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Manufacturing and Remanufacturing Production Activities Together in the Same Production System

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Abstract: ***This is the time for manufacturers to consider performing remanufacturing production activities accompanying their existing manufacturing. Including remanufacturing, production system is significantly different from conventional manufacturing production system. Instead of single forward flow of material in conventional supply chain, system now contains two material flows, named conventional manufacturing flow sourcing from new materials, and recovery flow sourcing from end-of-use products returned back to the production system. Therefore, to use current conventional production planning models in remanufacturing /manufacturing production system (RMPS) is questionable, and the optimal structure of the production system is still need to be further explored. This research focuses on this two flows characteristic and the return process that occurred in RMPS. We recognize that return process of end-of-use products forms sort of cyclical, or looping process in the system, that product release and return affect each other, and have significant influence for system performance. For optimal production planning, a cyclic optimization approach is introduced here. The basic idea is to simultaneously consider the whole cyclical process in the system that caused by the return of end-of-use products, and allowing product release and return process to be treated as variables to be determined in generating optimal production plan. Besides remanufacturing and manufacturing production activities, disposing or sending excessive returned end-of-use parts (products) to material recycler are also carefully considered in production planning mechanism, along with all respective inventories. The result shows a superior optimality performance compared to conventional approach, as a merit that the whole cyclical process are now being included in optimal solution generation model.***

Keywords: Remanufacturing; Remanufacturing / manufacturing production system; Production planning; Cyclical process; Cyclic optimization approach

1. Introduction

A huge disposal activity of end-of-use products is becoming a major concern as demerit of rapid advancement in production industry and technology. This becomes a part of environmental considerations in industrial system, as major developed countries now start to implement such regulations for manufacturer to take -back and properly recover their products [1,6], and also increasing consumers' consciousness regarding environmental problems.

Ferrer [5] particularly addressed the emerging topic of Product Recovery Management, that stands for the management of all used and discarded products, components, and materials that fall under responsibility of a manufacturing company, under the objective of recovering as much of the economic (and ecological) value as reasonably possible.

This research is concerning remanufacturing as one form of product recovery management. As strengthened by Gungor and Gupta [12], remanufacture that recovers product in part or module level, is environmentally preferable than recycle, which recovers only the material contents of products.

For manufacturer, there lie a number of business opportunities in addition to environmental benefits of performing remanufacturing, such as: cheaper material sources, expand company's business by offering also remanufactured products, improve company's image, increase efficiency of distribution channels, opportunity to establish profitable sales-collection policy, benefit comes as a result of investment in product design phase, and technical comprehension of their products. Therefore, as one of competitive advantage in future, it would become the major homework for manufacturers to wisely manage the existence of manufacturing and remanufacturing production activities together in the same production system.

In this remanufacturing/manufacturing production system (RMPS), end-of-use product is returned to production system. Firstly, product is subjected to disassembly process, which will release its constituting parts into the following remanufacturing activities, i.e.: cleaning, repairing, refurbishing and testing, to bring parts back to the conditions as good as its new conditions. Then remanufactured parts are sent to the assembly stage, and together with new parts from manufacturing activities, build final products to serve the same market. Figure 1.1 graphically expresses RMPS.

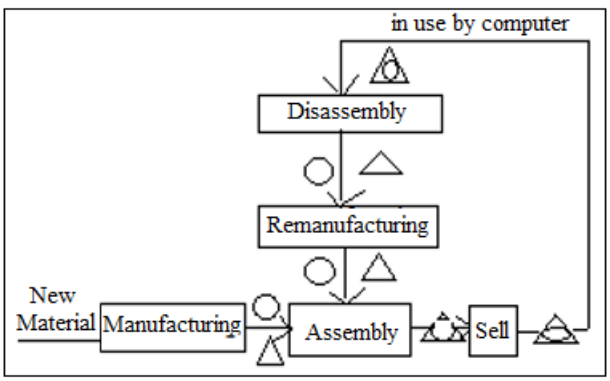


Figure 1.1: Graphical description of RMPS

Conventional flow means conventional manufacturing activities exist in system, sourcing on procurement of new

material from supplier, whereas recovery flow refers to remanufacturing and sourcing on return process of end-of use products.

