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Mechanical properties of as-cast microalloyed steels produced via investment casting

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ABSTRACT

Tensile and room temperature Charpy V-notch impact tests were used to evaluate the variations in the as-cast mechanical properties of a low-carbon steel produced via shell mould investment casting and containing combinations of vanadium, niobium and titanium. Tensile results indicate that the yield strength and ultimate tensile strength (UTS) have increased up to respectively 615 MPa and 770 MPa due to the fine-scale microalloy precipitates in the microalloyed samples. Room temperature impact test results show that while addition of vanadium individually has not changed the impact energy, Nb has decreased it considerably. However, examination of fracture surfaces reveals that all microalloyed samples have failed by transgranular cleavage. Based on the transmission electron microscope (TEM) studies, it seems that carbonitrides being greater than 50 nm in size and formed along prior austenite grain boundaries before γ transformation are responsible for the observed reduction in impact energies and brittle fracture. In comparison to sand mould casting, the yield and UTS obtained from investment casting are superior. Furthermore, although the impact energies of Nb-containing alloys are approximately the same as those obtained from sand moulds, the impact energy of the alloy containing only vanadium has improved considerably.

1. Introduction

Microalloyed cast steels are basically C–Mn steels which contain conventional microalloying elements such as vanadium, niobium and titanium [1,2]. The idea to develop these alloys originated from the successful wrought grades which a combination of superior strength and toughness can be achieved through fine ferrite grain size and precipitation hardening. Fine-scale carbonitrides play a major role in enhancing the mechanical properties by precipitation in austenite and ferrite during or after $\gamma \rightarrow \alpha$ transformation [3–5]. In order to achieve the desired properties, various heat treatment processes including quench and temper, normalizing and inter-critical heat treatments are generally employed. Hence, the effects of different heat treatment variables including prior homogenization, austenitizing time and temperature, cooling rate and tempering time and temperature on the mechanical properties of microalloyed cast steels have been the subject of many investigations [6–10].

In contrast to the heat-treated grades, few attempts have been made to characterize mechanical and microstructural properties of as-cast microalloyed steels. Composition control and achievement of consistent as-cast microstructures would be essential to obtain the desirable properties in the as-cast microalloyed steels without the addition of heat treatment costs. Therefore, it would be valuable to develop low-cost cast microalloyed steels in the as-cast condition that can be effective substitutes for some steel or cast iron parts with good combinations of properties in many industrial applications.

In a study conducted by the authors [11–14], effects of microalloying additions on the mechanical and microstructural properties of the heats poured into the sand mould in the form of Y-blocks have been investigated in as-cast condition. Based on the results, although not altering the ferritic–pearlitic microstructure, the presence of microalloying elements significantly increased the strength due to the precipitation of fine-scale carbonitrides being 10 nm or less in size. Observations revealed the carbonitrides in three different states including random and interphase precipitation along with heterogeneous precipitation on the dislocations. Moreover, in comparison to the sample without microalloying additions, the elongation of microalloyed alloys reduced a maximum of approximately 10%.

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