Machinability optimization of dry CNC turning of UNIMAX® tool steel in annealed and hardened states by implementing swarm intelligence algorithms

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Abstract: In this research work, the machinability of a special tool steel (UNIMAX® by Uddeholm, Sweden) under dry CNC turning is investigated. The working material was investigated under two states; annealed and hardened. As major machinability indicators, main cutting force Fz (N) and mean surface roughness Ra (μm) were selected and examined under different values for the cutting conditions; cutting speed, feed rate, and depth of cut. A systematic design of experiments was established as per the Response Surface Methodology (RSM). The experimental design involved twenty base runs with eight cube points, four center points in the cube, six axial points and two center points in axial direction. Statistical analysis to examine the effect of cutting conditions on the responses of main cut-ting force and surface roughness included analysis of variance (ANOVA) and contour plots under the scope of studying the interaction effects among process parameters and generating a full quadratic model for predicting the two responses. To assess the significance of models in predicting the responses of main cutting force and surface roughness standard statistical indices were examined such as F and P values, whilst Anderson–Darling normality test was conducted to verify the suitability of the models corresponding to the main cutting force and surface roughness, for practical applications. The two regression models served as the fitness functions and were iteratively evaluated by three swarm-based intelligent algorithms namely Grey-wolf optimization algorithm, Multiverse optimization algorithm and Ant-lion optimization algorithm, for optimizing main cutting force and surface roughness. The results obtained have shown that all algorithms were capable of producing robust Pare-to fronts of non-dominated optimal solutions, yet with some differences in their quality from the perspective of coverage of the solution domain.

Keywords UNIMAX® tool steel, dry CNC turning, main cutting force, mean surface roughness, optimization