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EVALUATION OF MECHANICAL PROPERTIES OF A356 CAST ALLOY/RHA/AL₂O₃ BASED HYBRID COMPOSITE AT DIFFERENT AGING CONDITIONS

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ABSTRACT

The aluminium alloys are used in marine, defence, aerospace, automobile and chemical plant applications because of their very high strength and lightweight properties. Due to these properties researchers are concentrating towards Aluminium metal matrix composite material. The stir casting process was used to fabricate A356 alloy based hybrid composites reinforced with various weight fractions of 1%, 2%, 3%, 4% & 5% RHA and Al₂O₃ particulates in equal proportions. Tensile strength and Hardness of the hybrid metal matrix composites have been evaluated. A scope of enhancement in both Tensile and Hardness is observed in Double aged with strain specimens over as-cast, single aged and double aged without strain condition.

Keywords: Hybrid composites, A356, Rice Husk Ash, Al₂O₃

INTRODUCTION

The requirement of space industries is to use the material having light weight and high strength leads to the development of new type of materials called composites. The Aluminium matrix composites are normally used in the areas where the weight is constraint [1], since they are light in weight and having a high strength to weight ratio. The aluminium alloys with reinforcement of ceramic particles leads to the latest generation of engineering materials with improved mechanical properties to weight ratio [2].

Few studies have shown, with the practical reinforcement, enhancement to the mechanical properties of Aluminium matrix composites can be achieved. The united advantages of the constituting materials can be achieved by development of composite materials. Metal Matrix Composites reinforced with various particles results in improvement in the properties processed by traditional routes [3].

In the process of reinforcement of aluminium alloy composites, Al₂O₃ is the most general particle added as a reinforcing agent. The properties of the aluminium matrix can be enhanced by including ceramic particles as strengthening materials. Wide varieties of materials for light weight applications has been developed using this method. For the manufacturing of the aluminium particles, reinforced composites stir casting method emerge as an encouraging method for various traditional processing methods. The process of Heat treatment can change the aluminium alloy composite microstructure. Many investigating experiments on composites of aluminium using SiC, Graphite, Fly ash, MgO, B₄C and Zircon are done by researches. These composites of aluminum are available in market in different structural forms [4].

Ramesh D et al.,[5] studied the tensile strength of frit reinforced aluminium metal matrix composites, revealed improved tensile strength with the increase in frit particle content to aluminum matrix. Rangnathan et al.,[6] studied hybrid aluminium composites reinforced with Mica/SiC particulates and concluded that better mechanical properties are exhibited by hybrid composites. Nall Ramanaiyah et al.,[7] has done investigation on the mechanical behavior of hybrid composites done by reinforced RHA and concluded that Rice Husk Ash acts as a guaranteed complementing reinforcement material for manufacturing of products which involves less cost. Zagade S et al.,[8] have reported the mechanical behavior of aluminium /fly ash/alumina hybrid composites, exhibited excellent tensile and hardness strength. A comparative study by Honnaiah C et al.,[9] tensile strength of alumina reinforced aluminium metal matrix composites revealed improved tensile strength with the decrease in particle size. Shenoy G et al., [10] have described in their work that the tensile strength of Al/Mica/E-glass fiber can be improved by solution heat treatment and aging conditions.

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AIM OF THE PRESENT STUDY

In this present investigation, A356 aluminium alloy based hybrid metal matrix composites have been developed by using RHA and Al_2O_3 particulates with stir casting method. The outcome of reinforcement weight fraction on microstructure and mechanical properties of the hybrid composites have been investigated.

MATERIAL SELECTION

In the present work, the matrix material used for experiment is A356 alloy. The table 1 shows the matrix material chemical composition. The reinforcement materials used are Al_2O_3 and RHA. The average size of the Al_2O_3 particulates is of $100\mu m$ and average size of the RHA particulates is of $75\mu m$. Table 2 shows the RHA chemical composition. To enhance the wettability between the matrix and the reinforcements during manufacturing of hybrid composites, wetting agent is required and magnesium was used as a wetting agent here.

Table -1: A356 Chemical composition

Element	Si	Mg	Fe	Ti	Cu	Mn	Zn	Ni	Al
Weight%	6.6	0.45	0.10	0.10	0.05	0.055	0.005	0.005	Bal.

