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Remanufacturing in Pearl River Delta Area China: Challenges and Opportunities

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Abstract *The promotion of remanufacturing for ecological and economical sustainable development lies in an effective and efficient recycling of materials, parts and components of end-of-life products. In this paper, a transverse and vertical analysis methodology is adopted to investigate the status quo of remanufacturing in Pearl River Delta Area (PRDA), one of the rapidest developing regions in China. For a transverse perspective, three industry sectors, i.e., furniture, household appliance and machine tool, are taken as examples to analyze the present situation of remanufacturing in PRDA. For a vertical perspective, strategic driven factors are discussed primarily from government legislation, enterprise motives and social environmental awareness. It is pointed out that the challenges of remanufacturing industry in PRDA are characterized not only by a greater and ever-increasing demand of products when reach their end-of-life, but also by the realization of landfill and the highly detrimental environmental impact of incineration. Since remanufacturing is at an early stage in PRDA, it is suggested that the objective of remanufacturing industry for PRDA should be set to dismantling-recycling-focused scenario, to improve material recycling rate.*

1. Introduction

Sustainable development is a crucial way to deal with the urgent problems of ever increasing resource exhaustion and environmental contamination. Remanufacturing, being defined as the process of bringing used old products to a like-new functional state, can benefit sustainable development from material and energy saving. Pearl River Delta Area (PRDA), one of top three economic regions in south China, has been seeing a rapid economical development in the last three decades. However this great achievements was at the cost of over energy and material consumption, environmental pollutions. So far, discarded products has accumulated to a huge quantity. Simultaneously, it is estimated that more and more products will enter their end-of-life phase in the years to come. Remanufacturing has been regarded as powerful tool to alleviate the situation.In this paper a investigation is presented to analyze the challenges of PRDA

remanufacturing engineering and to gain some insights, and to find opportunities to implement it in PRDA effectively.

2. Literature review and methodology

2.1 Literature review

Literature of remanufacturing engineering can roughly classified into two categories: analyzing factors and cases studies in industries.

(1)Factor analysis of remanufacturing

Dowlatshahi (2005) identified strategies factors and presented a comprehensive implementation framework for remanufacturing. Five strategic factors are costs, quality, customer service, environmental awareness and political or legal concerns. Barquet (2013) provided a integrated view of remanufacturing system and analyzed internal, external processes and their interactions and dependences and little analysis were concerned of implementation of remanufacturing. Fukushige (2012) studied product lifecycle design strategies at early stage of lifecycle design. The elements of lifecycle scenario include objective, concept, options, flow and situation(W5H1) which can be revised to remanufacturing engineering. Barquet (2013) viewed the remanufacturing as a system and presented an integrated vision of remanufacturing to gain a better understanding of remanufacturing. The author identified the importance of acquisition or relationship with the core supplier. however difficulties and barriers are not covered when companies adopting the concept. Sundin (2013) discussed the challenges of reverse logistics faced by independent small and middle-sized enterprises(SMEs) in remanufacturing automotive devices. The future difficulties include the handling, transportation and storing of cores. Wang et al (2013) studied the recycling problem for used automotive electronic control components in China, using electronic control unit as an example to evaluate success probability of remanufacturing. This investigation is expected to expand to identify bottleneck of collecting process and dismantling process in PRDA. Subramoniam (2013) presented a remanufacturing decision-making framework, Since major strategic factors were included in this comprehensive framework, it helps to make effective decisions earlier in the conceptual stage of remanufacturing engineering.

