Multi-Objectives Genetic Algorithm for Optimizing Machining Process Parameters

Authors : Dylan Santos De Pinho, Nabil Ouerhani

Abstract : Energy consumption of machine-tools is becoming critical for machine-tool builders and end-users because of economic, ecological and legislation-related reasons. Many machine-tool builders are seeking for solutions that allow the reduction of energy consumption of machine-tools while preserving the same productivity rate and the same quality of machined parts. In this paper, we present the first results of a project conducted jointly by academic and industrial partners to reduce the energy consumption of a Swiss-Type lathe. We employ genetic algorithms to find optimal machining parameters – the set of parameters that lead to the best trade-off between energy consumption, part quality and tool lifetime. Three main machining process parameters are considered in our optimization technique, namely depth of cut, spindle rotation speed and material feed rate. These machining process parameters have been identified as the most influential ones in the configuration of the Swiss-type machining process. A state-of-the-art multi-objective genetic algorithm has been used. The algorithm combines three fitness functions, which are objective functions that permit to evaluate a set of parameters against the three objectives: energy consumption, quality of the machined parts, and tool lifetime. In this paper, we focus on the investigation of the fitness function related to energy consumption. Four different energy consumption related fitness functions have been investigated and compared. The first fitness function refers to the Kienzle cutting force model. The second fitness function uses the Material Removal Rate (RMM) as an indicator of energy consumption. The two other fitness functions are non-deterministic, learning-based functions. One fitness function uses a simple Neural Network to learn the relation between the process parameters and the energy consumption from experimental data. Another fitness function uses Lasso regression to determine the same relation. The goal is, then, to find out which fitness functions predict best the energy consumption of a Swiss-Type machining process for the given set of machining process parameters. Once determined, these functions may be used for optimization purposes – determine the optimal machining process parameters leading to minimum energy consumption. The performance of the four fitness functions has been evaluated. The Tornos DT13 Swiss-Type Lathe has been used to carry out the experiments. A mechanical part including various Swiss-Type machining operations has been selected for the experiments. The evaluation process starts with generating a set of CNC (Computer Numerical Control) programs for machining the part at hand. Each CNC program considers a different set of machining process parameters. During the machining process, the power consumption of the spindle is measured. All collected data are assigned to the appropriate CNC program and thus to the set of machining process parameters. The evaluation approach consists in calculating the correlation between the normalized measured power consumption and the normalized power consumption prediction for each of the four fitness functions. The evaluation shows that the Lasso and Neural Network fitness functions have the highest correlation coefficient with 97%. The fitness function "Material Removal Rate" (MRR) has a correlation coefficient of 90%, whereas the Kienzle-based fitness function has a correlation coefficient of 80%.

Keywords : adaptive machining, genetic algorithms, smart manufacturing, parameters optimization
Conference Title : ICIRIEC 2020 : International Conference on Industrial Robotics, Industrial Engineering and Control
Conference Location : Zurich, Switzerland
Conference Dates : January 13-14, 2020