Table-2: The RHA Chemical composition

Element	Silica	Graphite	Calcium Oxide	Magnesium Oxide	Potassium Oxide	Ferric Oxide
Wt %	90.23	4.77	1.58	0.53	0.39	0.21

EXPERIMENTAL STUDY

The rice husk is burned and ash obtained as result is washed thoroughly with water. Washing with water removes all dirt then the resultant material is dried for 24 hours at normal room temperature. The moisture content and organic matter should be removed by heating the cleaned rice husk up to $200^\circ C$ for 60 min. Then carbonaceous material has been removed by heating it to $600^\circ C$ for 12h [1]. The ash, thus collected, was used as reinforcement material in the preparation of hybrid composites.

A356 aluminium alloy was charged in the electric furnace and superheated to a temperature of $800^\circ C$. RHA and Al_2O_3 particulates were preheated to a temperature of $450^\circ C$ for 1h to remove moisture and absorbed gases. Degassing of liquid metal was done by hexa-chloro-ethane tablets. Liquid metal temperature was maintained at $750^\circ C$ with sufficient viscosity. The molten metal was stirred at a speed of 500rpm for 5 - 10min with the help of impeller to create sufficient vortex. The stir speed chosen is high enough to get a sufficient vortex for proper mixing of the ceramic particles with the liquid metal and at the same time it is low enough to avoid the gas and air entrapment in the liquid metal. The preheated particles were introduced laterally in to the vortex of the molten metal. One percent Magnesium was added to increase the wettability of the particles. Stirring speed was maintained at 500rpm for next 10min to ensure the proper mixing. After this stage, the molten mixture was drained in to the mould. To accomplish the uniform solidification of the molten metal the mould was preheated to $200^\circ C$ for 30min. Thus, particle strengthened hybrid composite materials are formed by adopting the stir casting process and 1%, 2%, 3%, 4% and 5 % by equal weight proportions of RHA and Al_2O_3 are thus used.

Heat Treatment Procedure

The following steps are involved in heat treatment procedure:

- i. Solutionizing
- ii. Quenching
- iii. stretching/straining
- iv. Aging
 - a) Single aging step at lower temperature
 - b) Double aging step at higher temperature

Solutionizing and Quenching: Solutionizing at $540^\circ C$ for 2 Hrs followed by quenching in to water at room temperature.

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stretching/straining: This is a particular condition where, instantaneously after the heat treatment and quenching, before precipitation starts and the hybrid composite material become harder. One set of prepared samples is permanently deformed by 8 % to 10 % by applying external force (before 5Hrs).

Single aging: After quenching single aging is at the temperature of 140°C for about 12 Hrs of period is carried out.

Double aging: The Second step of aging procedure also done for the 12 Hrs of time and at a temperature of 190°C.

RESULTS AND DISCUSSION

The samples were machined according to the ASTM specifications. The samples were exposed to the solution heat treatment. The resulting A356 hybrid composite material mechanical properties have been investigated.

MICROSTRUCTURE ANALYSIS

The alloy matrix was subjected to the microstructure examination following Fig.1 to Fig.4 are the microstructures obtained in our experiment. The microstructure examination confirms the presence of the reinforcements inside the composites. Once the casting is ready, a cross section sample was collected from the castings. These castings are carrying through grinding at the beginning and then emery paper was used to polish the ground one, at last, engraved using Keller's solution and was examined through an optical microscope. The optical microscope has been used to investigate the A356 alloy based hybrid composite material. The Aluminium composites which are reinforced with RHA and Al_2O_3 particulate and microstructure obtained from optical microscope are shown from Fig.1 to Fig. 4.

