ABSTRACT

Austempered ductile iron (ADI) is an emerging engineering material belonging to the cast iron family. The material has the advantage of possessing excellent combination of strength, toughness and wear resistance. Due to its very good mechanical and tribological properties along with low manufacturing cost, ADI is replacing many steel forgings and castings.

The mechanical and tribological properties of ADI are dependent on the matrix microstructure which consists of bainitic plates interspersed with patches of retained austenite. It is known that microstructural changes in ADI have an impact on the mechanical and tribological properties. The microstructural changes in ADI can be effected by either adopting special austempering heat treatment process or by alloying additions, or a combination of both. Also, there are specific advantages of superior mechanical and tribological properties when ADI is cast in permanent moulds. Over the years, many researchers have experimented with various novel heat treatment methods to effect changes in the microstructure in order to achieve improved wear resistance and mechanical properties of ADI. Kobayashi successfully developed a special austempering process (QB^{I} process) to develop toughened ADI. The published information indicated that there was an improvement in the toughness and fatigue characteristics of ADI subjected to (QB^{I}) austempering process. Several researchers have reported that alloying elements like nickel and manganese have increased wear, strength and fatigue characteristics of ADI.

Extensive literature survey has indicated that there is no published information regarding systematic attempts to utilize specific

advantages of casting ductile iron in metal moulds and applying special austempering heat treatment process (QB^I process) to produce toughened ADI. This metal has the potential to develop as an alternative wear resistant material and has the capability to replace some steel and aluminum components for wear resistant applications.

Therefore in this research work, it has been proposed to produce permanent moulded toughened austempered ductile iron (PMTADI) by standardizing the heat treatment parameters like holding time in the $(\alpha+\gamma)$ temperature range, austempering temperature and austempering time.

Further, it has been proposed to study systematically the influence of alloying additions such as Nickel and Manganese in suitable proportions on mechanical properties, tribological properties and microstructure of permanent moulded toughened austempered ductile iron. The work is being planned to be carried out in four modules as indicated below.

In the first module, it is planned to develop toughened austempered ductile iron from permanent moulds.

In the second module, it is planned to carryout experiments to evaluate the effects of holding time in the $(\alpha+\gamma)$ temperature range, austempering temperature and austempering time on mechanical properties, tribological properties and microstructure of unalloyed PMTADI samples.

In the third module of the investigation, it is planned to study the effect of alloying elements Nickel and Manganese on the mechanical properties, tribological properties and microstructure of PMTADI samples.

In the fourth module of the study, it is planned to carry out fractographic analysis on the type of fracture of selected unalloyed and alloyed PMTADI samples.

Summarizing the results of the present work, Austempered Ductile Iron castings subjected to special austempering heat treatment have been developed from permanent moulds (PMTADI) using indigenously available charge materials. The microstructural features of PMTADI samples obtained in the present work are in line with the microstructures reported in the literatures on similar category of samples.

There has been influence of holding time in the (α+γ) temperature range, austempering temperature and austempering time on the mechanical properties, tribological properties and microstructure of PMTADI samples.

The optimum holding time in the (α+γ) temperature range was 120 minutes; optimum austempering temperature and time were 350^0C and 90 minutes respectively for superior mechanical and tribological properties. The ultimate tensile strength was in the range of 1170 MPa to 1340 MPa for PMTADI samples under different process parameters. PMTADI samples were found to possess about 8 to 14% increase in mechanical and tribological properties when compared to conventional PMADI samples under similar test conditions.

Alloying additions have resulted in enhancing the mechanical and tribological properties of PMTADI samples. PMTADI samples containing 2.5% Nickel content has shown about 8% increase in UTS compared to 2.0% Nickel PMTADI & 10.0 % increase in UTS compared to Nickel free PMTADI samples. .Additions of 2.5% Nickel content have improved the abrasive, erosive and dry sliding wear resistance of PMTADI samples with comparable strength values.

PMTADI samples with 2.0% manganese content have shown optimum abrasion, erosion and Pin-On-Disc dry sliding wear characteristics compared to other percentages of manganese content used in the current work.

PMTADI samples containing 2.0% Manganese content has about 13% increase in impact toughness and about 10% increase in Brinell hardness over conventional PMADI samples. The microstructural aspects of PMTADI samples for alloyed PMTADI samples have revealed that Nickel and Manganese additions have a pronounced effect on the morphology and fineness of bainite. The fractographic analysis of PMTADI samples has revealed that in tensile testing, the fracture surface of Nickel alloyed samples show predominantly ductile fracture than unalloyed PMTADI samples which have indicated brittle fracture.

Thus the advantages of alloyed PMTADI samples having superior wear and strength are boosted by an increase in the toughness to suit applications in mining, power, agriculture and automotive industries. The present investigation now enhances the scope of application of ADI to be used in wear environments and in the production of automotive and agriculture components.