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Remanufacturing production planning with compensation function approximation method

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ABSTRACT

Remanufacturing is becoming a strategic emerging industry in China. However, there are many uncertain factors such as remanufacturing rate of recycling products, reprocessing costs, quantity of recycling products during a remanufacturing process. Hence, it is difficult to make an accurate production planning. This paper aims at studying a new remanufacturing production planning model in view of some possible uncertain factors in a remanufacturing enterprise according to the features and characteristics of remanufacturing. Considering the production capacity constraint of recycling, reprocessing and reassembly under the condition of uncertain reprocessing amount, unpredictable reprocessing cost, unknown purchase volume of new parts, and uncertain customer demand, this paper develops a two-stage, multi-period hybrid programming model with compensation function based on uncertainty theory to minimize the total remanufacturing cost. A hybrid intelligent algorithm is designed combined with compensation function approximation, neural network training, and virus particle algorithm to optimize this two-stage uncertain remanufacturing production planning. By use of compensation function approximation method, it is to convert an infinite optimization problem in this algorithm into that of a finite one. Finally, one remanufacturing simulation case is studied to validate the efficiency and rationality of the proposed approach.

1. Introduction

Remanufacturing is a recycling process to manufacture a recycling product as good as a new one [1]. China's 12th Five-Year Plan for Circular Economy put forward a strategy deployment to build a circular industrial system clearly. As a strategic emerging industry, remanufacturing is also becoming an effective way to develop circular economy and promote social sustainable development [2]. Just taking automobile as example, it is estimated that the total number of Chinese civilian vehicles will be 200 million in 2015 and the discarded automobiles more than 10 million for the first time. With the emergency of discarded industrial products in a large scale and booming of remanufacturing industries, remanufacturing production planning and scheduling as one of key links in the production management, the study on it is of important theoretical and practical value for improving production management within a remanufacturing enterprise.

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Great stride has been made in the study of remanufacturing production planning optimization. Teunter et al. [3] create a manufacturing/remanufacturing batch production model when either of the two – new and remanufacturing product – can meet the production demand, which aims to minimize the total remanufacturing cost if demand and supply are given. Li et al. [4] develop a non-constraint, multi-period production planning model considering the possibility of substitution for remanufacturing products and find solution using a dynamic programming and heuristic algorithm. Li et al. [5] build a planning model for both manufacturing and remanufacturing hybrid production scheme including emergency procurement. To achieve the minimum cost, this model is solved by adopting the combination of genetic algorithm and heuristic dynamic programming method. Doh and Lee [6] establish a remanufacturing production planning model including mixed integer programming to maximize profit based on considering the influence and constraint of some links such as recycling disposal, disassembly, inspection, remanufacturing, and reassemble. However, a large number of uncertain factors exist in the remanufacturing production process [7], including: Uncertainty of recycling factors, such as unknown recycling time, variable recycling quantity, and unknown quality; Uncertainty of disassembly rate of recycling product and its component, it means that it is unknown whether a product or a component can be disassembled or not; Uncertainty of remanufacturing rate of recycling products due to out-of-tolerance, residual stress, internal cracks, surface deformation, and so forth; Uncertainty of customer demand; and so forth. Due to the existence of these uncertain factors, traditional production planning and control methods cannot adapt to remanufacturing production system, and it is more complicated to make a remanufacturing production planning than a traditional production planning. Therefore, Guide [8] study the influence on remanufacturing production planning and control because of a random uncertainty in a remanufacturing production system, the imbalance between recycling supply and demand, and other unknown factors of recycling products. For one-off product and the impact of a random machine failure, Kenne et al. [9] study a strategy scheme for a mixed production of both manufacturing and remanufacturing under a closed-loop reverse logistics network in order to reduce the inventory costing. Jing et al. [10,11] establish a production planning model for a hybrid manufacturing and remanufacturing system under an uncertainty environment, and develop a diploid genetic algorithm to find solution against the uncertainty of customer demand, recycling quantity, remanufacturing cost and remanufacturing rate. Wang and Wang [12] study a closed-loop optimal supply chain decision-making approach from the view of the supply chain when it happens variation in market demand, remanufacturing cost, as well as recycling cost. Mukhopadhyay [13] studies a remanufacturing production planning system when customer demand and recycling supply follow random distribution. Su et al. [14,15] create a hybrid uncertain programming model considering the stochastic and fuzzy parameters in the remanufacturing process taking profit maximization in multi-period and cost minimization in single period as goal respectively. Huang and Chen [16] construct a hybrid integer programming model for a fuzzy remanufacturing system and present a crisp equivalent form for this model to minimize the total cost based on the capacity constraints of recycling, disassembly, reprocessing, and reassembly.

During these studies mentioned above, some remanufacturing production planning models are only suitable for those remanufacturing production system whose factors related are known, and some could not adjust and compensate the production plan when the production plan must be changed because of disturbance events although some uncertain factors and disturbance events are taken into account. In this paper, a two-stage remanufacturing production planning model is established based on uncertainty theory in order to minimize the total cost. This model contains the influence of uncertain factors on remanufacturing production planning and regards some uncertain parameters including customer demand, remanufacturing quantity, purchase volume of new parts, and remanufacturing costs as uncertain variable with known distribution. It is divided into two stages: The first stage includes recycling and disassembly, and the second stage contains inspection, reprocessing, purchasing of new parts, and reassembly. Some decisions have to be made before some uncertain parameters are determined in the first stage, so it is allowable that the decision in the first stage is infeasible, then, some correspond measurements must be taken to find optimal scheme for the production plan in the second stage. Following, the compensation function approximation is studied and a hybrid intelligent algorithm combining compensation function approximation, neural network training, and virus particle algorithm is developed to solve this model. The purpose of this paper is to provide a new way to make a remanufacturing production planning under uncertain conditions.

The paper is organized as follows: Section 2 gives a mathematical description of a two-stage uncertain programming. Then a two-stage uncertain remanufacturing production planning model is established in Section 3. Following, a solution method of this proposed model is developed in Section 4. Section 5 gives a case study to validate the model and algorithm proposed in Sections 3 and 4. Finally, Section 6 draws conclusions and suggests the next study direction of this theme.

2. Two-stage uncertain programming definition and its mathematic description

Some decision parameters in the remanufacturing production plan are uncertain, and they are connected with each other [17,18].

At first, several definitions are identified as follows:

Definition 1. Let Γ be a nonempty set, $\mathcal{L}$ be one of algebra σ of Γ, and each element Λ in algebra σ is called an event. If function $\mathcal{M}$ meets the following three principles when $\mathcal{L} \in [0,1]$: