Techniques to Enhance Aluminium Alloy Performance

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Abstract:

A number of benefits of aluminium alloy include its low density, strong strength, and excellent ductility. It is frequently utilized in aerospace, aviation, automobile engineering, and other fields. Nonetheless, these areas have a greater need for aluminium alloy. For example, greater elongation, harderness, strength, and other performances are required. There are four potential efficient ways to enhance the performance of the aluminium alloy: heat treatment, plasma spraying, combination with graphene, and elemental composition changes. The trials confirm that every technique works. To understand the underlying principles of each technique, more research on these approaches is still necessary.

1. Introduction:

The element which makes up the largest portion of the earth's crust is aluminium. But humanity started to make use of aluminium until the 19th century. It is challenging to generate aluminium from aluminium ore because alumina has a significant reduction and cannot be reduced by hydrogen or carbon monoxide. Later on, it was discovered that aluminium had far superior qualities, leading to its widespread use. Aluminium alloy is significantly less dense than steel yet having strength that is comparable to that of steel. Furthermore, under typical circumstances, it is difficult to oxidize because to the thick layer of alumina covering its surface. However, several of aluminium's qualities still fall short of what humans need. A more demanding specification like improved corrosion resistance, stronger electric conductivity.

2. Methods:

2.1. Changing the content for the element:

The majority of aluminium alloys have an aluminium content of more than 85%, meaning that additional elements make up no more than 15% of the total. However, the characteristics of aluminium alloys are significantly influenced by other elements. The amount of trace elements in aluminium alloys has a significant impact on its mechanical characteristics, including hardness, tensile strength, and elongation.

The microstructure of the aluminium alloy is clearly refined when a certain quantity of Y is added. The absence of Y in the alloy results in primarily coarse, unevenly distributed columnar crystals in its microstructure. Y was added, which improved the microstructure and made the distribution uniform. Macroscopically, the mechanical characteristics of aluminium alloy steadily improve as Y addition increases when it is between 0.1% and 0.3%. The alloy's tensile strength and elongation were 154 MPa and 22.5%, respectively, at the 0.3% addition of Y [1].

Researchers have found in recent years that adding Ce into aluminium alloy may improve its mechanical characteristics. The mechanical properties of the aluminium alloy are improved by the addition of a modest quantity of Ce. The alloy containing 0.35 percent cerium has a microhardness that is 56.3 times higher than the alloy lacking cerium. Research has demonstrated that CeO2 can significantly enhance the mechanical characteristics of aluminium matrix composites. The mechanical characteristics of the composites rise with an increase in Ce concentration throughout a range of 0.5% to 2.5%. The alloy's tensile strength and bending strength are 123 MPa and 615.6 MPa, respectively, at 2.5 percent Ce [1].

Comparably, the characteristics of aluminium alloy are also affected by other rare earth elements as Yb, Sm, Er, and La.

The study examined how the amount of Bi content affected the microstructure, mechanical, and cutting characteristics of aluminium alloy bars. It found that the more Bi phase and BiSn eutectic phase present, the higher the Bi content, the better the aluminium alloy bars' cutting performance, and the shorter the chip length, but the tensile strength and elongation decreased slightly. As seen in figure 1, the average length of the aluminium alloy rod chip is 3 mm, the tensile strength is 283.5 MPa, and the elongation is 25.9% as the Bi content rises to 1%.

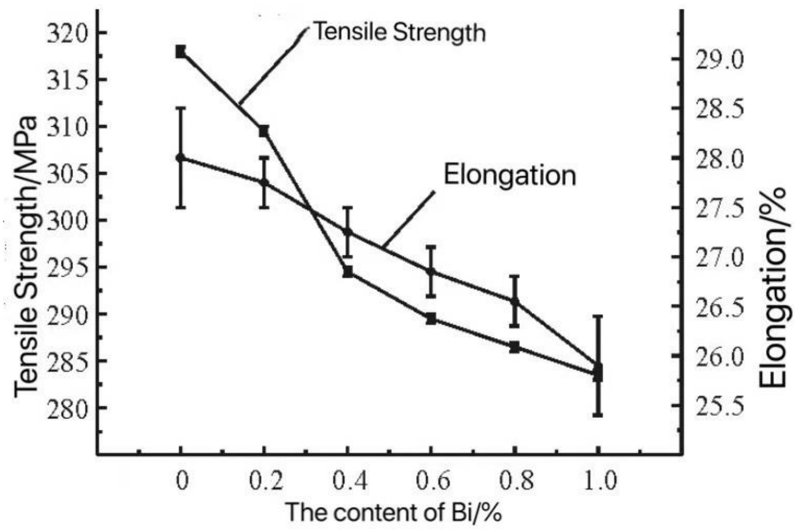

Figure 1 shows how tensile strength and elongation change as the number of Bi changes [2].

