PRODUCTION PLANNING PERSPECTIVE FOR HYBRID MANUFACTURING–REMANUFACTURING SYSTEMS

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Abstract

Recycling for used products, collected from customers for recycling and disassembly of them for remanufacturing, is very critical addressing of the sustainable manufacturing systems. The concept of remanufacturing, which is frequently used for the production stages of electronic parts, especially in the automotive sector, is preferred for reducing costs, increasing efficiency, and legal regulations. We discussed the operation of a hybrid manufacturing system that uses raw materials and returned products together in the production process in this paper. This type of system has system complexity compared with the traditional manufacturing systems. Besides such challenges, remanufacturing can provide economic value considering sustainable benefits, as it preserves the geometric shape of the product.

Keywords
Remanufacturing, Production Planning, Recoverable Systems, Assembly Systems and Uncertainties

1. Introduction

As a result of the rapid developments in technology, natural resources are consumed quickly, thus causing the emergence of waste. This situation has caused some problems that people to minimize the harmful effects of waste on the environment. The recycling process was introduced to recycle discarded products for making them reusable. Afterward, the concept of remanufacturing emerged due to the emergence of technological products and rapid changes in technology. Remanufacturing ensures that obsolete products can be reused without losing their properties. In addition to the benefits of remanufacturing, such as reduction of waste and positive effects on the environment, it also provides economic benefits to companies.

Remanufacturing also requires good supply chain management. Until the concept of remanufacturing emerged, the concept of forwarding supply chain management was concerned. Due to increasing environmental problems and waste, concepts such as reverse logistics, product recovery options, and reverse supply chain management have emerged. In recent years, companies have given importance to reverse logistics and thus have considered gaining cost and competitive advantage.

Although production, inventory, and distribution decisions are processed as traditional manufacturing in the remanufacturing environment, the conventional manufacturing methods cannot be used for remanufacturing processes. Management, planning, and control of remanufacturing operations are quite difficult and complex. Production planning in the remanufacturing process is complex due to uncertainties in the quality and quantity of the returned product, the lead time for the disassembly process, and the new part purchased. Due to such difficulties and other constraints, appropriate solution methods are required. In this study, the characteristics of a hybrid system in which manufacturing and remanufacturing systems are considered together. The flow of the hybrid system, the difficulties experienced, and the methods used in the solution of production activities are also discussed in the following sections.

1.1 Objectives

We investigated remanufacturing systems and their difficulties concerning production planning and control perspectives. The main difficulty for planning and controlling processes in the remanufacturing systems is the uncertainty issue. There are some uncertain issues in the remanufacturing systems, such as lead time, quantity, repair time, quality requirements, managing the system performance, and other decision-making requirements. Therefore, the development of the methodologies that capture the uncertainty component and model of them is required in today's competitive and complex production systems. For this reason, we present a framework study to propose basic principles and uncertainty sources of the remanufacturing systems.

2. Literature Review

There are some recent papers in the literature related to the remanufacturing process, and we discussed some of them in this section. Some recent papers are listed in Table 1. We can see from Table 1 that the recent paper's objectives are mainly related to the decision-making and performance evaluation of the remanufacturing systems. Some of the studies in Table 1 are related to fuzzy decision-making modeling subjects. But they mainly include the fuzzy multi-objective decision-making problems. New models that included scope for the uncertainty issues are required for competitive and complex remanufacturing systems to solve planning and controlling problems.

On the other hand, Liu et al. (2019) compared the original manufacturing assembly system and remanufacturing assembly system considering the uncertainty issue. They stated that the remanufacturing assembly systems have a crucial weakness related to the quality of remanufactured products. However, this weakness is forced of them to improve their core competitiveness advantages. According to Liu et al. (2019), the uncertainty issues of remanufacturing assembly production systems must be analyzed and understood systematically. Also, Liu et al. (2019) offered to develop the new generation mechanism for coupling with the quality errors in the remanufacturing assembly systems to design and develop the new processes and technologies. We understood from the quick survey in the literature that remanufacturing and remanufacturing in the assembly systems is a hot topic. Uncertainties should be measured in the remanufacturing systems when developing usable decision-making tools for managing the remanufacturing activities effectively.