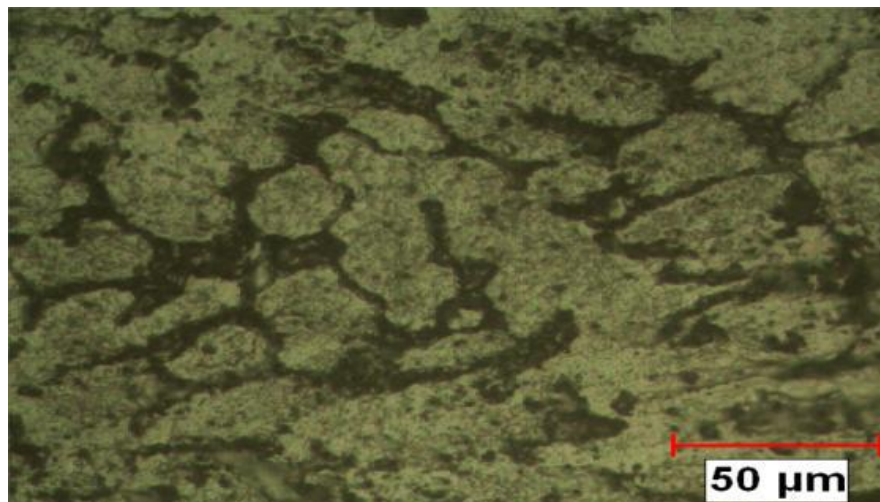


Fig -1: Microstructure of As-cast A356 composite (4% RHA and 4% Al_2O_3)

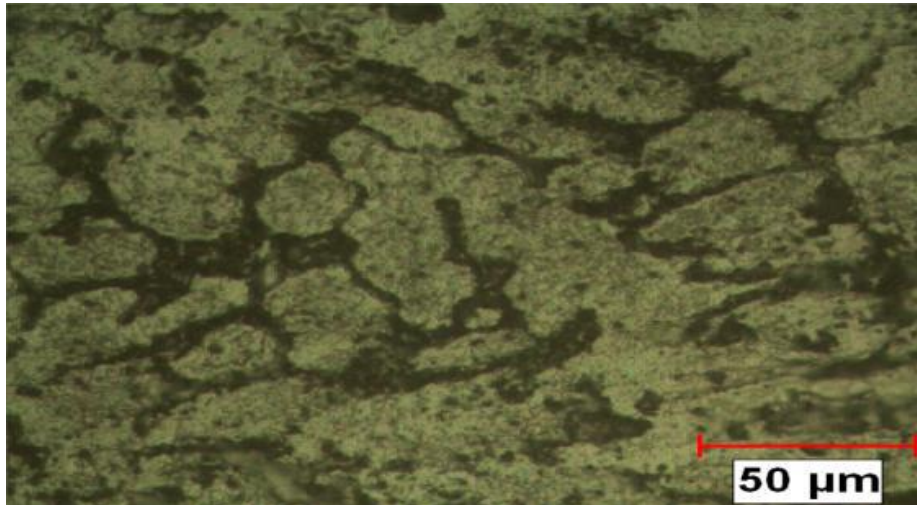


Fig -2: Microstructure of Single aged A356 composite (4%RHA and 4% Al₂O₃)

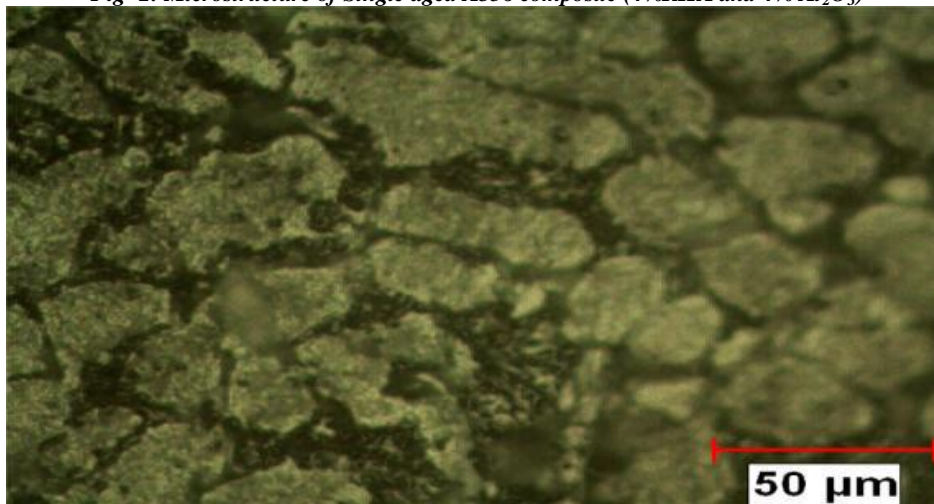


Fig -3: Microstructure of Double aged without strain A356 composite (4%RHA and 4% Al₂O₃)

