Evaluation and Indexing of Process Plans Based on Electrical Demand and Energy Consumption

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ABSTRACT

This paper presents the concept of including the energy cost as a part of the total cost of manufacturing using machining processes in the development of computer aided process plans. The research objective is to index and evaluate the process plans based upon the energy consumption of the machining operations while considering machining cost and to rank or index the process plans based on energy consumption for purposes of decision support in process plan selection. The paper also discusses energy evaluation of process plans and their subsequent effectiveness in terms of overall cost associated with the utilization of effective machining parameters. The MPSEL system, which is an expert system based application, was used to develop alternative process plans. The MACH program, which is a spreadsheet based system, was used to determine the cost associated with machining. The developed process plans are compared based upon the cost associated with utilized energy and machining.

KEYWORDS

Energy Efficiency, Machining, Manufacturing, Process Planning, Sustainability

INTRODUCTION

In metal cutting and manufacturing industry, the electrical energy cost is always treated as an indirect cost and only the total machining cost, which includes tooling cost, machine and labor cost, is attributed to the cost of the part. The cost of electrical energy has increased over time and industry realizes the importance of energy cost invested in manufacturing. A part that can be produced based upon varying machining or metal cutting process plans can vary not only in its machining cost but also in energy cost. Based on the process plan developed, the cost of energy, which includes electrical energy cost as well as the electrical demand cost should be used in the selection of process plan. Process plans are selected based upon the production rate, machining and tooling cost and not based upon the energy consumed in the machining process. Enhanced energy indexing and evaluation of process plans should be made available to the process planner and manufacturing engineers and managers so as to contribute towards cost reduction and enhance the sustainability initiatives.
In metal cutting and manufacturing, electricity is treated as an indirect cost. The machine tools are driven by electrical motors which consume significant electrical energy. The machine tools, irrespective of their age and level of sophistication, utilize electrical motors for spindle movement, table movement, and alignment of part and machine elements. The spindle motor consumes the most energy as it positions the part or rotates it for precision manufacturing. The actual power and energy consumed will depend upon the load on the motor, often influenced by the material hardness and the intensity of metal removal dependent upon the depth of cut.

The domain of computer aided process planning, whether it is generative or variant, involves the specification of steps in producing the part with details on process parameters. Significant variations are possible in terms of the steps used in process planning due to the variety of process parameters that are available to utilize. The process plans, in their attempt to fulfill the product design attributes, focus on achieving it with the least possible cost of manufacturing the part. Adding the consideration of energy cost into the mix creates an interesting and important sustainability consideration in product manufacturing. Hence, the objective of this research is to analyze the process plans and process parameters used in the machining process and to compare and contrast the process plans in terms of machining cost, tooling cost, and energy cost.

The objectives of the process plan may differ variously due to following reasons:

1. Manufacture of a new product
2. Greater stability in the attainment of desired quality level
3. Increase in product volume
4. Increased utilization of facility resources
5. Cost reduction

The process plan typically includes the following information:

1. Type of process
2. Type of machine and cutting tool used
3. Sequence of processes
4. Cutting fluid used
5. Cutting parameters involved in each process
6. Type of jigs and fixtures
7. Labor cost and machining cost
8. Machining time in each process and tooling time in each process.

This work has been based on the research done at West Virginia University (Rangaswamy, 2003).

BACKGROUND

In the domain of computer aided process planning, various methodologies have been developed for process planning which focus on cost reduction and optimization (Rangaswamy, 2003). Gupta & Gopalakrishnan developed a process planning methodology based on the characteristics of the work material surface (2010). A real time computer aided process planning (CAPP) system as a support tool for economic product design was developed by Fuh, Chang, & Melkanoff (1992). The reduction of the idle time of machines and other resources in process planning was analyzed by Park & Khoshnevis (1993). Petuelli (1995) & Akturk & Avci (1996) developed a mathematical model for the operation of CNC machine tool which included system characterization, cutting conditions and tool life relationship and related constraints to optimize cutting and idle time by considering tool consumption and non-machining time cost components. Gupta & Gopalakrishnan (2010) & Leonesio,
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