The Flank Wear Optimisation of 316 Stainless Steel using Response Surface Method in Dry-Down Milling using Carbide Insert

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Abstract: 316 stainless steel is widely known as difficult to machine material and as a result of the excellent mechanical properties that it possesses, the tendency of tool breakage is very high. Thus, it becomes a major concern in machining field industry. Therefore, the study on the optimisation of the cutting parameters during machining 316 stainless steel is crucial. This study has been conducted on 316 stainless steel in dry down-milling with the use of carbide inserts. In identifying the dominant cutting parameters that affect flank wear and the optimum cutting parameters to optimise the flank wear, response surface (RSM) method was used. From the observation, it was found that the factor that was most influential was the feed rate, and subsequently followed by cutting speed and depth of cut. The combination of 0.2 mm/tooth feed rate, 100m/min cutting speed, and of 0.8mm depth of cut made optimum milling parameters.

1. Introduction

316 stainless has been used widely in manufacturing industry because of its great hardness in mechanical properties, possession of good heat and corrosion resistance, along with its excellence in toughness. The application of this material involves medical implant, marine industries and food preparation sector. However, with the outstanding mechanical characteristic, this material is then considered as difficult-to-machine material which is explained by its high level of strength, the tendency of work hardening along with its low thermal conductivity that occur while machining as asserted by Uysal et al.,2015. Furthermore, there is also a propensity of built-up-edge (BUE), flank wear and crater wear formation by this material.

Milling operation is common in machining 316 stainless. The use of down-milling in which the feed has the same direction with the rotation minimises the tendency of tool wear to occur [2]. Based on Hadi et. Al., 2003 [3], to perform a down-milling or also called as climb milling, the workpiece is cut beginning from the top of the depth of cut (*DoC*) and then stays to the bottom. Thus, thick chips are formed as a result of the high force while being in contact in which they are thinner progressively at the feed end. This prevents the rubbing off between the edge of tool and workpiece surface that has been machined before their engagement in the cutting pass. Hence, tool deterioration is reduced.

Based on the ISO Standard 8688 [4] of tool wear and tool life testing during milling, the definition of tool deterioration refers to the occurrence of all changes in terms of mechanical at the area of cutting of the cutting tool following the process of cutting. There are two further classifications of tool deterioration; (a) tool wear; the loss of cutting tool material that happens gradually and (b) chipping; brittle fracture that happens at the edge of tool. It has been found that flank wear; the wear that occurs on the tool flank face while cutting is in progress, leading to the form of a flank wear progressively is the wear mechanism that has most influence on most of the tool life.

Following the ISO 8688 tool life testing in milling, a number of two criteria are recommended in lengthening the tool life which are:

(a) Uniform flank wear; V_B = 0.3mm

(b) Maximum flank wear, V_{Bmax} = 0.5 mm.

Hence, it is considered as breakage for the tool provided that it belongs to the category under one of those ISO-8688 criteria.

Based on Senthil et. Al., 2006 [5], flank wear happens due to the rubbing of cutting tool and workpiece in contact which contributes to high temperature. This high excessive heat could be a harmful factor to the tool insert's mechanical properties, leading to deterioration of the tool. A sudden temperature change in machining is a necessary consideration, since it can affect the tool life, surface integrity and dimensional accuracy with regard to the workpiece machined as stated by Karaguzel & Budak, 2018 [6].

Besides, Iqbal et al. 2016 [7] highlighted that longer operating time of a cutting tool contributes to rougher workpiece machined. A study on carbide tool wear during micro milling UNS S32205 duplex stainless steel was as well conducted by Dos Santos et al., 2018 [8]. Cutting speed was discovered as the factor that is most influential in determining tool wear. Increased cutting speed leads to the increase in temperature tool-workpiece-chip region, resulting in the reduction of tool materials in terms of its strength and causing plastic deformation to occur. Thus, the deformation and the wear that belong to the cutting tip become critical. Çalışkan and Küçükköse, 2015[9] said that BUE is the dominant tool failures where BUE is one of the forms of adhesion locating on the tool cutting edge. However, Dos Santos et al., 2018 [8] found that presents of BUE provides a protection on the tool edge and prolong the tool life.