Drilling Optimization via Particle Swarm Optimization

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ABSTRACT

The drilling process based on Material Reduction Rate (MRR) is modeled in this work. The modeling of this process is rather time-consuming and expensive as it involves 32 experiments with appropriate apparatus. Having had the model, the authors employed the well-known algorithm, namely Particle Swarm Optimization (PSO) to solve the maximization problem with some constraints present. All the results obtained showed non-violation to the constraints imposed. It means the solutions found are all feasible. The developed program may be useful for some practical purposes such as estimating the drilling duration, proper time to change the drill etc.

Keywords: Algorithm, Drilling, Manufacturing, Material Reduction Rate (MRR), Particle Swarm Optimization (PSO), Process Optimization

INTRODUCTION

Drilling is one of the basic, most frequently performed materials removing process in manufacturing industry. It has been reported that one-third of material removal process performed in industry is drilling operation. In spite of significant increase in the demand of producing holes economically, drill manufacturing is still considered as an esoteric art. The drilling operation is frequently used as a preliminary step for many operations like boring, reaming and tapping. This complex cutting operation holds a substantial portion for all metal cutting operations and the largest amount of money spent on any class of cutting tool. Drilling is crucial from the viewpoint of cost, productivity and manufacturing. Effective drilling also reduces the down time of the manufacturing processes. One way to overcome this challenge is by constantly monitoring the cutting process and thus determines the right time for the tool change. The other way is to optimize the cutting variables of the drilling process in order to improve the tool life and apparently increase the cutting length in the period of improved tool life.

Li and Wu (1998) have introduced a new approach for online monitoring of drill wears by using a fuzzy c-means algorithm. Experimental and simulation results have shown that wear conditions can be represented by fuzzy grade. Dutta, Kiran, Paul, and Chattopadhyay (2000) have proposed machining features in tool condition monitoring during the drilling

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process, in which process parameter coupled with machining responses and experimental observations provide a basis for monitoring the tool wear. Yao, Li, and Yuan (1999) have proposed tool wear detection by fuzzy classification and wavelet fuzzy network. El-Wardany, Gao, and Elbestawi (1996) have proposed vibration analysis for drilling process monitoring. Drilling wear monitoring based on current signals was proposed by Li and Tso (1999). Thangaraj and Wright (1998) used change rate of thrust force for drilling failure monitoring. Liu and Wu (1990) incorporated sensor fusion methods for monitoring drill wear. Singh, Panda, Pal, and Chakraborty (2006) used an artificial neural network to predict drill wear. The performance of the network to predict the wear has been tested against the experimental data and found to be satisfactory. Ghaiebi and Solimanpur (2007) have proposed the use of an ant algorithm to optimize drill making operation using tool airtime and tool switch time as the objective function.

On the other hand, Lee, Liu, and Tarng (1998) used the abductive network for modeling and optimization of drilling process. Once the process parameters such as drill diameter, cutting speed and feed are given, the drilling performance such as tool life, removal rate and thrust force can be predicted by this proposed network. Other optimization methods that have been published in literatures and applied to the related machining processes are deterministic optimization approach (Wang, Kuriyagawa, Wei, & Guo, 2002; Armarego, Smith, & Wang, 1993) applied to turning and peripheral milling processes; polynomial geometric programming (Gopalakrishnak & Al-Khayyal, 1991) for turning process; fuzzy optimization (Fang & Jawahir, 1994) for turning; particle swarm (Tandon, El-Mounary, & Kishawy, 2002; Lee, Ting, Lin, & Hay, 2006) for end milling and grinding, and genetic algorithm (Gopal & Rao, 2003) for grinding.

EXPERIMENTAL DESIGN AND PROCEDURE

Experimental design is an extremely important tool for engineers and scientists, who are interested in improving the performance of a manufacturing process. It also has extensive application in the development of a new process and in the design of a new product. The basic objective is to obtain a broad picture of the effect of the factors or the combinations of levels of the factors that gives a maximum response.

Hereby, the 2^4 factorial design (Hines, Montgomery, Goldsman, & Borror, 2003) was used for the experimental design whereby parameter 2 is equal to two levels and 4 is equal to four factors (cutting speed, feed, number of holes and cutting fluid). Therefore, total of 32 experiments were conducted for drilling 10 mm diameter holes with two different tool manufacturers X and Y, respectively. The experimental setup is shown in Figure 1. Thrust force and torque were measured by using mechanical tool dynamometer with independent digital output that was attached to the base of the work piece chuck. Rockwell hardness tester was used to measure the values implying the degree of hardness for both tools.

The specifications of drill tools and process parameters used for the entire experiment are as shown in Table 1. Thirty-two work pieces have been used for this entire research experiment. The work piece material selected was mild steel bright bar (EN-31) with the dimensions of 80mm ×80mm with the thickness of 25mm. Tool wear $T_w$ was calculated as the average of four measurements taking two readings on each of the cutting edges as shown in Figure 2, where the $T_w = (A+B+C+D)/4$.
Olga Wenge, Dieter Schuller, Christoph Rensing and Ralf Steinmetz (2014). *International Journal of Organizational and Collective Intelligence* (pp. 22-43). 
www.igi-global.com/article/on-developing-fair-and-orderly-cloud-markets/117718?camid=4v1a

Taguchi-Particle Swarm Optimization for Numerical Optimization
T. O. Ting, H. C. Ting and T. S. Lee (2012). *Innovations and Developments of Swarm Intelligence Applications* (pp. 44-59). 
www.igi-global.com/chapter/taguchi-particle-swarm-optimization-numerical/65805?camid=4v1a