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ORIGINAL PAPER

Multi-objective optimization of cutting parameters and helix angle for temperature rise and surface roughness using response surface methodology and desirability approach for Al 7075

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Abstract

The heat generated during metal cutting processes like end milling results in to higher temperatures which affects the quality of the surface produced. So, in order to get better surface quality, it is important to reduce the cutting zone temperatures. In the materials having high thermal conductivity the internal temperature rise of the workpiece also needs to be controlled. In this work, the study of the effects of controllable process parameters of CNC end milling on workpiece surface temperature rise, workpiece internal temperature rise and surface roughness during machining of aluminium alloy (Al 7075) was undertaken. The input parameters were spindle speed, feed rate, axial depth of cut, radial depth of cut and tool helix angle. The inclusion of helix angle as an input factor and, simultaneous reduction of workpiece surface temperature rise and workpiece internal temperature rise without compromising on the quality of the product were the major highlights of this work. This work also evaluates the trade-offs between heat generation and cutting quality. The central composite rotatable design was used for planning of the experiments and to develop predictive models. The direct and the interaction effects of the input parameters were studied and discussed. The optimization of process parameters was carried out by desirability analysis. The individual and composite desirability values were unity, which highlights, the successful implementation of the adopted methodology for achieving the desired goals. The optimum values of input parameters were: spindle speed: 4407 rpm, feed: 493 mm/min, axial depth of cut: 0.51 mm, radial depth of cut: 6.46 mm and helix angle: 30°. The results of the optimization were confirmed through the confirmation experiments with reasonable accuracy.

Keywords End milling · Workpiece surface temperature rise · Workpiece internal temperature rise · Predictive modelling · Response surface methodology · Desirability approach

1 Introduction

During the commonly used metal removal machining processes like, turning and milling, hefty amount of energy gets consumed, which is gets converted into heat [1, 2]. The heat gets generated mainly because of plastic deformation of metal along the shearing plane (primary deformation zone). Heat also gets generated at line between tool and workpiece due to friction (secondary deformation zone) and also because of the flank friction (tertiary zone) [3]. In case of high speed process like end milling, due to higher cutting speeds, the heat generated is also more, which results in to increase in the cutting temperatures which normally results in to reduction in the quality of the surface produced. The modern industries are always trying to attain higher rate of productions with improved surface quality with minimum production costs by satisfying the stringent environmental

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