As a result, more thorough quantitative studies may be necessary to determine the impact of each component. The research that is now available also leads us to the general conclusion that aluminium alloy performance can be enhanced by logically adjusting the content of additional elements.

2.2 In combination with graphene:

The substance graphene is relatively new. With a tensile strength of 130GPa and a Young's modulus of up to 1GPa, it possesses exceptional mechanical qualities. Its electrical and thermal conductivity are also excellent. Furthermore, graphene's chemical characteristics are often stable. It is possible that the qualities will improve if graphene and aluminium alloy are combined in any way.

The mechanics of aluminium-graphene composites are being studied extensively at the moment, and significant advancements have been achieved. Numerous experimental evidence points to the fact that incorporating a tiny quantity of graphene nanophase into a pure aluminium matrix might enhance the tensile strength of aluminium matrix composites while preserving their high ductility. Aluminium alloys have lower conductivity but higher tensile strength than pure aluminium, while pure aluminium has better conductivity but lower tensile strength. Aluminium alloy is now used for high voltage overhead transmission lines due to its high tensile strength requirements. When graphene is utilized in electric power transmission, there will be less energy since the transmission line's resistance will be decreased.

The addition of graphene can significantly enhance the mechanical characteristics and electrical conductivity of aluminium alloy, according to the findings of an experiment investigating the impact of graphene on the microstructure and properties of the alloy. Tensile strength rose by 21.5% under the same conditions, from 95.7 MPa to 116.3 MPa when comparing 0Z and 1JZ, as Table 1 illustrates. Along with the minor rise in conductivity, there was a decrease in elongation.

Table 1. The tensile mechanical properties, hardness and conductivity of metals [3]

Serial number	Hardness/HV	Electric conductivity %IACS	Tensile strength/MPa	Yield strength/MPa	Elongation
0Z	35.8	33.2	95.7	73.0	26.4%
1JZ	39.2	34.7	116.3	92.8	22.9%
1P	35.9	31.2	103.3	82.8	25.3%
1Z	36.8	34.3	109.2	84.7	25.7%
2Z	38.5	34.3	111.2	85.8	25.4%

(Number 0Z contains no graphene while number 1JZ has the highest graphene content)

However, there are a lot of technical issues that need to be resolved. First of all, stable and high-quality graphene is hard to come by. Furthermore, additional innovation and improvement in preparation methods and process parameters are required because the current methods cannot generate a large number of mixed powders, which restricts the industrialization of aluminium-graphene composites. Lastly, a thorough theoretical analysis of the combination of graphene and aluminium alloy is lacking. More research is required to clarify the binding, orientation relationship, and interfacial response mechanism between graphene and the aluminium matrix.

2.3 The way aluminium alloy is heated:

The four primary heat treatment technologies are quenching, normalizing, tempering, and annealing. Usually, the metal becomes hard but brittle simultaneously after quenching, and tempering is needed to lessen brittleness. The goal of annealing is to achieve good performance by bringing the metal's internal structure as close as possible to its equilibrium condition. Normalization has an effect akin to annealing, but it produces a finer microstructure, which is frequently utilized to enhance metals' cutting qualities. The effects of the annealing process on the characteristics of aluminium alloy sheets are the primary focus of one experiment. The sheet has a high yield and tensile strength prior to heat treatment, according to the experimental data. There is only 8% elongation, a yield strength of 390 MPa, and a tensile strength of 412 MPa. The mechanical parameters of the plates underwent considerable changes upon annealing at 270°C and 300°C. Notably, the elongation increased dramatically while the tensile and yield strengths fell. The elongation increased and the tensile and yield strengths fell when the material was annealed over 300 °C, but the changes were subtle. About 300–310 MPa of tensile strength, 140–150 MPa of yield strength, and approximately 23%–25% of elongation was retained [6].

