INVESTIGATIONS ON HIGH-SPEED DRILLING OF Ti-6Al-4V ALLOY

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ABSTRACT

The fascinating properties of titanium alloy makes it fit for large extent of applications in different fields of manufacturing industries. Its extraordinary properties such as high specific strength, exceptional corrosion resistance and its capability to withstand the strength at elevated temperatures make it as the excellent material for aerospace application. It also has its application on biomedical fields and commercial industry usage. Owing to the higher strength and reduced thermal conductivity, machining of this material was extremely tough as it generates large cutting forces and higher tool temperatures resulting in shorter tool life. As current industrial scenario demands increased productivity, there is a desperate need for improving the machinability of these alloys. Hence this work aims in developing certain approaches for uplifting the machinability of these alloys particularly in drilling, which contributes for 30-40% of the entire process done on these materials.

Drilling plays an essential role in aerospace components manufacturing. In particular, Grade 5 Titanium alloy is used for most of the applications. From the literature survey, it is found that most of the attempts on improving the machinability of Ti alloys was done on low and medium cutting conditions, and hence this study starts with selection of process parameters belonging to higher levels to improve the machinability. The selected machining parameters are Cutting Speed (Vc), Feed (f) and Depth of Cut (DOC). Three different levels of cutting speed and feed with constant depth of cut were considered for the experimentation.

The tool selected was solid carbide drill tool with a point angle of 118º. Plain through holes are drilled in Ti-6Al-4V alloy plate with the thickness of 9mm. Taguchi L16 Orthogonal array was designed for proceeding with the experiments by using various coolants and texturing patterns on drills. In case of coolants, Dry, MQL, Wet and Cryogenic coolants are used to perform the drilling, whereas for texturing, plain twist drills and textured tools are taken for the investigation. Also, the combined effect of textured and non-textured tool with Dry, MQL and Wet coolants was also investigated.

In the first phase, high-speed drilling on Ti-6Al-4V alloy was attempted under dry, MQL and wet coolant for the selected cutting parameters using plain standard twist drills. Output parameters such as torque, thrust force and temperature during drilling were recorded and hole quality determinants such as circularity, cylindricity and surface roughness were measured. Results indicate that usage of MQL is not suitable for high-speed drilling than dry drilling as it generates higher cutting forces and poor-quality holes. Better quality of holes was obtained in dry than MQL cutting although it is not advantageous as wet drilling. Wet drilling behaves better than dry and MQL drilling in all the aspects and it proves to be the suitable technique for high-speed drilling.

To investigate the suitability of cryogenic coolant for high-speed drilling, experimental investigation using plain tool using Liquid Nitrogen (LN2) coolant was performed and compared with dry cutting. Reductions in torque, thrust force and temperature was obtained for cryogenic coolant when compared with dry cutting. In case of hole quality for LN2 condition, better reduction in circularity error, cylindricity error and surface roughness was detected. Also, the energy required to drill the hole was calculated which indicates the cryogenic coolant as effective option for higher cutting conditions.

In the next phase, a combined coolant and textured machining process was developed and experiments were conducted. Texturing was done on flute and margin of the drill bit using laser machining. High speed drilling was executed using the textured tool

for dry, MQL and wet cutting conditions. Experimental results exhibited that there was not much difference between non-textured dry and textured dry cutting. Results indicates the better performance of wet textured drilling than dry and MQL drilling for the generated machining forces and hole quality.

In the last phase of research work, optimum parameter for different coolant conditions under textured and non-textured drilling was obtained using Grey relational analysis. Drilling was done at optimum parameters for every single cutting condition and life of the tool for these conditions were identified. Microstructural analysis of workpiece and chip morphological analysis were also done to investigate on the behaviour at higher cutting speeds.