(2) Industry cases of remanufacturing

While the objective of most literatures addressing industrial cases is set to evaluate certain remanufacturing solutions, valuable information or facts about remanufacturing cases can also be observed. Du (2014) studied a so-called solution-based, OEM-based remanufacturing model which also presented valuable case of production line level implementation paradigm. Dowlatshahi (2005)

presented two industrial cases, one is an automobile electronic components company and the other is a medical manufacturer company. However, the two companies are all limited to OEM inner business. Matsumoto (2011) presented four excellent remanufacturing case studies in Japan and compared OEMs' remanufacturing to independent party remanufacturing. Featured of high-techs, the cases are not fitting well with PRDA products of big volume and lower value. Felix (2008) conducted a questionnaire survey study of recycling mobile phones in Hong Kong and suggested mobile phones unsuitable to implement remanufacturing. How to deal with those "lower level" mobile phones was left unanswered. In fact, old or unused mobile phones makes up a noticeable parts of WEEE in PRDA. Hatcher (2013) case study turned to electrical and electronic equipment manufacturing industry in China. The authors thought Chinese OEMs would be more relevant to design for remanufacturing. Similar to Felix (2008), the authors suggested that "electrical and electronic products are not presently highly suited to the remanufacturing process". Still, how to deal with those e-waste was not answered.

2.2 Methodology

This research intends to provide an understanding of challenging factors affecting remanufacturing engineering in PRDA. To gain this objective, a holistic view, integrating transverse and vertical analysis, contributes to provide further understanding of the current ongoing situation. As shown as fig 1, transverse investigation refers to different parallel independent industrial sectors engaged in remanufacturing engineering and vertical analysis refers to factors of evaluating feasibility, availability, sustainability and so forth. Used furniture, household electrical appliances, and machine tools are taken as sector examples for transverse investigation. Governmental regulations, economic benefit, social and customer awareness are selected as factors in vertical analysis.

3. Transverse and vertical perspective analysis

3.1 Transverse industry sector investigation

(1) Furniture remanufacturing

PRDA is one largest furniture manufacturing base in south China. It is estimated that there are over 8000 furniture manufacturing firms in PRDA, employing 130 million labors and manufacturing 129,25 million pieces in 2012, 19.75% of China. Even some small towns in PRDA have a very huge manufacturing capability. For example Lecong, a small town in Foshan city of PRDA is one biggest furniture market in south China, seeing a 3450 furniture stores. Great quantities of

throughout implies great quantities of old or used products. Supposing average 5% end-of-life furniture, the end-of-life furniture can reach to 6.4 million pieces.

Huge quantity of old or failed furniture attributes to crowded population of PRDA. About 100 million population lived in PRDA in 2013, it implies huge quantities of furniture, and also, huge quantities of end-of-life furniture. Fashion is becoming an obvious factor to increasing the number of old furniture, to much extent alike cloth manufacturing in PRDA. Because of comparative simple processing and lower precision, upgrading occurs very fast in this industrial sector, also resulting quantity furniture out of use.

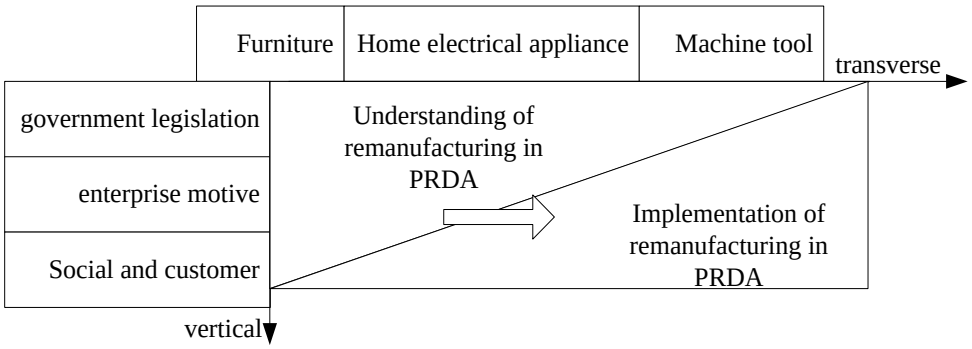

Fig. 1 transverse and vertical analysis methodology

Ideally, a complete remanufacturing for furniture will be as follows: (a) old or failed furniture are collected from owners and delivered to remanufactures (Original Equipment Manufacturer or independent third-party). (b) the returned furniture dismantled to wood board, metal, glass, cloth, foam, and waste. Wood board can be used to producing new furniture. metal and glass can be sorted and reused respectively. Cloth and foam can be used to make such recycle products as mops. (c) Little was left as waste to landfill.