In general, conventional flow consists of new raw material procurement, part manufacturing and assembly process, while recovery flow might consists disassembly, remanufacturing (including cleaning, repairing, refurbishing, testing) and the same assembly process as the one in conventional flow to build new final products using remanufactured as well as new parts.

Different from material procurement mode in conventional manufacturing flow, in recovery flow production materials are procured in the form of final product. Then it becomes the role of disassembly process to disassemble products and simultaneously release its constituting parts. However, demand of each part might be different, and requirements of part to be remanufactured may appear not proportional to the parts released by disassembly process. Disassembly products according to higher part requirement, will generate excessive inventory for part with lower requirement. In other side, performing disassembly according to part with lower requirement can generate shortage for part with higher requirement.

In RMPS environment, manufacturing itself can play a role as a balancer for this problem. It allows production system to keep returns not to be disassembled yet and rather to procure parts with higher requirement by manufacturing when holding returns as product is more cost efficient than holding it as disassembled part. A proper disposal mechanism is also worth to be considered as a way to balance production system, when inventory for certain parts become excessive and costly. However, this disposal mechanism is should be carefully considered simultaneously with company's & desires in remanufacturing products from ecological point of view.

Those significant characteristics show that for this emerging RMPS, conventional existing production planning models for manufacturing system cannot be directly employed and need to be further explored. As stated in following section, a number of research works have been performed to address production planning of RMPS. Our research is trying to explore the more optimal structure of RMPS and propose cyclic optimization approach for generating production plan that strengthen the consideration of cyclical process in the system due to return of end-of-use products.

2. Works on Production Planning for RMPS

Related to RMPS, remanufacturing itself has been addressed by a number of research works, such as ones concerning scheduling [8], capacity planning [9], disassembly [13,15], production planning [10,11], as well as current practices and view of remanufacturing [1, 2, 7]. Those researches contain a harmonious thoughts that remanufacturing processes posses more uncertainty in timing, quantity, and quality, compared to manufacturing.

Van der Laan et al. [18] propose inventory control strategy for RMPS. They distinguish two reorder points in inventory system which are remanufacturing order and manufacturing order. Manufacturing acts as a buffer when there is not enough remanufacturables to remanufacture due to its uncertainty. Following the previous research, in [17] Van der Laan and Salomon furnish their work by recognizing disposal option in the system, and put certain correlation between demand and return processes into consideration, that return process is potential to generate demand.

However, major simplification made in those researches, that system only has one module/part, makes difficulties in implementation of proposed strategy in real industry. It is possible though, to implement this model in downstream remanufacturing processes after returned products has already been disassembled. But the relation among parts in system does not have any room to be considered.

Clegg et al. [4] construct a linear programming production planning model for companies with remanufacturing capability. It allows existence of multi products and multi parts considerations in the system, also considering production capacity availabilities in the system. Disposal activity as one treatment for returned product/parts is covered also in the model. Then, all production activities are to be done to meet deterministic demand in production planning period. Determined returns value is also required in this model and completely independent from demand.

Relation that future return of end-of-use products is influenced by demands in the past production periods could be found in one done by Hoshino et al. [14]. Using goal programming, they particularly analyzed optimization performance of recycle-oriented manufacturing systems in two performance parameters, which are profit and recycling rate. In their model, a product return in certain periods is determined according to demand in past periods multiply collectable rate for each period after products being sold.

In works by Yura et al. [19], we can find also model using this approach of relation between demand and returns. The research itself is more concerning on part-mix analysis, and the production planning itself is simplified, where demands are assumed to be deterministic constant. Anyway in their production model, they had recognized the relation between demand and return, and mathematically replaced return process by collectable function of past demands.

Recent work by Chiyokura and Aihara [3] describes RMPS practices in real industry for product single-use camera in Fuji Corporation. And they explicitly mention the application of sales-return lead times distribution function that the company uses for determining number of products that will be returned back to company to be remanufactured.

