Weighted Average-Based Multi-Objective Optimization of Tube Spinning Process using Non-Traditional Optimization Techniques

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ABSTRACT

Tube spinning is an effective process for producing long and thin walled tubes. It is important to note that the quality of parts produced in tube spinning process, namely internal surface roughness, external surface roughness, change in diameter and change in thickness depends on the right combination of input process parameters, such as mandrel rotational speed, feed rate of rollers, percentage of thickness reduction, initial thickness, solution treatment time and ageing treatment time. As the 2024 aluminum tube spinning process contains four objectives, it is very difficult to achieve a set of optimal combination of input process parameters that produce best quality product. This paper presents a weighted average-based multi-objective optimization of tube spinning process using non-traditional optimization techniques, namely genetic algorithm, particle swarm optimization and differential evolution. Multiple regression equations developed between the control factors and responses have been considered for optimization.

Keywords: *Differential Evolution, Genetic Algorithm, Multi Objective Optimization, Particle Swarm Optimization, Tube Spinning Process*

INTRODUCTION

Tube spinning is an effective metal forming process for making thin walled cylindrical parts without changing their inside diameter. In this process, a tubular blank is supported by a mandrel, which is mounted in between the head stock and tail stock of the tube spinning machine, and pressure is applied on the blank by one or more rollers to reduce the wall thickness. Many researchers had developed and improved the process. An approximate analysis was per-

DOI: 10.4018/ijsir.2013070103

formed by (Kobayashi & Thomson, 1962) to solve the spin-forging problem of a tube. The problem was solved by dividing the process into drawing and extrusion types. In Gur and Tirosh (1982), the authors analyzed the instability of plastic flow under the shearing load, using upper-bound method. In addition to this, the effect of heat treatment of preform material on the mechanical properties of tube spinned components was investigated by (Rajan & Narasimhan, 2002). They also verified the validity of using empirical relations in predicting the properties of the flow formed components. Later on, (Davidson et al., 2008) studied the effect of process parameters on flow forming of AA6061 aluminum alloy tube. It was observed that the depth of cut, the feed, the starting dimension of the preform had significant contribution on the quality of the final product. It is important to note that conducting the experiments by varying one parameter at a time is very tedious, expensive and time consuming.

Several attempts were made to model the tube spinning process with the help of multiple regression analysis (Fazeli & Ghoreishi, 2009; 2011). In both the studies, mandrel rotational speed, feed rate of rollers, thickness reduction, initial thickness, solution treatment time and aging treatment time were considered as the input parameters. Analysis of variance had been performed to check the statistical adequacy of the models. Since, the statistical models will be developed response-wise, it may not be able to capture the dynamics of the process. In order to capture the dynamics of the whole process, soft computing (Partihar, 2008) based approaches were developed to model the tube spinning process (Ko et al., 1999; Jiang et al., 2008). It is important to note that soft computing-based approaches help in predicting the responses in an optimal sense. However, it is not possible to obtain the optimal combination of input process parameters that optimize various responses. Moreover, the tube spinning process contains multiple responses to be optimized.

The selection of optimal tube spinning parameters, such as mandrel rotational speed, feed rate of rollers, percentage of thickness reduction, initial thickness, solution treatment time and ageing treatment time that optimize various responses, namely internal surface roughness, external surface roughness, change in diameter and change in thickness is a very important issue for tube spinning process. Hence, there is a need for a multi-objective optimization method to arrive at the optimal solutions to this problem. Therefore, this multi-objective optimization problem can be converted to a single objective problem after applying a suitable method. There exits two classes of multi-objective optimization problems. The first class deals with formulating a single composite objective after considering the weighted sum of individual objectives. The second class is based on generating Pareto-optimal solution sets that are non-dominating with respect to each other. The present research falls into the first category and this type of problems can be best solved by utilizing evolutionary algorithms, such as genetic algorithms (GA), particle swarm optimization (PSO), differential evolution (DE) and artificial bee colony (ABC), etc.

Evolutionary algorithms can find global optima more quickly through cooperation and competition among the population of potential solutions. It is important to note that GA was used to solve multi-objective optimization problems related to abrasive flow machining (Tavoli et al., 2006), turning (Yang & Natarajan, 2010), die sinking electric discharge machining (Joshi & Pande, 2011) and green sand mould system (Surekha et al., 2012), etc. Moreover, DE had successfully been applied to optimization of processes, such as grinding (Lee et al., 2007), turning (Yang & Natarajan, 2010), structural optimization (Kitayama et al., 2011) and milling operation (Yildiz, 2012), etc. In addition to these optimization algorithms, PSO algorithm had also been used for the optimization of electro chemical machining (Rao et al., 2008), multi pass turning (Zheng, 2010), milling (Rao & Pawar, 2010) operations and adaptive controller of a robot (Rajendra & Pratihar, 2011), etc. Even though, all the three evolutionary algorithms, such as GA, DE and PSO are used to obtain global optimal solution,

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