In fact, furniture remanufacturing in PRDA are far from a complete scenario. Firstly, the residual value of old furniture is too lower to be remanufactured. Medium Density Fiberboard(MDF) is main and popular material of making furniture. Because of inner structure and processing method, MDF's waterproofing attribute deteriorate seriously at the end of life, often resulting in broken, soften, layering, swelling or carbonization faults. Often, MDF can be shredded and then used to remanufacture MDF. Secondly, old furniture is not feasible for remanufacturing since its higher collecting cost. Granted, the used furniture is in a good condition, large volume of old furniture makes it difficult to remove from inner house of tall

building by hand. More labors and vehicle are needed for moving, uploading and unloading. Lower residual value combining with higher collecting cost makes old furniture less attractive. In many cases in PRDA, old furniture's residual value drops to negative, which means it is the old furniture owners duty who pay for the logistic cost, regardless of old furniture.

An interesting phenomena is that second hand furniture market is supported by capable of old furniture. That is to say, remanufacturing here only concerns minor repairing operations(such as cleaning, painting, replacement simple parts et al) on the old one. Often old furniture here will not cover whole reverse supply chain, but reach market by a "swallow bridge" between forward- and reverse-supply chain, shown in Fig.2. The value of this kind remanufacturing lies in old or used furniture's relatively good condition and short circuiting in the closed supply chain.

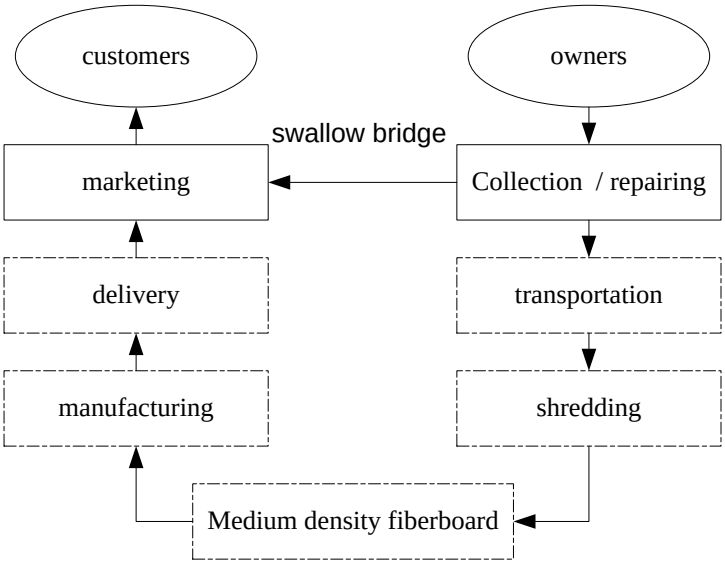

Fig. 2 Furniture recycling in PRDA

The problem in furniture remanufacturing is that disassembly and sorting can not reach good level. Too much waste have been produced. Landfill these waste means consumption resource, incinerate it cause environment pollution.

(2) Household electrical appliance remanufacturing

In 2006, the number of household electrical appliance in PRDA including TV set, refrigerator, washing machine, air-conditioner, home PC has reach to about 150 million pieces. Supposing a 10 years average life span for a item, there are 1.2 million each year out of use. General waste electrical and electronic

equipment(WEEE) constitutes 8% of municipal waster in west countries, this number in PRDA is believed to be higher since many household appliance has enter their end-of-life period. Materials in electrical and electronic equipment are made up of nearly 50% iron and steel, 21% plastic, approximately 13% no-ferrous metal of the total weight [Rolf Widmera, Heidi Oswald-Krapfa, et.al,2005]. If remanufactured successfully, the absolute terms of huge amount of used appliance could lead to huge material saving, energy saving, it is thought as a "hidden huge mineral in metropolis".

In PRDA, a fraction of used, proper functional household electrical appliance as second hand commodities, are sent to sell in rural region market. Majority of used items were recycled as waste. With rapid economic development, second hand household electrical appliance are diminishing in rural areas. Plenty of old appliances nowadays has become a serious impact on PRDA environment.

