Ref: 66/18

In the name of God

The Influence of Molybdenum on the Kinetics and Mechanical Properties of Austempered Ductile Iron

A thesis submitted to the

University of Manchester

for the degree of PhD

in the Faculty of

Science & Engineering

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1998

Materials Science Centre

ABSTRACT

Studies of the austempering kinetics and properties of irons containing nominally, 3.5%C, 2.7%Si, 0.25%Cu, 0.25%Mn and Mo contents of 0.13, 0.25 and 0.45% are described. Microscopic observations and measurements of the volume fraction of high carbon austenite and associated carbon content, unreacted austenite volume, hardness, 0.2% proof strength, ultimate tensile strength, elongation and unnotched Charpy impact energy are presented as a function of austempering time in the range of 1 minute to 3 days for austempering temperatures in the range of 285 to 400°C and austenitising temperatures in the range of 840 to 950°C. Microsegregation profiles of silicon, manganese, molybdenum and copper were determined for the as-cast and austenitised samples. The research has shown that austenitising does not change the distribution of alloying elements significantly. The kinetic studies show that the alloying level for the 0.13%Mo iron is insufficient to cause a significant delay in ausferrite formation in the intercellular boundaries. This means that the heat treatment processing window is open for all austempering conditions studied. The hardenability of this iron is limited so that the standard is not likely to be achieved in thicker section components. Increasing the austenitising temperature to improve the hardenability also narrows the heat treatment processing window but does not close it. Mechanical property measurements show that the ASTM A897:1990 ADI standard is satisfied using austenitising temperatures 920, 870 and 840°C but the tensile properties just fail to satisfy the standard with an austenitising temperature of 950°C. This is attributed to the fact that the definition of the processing window

does not make allowance for mechanical instability of the ausferrite structure. The properties satisfy the new European ADI standard BS EN 1564:1997 for all four austenitising temperatures. Measurements for the 0.25%Mo iron are compared with similar measurements for the 0.13%Mo iron. The comparison shows that increasing the molybdenum content in order to increase hardenability delays the stage I reaction slightly but the processing windows remain open for all the austempering temperatures studied for an austenitising temperature of 870°C. The hardenability of the 0.25%Mo iron can be increased further by increasing the austenitising temperature from 870 to 920°C. This delays the stage I reaction particularly at higher austempering temperatures but all the processing windows remain open and the ASTM standard is satisfied. Further increase of the molybdenum content to 0.45% to increase hardenability, does not delay the austempering reaction significantly and the processing window remains open for all the austempering temperatures studied. The ductility of the 0.45%Mo austempered iron is reduced compared to that measured in 0.13%Mo and 0.25%Mo irons austempered under the same conditions. This is attributed to an increased amount and continuity of intercellular carbide as the molybdenum content increases. Studies on three irons confirm that molybdenum does not delay the austempering reaction significantly. Consequently, the heat treatment processing window remains open for all the irons and austempering conditions studied and the ASTM standard can be satisfied as predicted by the open processing windows. This is shown to contrast with the influence of manganese which delays the reaction leading to the closure of the processing window at higher austempering temperatures and difficulty in producing the higher ductility grades of the ASTM standard. These studies show that with respect to their influence on austempering kinetics, molybdenum is more suitable than manganese for increasing the hardenability of the iron.