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Multi-process parameter optimization in face milling of Ti6Al4V alloy using response surface methodology

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Abstract

Titanium alloy, Ti6Al4V, is an exceptional material with several desirable properties, namely, high specific strength, high corrosion and heat resistance, which make it a promising contender in number of demanding applications. However, it has poor machinability, resulting from low thermal conductivity, high chemical reactivity with tool and spring effect during cutting. These properties lead to reduced tool life during machining, due to which its usage is limited despite excellent mechanical properties. Therefore, optimization of process parameters using response surface methodology in face milling of Ti6Al4V alloy with uncoated carbide tools has been investigated experimentally in this work. This article is focused on developing mathematical relation between input factors and response parameters, namely, surface roughness (R_a), tool wear (T_w) and tool vibration (T_v). The machining parameters are optimized for minimum R_a, T_w and T_v values. The optimal parameters are validated experimentally which showed a good agreement with the predicted results. The feed rate was found to be the most influential parameter affecting R_a and T_v, whereas cutting speed is the most effective in influencing T_w.

Keywords

Surface roughness, tool wear, tool vibration, face milling, central composite design

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Introduction

Ti6Al4V is the most widely used titanium alloy due to its versatility in properties including high specific strength, exceptional corrosion resistance, biocompatibility and ability to retain its mechanical properties at elevated temperatures which make them suitable for aerospace, automobile and biomedical industries.[1] All these applications demand high-dimensional tolerances which generate the need for one or the other machining operation in processing this alloy. However, the poor machinability of this alloy, arising from low thermal conductivity, high hot hardness, high chemical reactivity with cutting tool and low elastic modulus, is a hindrance in its economical usage as conventional material. Rebeiro et al.[2] presented the chemical reactivity of Ti6Al4V alloy with tool material and conducted dry turning operations and found the machining results to be satisfactory at low cutting speeds. Sun et al.[3] carried out experiments to represent tool wear evolution and growth in dry machining of Ti6Al4V alloy. Furthermore, Boyer[4] mentioned the limited use of Ti6Al4V in specific fields like aerospace applications due to high cost of manufacturing compared to steel and aluminum, and suggested economic measures to reduce this cost. These factors lead to reduced tool life in Ti6Al4V alloy machining, demanding specialized machining practices, thus increasing its processing cost. A number of measures have been adopted by researchers to increase the tool life in Ti6Al4V alloy machining which includes utilization of superior tooling, coated tools, non-conventional machining and use of variable coolant systems including cryogenic cooling. Bermingham et al.[5] suggested the use of cryogenic cooling for improved tool life in high cutting heat generating materials like Ti6Al4V. These techniques have proved to be effective in tool life enhancement, but

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