INVESTIGATION OF THE CAUSES OF CHATTER IN MACHINE TOOLS AND DEVELOPMENT OF A NEW CHATTER MODEL

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Abstract: Chatter is an unwanted but sometimes unavoidable phenomenon in machining due to its adverse effects on the product quality, machining accuracy, cutting tool and machine tool life and consequently operation cost. This research work mainly focuses on investigation of the causes of chatter and development of a chatter model that would be helpful in removing major obstacles towards higher machining quality and productivity. Preliminary experiments on thread cutting and turning on a nascent and non wavy surface in the work were conducted to verify the existing regenerative chatter theory. It has been concluded from the preliminary experiments that the waviness of the previous pass is not the primary cause of chatter during metal cutting, which is the main proposition of the regenerative chatter theory. However, the positive role of chip formation instabilities during machining and the role of prominent mode frequencies of the system components in the formation of chatter have been confirmed. Further experiments were conducted on titanium alloy (Ti6Al4V), stainless steel (SS304) and medium carbon steel (AISI 45) to investigate the effect of chip formation instabilities on chatter formation in end milling operation using TiN coated WC-Co insert. It has been concluded from these experiments that the chip formation process has a discrete nature associated with the periodic shearing process of the chip, which is a typical instability of periodic nature, in the form of serrated teeth. Primary saw or serrated teeth which are formed in the entire cross-section of the chip are prominent in titanium alloy (Ti6Al4V) and stainless steel (SS304) whereas secondary serrated teeth appears at the free edge of chip in the case of carbon steels (AISI45). Frequency of the chip formation instabilities (chip serration frequency) associated with this primary and secondary serration have been determined for various combinations of cutting parameters for the investigated materials and the mechanism of formation of these serrated teeth has also been studied. Chip serration model for different work materials have also been developed using response surface methodology. These models were then optimized using fuzzy logic and artificial neural network techniques. The different mode frequencies of the vibrating components of the machine tools have been determined using experiment modal analysis and finite element modal analysis, since it is assumed that chatter is formed due to interaction between the chip serration instabilities and the prominent mode frequencies (natural frequency) of the system components. The vibration responses during actual cutting have also been recorded using an online vibration monitoring system. The vibration signals in frequency domain (FFT) have been analyzed to identify the chatter frequencies, which then have been compared with the chip serration frequencies in a wide cutting speed range for different conditions of cutting for three different work materials. It has been found from the findings of these experiments that chatter is the outcome of resonance, which occurs in the system when the frequency of primary or secondary serrated teeth formation is approximately equal to or integer multiple(s) of the 'prominent natural frequency' of the system components.

Based on the experimental findings, a new chatter model has been developed using classical analysis for the prediction of the cutting speed ranges at which chatter could be expected during end milling of the given work materials. Instability of the closed loop system comprising the machine tool fixture work and the chip formation process has been taken into consideration in developing the above model. The model has been validated by confirmation tests and the predicted and experimentally values were found to be in good agreement.