Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 61 (2017) 517 – 522

www.elsevier.com/locate/procedia

The 24th CIRP Conference on Life Cycle Engineering

Optimization of Machining Parameters for Improving Energy Efficiency using Integrated Response Surface Methodology and Genetic Algorithm Approach

Kuldip Singh Sangwan[a]*, Girish Kant[a]

[a]*Department of Mechanical Engineering, Birla Institute of Technology and Science, Pilani 333031, India*
* Corresponding author. Tel.: +911596515205; fax: +91-1596-242-183. *E-mail address:* kss@pilani.bits-pilani.ac.in

Abstract

Machine tools consume enormous amount of energy during machining, build-up to machining, post machining and idling condition to drive motors and auxiliary equipments in the manufacturing system. Reduction of energy consumption during the machining phase is extremely important to improve the environmental performance over the entire life cycle. This paper presents a predictive and optimization model based on integrated response surface methodology and genetic algorithm approach to predict the energy consumption and the corresponding machining parameters during the turning of AISI 1045 steel with a tungsten carbide tool. Experiments using Taguchi design are performed to develop the predictive model. The developed predictive model is used to formulate the objective function for genetic algorithm. The confirmation experiments are performed to validate the developed model and the results are found within 4% error. The statistical significance of the developed model has been tested by the analysis of variance test. This research will be beneficial for a number of manufacturing industries for selection of machine tools on the basis of energy consumption. The reduction of peak load through optimization will results in lowering the energy consumption of the machine tools during non-cutting time.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering

*Keywords:*Optimization; Sustainability; Response Surface Methodology; Energy Efficiency; Machining; Genetic Algorithms

1. Introduction

Optimizing the energy efficiency of processes has become a priority in the manufacturing sector; driven by soaring energy costs and the environmental impact caused by high energy consumption levels [1]. More than 99% of the environmental impacts are due to the consumption of electrical energy used by the machine tools in discrete part machining processes like turning and milling [2]. The cost of energy used over a ten-year period is about 100 times higher than the initial purchase cost of the machine tools used to manufacture products, and therefore, if energy consumption is reduced, the operating cost and the environment impact generated from energy production are diminished [3]. With the implementation of sustainability principles in machining technologies, end-users have the potential to save money and improve their environmental performance even if their production stays in the same range or decreases [4]. In machining processes, money saving and sustainability performance can be improved by reducing energy consumption [3]. Lot of research has been done on machining processes but energy consumption aspect of machine tools has not given significant attention. In the past, metal cutting operations have been mainly optimized on the basis of economical and technological considerations without the environmental dimension [5]. Reduction in energy consumption will improve the environmental impact of machine tools and manufacturing processes. The optimization of machining parameters for minimum energy requirement is expected to lead not only to the application of lower rated motors, drives and auxiliary equipment, but also energy saving during machining, build-up to machining, post machining and idling condition [6]. The first step towards reducing the energy consumption in machining is to analyze the impact of machining parameters on energy consumption. Recently, the researchers have started to analyze and optimize the energy

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.11.162

consumption in machining [7-9]. The literature review reveals that researchers have focused on various predictive modelling and optimization techniques to determine optimal or near-optimal machining parameters [10-13].

This work aims at developing a predictive and optimization model to obtain minimum power consumption (*P*) as a function of machining parameters; cutting speed (*v*), feed rate (*f*) and depth of cut (*d*) using Response Surface Methodology (RSM) and Genetic Algorithm (GA). The work makes an important contribution to the machining science by reducing the power consumption through optimal selection of machining parameters and resulting in minimizing harmful emissions. This research will be beneficial for a number of manufacturing industries for selection of machine tools on the basis of power consumption. It can be further extended during process planning for various advanced materials, cutting conditions and cutting tools.

2. Research Methodology

Fig. 1 shows the research methodology used for the study. The research methodology can be broadly classified into four phases – experimental planning; predictive modeling by using RSM; optimization using GA; and confirmation experimental studies.

