ABSTRACT

Superalloys play an important role in the turbine components of aircraft, oil and gas turbines, nuclear turbines, submarine engines, chemical and other manufacturing industries where high temperature is desirable. These alloys are nickel, iron-nickel, and cobalt based. They possess excellent mechanical properties which include high strength, hot hardness, creep resistance, and oxidation resistance. These properties make these alloys use at places where higher temperatures are needed. Good mechanical properties make these alloys difficult for machining. The low thermal conductivity accumulates the entire heat at the machining zone which makes the cutting tool blunt and increases friction and generates high temperatures. These difficulties led to increased tool wear due to abrasion, adhesion, and coating failure. To overcome such problems, researchers and industrialists are continuously working on the type of lubrication provided at the cutting zone as well as the coating of the cutting tool.

The current research is focused on the type of lubrication to be used in the machining zone which includes five different machining environments: dry, compressed air, nanofluid assisted minimum quantity lubrication (alumina, hBN, and hybrid). The nanofluids are prepared by a two-step method of preparation and the hybrid nanofluid is prepared by mixing the two nanofluid in a magnetic stirrer. The nanofluid's base material consists of ethylene glycol in deionized water (1:20). The prepared nanofluids are characterized by visual observation clubbed with UV-Visible absorption, cell toxicity analysis, zeta potential, dynamic light scattering, friction analysis, thermal conductivity, and contact angle measurements. The shelf life of the prepared nanofluids are thoroughly studied and it was found that the hybrid nanofluid is more stable in nature.

The second part of the work contains the fabrication of titanium nitride and aluminium titanium nitride coating with a hybrid physical vapour deposition process which utilises cathodic arc evaporation and magnetron sputtering processes. Nitrogen is allowed to enter the high vacuum chamber where coating is to be done so that it reacts with the pure titanium in the cathodic arc evaporation and Al/Ti target in the magnetron sputtering process. The fabricated coatings are deposited on polished tungsten carbide flats which are then characterized by evaluating the adhesion strength of the deposition with varying current, biasing, and nitrogen gas flow rate. The fabricated material is confirmed by X-ray diffraction analysis, Raman spectroscopy, and EDAX analysis.

The third part of the research utilises a hybrid Taguchi-Grey-PCA algorithm to optimize the input process parameters (cutting speed, feed, axial and radial depth of cut) in the end milling of Nimonic 90. The optimised process parameters are then utilised for the comparison of the commercially available AlTiN coated inserts with the indigenously prepared AlTiN/TiN coated inserts under the hybrid nano-MQL environment. The coatings are prepared by multistage deposition in which the deposition of titanium nitride is done by cathodic arc evaporation and deposition of AlTiN is done by radiofrequency magnetron sputtering.

It can be concluded that the hybrid nanofluid prepared by mixing two mono nanofluids by magnetic stirrer is highly stable and provides ball bearing, polishing, and thin film formation effects between the workpiece and the cutting tool and between the cutting tool and chips. There is subsequent reduction in cutting forces, surface roughness, tool wear, and cutting temperature when hybrid nanofluid assisted machining is compared by dry, compressed air, and mono nanofluids assisted MQL machining. Further, the hybrid Taguchi-Grey-PCA algorithm provided better results, exhibited its robustness and accuracy while optimizing machining parameters. The Taguchi S/N ratio for the case of tool coating had given promising results and the coated tool deposited by hybrid PVD process outperformed when compared to tools coated by cathodic arc evaporation.

Keywords: Machining, Nimonic 90, Physical Vapour Deposition, Hybrid Nanofluid, Hybrid Taguchi-Grey-PCA.