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Tool Path optimization by Genetic algorithm for Energy Efficient Machining

B.Raja chinna karuppanan
Anna University,
Chennai, 600 025, India.
scbraja@gmail.com

M. Saravanan
SSM Institute of Engineering and Technology,
Dindigul, India -624002.
drmsaravanan@yahoo.com

Abstract— The highly flexible CNC machines are used extensively by manufacturing industries for producing a variety of components. The cost of energy is about one fifth of the operating cost of these machines and this cost is increasing steadily. Many strategies are practiced to reduce energy consumption by these machines in order to lower manufacturing expenditures and also to minimize the carbon footprint. The feed drives share considerable amount of energy in the total power consumption of a CNC machine. In this research work, a tool path optimization method is presented to improve the energy efficiency of the machine. This is achieved by making use of the difference in energy requirement of the various feed drives. Genetic algorithm with modified cross over method was used for this purpose. The presented method was experimented analytically with a drilling problem to find an energy efficient path. An optimized tool path for minimum cycle time was also found and the two tool paths were compared in an energy perspective. Results show that the energy efficient tool path consumed less energy than the tool path optimized for minimum time. The proposed method can be adapted to CNC machines with multiple axis with interpolated movements to predict the minimum energy toolpaths.

Keywords— Tool path Optimization, CIM, Energy efficiency, TSP, Energy Modelling, Genetic algorithm

I. INTRODUCTION

Manufacturing processes are found to be energy intensive and the impact on environment by the carbon footprint left by them is high [1,2]. The rising cost of energy also is affecting the manufacturing industry economically. Hence the optimization of the electricity consumption at the production and process level stages of manufacturing is necessary. Researchers accept that performing an exclusive analysis of manufacturing processes to estimate overall energy demand is necessary[3]. For reducing energy demand of machine tools, it is essential to devise methods to characterize the energy consumption of manufacturing processes [4].

Most of the existing works on energy reduction in the manufacturing industry were focused on making energy efficient machining methods. Machine tools which are used in great numbers constitute substantial size of industrial energy consumers [5,6]. The reduction of energy consumption of machines may bring considerable reduction in the environmental impact of consumer products [7]. CNC machines are highly utilized machines for machining operations which require enormous electric power[8]. The ever increasing cost of energy and the release of greenhouse gases by fossil fuels necessitates researchers to minimize the use of energy by these machines [9]. The environmental impacts of CNC machines are mainly due to their electrical energy demand and CO2 emissions [10,11,12]. The efficient use of energy is an important problem, making the manufacturing industries continuously look for solutions. Energy efficiency of machine tools could be improved by identifying strategies for reducing its non-cutting energy demand [13].The electrical energy consumed by these machines during the material removal process is dominated by the energy required for supporting the non-cutting operations, machine tool feed axes and auxiliary units[14]. The energy spent for non-cutting operations takes major share of the total energy consumption in machining [15]. This means that the machine consumes huge energy even during the non cutting tool movements because of the fixed energy requirements.

A. Tool path Optimization for productivity by minimum cycle time

Research works on toolpath optimization were mainly aimed at minimizing the time for metal cutting, minimizing the tool in air time, minimizing the tool change time and inspection time. Most research papers presented techniques for the optimization of machining parameters, tool selection and the type of toolpaths to be used [16]. Many researchers presented methods to optimize tool sequence to minimize the tool switch time [17,18]. Optimization algorithms with heuristic approach were used to arrive tool paths in metal cutting operations to minimize the non cutting tool time [19, 20]. Abu Qudeiri et al.[21] proposed a method to optimize the tool path for different operation processes that were located asymmetrically on more than one level, with a single cutting tool. Danijela Peter [22], compared the tool paths created by CAM software and by Genetic Algorithm. A Kumar et al.[23], optimized drilling tool paths using GA . Abu Qudeiri [24] solved The Traveling Salesman Problem (TSP) for two different arrival and departure points with constraints for tool collision. Alwis et al.[25] applied a row by row technique to

Dr.D.SENTHIL KUMARAN, M.E., Ph.D., (NUS)
Principal
SSM Institute of Engineering and Technology
Kuttathupatti Village, Sindalagundu (Po),
Palani Road, Dindigul - 624002.