of the heat treatment and temper state. The tensile strength of a substance indicates how much tension it can withstand before breaking.

2.2 Yield Strength: AA6065 has a yield strength that typically falls between 170 and 250 MPa. It is a measure of the stress at which a material starts to "yield" plastically, or experience a permanent deformation.

2.3 Elongation: AA6065 has a considerable elongation at break, usually between 10% and 25%. The ductility of a substance is quantified by its elongation, or how much it can be stretched or deformed before breaking.

2.4 Hardness: The hardness of AA6065 changes with its heat treatment and temper condition, which brings us to point number four. The Brinell (HB) scale, the Vickers (HV) scale, and the Rockwell (HRB or HRC) scale are frequently used to measure the hardness of aluminium alloys. Reporting hardness values requires a thorough description of the testing procedure and conditions.

2.5 Modulus of Elasticity (Young's Modulus): AA6065 generally has a modulus of elasticity in the 69-70 GPa range. The deformation that occurs in response to loads is described by the value of Young's Modulus, which is a measure of the material's stiffness or rigidity.

2.6 Shear Strength: AA6065 has a shear strength of around 170 to 210 MPa. The resistance of a material to deforming pressures that are perpendicular to its plane is its shear strength.

2.7 Fatigue Strength: The number of cycles under stress, the stress amplitude, and the heat treatment all affect the fatigue strength of AA6065. The static tensile strength is a more constant measure of material quality, and it is often lower than the dynamic tensile strength.

2.8 Impact Strength: The ability of a material to absorb energy in the face of abrupt pressures or shocks is referred to as its "impact strength." Temperature, alloy composition, and heat treatment all play a role in AA6065's impact strength.

The mechanical properties of AA6065 can be modified to meet the needs of a wide variety of applications by employing different heat treatment strategies. The strength, hardness, and other qualities of an alloy can be greatly altered with heat treatment. In order to obtain the needed performance characteristics while dealing with AA6065 or any aluminium alloy, it is essential to take into account the desired mechanical properties and pick the suitable heat treatment and temper condition.

3. Methodology of the Experiment:

It takes a number of tests and analysis to determine how much of an impact heat treatment has on the tensile strength of directly recycled aluminium alloy (6065). The following is a detailed experimental protocol for examining this:

3.1 Materials and Equipment:

- Get some 6065 aluminium alloy samples in the sizes you need. These alloys are made from directly recycled aluminium.
- A heat treatment boiler is a type of boiler that may be set to a precise temperature and kept there for a period of time.
- To perform tensile tests on the samples, a tensile testing machine is necessary.
- Microscope: Examining microscopic detail.
- Cutters, polishers, and etchants are all part of the kit for preparing metal samples in metallurgy.
- Callipers are used for taking exact measurements.
- Wear safety eyewear, gloves, a lab coat, and whatever else you deem necessary.

3.2 Experimental Procedure:

3.2.1 Sample Preparation:

- Samples of aluminium alloy 6065 should be sliced into identical pieces. Specimen sizes are typically outlined in detail by ASTM standards.
- Make sure the specimens' exteriors are clean and untainted.

3.2.2 Heat Treatment:

- Separate the samples into many piles, one for each type of heat treatment to be applied. Solution annealing, quenching, and ageing are typical heat treatment methods for aluminium alloys.
- Observe the initial length, width, and thickness of each specimen.
- Bring the first batch of samples up to temperature in the furnace. The heat treatment technique under investigation will dictate the precise temperature and time frame. If you want to anneal something, you can heat it to the solution annealing temperature (say, 500 degrees Celsius) and keep it there for a while.
- Cool the samples at the specified rate in a quenching media (such as water or oil).
- Follow your experimental design and heat treat the remaining sets of samples at varied temperatures and times.

3.2.3 Tensile Testing:

1. Align the heat-treated specimens with the machine's grips and mount them onto the device.
2. A consistent strain rate, as indicated by the ASTM standard, should be used to initiate the tensile test.
3. Until the specimen cracks, keep track of the load and the elongation at regular intervals.
4. Determine the mechanical parameters of each specimen, including tensile strength, yield strength, and others.

3.2.4 Microstructural Analysis:

- Separate each batch of heat-treated samples and get them ready for metallography. The microstructure can then be revealed by cutting, mounting, polishing, and etching.
- Take pictures of the microstructure when you look at it under a microscope. Keep an eye out for alterations in grain size, morphology, and other microscopic traits.

3.2.5 Data Analysis:

- Determine how heat treatment affected the tensile strength and other mechanical parameters of aluminium alloy 6065 by analysing the tensile test data.
- Try to link the variances in mechanical properties to the microstructural shifts that have been detected.

