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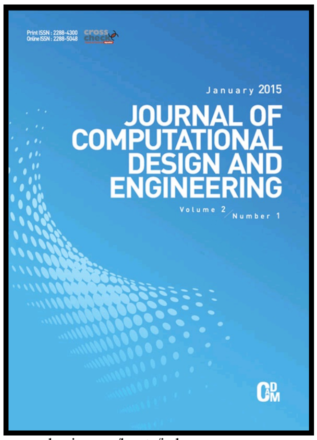

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Multidisciplinary Design Optimization to Identify Additive Manufacturing Resources in Customized Product Development

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Abstract: Additive manufacturing (AM) techniques are ideal for producing customized products due to their high design flexibility. Despite the previous studies on specific additive manufactured customized products such as biomedical implants and prostheses, the simultaneous optimization of components, materials, AM processes, and dimensions remains a challenge. Multidisciplinary design optimization (MDO) is a research area of solving complex design problems involving multiple disciplines which usually interact with each other. The objective of this research is to formulate and solve an MDO problem in the development of additive manufactured products customized for various customers in different market segments. Three disciplines, i.e. the customer preference modeling, AM production costing, and structural mechanics are incorporated in the MDO problem. The optimal selections of components, materials, AM processes, and dimensional parameters are searched with the objectives to maximize the functionality utility, match individual customers' personal performance requirements, and minimize the total cost. A multi-objective genetic algorithm with the proposed chromosome encoding pattern is applied to solve the MDO problem. A case study of designing customized trans-tibial prostheses with additive manufactured components is presented to illustrate the proposed MDO method. Clusters of multi-dimensional Pareto-optimal design solutions are obtained from the MDO, showing trade-offs among the objectives. Appropriate design decision can be chosen from the clusters based on the manufacturer's market strategy.

Keywords: Additive manufacturing, Customized products, Multidisciplinary design optimization

1. Introduction

Additive manufacturing (AM) is an emerging advanced manufacturing technique whose working principle relies on the progressive layer-wise material consolidation from the bottom to top [1]. Due to the enhanced design flexibility, AM processes are suitable for producing customized products that need to satisfy the requirements of different individual customers [2]. Previous researches in design for additive manufactured customized products have been studied in literatures. Thompson et al. [3] illustrated a broad range of AM applications in customized products, including medical devices, custom-fit packaging for shipping, and furniture. Personalized surgical guides made by AM techniques were designed to improve accuracy in surgical operations [4]. Additive manufactured functional hearing aids were designed based on the patients' ear shapes, while the color of the ear bud can also be customized to meet the patients' preferences [5]. Petrovic et al. [6] introduced various biomedical implants and prostheses were manufactured by AM, while their shapes and mechanical properties could be customized individually for the customers. Oxman [7] applied the method of "variable property prototyping (VPRP)" to design customized protective gloves against carpal tunnel syndrome (CTS). Multiple materials with different stiffness values were distributed on the glove to constrain wrist rotation

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