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Tool Wear and Temperatures Analysis While Machining Ti-6Al-4V in MQCL-MIST Environment

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ABSTRACT

Sustainable machining of titanium alloys have deficiency of studies on the built-up edges over the cutting tools and temperature correlation in minimum quantity cooling lubrication (MQCL) environment. Researchers focused on experimentation in dry, wet, and MQL (minimum quantity lubrication) conditions to analyze surface finish, cutting forces, and metal removal rates. This work focuses on the study of cutting parameters effects on temperatures and tool wear analysis by consideration of individual response and their optimality basing on signal-to-noise ratios. Efficacy of process parameters on wear of tool and temperatures requires a comprehensive understanding. An elaborated tool wear analysis is carried based on the microscopic flank wear investigations. Machining of Ti-6Al-4V alloy is carried in the environment of MQCL in form of mist using semi-synthetic fluid. Correlation study of tool wear with regard to temperatures is analyzed and regression models generated on tool wear and cutting temperatures individually showed 83% of goodness-of-fit and correlation regression is 85%.

KEYWORDS

Low Machinability, Mist, MQCL, Sustainability, Temperature, Ti-6Al-4V, Tool Wear

1. INTRODUCTION

Metal cutting industries deprive of the cutting tool wear and tear studies for better production efficiencies and optimum costs. Titanium alloys are of low mass with respect to strength and offer high resistance at high temperatures which makes their suitability to aeronautical applications. But they have a limitation of low machinability affecting the cutting tools wear and thereby encompass the application of cutting fluids to reduce the temperatures while machining process and tool-wear

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leading to an overall increase of machining cost. More over the α-β alloy (Ti-6Al-4V) is most widely used alloy aggregates up to 60 percent of the total titanium produce. Of late sustainable manufacturing is gaining importance and manufacturing sectors are adopting at all levels - systems, process and design. (David Zelinka & Bernard Amadei, 2019) in their study tabulated seventeen 'sustainable development goals, (SDG)', targets and effect of their interactions on goals and targets with system dynamic modelling. Of the SDG's listed for manufacturing process health, environment, education, energy and economy are key indicators towards sustainabile production. At process level machining –removal of material is the major manufacturing process (Jayal, Dillon & Jawahir, 2010), heat energy is produced owing to friction and plastic deformation of work-piece material. (Rahman, Sun, Wang & Dargusch, 2012) in their work on titanium alloys machining reported the temperature in cutting zone vicinity was as high as 800^0c during machining of β-titanium alloy Ti-6Cr-5Mo-5V-4Al. It is imperative to use lubricants in huge quantity to keep the work-piece and cutting tool interaction zone cool. Contrary, such high volume lubricant application results in unsustainable practices such as cost parameter escalation, pollution, machining workmen safety are issues. The use of lubrication in machining has been a threat to environment due to hazardous nature of the lubricant and also the chemical fumes they emanate at elevated temperatures. The main intended functions of lubricants are to reduce heat by carrying it away - coolant, reduce friction –act like a film and flush chips. During high speed machining the other difficulty noticed is lubricant action as film to friction reduction is very poor resulting under performance. Therefore research focus shifted to mechanisms that reduce the lubrication volume as stated by (Dahmus & Gutowski, 2004) or use of eco friendly lubricants without compromise on quality or costs. Hence a lot of researchers have focused on eco friendly lubricants, nano lubricants, usage of bio oils. Avant-garde techniques developed for application during machining to either reduce cutting-fluids or eliminate them such as dry machining (absence of cutting-fluids), minimum quantity lubrication (MQL), Mist(application of pressure to supply fluid to cutting zone in form of aerosols), use of solids as lubricants, cryogenic cooling and application of nano lubricants. Dry environment though economical and eco friendly poses difficulties while machining of super alloys, hard alloys with poor conductivity resulting in overheating, adherence of chip to tool face, residual stresses and many time necessitates the use of costly coated tungsten carbide cermets, poly-crystalline-diamond 'PCD', and polycrystalline cubic-boron-nitride 'PCBN' (Singh, Dureja, Dogra & Bhatti,2016). MQL is considered a "green manufacturing" technique as it offers lower pollution, and ensure safety at work place. All these techniques though offer reduced use of fluids have economical and other effects implications on tool life based on the work piece and tool selection combination. Each of the technique has its merits and demerits based on tool, work-piece combination and machining process adopted in addition to process parameters.

The aspect of enhancement of the cutting tool life and reduction of wear attracts researchers to work with titanium making these materials of fastest growing materials applications. Sustainable machining of hard and low-machinability materials like Titanium alloys, have deficiency of studies on the cutting tools wear mechanisms and temperature correlation in Minimum Quantity Cooling lubrication (MQCL) environment. Researchers till date, focused more on experimentation in varying environments dry, wet (flood), and MQL (Minimum quantity Lubrication) conditions to analyze surface finish, cutting forces and metal removal rates. In many studies one of the parameter is kept constant varying other two. Except for few researchers the temperatures are not considered during turning of Ti4Al6V alloy. Therefore this paper focus on, study of cutting parameters and their significance varying all parameters simultaneously at four levels on cutting temperatures (tool and work-piece) and tool wear analysis by consideration of individual response and their optimality basing on Signal-to-noise ratios. An elaborated tool wear analysis is carried based on the microscopic flank wear investigations. Machining is carried on Ti-6Al-4V titanium alloy in the environment of minimum quantity cooling and lubrication in form of mist with pre-designed experiments like Taguchi design of experiments. Correlation study of tool wear with regard to temperatures is analyzed for each and every experimental run.