ABSTRACT

Inconel 718 is well known due to its wider application in aerospace, defense and petrochemical sectors. However, machining of Inconel 718 is very difficult due to its high strength at elevated temperature, poor thermal properties, presence of hard carbides in its microstructure, work hardening behavior and high chemical affinity with most of the tool materials. Hence, the aim of this research is to investigate the machinability of Inconel 718 under high pressure jet (HPJ), cryogenic, minimum quantity lubrication (MQL) and nano minimum quantity lubrication (nMQL) environments and compare the same with machining under dry environment.

Indigenous setups for HPJA, MQL, nMQL and cryogenic machining have been developed to provide different cutting environments. For HPJA, preliminary experiments have been conducted for selection of appropriate jet pressure. Droplets and spray pattern analysis have been conducted to select the flow rate, and air pressure for MQL environment.

Spreadability studies of nanofluids added with different surfactants have been performed to select the suitable fluid for nMQL machining environment. Anionic, cationic, non-ionic and polymeric surfactants are used to prepare the different nanofluids. The relation between tool surface and cutting fluids have been evaluated by calculating the spreading coefficient.

Further the machining experiments were conducted using these fluids.

Comparative study has been conducted to find out the suitable environment for machining of Inconel 718. A wide range of machining speed, feed and rake angles are chosen based on TiAlN coated tool and work material combination for machining of Inconel 718. The effect of HPJ, MQL, nMQL and cryogenic machining mode on cutting force, tool wear, and surface integrity have been studied. The results show that the cryogenic and nMQL machining
environments significantly lowered the cutting forces, the tool wear and the surface roughness. Minimum adhesion of built up edge (BUE) residues and chip fragments on the machined surface are found when cryogen was used as a cutting fluid. The deeper compressive residual stress zone under the machined surface has also been observed while machining under cryogenic condition. From the comparative study it has been concluded that cryogenic machining environment is a promising solution for improvement in machinability of Inconel 718.

A force model has been developed for predicting forces under MQL machining mode. The modeling approach is based on Oxley’s machining theory. Oxley’s machining theory is modified to capture the lubrication effect at the chip-tool contact zone. A dual contact zone model is used to formulate the variation of frictional force at chip-tool contact zone. An indigenous tribometer has been developed and used for evaluation of sliding contact friction at the chip-tool contact zone. A mechanistic model has been formulated for evaluating the sliding contact friction and the same has been used in the force prediction model. Finally, the predicted cutting forces have been validated with the experimental results. The proposed model predicted the cutting forces with reasonable accuracy. The average estimation errors of predicting the main cutting force and thrust force are 6.53% and 8.3% respectively.

**Keywords:** Inconel 718; HPJ; nMQL; Cryogenic; Surface integrity; Dual contact zone; Tribometer