In the first phase machine tool, cutting tool, workpiece material, machining parameters (cutting speed, feed rate and depth of cut) and their levels and corresponding response variable (power consumption) were selected to develop the experimental plan for the study. Taguchi's L27 orthogonal array was used to design the experiments. Next, machining experiments were conducted for the 27 combinations to get the power consumption values. In the next phase, RSM was used to develop the second order polynomial response surface mathematical model for the prediction of the power consumption. This predictive model provides the relationship between machining parameters and power consumption using regression analysis. The statistical significance of the developed model was analyzed using Analysis of Variance (ANOVA). The adequacy of developed model was checked using normal probability plot and residual plot. The parametric influence of machining parameters on power consumption was analyzed using main effect and 3D surface plot. In the last phase, GA was used to find the optimum values of the machining parameters for minimization of power consumption. Next, experimental tests were conducted at the optimum values of the machining parameters predicted by integrated RSM and GA approach to confirm the results.

3. Experimental work

A centre lathe having a maximum spindle speed of 2300 rpm and a spindle power of 5.5 kW was utilized to perform experiments in dry conditions. The TNMG 16 04 04 tungsten carbide inserts from Sandvik were mounted on the tool holder PTGNR 2020 K16 having a rake angle of 7º, clearance angle of 6º and 0.4 mm nose radius. The workpiece material used for the experiments is AISI 1045 steel due to its unique combination of strength, formability and versatility; and widely used in infrastructure, agriculture and automotive industries. The workpieces are machined from a solid cylindrical bar to a final dimension of 47 mm diameter and 250 mm cutting length. The power measurement method and experimental details are shown in Kant and Sangwan [6].Taguchi's L_{27} orthogonal array is used to design the experimental plan. Experiments are carried out for all combinations using full factorial array. It is the most suitable array which has 27 runs and 26 degrees of freedom. The three main factors (cutting speed, feed rate and depth of cut) take 6 degree of freedom and the remaining are taken by interactions.

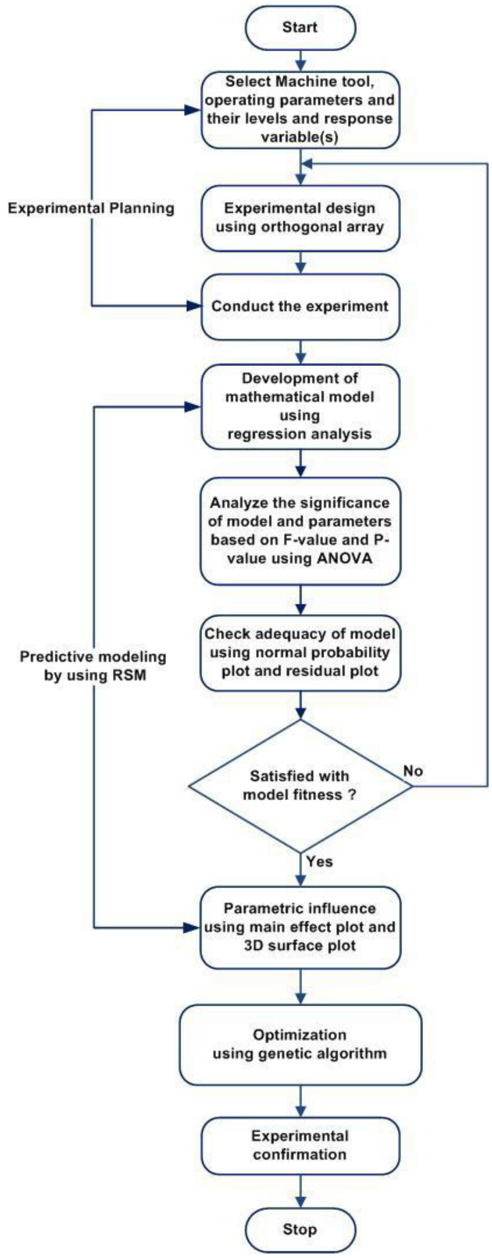

Fig. 1. Research methodology used in this study.