3. Cyclic Optimization Approach for Production Planning in RMPS

In this research, it is strongly considered that return flow in the system will influence system performance due to the arrival of returned end-of-use products, needs to disassembly, remanufacture, dispose or send parts to material recycle and also respective inventories throughout the processes in recovery flow. Therefore, in optimal

structure of optimization model for production planning in RMPS, the real optimal production plan can be generated if return process of end-to-use is included in the model not merely as determined input, but rather as dynamic value to be generated, together with other production planning variables. Hence, the whole cyclical processes in RMPS can be covered in generation of optimal production plan.

Since return has certain relationship with product released to the consumer, setting returns of end-of-use products as variables also means setting the number of products released to the consumer as variables to be determined. Therefore, we rather use term "sales" as variable rather than directly use determined "demands" as the base for calculating returns.

By approaching the problem in this way, this research allows sales and returns to be considered as influencing variables in optimization mechanism to generate the optimal production plan. Below figures describe cyclic optimization approach being introduced in this research, and show how the production plan generated is supposed to be superior than the one generated by conventional approach.

Demand information itself will play a role in constraining sales as upper limit. Therefore, there will be no waste of excessive products in the market due to overproduced. Sales under demand in certain production periods will occur if selling equal to demand in the periods generates return process in future production periods that have negative impact on optimality performance of the whole system.

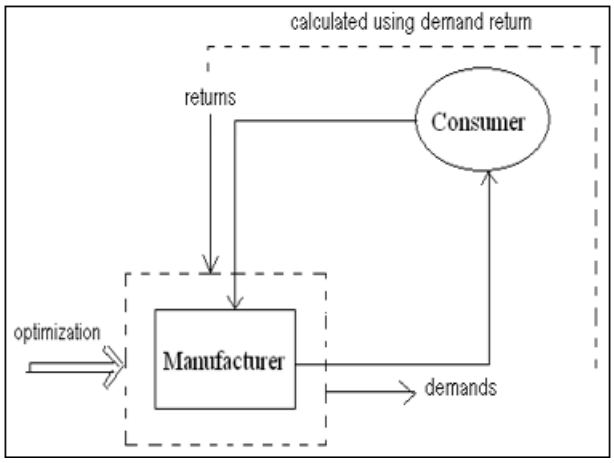


Figure 3.1: Conventional approach in production planning model for RMPS

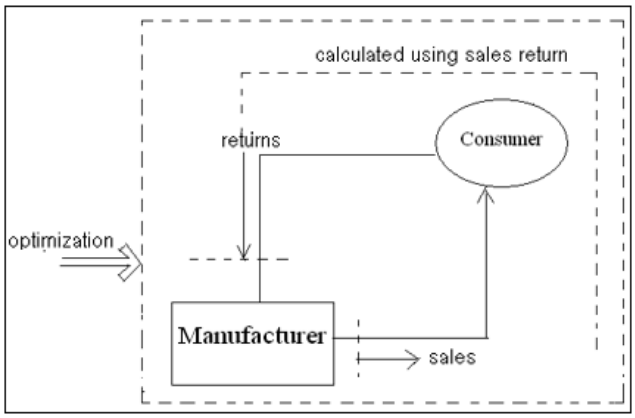


Figure 3.2: Cyclic optimization approach in production planning model for RMPS

4. Model Development

We consider the system is to be modeled to represent RMPS and its characteristics that have been described in introduction section as close as possible. Two flows, which are conventional flow and recovery flow are performed in producing products.