Table 1. Recent papers related to the remanufacturing process

Reference	**Subject**	**Related main subject for remanufacturing**
Jiang, Z., Ding, Z., Zhang, H., Cai, W., & Liu, Y. (2019)	Data-driven ecological performance evaluation for remanufacturing process	Performance evaluation
Kurilova-Palisaitiene, J., Sundin, E., & Poksinska, B. (2018)	Remanufacturing challenges and possible lean improvements	Lean perspective
Reimann, M., Xiong, Y., & Zhou, Y. (2019)	Managing a closed-loop supply chain with process innovation for remanufacturing	Supply chain management
Singhal, D., Tripathy, S., & Jena, S. K. (2020)	Remanufacturing for the circular economy	Economical perspective
Goodall, P., Sharpe, R., & West, A. (2019)	A data-driven simulation to support remanufacturing operations	Performance evaluation
Liu, C., Zhu, Q., Wei, F., Rao, W., Liu, J., Hu, J., & Cai, W. (2019)	Remanufacturing assembly management	Review
Zhou, Y., Xiong, Y., & Jin, M. (2021)	Closed-loop supply chain and remanufacturing	Supply chain management
Liu, C., Zhu, Q., Wei, F., Rao, W., Liu, J., Hu, J., & Cai, W. (2020)	Optimization remanufacturing assembly system.	Performance evaluation
Xiong, S., Ji, J., & Ma, X. (2020)	Remanufacturing of lithium-ion batteries from electric vehicles	Industry specific performance evaluation
Zhang, X., Ao, X., Cai, W., Jiang, Z., & Zhang, H. (2019)	Sustainability in remanufacturing systems	Performance evaluation
Du, Y., Zheng, Y., Wu, G., & Tang, Y. (2020)	Development of an AHP-entropy weight and extension theory based method for heavy-duty machine tool remanufacturing	Decision making
Hasanov, P., Jaber, M. Y., & Tahirov, N. (2019)	Four-level closed loop supply chain with remanufacturing	Supply chain management

Saxena, N., Sarkar, B., & Singh, S. R. (2020)	Selection of remanufacturing/production cycles	Decision making
Bhatia, M. S., & Srivastava, R. K. (2018)	Analysis of external barriers to remanufacturing	Decision making
Liao, H., Deng, Q., Wang, Y., Guo, S., & Ren, Q. (2018)	Sustainability model for remanufacturing process under quality uncertainty	Performance evaluation
Li, G., Reimann, M., & Zhang, W. (2018)	Product quality improvement based on cost issues	Performance evaluation
van Loon, P., & Van Wassenhove, L. N. (2018)	Environmental impact of remanufacturing	Economical perspective
Assid, M., Gharbi, A., & Hajji, A. (2019)	Planning of an unreliable hybrid remanufacturing system	Decision making
Talay, I., & Özdemir-Akyıldırım, Ö. (2019)	Planning for multi-product multi-stage production system under yield uncertainty	Decision making
Su, T. S., & Lin, Y. F. (2015)	Fuzzy multi-objective modelling for recoverable manufacturing systems	Lot Sizing-Production Planning
Liu, W., Ma, W., Hu, Y., Jin, M., Li, K., Chang, X., & Yu, X. (2019)	Production planning for stochastic manufacturing/remanufacturing system	Decision making
Assid, M., Gharbi, A., & Hajji, A. (2021)	Production planning of unreliable hybrid manufacturing-remanufacturing systems based on quality-characteristics	Decision making
Su, T. S., & Wu, C. C. (2021)	Fuzzy multi-objective decision making model for recoverable remanufacturing system	Systematic analysis
Nuamchit, K., & Chiadamrong, N. (2021)	Fuzzy linear programming model to optimize inventory control in a hybrid manufacturing/remanufacturing system	Decision making
Su, T. S., Wu, C. C., & Lin, L. T. (2019)	Planning of remanufacturing systems using a fuzzy multi-objective model	Decision making

3. Hybrid Manufacturing – Remanufacturing System

The purpose of remanufacturing, which is among the product recovery processes, is to make the used product conform to the quality standards applied to the new product. Remanufacturing includes the processes of disassembly, sorting, cleaning, checking, renewing, or replacing necessary parts of products that have become unusable and scrapped. The flow of a hybrid system with manufacturing and remanufacturing is given in Figure 1.