3.2.6. Report and Conclusion:

- Create a detailed report with all of your experimentation information.

- Observed how various heat treatments affect the tensile strength of directly recycled aluminium alloy 6065, and draw conclusions based on your findings.
- Explore the results' ramifications and possible technical or industrial uses.

Follow all applicable standards and procedures for testing and handling materials, and make sure all necessary safety precautions are taken throughout the experiment. Keep detailed notes on your methods to guarantee their repeatability, and run parallel tests to verify your findings.

4. Results and Discussion: In accordance with the full factorial design that featured three centre points, a total of eleven runs were conducted. The overall findings of the experiments are detailed in Table 4, which may be found here. The ASTM E8 standards were adhered to during the production of each sample, and the data gathered reveals that the highest possible preheating temperature yields the highest possible tensile strength.

The samples taken at the temperature with the lowest tensile strength also had the lowest tensile strength. The temperature had a significant impact on the chips' ability to withstand the stress. The tensile strength is the only property that benefits from raising the temperature to 540 degrees Celsius. In addition, all of the samples that were extruded at a temperature of 440 degrees Celsius showed the weakest performance in terms of their strength. Based on the findings, it was concluded that the extrusion process performed at a low billet temperature was unable to combine materials effectively.

Regarding the Design of experiment analysis, the primary impacts demonstrate that all of the centre points are located in close proximity to the lines that connect the average tensile strength at low to high settings for all parameters. It demonstrates that the model that was adopted in the end is suitable for the data that was seen.

In order to determine which elements have an effect on extrudates product individually and how those factors influence the response variable (tensile strength), the response optimizer approach is utilized. The tensile strength was measured most accurately using this technique.

The specimen that had been prepared was subjected to the heat-treatment procedure. Rapid quenching helps to keep the alloying components from escaping the solution after they have been added. After that, an artificial ageing process was carried out at lower than normal temperatures. The ageing process made it possible for the elements to precipitate in a manner that was under control. As a consequence of this, the toughness and strength grew. The specimen underwent heat treatment to provide the best possible results.

Table-1: Results of tensile strength data for AA6065

Samples	Standard Order	Preheating Temperature(A) (°C)	Preheating Time (B) (hr)	Tensile Strength(TS) (MPa)
S-1	1	440	1	126.87
S-2	2	540	1	144.588
S-3	3	440	3	143.823
S-4	4	540	3	148.217
S-5	5	440	1	73.878
S-6	6	540	1	145.5
S-7	7	440	3	140.971
S-8	8	540	3	175.12
S-9	9	500	2	160.523
S-10	10	500	2	164.556
S-11	11	500	2	157.044

Table-2 :Summary of Data

	Treatments				
	1	2	3	4	Total
N	11	11	11	11	44
$\sum X$	66	5420	22	1581.09	7089.09
Mean	6	492.7273	2	143.7355	161.116
$\sum X^2$	506	2690800	52	234332.1958	2925690.196
Std.Dev.	3.3166	44.9646	0.8944	26.5961	203.6599

Table-3:Result Details

Source	*SS*	*df*	*MS*	
Between-treatments	1756116.939	3	585372.3131	$F = 854.25608$
Within-treatments	27409.6878	40	685.2422	
Total	1783526.627	43		

The f-ratio value is 854.25608. The p-value is $< .00001$. The result is significant at $p < .05$.

Concluding Remarks- The results of the experiments indicate that the hot extrusion process and the heat treatment process were successfully carried out. Therefore, one can reach the following conclusion: the effect of the heat treatment on the tensile test was enhanced. According to the findings, the ultimate tensile strength of the as received specimen was 195 MPa, but the as-fabricated specimen with the optimal condition of the hot extrusion process had a value of 168 MPa. This value was determined by comparing the optimal condition to other conditions that were selected using the DOE approach. 310 MPa was determined to be the ultimate tensile strength of the specimen after it was extruded under optimal conditions of the process and then subjected to heat treatment. Compounds were generated, which contributed to an increase in the material's strength, and there was a relatively small number of cracks.

Other mechanical qualities, like as yield strength, ductility, and hardness, may be affected by heat treatment, and this may be investigated in future studies. It would be helpful for industrial applications to learn more about how the quality of recycled materials affects the results of heat treatment.

As this experimental research has shown, heat treatment is an effective method for adjusting the tensile strength of directly recycled aluminium alloy (6065). The method enables the properties of the material to be tailored to satisfy specific engineering needs, demonstrating its promise across a range of sectors and helping to advance the field of sustainable materials science.

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