Nevertheless, those WEEE are not landfilled or incinerated directly in PRDA. On the contrary, dismantling WEEE is profitable and many people are engaged in. An extreme example is Guiyu, a small town with 152,000 population in PRDA, owns 5169 firms and 60,000 employees engaging dismantling electrical wastes. The profit derivates from precious metal extracted from used electrical components. Comparing to only 0.002kg gold from 1000kg ore, it is reported that 130kg copper, 0.5kg gold, 58kg mercury, 24.6kg chromium and 340kg arsenic can be extracted from 1000kg electrical wastes. In fact, great economic benefits from dismantling e-waste has turned some cities and towns one important destination for importing so call e-waster from overseas.

Household electrical appliance dismantling in PRDA are characterized by plenty of family firms and roughly extracting process. Besides of economic benefits, one advantage of this scenario is it provides a plenty of job opportunity since much of this dismantle are manual work. However, primitive processing of harmful heavy metal has caused a very serious problems, not only to environmental pollution but also to dismantling workers.

Contrary to such small family firms and primitive recycling methods, several manufacturing companies built advanced automatic production line to dismantle old/used appliances. Although the imposing benefits being recognized, exploring this huge mineral mountain has been reported " uneven". The hub problem is that they can not get enough old appliances. One reason is that the designed throughout is inappropriate higher, another reason is that they are often in a inferior position when competing with family firms, which do not strictly comply to government remanufacturing laws and regulations.

(3) Machine tool remanufacturing

PRDA has three earliest opening cities three decades ago and has become one important world factory. It is estimated that PRDA have 18.3% of China machine

tools. Considering there are 8,000,000 machine tools in service in China and about 50% of that have been over 10 years duration, quantities of machine tools are now out of date and entering recycling period.

In fact many companies in PRDA have engaged in collecting out of date machine tools for a long time. In comparison to furniture recycling firms or household electrical appliance firm, however, the number of recycling machine tool firms is less because of (a) machine tool is technology-intense and (b) machine is a volume large making it difficult to transfer.

Most remanufacturing in PRDA has a close relationship with OEMs. Often, remanufacturing originates from OEM's after-sail service of maintenance and repairing. Machine tool manufacturing firms has seldom set up independent remanufacturing departments so far. Usually remanufacturing is affiliated to maintenance or repair departments. For lack of remanufacturing technology, documental specifications, advanced repairing technology and other costs, the objective for machine tool remanufacturing is set to recover its original function. Seldom are the goals to improve performance such as manufacturing precision. Usually, old machine tools are sold as waste.

Manufacturing industry is greatly influenced by PRDA's economic development mode. Machine tools are generally used to manufacture exported products. Since world financial crisis in 2008, many manufacturing factories are facing fewer oversea order. A number of middle and small factories have shrunk outputs, some even shut down. Plenty of second hand machine tools are sold in market with a unbelievable price. Plenty of old machine tools promise a good foundation for remanufacturing in PRDA.

3.2 Vertical factors analysis

(1) Government regulations and impetus

Chinese central government has paid more and more attention to the remanufacturing engineering recent years and has legislated several important law to promote remanufacturing. The fortieth provision of "Circular Economy Promotion Law of the People's Republic of China", implemented in January 2009, stated clearly that remanufacturing is supported by state. On the heel of it, the document “Promote the Healthy Development of Remanufacturing Industry”, jointly issued by eleven central government departments on May 13,2010, signified the importance of remanufacturing. China has implemented legislation "Regulation of collecting and disposal of electrical and electronic equipment" on January 2011 with the intention of reducing e-waste. "Pearl River Delta Area Reform and Development Plan(2008-2020)", a special national strategy plan for PRDA stated that PRDA will upgrade traditional development mode to a recycling, sustainable development

mode. As for Canton province government of PRDA, remanufacturing engineering has been identified as key technology for recycling economic development. Compliance with the recycling regulatory for each industry is a must with regard to remanufactured products. And extended producer responsibility(EPR) will be adopted in coming regulations.