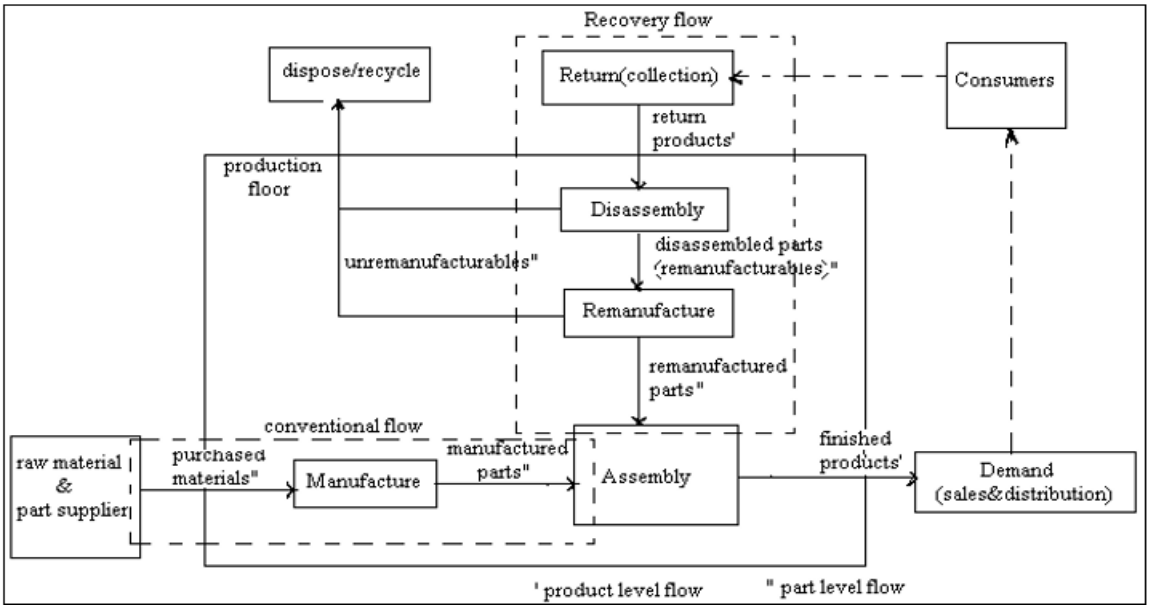


Figure 4.1: Graphical description of system

As shown in figure 4.1, products sold will return to production system, put into inventory of returns, and act as production material in recovery flow. Firstly, returned products are to be disassembled to release its constituting parts, and to be sent to inventory of disassembled parts. In order to achieve the most economically profitable production plan, disposal or sending disassembled parts to material recycle is allowed instead of remanufacturing them.

In remanufacturing process, due to highly variable condition of parts, some parts are assumed to be failed in quality to serve requirements of as new condition for remanufactured parts. Then the activity of disposal or sending disassembled parts to material recycle is also to be performed for those failed parts. Remanufactured parts are then kept in inventory point of remanufactured parts, to be together with manufactured (new) parts assembled to build final products. Meanwhile on the other side, conventional flow performs manufacturing operations to provide new parts to be assembled.

RMPS being examined produces multiple products that share some common parts. To be noted also that system has two production activities level, which are product level and part level. Activities to be subjected in product level are disassembly, assembly and sale. Meanwhile manufacturing and remanufacturing are to be performed in part level. Managing dependent part and inventory relations in system also triggers the need to explicitly model the inventory points. According to activities in both flows, we have five distinct inventory points, which are inventory of returned products, disassembled parts, remanufactured parts, manufactured parts and finished products. Considering that procurement / ordering of new raw material optimization problem has been addressed abundantly in conventional production planning or supply chain research, this research's model excludes the problem of material procurement, and therefore also omit the respective raw material inventory consideration.

5. Discussion and Conclusion

Obviously, high new material cost, high manufacturing cost, low collection cost, high disposal cost, low remanufacturing cost are preferable in RMPS.

The model developed could provide a decision analysis tool to improve RMPS performance, ex: cost structures, product structures, sales-collection policy, pricing, etc. Therefore, using this production planning model as the basic model in obtaining optimal production plan solution to be analyzed, there are opportunities to construct decision analysis or decision support system for RMPS.

Moreover, this research opens the room to integrate wider function of company to construct an integrated product recovery optimization method, which connect the RMPS with other company's element such as product design and innovation, marketing, etc.