An additional experiment was conducted on the aluminum alloy quench.
PAG, a quenching liquid, was utilized in place of water.
Numerous experiments demonstrate that, in comparison to hot water, this type of quenching agent may greatly red uce deformation, residual stress, and achieve the necessary strength performance.
The primary goal was to investigate how the concentration of the quenching agent affected the characteristics of t he aluminum alloy.
The findings demonstrated that there is a small range of fluctuation in the final tensile strength and elongation wit h increasing quenching agent concentration.
As can be seen in figure 2, at a concentration of 10% for the quenching agent, the
tensile strength achieves its maximum, and at 15%, the elongation reaches its maximum.

Figure 3 illustrates how the tensile strength and elongation both reach their maximum values simultaneously at a concentration of 10%. Based on the two types of aluminium alloy that were used in the trials, we can approximate that the optimal concentration of this type of quenching agent for the comprehensive properties of aluminium alloy is between 10% and 15%.

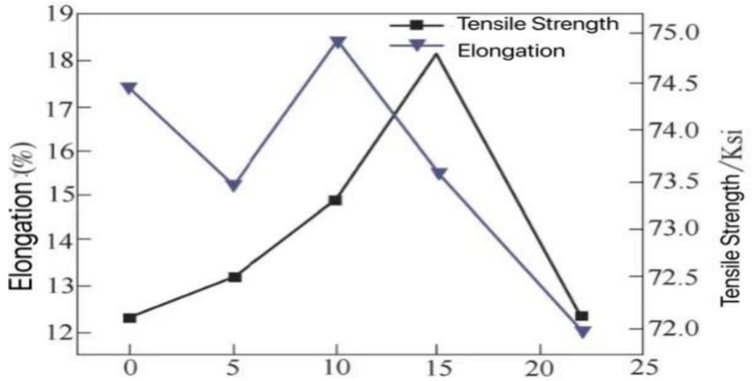

Figure 2. Tensile properties of 7075 aluminum alloy quenched by different concentrations ofquenching agent [7]

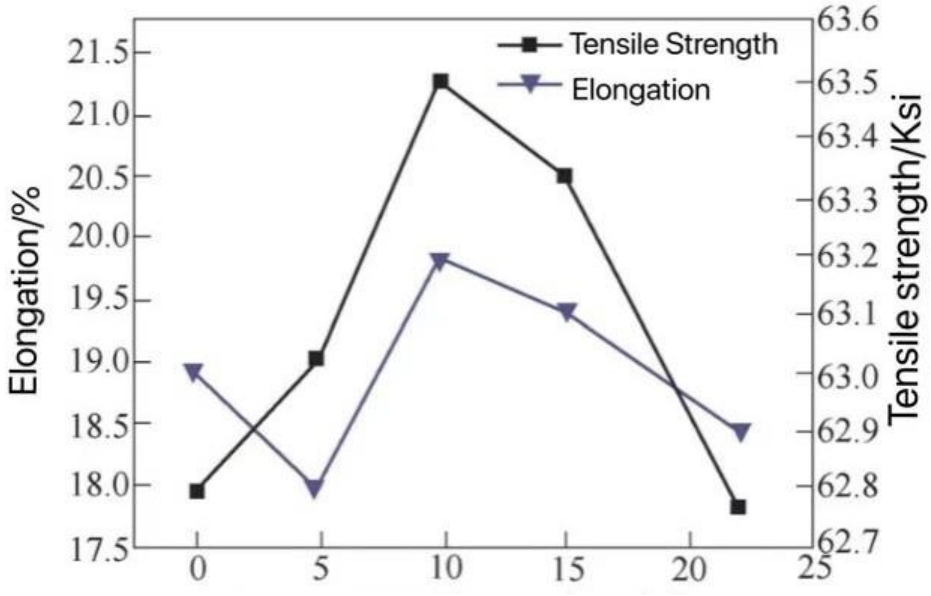

Figure 3. Tensile properties of 2024 aluminum alloy quenched by different concentrations ofquenching agent [7]

3. Conclusion:

The performance of aluminium alloy can be effectively enhanced by four practical methods: heat treatment, combining with graphene, altering the content of other elements, and plasma spraying. Every technique has benefits and drawbacks of its own. Given its excellent performance, additional research on aluminium alloy is required in the future. High performance, high quality, high homogeneity, and low cost continue to be the primary goals of new materials and processing technologies for aluminium alloy development [8].

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