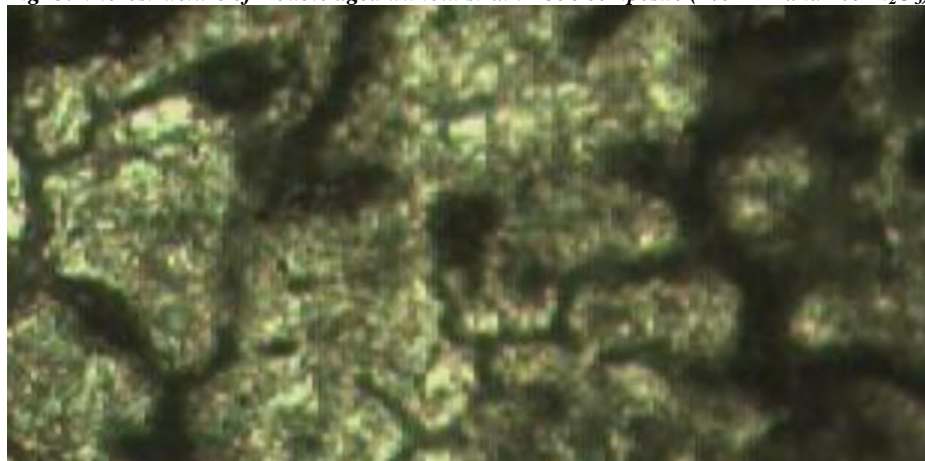


Fig -4: Microstructure of Double aged with strain A356 composite (4%RHA and 4% Al₂O₃)

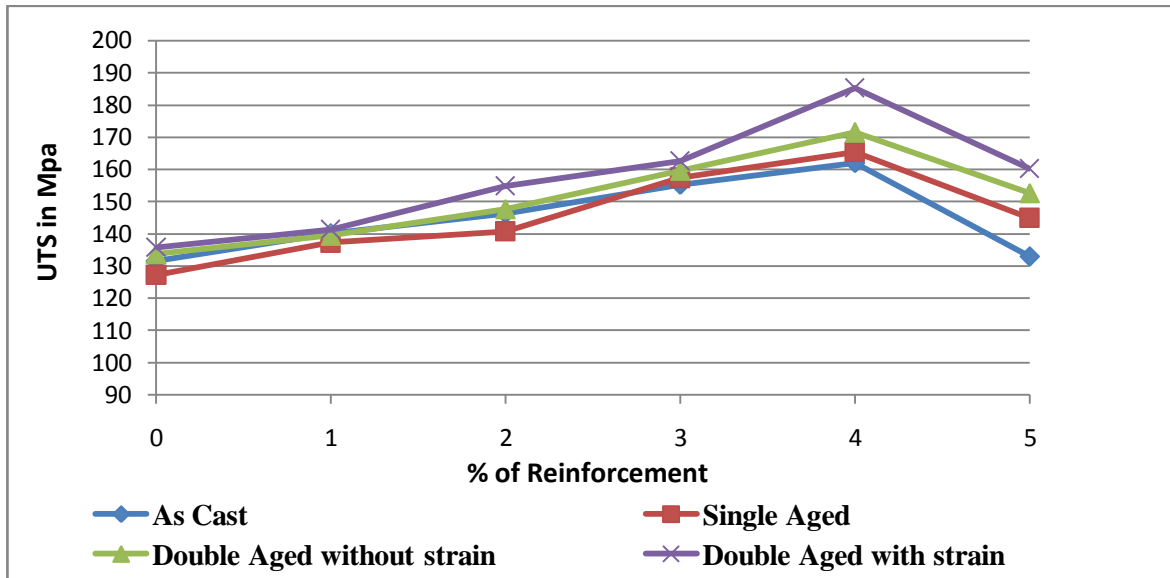
The optical micrographs demonstrate the uniform distribution of RHA and Al₂O₃ reinforcement particles in the matrix. And it is evident that there are no void and discontinuities in the A356 alloy composite material. Thus, we can say that the good interfacial bonding among the reinforcement particles and matrix material.



