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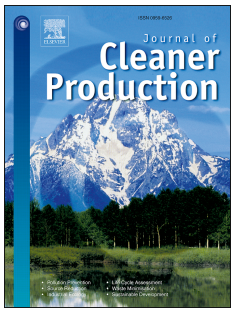

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PII: S0959-6526(15)01328-1

DOI: 10.1016/j.jclepro.2015.09.100

Reference: JCLP 6190

To appear in: *Journal of Cleaner Production*

Received Date: 4 September 2014

Revised Date: 18 July 2015

Accepted Date: 22 September 2015

Please cite this article as: Xie N, Duan M, Chinnam RB, Li A, Xue W, An Energy Modeling and Evaluation Approach for Machine Tools Using Generalized Stochastic Petri Nets, *Journal of Cleaner Production* (2015), doi: 10.1016/j.jclepro.2015.09.100.

An Energy Modeling and Evaluation Approach for Machine Tools Using Generalized Stochastic Petri Nets

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Abstract-Lower production cycle time and higher energy efficiency have become a paramount requirement for machining processes under global competition. A formalized method to assess multiple performance indicators (e.g. production time, energy consumption) of machine tools for comparable analysis of production data is indispensable given the increasing scrutiny of manufacturing systems. A novel energy consumption model based on Generalized Stochastic Petri Nets is proposed and an analysis method is also presented. Furthermore the model was successfully applied to a turning machine tool. The main trend of energy consumption and other related indicators of studied machine tool are then compared and the optimal parameters for energy efficiency are discussed under various cutting parameters and different production plans.

Key words: Machine tool, energy consumption, GSPN, evaluation

1 Introduction

Global warming concerns and other factors have accelerated the attention to environmental aspects and are in turn exerting pressure on companies to do their part. In addition, the increasing energy, raw material prices and regulative incentives of carbon emission reduction are issues affecting manufacturing enterprises. Energy efficiency remains one of the major issues in the machining domain. Rapid and flexible machine tool energy modeling in a distributed and collaborative machining environment emerges as a new research area[1]. Therefore, apart from traditional economical production aims (e.g. cost, time, quality), enterprises are also focusing on environmental driven objectives[2]. Manufacturing plays an important role in achieving environmental sustainability. Manufacturing generates over 60% of annual nonhazardous waste and more than one-third of all energy consumed is attributed to industrial use[3,4].

A prerequisite to improving the energy utilization is the establishment of effective models for quantification of energy consumption. Gutowski proposed a thermodynamic framework to characterize the material and energy resources used in manufacturing processes[5]. Li and Kara presented an empirical model based on power measurements under various cutting conditions and also provided a reliable prediction of energy consumption[6,7]. Zein *et al*. proposed an axiomatic approach based functional requirements model for improving energy efficiency of machine tools[8]. Lv and colleagues defined a set of fundamental motions and proposed therblig theoretical power models for calculating the energy supply of machine tools using machining process parameters[9,10]. Apart from the energy models using different theoretical bases, the literature also offers specific models for individual machining processes. Behrendt *et al*. divided the machine

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