STUDIES ON DEVELOPMENT OF MICROALLOYED CAST STEELS

A THESIS

Submitted by

CHOKKALINGAM B

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ANNA UNIVERSITY OF TECHNOLOGY, COIMBATORE

COIMBATORE - 641047

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ABSTRACT

Steel has the advantage of the best eco engineering material as well as economical and hence investigated in this work towards more applications. Generally steels as per ASTM A216, A217, A352 and A487 are cast in the foundries. In this research work microalloying elements like vanadium, niobium, titanium and zirconium were added to the cast steel and the effect of these microalloying elements on hardness, ultimate tensile strength, room temperature impact strength, percentage elongation microstructure, EDS analysis and SEM analysis were studied. The alloys were melted in induction furnace and y block castings were poured for testing of the material. Various combinations of these alloys at micro level were added with the standard cast steel grades. The properties and micro structures were analyzed for these combinations. Then the cast specimens were heat treated and properties and microstructures were studied. Finally the best combination of micro alloyed cast steel which has better properties was identified in this research work.

The effects of microalloying on hardness, tensile strength, room temperature impact energy and elongation of low carbon as cast steel have been investigated and compared with non-microalloyed as cast steel. Elements such as vanadium, niobium, titanium and zirconium were added together in cast steel as microalloys. The results show that the addition of these elements in the cast steel in normalized form increases the hardness to 200HV and tensile strength to 780MPa, while decreases the percentage elongation to 14% and room temperature impact energy to 14Joules

respectively . This method of alloying refines the microstructure of the cast steel in as cast form.

In this study, Taguchi method is used to find out the effect of micro alloying elements like vanadium, niobium and titanium on the hardness and tensile strength of the normalized cast steel. Based on this method, plan of experiments was made by using orthogonal arrays to acquire the data on hardness and tensile strength. The signal to noise ratio and analysis of variance (ANOVA) are used to investigate the effect of these micro alloying elements on these two mechanical properties of the micro alloyed normalized cast steel. The results indicated that in the micro alloyed normalized cast steel both these properties increases when compared to non-microalloyed normalized cast steel. The effect of niobium addition was found to be significantly high to obtain higher hardness and tensile strength when compared to other micro alloying elements. The optimum condition to obtain higher hardness, tensile strength, percentage elongation and room temperature impact toughness were determined. The results were verified with experiments.

In factorial design, three factors vanadium, niobium and titanium were varied on upper and lower level. The linear equations were developed for hardness, tensile strength, percentage elongation and room temperature impact toughness from the experiment. The average of the response variables were used for the calculation. The predicted results using the equation with coded factors and obtained results were agreement with each other.

In the detailed literature review, microalloy was defined as content of the microalloying elements below 0.10% weight. In microalloyed steel, minor amounts of vanadium, niobium, titanium and/or zirconium etc are added. The addition of these individual elements is generally less than 0.10% and the total micro alloying of all these elements combined together is less than 0.20%. Microalloying elements influenced the microstructure through precipitation. Grain refinement achieved in microalloyed steel increases the strength and improves toughness. The growth of microalloyed wrought steels was more in the later half of the 20th century. The common grade C-Mn steel was transformed into HSLA steel by means of microalloying the elements such as vanadium, niobium, titanium, and zirconium etc. More amount of literature is available for wrought micro alloyed steels whereas as very little amount of literature is available for cast microalloyed cast steels.

Extensive research work on production and characterization of microalloyed wrought steel has been done whereas the production of microalloyed cast steel has been found very limited. In some cases microalloying in cast and heat treated forms were reported. The same steel which was as cast microalloyed and later the same cast steel heat treated have not been reported. The present work involves production of microalloyed cast steel with vanadium, niobium, titanium and zirconium as microalloys. The effect of vanadium, niobium and titanium as microalloys in cast normalized steel was studied using Taguchi and factorial design of experiments.

The scope of the present investigation is limited to study the effect of addition of microalloying elements vanadium, niobium, titanium and

zirconium in low carbon cast steels. The characterization in non-microalloyed and microalloyed cast steels is limited to hardness, ultimate tensile strength, room temperature impact strength, percentage elongation, microstructure, EDS analysis and SEM analysis.

In phase I, the results and discussion of non-microalloyed and microalloyed cast steel are presented. Among the eight melts, one is used as base melt and four melts with individual microalloying of vanadium, niobium, titanium and zirconium were made. Three melts with combination of these microalloying elements were made and studied. Discussions are made on micro examination , hardness, ultimate tensile strength, room temperature impact strength, percentage elongation, micro structure, SEM analysis and EDS analysis.

In phase II, the non-microalloyed and microalloyed cast steel test bars were normalized by heating them from ambient temperature up to 920^{0}C in a muffle furnace and remained at this temperature for two hours. Then, they were removed from the furnace and air cooled up to the ambient temperature. Discussions were concluded on micro examination, hardness, ultimate tensile strength, room temperature impact strength, percentage elongation, microstructure and SEM analysis.

This research clearly showed that micro alloyed steel has better mechanical properties in as cast and normalized forms than the non-microalloyed cast steels.