ABSTRACT

Austempered ductile iron (ADI) is the family of ductile iron with wide range of mechanical properties. This material is known for its higher toughness, wear resistance and the ductility. This ADI will replace the steel forgings with low production cost and aluminium components where higher strength-to-weight ratio is required.

The properties of this material are improved by alloying and also by varying the austempering heat treatment process parameters. The microstructure of ADI contains ausferrite matrix and graphite nodules. The ausferrite matrix gives higher wear resistance due to its strain hardening effect during the wear applications. The wear resistance of this ADI is further improved by introducing carbides because carbides are wear resistance compounds. ADI with carbides are called as carbidic austempered ductile iron (CADI). The production process, characterization and optimization of mechanical properties of CADI are done in this research work.

Chapter 1 deals with the introduction, production process, microstructure, variables governing the properties and applications of ADI and CADI. An extensive literature review has also been carried out on the constitutions of microstructure, mechanical properties and their relationship with the alloying elements and the production process parameters.

In the first phase of the research, ductile iron is formed without alloying, with copper alloying and with copper and molybdenum alloying. Suitable specimens are prepared from the ductile iron castings and subjected to austempering heat treatment. The unalloyed ductile iron does not show the ausferrite matrix after austempering but small improvement in the mechanical properties. Alloy additions form ausferrite matrix during austempering. This alloyed ADI gives higher improvement in the mechanical properties compared to the unalloyed ADI.

- A clear upper ausferrite matrix at higher austempering temperatures and lower ausferrite matrix at lower austempering temperatures are noticed on the microstructure of copper, copper and molybdenum alloyed ADI.
- Maximum hardness of 444 BHN [HBW] and ultimate tensile strength as high as 1781N/mm^2 is noticed at 250°C austempering of copper and molybdenum alloyed samples. This hardness is 200% higher than the as-cast ductile iron of same composition.
- Maximum impact toughness of 109 joules is noticed at 350°C austempering of copper alloyed ductile iron. This is 76% higher compared to the as-cast ductile iron with pearlite matrix.
- Wear resistance of copper, copper and molybdenum alloyed ductile iron austempered at 250°C for two hours is higher when compared to the other heat treatment conditions.

Second phase of the research work discusses about the CADI. The carbide stabilizing element chromium induces carbides during solidification in the ductile iron. As-cast ductile iron with carbides is called as carbidic ductile iron. Addition of 1% chromium induces 28% of carbides. Amount of carbides are varied by different chromium additions. The as-cast carbidic ductile iron is austempered to form the CADI. The austempering process parameters like austempering temperature and time are varied to study the effect of these parameters on the mechanical properties of CADI. An extensive mechanical property analysis, microstructure analysis and SEM analysis of impact fracture and wear surfaces have also been studied.

- The lower ausferrite matrix is formed during lower austempering temperature in all chromium alloyed CADI.
- One percentage chromium CADI formed at 250°C for one hour possesses higher hardness value of 584 BHN and an ultimate tensile strength of 1520 N/mm^2.
- A higher impact toughness value of 74 J is noticed at 0.4% chromium iron austempered at 400°C for four hours. The upper ausferrite matrix and lower carbide content in this CADI give better impact toughness.
- An increase of 151% wear resistance is noticed on the 1.0% chromium specimen austempered at 250°C for one hour compared to the copper and molybdenum alloyed iron austempered at the same conditions.

- Transgranular cleavage type fracture is noticed on the SEM fractography of samples austempered at lower temperatures. Dimple ductile fracture is found at higher austempering temperatures.
- The specimen having dimple ductile fracture mechanism exhibits higher impact toughness.

The optimization of process parameters of CADI using the Taguchi technique and the grey relational analysis (GRA) are done in the third phase of the research work. Calculations of S/N ratio, grey relational grade, analysis of means and ANOVA have been made.

- 1.0% chromium iron austempered at 250ºC austempering temperature and one hour austempering time gives the optimum value of mechanical properties.

An artificial neural network (ANN) model is created by considering the process parameter as input and the mechanical properties as target values. The network is trained and simulated using feed forward back propagation technique with 11 neurons in the hidden layer. Three variants are used in this analysis. The correlation coefficient, mean square error and the coefficient of variance are used to find out the performance algorithm. The proposed NN model with Levenberg–Marquardt algorithm shows better performance.