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Fuzzy Logic-Based Expert System for Prediction of Wear Rate in Selective Inhibition Sintered HDPE Parts

D. Rajamani*, Balasubramanian Esakki, P. Arunkumar, R. Velu

Centre for Autonomous System Research (CASR), Department of Mechanical Engineering, Vel Tech University, Avadi, Chennai- 600062, India.

Abstract

Selective inhibition sintering (SIS) is a novel additive manufacturing process to build parts with least human effort and cost. The SIS made high density polyethylene (HDPE) parts undergo wear, which is robustly influenced by the SIS process parameters like layer thickness, heat energy, heater feed rate and printer feed rate. Predicting the wear rate being a complex phenomenon, a fuzzy logic based expert system is proposed to evaluate the wear characteristics of SIS made HDPE specimens. Experiments are conducted using pin-on-disc wear testing apparatus to examine the wear rate. Comparative evaluation of experiments and fuzzy approach suggested that the obtained average error of wear rate using fuzzy system is concord with experimental results. Hence, the developed fuzzy rules can be effectively utilized to predict the wear rate of SIS polymer parts in automated manufacturing environments.

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* Corresponding author.
E-mail address: rajamanitamil1991@gmail.com
1. Introduction

Rapid prototyping (RP) technique is to realize the complex and intricate parts or an assembly from a three dimensional (3D) computer aided data in short span of time. For the past two decades, RP techniques have gained a lot of attention by building functional prototypes in the earlier design/product development stages. The fabricated parts could be useful in performing functional verification, design modification, product confirmation and engineering analysis that lead to decrease in product development cost and increase in the probability of success. In comparison to other conventional methods such as casting, moulding and machining, RP process does not necessitate any specific tools, jigs and fixtures, thus reducing the manufacturing cost significantly. The effective usage of raw materials and no or minimum wastage make the RP process superior than conventional manufacturing processes. Presently, various RP processes such as stereolithography (SL), Polyjet, fused deposition modeling (FDM), laminated object manufacturing (LOM), 3D printing (3DP), selective laser sintering (SLS), laminated engineered net shaping (LENS), and electron beam melting (EBM) are playing a vital role in Automobile, Aeronautical, Medical, and Architectural applications [1]. However, the cost of the process would increase based on the laser system employed and import of materials. In order to reduce the cost, the commercially available heating system and indigenous polymers are utilized. Considering these aspects, a novel RP process, called as Selective Inhibition Sintering Process (SISP) is developed by University of Southern California, USA [2]. Compared to other RP processes, the following are the advantages of SISP:

- Wide range of indigenously available polymer materials, such as poly propylene, HDPE, LDPE, poly carbonates and poly styrene are used for this process. Without any serious modification in SISP system, wide varieties of polymer materials can be used.
- Unlike FDM, SISP does not require support structures. SISP does not use high power lasers or electron beams, thus reducing the system cost appreciably.
- The nozzle prints the layer on the boundary area of part only. Hence, dimensional accuracy, surface integrity and quality of the fabricated parts are superior to that of 3D printing and SLS.
- The SISP machine is less expensive compared to equivalent SLS machine, since in SISP high power laser generator is replaced with low cost heat element.

In SISP, polymer powder particles are heated just below the melting point resulting in cohesion of particles and then allowed for curing to form the solid part. The inhibitor acts as a supporting element. Melting point of inhibition materials have to be maintained at least 3 to 4 times than that of the polymer particles being considered. The properties of SIS fabricated parts, such as dimensional accuracy, part strength, surface roughness, and wear rate are significantly improved by proper selection of process parameter ranges. There are two different approaches that are generally used for selection of appropriate process variables: [3] (i) development of new materials to build parts, and (ii) construction of mathematical models. The first approach may require expert knowledge about material characteristics at different operating conditions. The second method can be used as an alternative for developing mathematical models to establish the relationship between process parameters and their significant effects on responses. In this context, several well-known artificial intelligence (AI) techniques, such as fuzzy logic [4], artificial neural network [5,6], adaptive neuro-fuzzy inference system [7], support vector regression [8], and genetic programming [9] are being used to develop the relationship between given input parameters and output responses in various RP techniques. Among these schemes, fuzzy logic possesses the ability to model a complex process containing uncertain and vague information with less hardware and software resources [10]. Fuzzy logic theory has proved to be an effective means to deal with objectives that are linguistically specified [11]. In the past, many researchers have effectively utilized fuzzy-rule approach for modeling of various RP processes [12-13].

To the best of the author’s knowledge, no work has been reported on intelligent modeling of SIS process using fuzzy logic approach. In this study, a fuzzy logic rule-based expert system is presented to predict the wear rate of SIS fabricated HDPE parts. The experiments are conducted as per response surface methodology based box-behnken design. The fuzzy model includes layer thickness, heat energy, heater feedrate, and printer feedrate as process parameters and wear rate is considered as response.
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