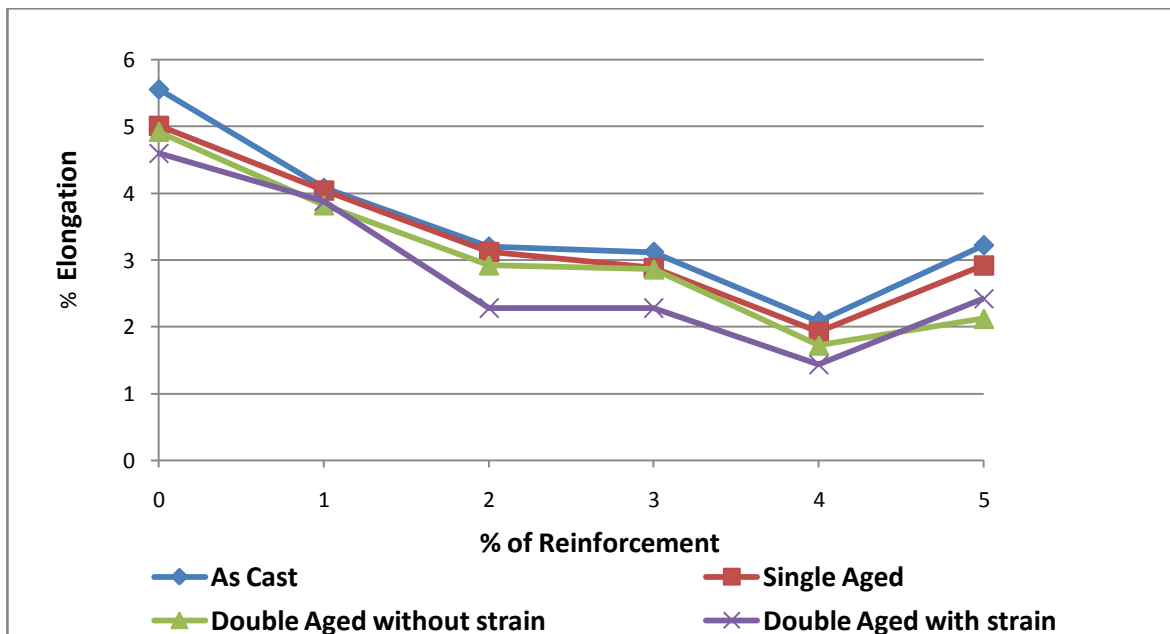
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Tensile test

The set of specimens were loaded in uni-axial tensile testing machine as per ASTM E8 standards and loaded until the failure of the specimen occurs. Tensile tests were conducted of different compositions of RHA and Al_2O_3 particulates reinforcing materials and aging conditions. UTS (Ultimate tensile strength) and % elongation were measured.



Graph -1: Evaluation of UTS for samples with various RHA and Al_2O_3 Compositions and Aging conditions



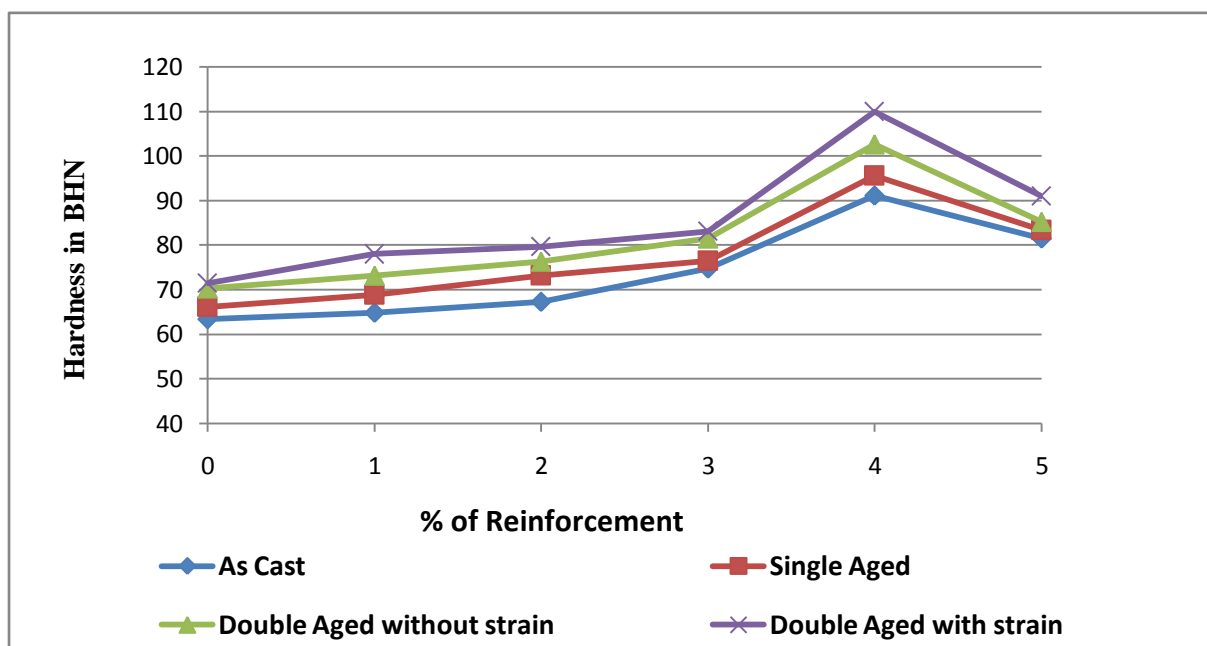
Graph -2: Percentage Elongation for samples with various RHA and Al_2O_3 Compositions and Aging conditions

