

## **Abstract**

Machining of the nickel based superalloys requires cutting tools that can withstand dynamic stresses as well as high cutting temperatures. Various cutting tool materials have been developed in the past with the aim of fulfilling these requirements, but the high cost associated with them does not make them a viable option for industrial and research purposes. Coated cutting tools provide an alternative to these kinds of tools as they serve the intended application. The coatings over these tools are deposited using conventional techniques such as magnetron sputtering and cathodic arc evaporation. But the limitations associated with these processes in terms of low ionization rates, poor adhesion, and surface defects warrant for a better alternative. Therefore, with an aim to improve the machining performance of difficult to cut materials, the present study focuses on the development of surface engineered tools utilizing advanced coating deposition and surface modification techniques. The application of these tools can make the machining processes more economical and eco-friendlier.

The surface and sub-surface of the tools were modified utilizing micro abrasive blasting at various blasting pressures before and after the coating deposition. The blasting pressures were selected in such a way that both detrimental as well as benign effect can be observed. The coatings on the cutting tools were deposited using arc enhanced high power impulse magnetron sputtering (arc enhanced HIPIMS) technique. This technique is basically a combination of conventional magnetron sputtering and cathodic arc evaporation process. The substrate modified coated tools, as deposited coated tools and post treated coated tools were later analyzed using various evaluation techniques for physical and mechanical characteristics. During the analysis, it was observed that high pressure substrate blasting helped in better adhesion characteristics as well as refined grain structure while low pressure micro blasting on coated tools helped in improving the coating hardness. The micro blasting process also causes change in the stress state, crystallinity and surface energy of the samples.

The efficacy of the modified as well as untreated tools were judged during dry machining of Nimonic C 263 under aggressive process parameters. During the analysis, it has been found that coated tools are useful for limited runs, however, for prolonged machining these tools undergo severe wear and chipping. The utilization of the micro blasting pre treatment and post treatment has significantly improved the performance of the coated cutting tools. The analysis revealed the better performance of pre treated tools at high blasting pressure, while the post treated tools exhibited improved performance at low blasting pressure.

In the later part of the study, surface engineered tools were developed by carrying out micro blasting pre and post treatment at optimized pressures. The developed tools were characterized for changes in morphology, adhesion, and hardness. The performance of these tools was studied under dry and Cryo-MQL environment and was compared with the as deposited tools (coated tools without any treatment). The utilized Cryo-MQL setup was indigenously developed in the laboratory, in which MQL and cryogenic liquid are supplied at rake and flank surface simultaneously. During machining under dry environment, it was found that surface engineered tools helped in reducing the wear and cutting forces by a significant amount compared to as deposited tools. The utilization of the Cryo-MQL technique further reduces this wear value.

In the last section of the study, a pseudo analytical model for flank wear progression was developed. In this model, for the first time an attempt has been made to incorporate the work material properties as well as the tool conditions after micro abrasive blasting for the tool wear prediction. The developed model was validated with the experimental results during the machining of Nimonic C 263 using AlTiN coated tools. During the analysis, it has been found that the experimental results are very much in agreement with predicted values of the flank wear, and the flank wear progression also followed the similar pattern as that of the latter.

**Keywords:** *Nimonic C 263, Micro abrasive blasting, Machining, Cryo-MQL, Modelling.*