All recovery options in reverse logistics involve the collection, reprocessing, and redistribution of products. So, reprocessing issues in systems may differ from the others according to the characteristics of the products. Reprocessing activities include repair, product renewal, product specifications, and remanufacturing processes in the remanufacturing system shown in Figure 1. If the product cannot be reprocessed into the remanufacturing system, it must be disposed of from the system. However, the appropriate parts are transferred to the repair department for to repair process. But, if some of them are assembled parts, they can need a disassembly process. After the disassembly process, parts are separated into sub-parts or components that are disposed of or reused in the manufacturing processes depending on their suitability. Suitable parts can be used in the production system with remanufactured or newly purchased parts to meet customer demands.

Similar to traditional production activities, production, inventory, distribution, and marketing decisions are used in remanufacturing activities. However, the methods are available for traditional production activities cannot be used directly for remanufacturing activities. Applicable techniques vary according to the system. Therefore, the remanufacturing processes aim to reduce wastes in the manufacturing process. In addition to pushing the material or product flow in the production system, the concept of reverse flow emerges in the field of logistics. The uncertainty rising on the number of returned products must be considered in today's production planning concept. At the same time, the concept of disassembly and reassembly are emerging in the remanufacturing environment. In the purchasing process, the uncertainties in the quantities of the returned products cause uncertainties in the part requirements.