It is noticeable from Graph 1 and 2 the ultimate tensile strength(UTS)gradually increases with increase in weight % of RHA and Al_2O_3 reinforcement particles and % elongation decreases with the increase in weight % of RHA and Al_2O_3 reinforcement content. This is due to the resistance to dislocations and hence, strength increases with the weight percent. An effective bonding between reinforcements and matrix favors an improvement of the tensile strength.

Hardness test

The Binell hardness tester was used to carry out the hardness tests. The test specimens of 20mm thickness were machined from As-cast, aging at lower and higher temperature with the use of various composite specified. The steel ball with a diameter of 2.5mm and 60 Kgf of the load was adopted. The average value of the tests done at three different locations was considered as the hardness value of the composite specimens. The outcomes appear as underneath.

From the Graph -3, it is noticeable that the hardness of the composite material obtained in this experiment is higher enough than parent metal from which it is derived. It is likewise presented that increase in the weight fraction percentage of reinforcement materials, hardness of the composite material increases. As the content of silica substance increases, the result of the addition of reinforcement makes the A356 composite into more brittle and hard. Furthermore the heat treatment and aging results in the production of intermetallic precipitates. At the point when the specimens are subjected to double aging with strain, the resulting grains have obtained much more uniform and closer structure and this prompts to improve hardness which is found in the Graph -3.



Graph -3: Evaluation of Hardness for samples with various RHA and Al_2O_3 Compositions and Aging conditions.

CONCLUSION

The A356 based Hybrid composites were successfully produced by stir casting method with different weight percentage of RHA and Al_2O_3 particulate reinforcements with A356 as matrix material. Within purview of the study following conclusions have been drawn.

- By making use of stir casting method, RHA and Al_2O_3 particulates can be successfully introduced in the A356 matrix alloy material to fabricate hybrid composite materials.
- From the microstructure analysis, it is noticeable that reinforcement in the fabricated composite material is distributed inadequately even manner.
- The grain structure of the specimens which are treated with Double aging with strain have denser structure when compared to other samples, because of nucleation of precipitates and the reinforcement material is well bonded with the matrix material.
- When the percentage of RHA and Al_2O_3 increases in the composite, the UTS of that of composite also increases. UTS is significantly affected by the heat treatment procedure and aging procedure and results obtained for specimens which undergo double aging with strain has peak values.

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- If the reinforcement content in the composite increases, then the hardness of the specimens also increases. Peak values have been shown up for Hardness of material and specimens after double aging with strain and they are noticeably affected by the Heat treatment and aging procedures.
- However, beyond four percentages of reinforcement, loss of reinforcements has started taking place due to floatation of the reinforcements in particular RHA. Further, it was difficult to stir and mix them in the molten metal uniformly due to increase in volume.
- The outcomes obtained clearly demonstrate that the double aged with strain specimens shown improved tensile strength and hardness in comparison with the single aging and as cast specimens.

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