ABSTRACT

The rising demand in energy economy has contributed to the growth of lightweight materials to lessen the weight of existing materials without compromising on their properties. A large measure of investigation is under way for enhancing the properties of the materials. Austempererd ductile iron (ADI) is the latest development within the region of ductile iron or spheroidal graphite iron. It is a heat treated form of as-cast ductile iron. ADI is produced by 2 stage heat treatment process of austenizing and austempering. The austempering process was developed with the intent of improving the strength and toughness of ferrous alloys. It offers a wide range of mechanical properties superior to those of other forms of cast iron and shows excellent economic competitiveness with steel and aluminum alloys. Heat treatment of SG iron offers a distinctive microstructure of ausferrite, which provides valuable material properties to the ADI. Possibly the foremost important barrier for the engineering society is to beat and understand the potential of ADI, in its successful machining. Machining before heat treatment presents no considerable difficulty, but machining after heat treatment is a complex process. The austenite phase transformation into martensite leads to poor machinability characteristics which may be a common drawback throughout the machining.

This investigation is divided into two parts: (i) the study of microstructure and mechanical properties of ADI and (ii) turning experiments on SG iron and ADI to evaluate cutting force, surface roughness, tool life. The as-cast ductile iron is austenitized at 900 °C for 90 min and followed by austempering over a range of temperatures 340, 360, 380, and 400 °C to obtain distinctive microstructures. Each sample was austempered for the
durations of 60, 90 and 180 min. The influence of these austempering temperatures and times on the microstructure and mechanical properties were investigated at room temperature.

The microstructure examination shows that the austempering heat treatment produces various matrix mixture of bainite and retained austenite depends on austempering temperature and corresponding holding time. The material austempering at higher temperature form upper bainitic structure and austempered at lower temperature forms lower bainitic structure. The mechanical properties decrease as austempering temperature increases. At lower austempering temperature, hardness increases due to the presence of martensite mixed with ausferrite matrix.

The SG iron and ADI were turned at dry condition with two different types of cutting tools, namely TiN coated cBN and coated (TiCN+Al₂O₃+TiN) tungsten carbide tool to evaluate the influence of cutting parameters. The cutting speeds employed in these tests were 102, 174 and 245 m/min with feed rates of 0.051, 0.102 and 0.143 mm/rev and depth of cuts as 0.5, 0.75 and 1 mm.

The nodular irons have more ductility which is required in mechanical components, where they demand a high fatigue resistance like crankshaft, cam shaft, bearing cap and clutch housing. The impact of various process parameters like the depth of cut, cutting speed and feed on the surface roughness, cutting force of SG iron and ADI have been studied and optimized by using the RSM mathematical model. The experimental outcomes of the SG iron reveal that both the tools offer a better surface roughness at the optimal combination of cutting speed at 102 m/min, feed at 0.051 mm/rev and depth of cut at 0.5 mm. Similarly, cutting force was minimized at the cutting parameter combination of lower cutting speed (102 m/min), lower feed (0.051
mm/rev) and lower depth of cut (0.5 mm) when machining with TiN coated cBN tool. For coated tool the lowest cutting force was observed at 174 m/min cutting speed, 0.102 mm/rev feed and 0.75 mm depth of cut. The tool life has been found to be 47 min using TiN coated cBN tool and 52 min for coated tool in turning of SG iron at their optimum levels.

Test results reveal that the cutting speed and feed as the most influencing parameters for both cutting tools while machining SG iron. For TiN coated cBN tool, cutting force increases with increasing cutting speed (102 – 174 m/min) along with feed but further decreases with increase in speed. On the other hand, the cutting force increases with increases in both cutting speed and feed for the coated WC tool. The depth of cut does not have any influential effect on machining SG iron with TiN coated cBN and coated WC tools.

Grade three ADI material was machined on a conventional lathe. The TiN coated cBN tool performed well as compared to coated carbide tool machining with ADI in terms of getting lower cutting force and better surface roughness. The lower the cutting force was obtained at 245 m/min cutting speed, in the range of 0.051-0102 mm/rev feed, and 0.5 mm depth of cut in TiN coated cBN tool, whereas, for a coated tool, it was obtained at 245 m/min cutting speed, 0.051-0.09 mm/rev feed, and 0.5 mm depth of cut. In the view of best surface roughness, the TiN coated cBN tool offers better result at 245 m/min cutting speed, 0.143 mm/rev feed, and 0.5 mm depth of cut, whereas coated carbide tool offers best surface finish at 174 m/min cutting speed, 0.102 mm/rev feed and 0.5 mm depth of cut. The tool life has been found to be 41 min using TiN coated cBN tool and 38 min for coated tool in turning of ADI at their optimum levels.
At the time of machining with increased feed and depth of cut there is a heat treatment effect, occurs at low austempering temperatures, which substantially increases the cutting force due to the transformation of austenite into martensite. Higher austempered temperature leads to reduced cutting force. The increase in cutting speed and decrease in both depth of cut and feed result in a better surface roughness. The depth of cut does not show any perceptible difference in affecting the surface roughness.