Assumptions of given value for some parameters, particularly newly introduced parameters, which are sales return lead times distribution functions and remanufacturability rate also require a strong and reliable method in determining the values to be used as input in this production planning model.

Development of cyclic optimization model for stochastic production environment can also sharpen the applicability of the model considering the high rate of uncertainty in recovery flow.

For very high value products such as ships, aircrafts, high-scale machines, which are produced in low number of production, an integer solution searching mechanism is also a direction of development of production planning model for remanufacturing/manufacturing production system.

References

[1] Ayres, Robert, Gerald0 Ferrer and Tania van Leynseele : Eco-Efficiency,Asset Recovery and Remanufacturing, *European Management Journal* vol.15 No.5 pp.557-574,1997.
[2] Bras, Bert and Mark W. McIntosh: Product, process and organizational design for remanufacture - An overview research; *Robotics and Computer Integrated Manufachrring* 15 (1999) 167-178.
[3] Chiyokura, Mitsuhilo and Yasuhiro Aihara: Film with Lens Recycling oriented Production System; *Keiei sisutemu,* Vol. 9 No. 4, 1999.
[4] Clegg A., Williams W. and Uzoy R.: Production planning for companies with remanufacturing capability; *Proc I995 IEEE Int Symp on electronics and the environment* Orlando, FL: IEEE, 1995; 186-191.
[5] Ferrer G: *Product recovery management: industry practices and research issues;* working paper, INSEAD, 1996.
[6] Frankel, Carl: The Environment, *IEEESpectrum* January 1996.
[7] Gene, Bylinsky: Manufacturing for reuse, *Fortune* February 6, 1995.
[8] Guide Jr., V. Daniel R., Mark E. Kraus and Rajesh Srivastava: Scheduling policies for remanufacturing; *International Journal of Production Economics* 1997, Vol. 48 187-204.
[9] Guide Jr., V.D.R., R. Srivastava and M.S. Spencer: An evaluation of capacity planning techniques in a remanufacturing environment; *International Journal of Production Research* 1997, Vo1.35 no. I, 67-82.
[10] Guide Jr., V. Daniel R., Vaidyanathan Jayaraman and Rajesh Srivastava: Production planning and control for remanufacturing: a state-of-the-art survey, *Robotics and Computer Integrated Manufbcturing* 15 (1999) 22 1 -230.
[11] Guide Jr. and V. Daniel R: Production planning and control for remanufacturing: Industry practices and research needs, *Journal of' Operations Management* 18 (2000) 467-483.
[12] Gungor, Askiner and Surendra M. Gupta: Issues in environmentally conscious manufacturing and product recovery: a survey, *Computers & Industrial Engineering* 36 (I 999) 811-853.

[13] Gupta, S.M. and K. N. Taleb: Scheduling disassembly, *International JournalqfProduction Research,* 1994 Vol. 32, No.8, 1857-1866.
[14] Hoshino T., K. Yura and K. Hitomi: Optimization analysis for recycleoriented manufacturing systems *International Journal of Production Research* 1995 Vo1.33 No.8,2069-2078.
[15] Taleb, K.N. and Surendra M. Gupta: Disassembly of Multiple Product Structures, *Computer & Industrial Engineering* 1997 Vol. 32, No.4,949- 961.
[16] Uzsoy, Reha: Production Planning for Companies with Product Recovery and Remanufacturing Capability; Proc 1997 IEEE 285-290.
[17] Van der Laan, E.A. and Marc Salomon: Production planning and inventory control with remanufacturing and disposal; *European Journal of Operational Research* 102 (1 997) 264-278.
[18] Van der Laan, E.A., M. Fleischmann, R. Dekker and L.N van Wassenhove: Inventory control for joint manufacturing and remanufacturing in *Quantitative Models for Supply Chain Management,* Kluwer Academic Publishers, 1999
[19] Yura, Kenji, Hiroki Ishikura and Katsundo Hitomi: Partsmixanalysis in recycling- oriented manufacturing systems for multipleitem production; *International Journal ofl'roduction Research* 2000, Vol. 38 no. 2,447-456.