

**UNIVERSITI TEKNOLOGI MARA**

**THE EFFECTS OF NIOBIUM ADDITION ON  
MECHANICAL AND PHYSICAL PROPERTIES  
OF AUSTEMPERED DUCTILE IRON**

**SITI KHADIJAH BINTI ALIAS**

**MSc**

**June 2010**

**UNIVERSITI TEKNOLOGI MARA**

**THE EFFECTS OF NIOBIUM ADDITION ON  
MECHANICAL AND PHYSICAL PROPERTIES  
OF AUSTEMPERED DUCTILE IRON**

**SITI KHADIJAH BINTI ALIAS**

Thesis submitted in fulfilment of the requirements for the degree of

**Master of Science in Mechanical Engineering**

**Faculty of Mechanical Engineering**

**June 2010**



## ABSTRACT

Austempered Ductile Iron (ADI) is merging as one of potential material in many engineering applications especially in automotives components and heavy machineries applications. The development of Austempered Ductile Iron is a significant necessity, as this material possessed superior properties, high castability, and lower cost compared to steel. This thesis investigates the effect of Niobium element addition on the mechanical and physical properties of alloyed ductile iron before and after austempering process. The constitution of ductile iron (DI) and two newly developed materials which were 0.5wt % Niobium alloyed ductile iron (0.5wt % Nb-DI), and 2wt % Niobium alloyed ductile iron (2wt % Nb-DI) were made through Y block (300mm x Ø25mm) CO<sub>2</sub> sand casting. Samples were then austenitized at 900 °C for 1 hour before austempered at 350 °C at 3 different holding times which were 1 hour, 2 hours and 3 hours consequently. Mechanical and physical properties of as cast and austempered samples with different holding time were evaluated through hardness, impact (ASTM E23), tensile (TS 138 EN1002-1) and density test. Microstructure observations which was obtained through Olympus B X 41M microscope and Scanning Electron Microscopy (SEM) observation were also done after 2% Nital chemical etched. Microstructure observations revealed that ductile iron possessed the structures of graphite nodules surrounded by island of ferrite and pearlite and addition of Niobium had promoted graphite nodules and Niobium Carbide (NbC) in polygonal form dispersed in matrix of pearlite. The experimental results explicitly indicated samples of 2wt % Nb-ADI (1 hr) gives the optimum tensile strength and impact toughness properties among all types of samples which associated with the fine bainitic and retained austenite matrix, in coupled with the presence of Niobium Carbide in the material structure. It was also demonstrated that the tensile strength and impact toughness properties of Nb alloyed austempered ductile iron decreased corresponding to longer austempering time as coarser retained austenite and bainitic structure were observed. In opposition to that, austempering process at 350°C for 3 hours holding times gives maximum obtainable hardness properties which is due to formation of martensitic and bainitic structure due to longer holding time. The densities of alloyed ductile iron and austempered ductile iron however had only slightly variations as compared to conventional ductile iron and austempered ductile iron with approximately 1.94% differences.

*Keywords: Mechanical Properties, Sand Casting, Austempered Ductile Iron, Cast Iron, Niobium*

## **ACKNOWLEDGEMENT**

First and foremost, all the graciousness to Al-mighty Allah, for Him I am here as the completion of this dissertation has been a monumental accomplishment in my academic career. I am thankful for this opportunity to recognize and acknowledge all those that have helped me throughout this process.

I would like to express my sincere gratitude to my advisors, Prof. Madya. Ir. Dr. Ahmed Jaffar and Pn. Bulan Abdullah, for accepting me as their students and for all their helps and guidance all throughout these years. Without their help and support, this work would never been succeeded.

I would also like to acknowledge the Ministry of Science and Technology , Malaysia (MOSTI) for the financial support given to this work through the Project Grant No : 03-01-01-SF0117 and also for the Malaysia National Science Fellowship (NSF) scholarship given to me.

I would like to express my appreciation to my colleagues, fellow students, lecturers and technicians for providing me valuable helps in using all the machines and for sharing their knowledge in the completion of this research. Lastly, millions thanks for my families, friends and love one for supporting me and never lose hope in me. Thanks to all.