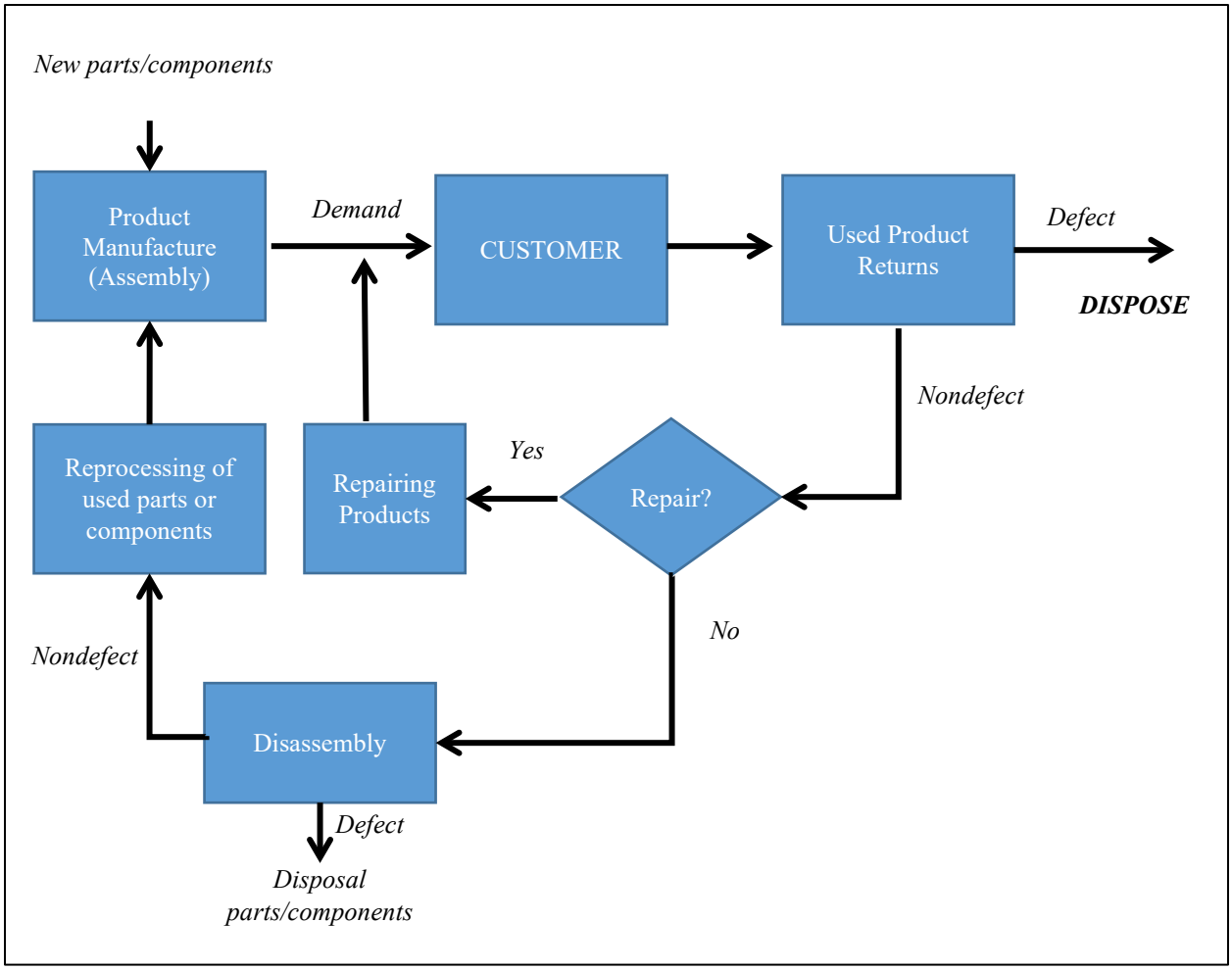

Figure 1. Illustration of the Hybrid Manufacturing-Remanufacturing System

In remanufacturing, criteria are used for the availability of appropriate technology for the renewal of the products, the fact that the products are made of standard parts, the cost of repairing the product is low, and the market demand is sufficient for the continuity of the enterprise. These criteria are necessary for the successful remanufacturing of a product. It must be possible to disassemble and reassemble the process for the product. Remanufacturing process has some benefits for the companies to reduce energy consumption, parts amounts, labor requirement, solid waste, and production costs. However, the uncertainty of the returned products in terms of quantity, quality, and time criteria causes difficulties in the implementation of remanufacturing.

4. Production Planning and Control for Hybrid Manufacturing - Remanufacturing System

With the increasing importance of environmentally friendly production activities, the interest of enterprises in recycling, reuse, and remanufacturing activities has increased. Depending on the increase in activities aimed at remanufacturing, effective planning of these activities has also gained importance. Remanufacturing facilities have a very complex structure due to the characteristics of remanufacturing activities. Therefore, the planning and control of remanufacturing activities are much more difficult than traditional production activities.

The need for different processes for each product returns and coordinating many independent processes complicates production planning. The reproduction environment is also quite complex in terms of routing. A high level of coordination is required due to the independence of the different parts. Capacity problems may also arise if many parts require operation at the same time. Products can be returned for many reasons:

- Products may be returned due to poor quality.

- In some cases, it may be necessary to ensure that faulty products are returned when they are sent to the customer.
- If the product has completed its life, it can be returned.
- In addition, products under warranty may be returned for repair.

Planning and control decisions are different in remanufacturing activities from the decisions in traditional production activities. It is difficult to determine the product characteristics in remanufacturing. Uncertainty in remanufacturing activities is quite high, which makes it difficult to apply traditional production planning methods in remanufacturing activities. Due to the high variability of the remanufacturing process time and the large variety of parts, the planning activities are more complex, and different decision-making methods are needed. Depending on the different operating conditions of the parts and the different periods of use, the processes required for the parts may differ. While some tasks such as cleaning in remanufacturing operations are precisely known, other routes can vary and depend on the age and conditions of the part.

The first of the difficulties that arise for production planning and control activities in remanufacturing is that the returned products are uncertain in terms of quantity and time. This uncertainty creates the need to balance demand and returned products. The need to balance return and demand rates complicates inventory management and control functions. It also affects the material management and resource planning functions. The disassembly process for returned products affects many causes considering production control, scheduling, material, and resource planning subjects. Also, uncertainty in the condition of the parts obtained after disassembly affects inventory control and purchasing activities. On the other hand, uncertainty due to quantity and quality criteria in returned products can cause uncertain processing times in disassembly, repair, and reassembly processes.

5. Conclusion

We discussed remanufacturing systems and their complexities concerning production planning and control concepts. The main and most important difficulty for planning and controlling activities in the remanufacturing systems is the uncertainty issue. There are many uncertain components in the remanufacturing systems, such as quantity, lead time, quality requirements, repair time, repair requirements, additional investment requirements, managing the system performance, and other decision-making requirements. So, the development of the methodologies that capture the uncertainty component and model of them is necessary for today's sustainable, competitive, and complex production systems. For future studies, researchers can be developed such models to improve the remanufacturing production system performances.

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