However, comparing to other regions in China, Guangdong local government regulations and documents for PRDA remanufacturing engineering are staying in a planning level. Detailed regulations to support remanufacturing industry needed to be worked out. A further problem is that regulations concerned remanufacturing engineering are not implemented well in practice.

(2) Enterprise interest and constraints

Numerous companies have realized that remanufacturing are not only economic profitable but also helpful to maintain a favorable social image. To implement remanufacturing, a in-depth understanding of remanufacturing is critical. The relationship of remanufactured products and virgin products should be balanced with regard to business operation. For OEMs EPR, remanufacturing cuts across several functional departments within a company, it is a hard work to collaborate such as sale, logistics, maintenance, manufacturing, marketing departments to a profitable remanufacturing engineering.

So far two constraints should be considered. one is of accessibility of old products. the other is innovation. (a)It sounds ironical that automatic dismantling lines are at an unfavourable position in competing with manual dismantling small firms. Considering huge quantity of old products in PRDA , modern dismantling lines advantages are their efficient productivity. However, small and middle dismantling firms advantages are their agile or even Illegal ways of collecting old or used products. To keep running industrialized dismantling production line necessitates a continuously enough old products to feed. The logistic channel for old products should be guaranteed, whether integrated into virgin products supply chain or built a new one. In fact, it was reported in PRDA that some remanufacturing companies can not afford get enough old or used products to feed up remanufacturing production line, resulting a difficult to keep the lines operating. (b)As for innovation constraint, its importance depends on a recent factor and a long term factor. Recent factor is due to labor cost increasing quickly, tools and techniques should be developed to substitute labor. Long term is due to lower utilization rate of old product. Design for remanufacturing is a promising innovation to explore higher values from the old products.

(3) Social and customers awareness

Social awareness is increasing not only from discarded products environmental pollution. When extracting a fraction useful material from old products, hazardous waste are discharged carelessly and large remains are disposed of with landfill or

incineration, which have a highly detrimental environmental impact. On the other hand, consumer acceptance of remanufactured product are generally relative lower, which is a negative factor to develop remanufacturing engineering.

4 Discussion and suggestions

4.1 Discussion

(1) Characteristics of PRDA remanufacturing

From the three industry sector cases, a comparison is given in tab.1. Firstly, vast number of extant old or used products provides a good "raw material" input for remanufacturing engineering. (b)Secondly, remanufacturing engineering in PRDA is at its earlier stage as far as modernization is concerned. As a labor intensive sector similar to western developed countries, but the operation of dismantling and sorting is inferior, rough dismantling resulting in huge loss of potential residual value in the returned products. (c)Thirdly, contrary to general viewpoint of remanufacturing engineering as a green business, remanufacturing engineering are partly responsible for environmental problem, to a great extent, due to rough dismantling old products, especially by electrical old printed circuit board.

Tab.1 comparison and characteristics of three remanufacturing sectors

	furniture	household electrical appliance	machine tool
quantity in service	huge	huge	huge
quantity of old	huge	huge	huge
customer/owner	discarded	discarded or idle	idle
residual value	little/negative	lower	high
collector	uninterested	interested	interested
dismantler	uninterested	extract expensive metals	retrofit
dismantle process	manual	manual	manual
negative impact	waste	waste and detrimental	idle machines

(2) Advantages and tendency of PRDA remanufacturing

Advantages of remanufacturing engineering in PRDA are quantities and lower prices of old products. However, remanufacturing engineering now are driven merely by economic factor, neglecting social and environmental factors. This disadvantage situation is changing with upgrading and adjusting industry by local government which has set out orders, policies, guideline, projects to promote recycling economics. Meanwhile more and more companies are engaging to remanufacturing. At its very beginning stage, the main form of remanufacturing engineering today in PRDA is of material retrieval scenario which is shown in Fig.3.

Improving recycling material rate is of great importance in PRDA. Therefore, emphasis should be placed on the dismantling depth and width.

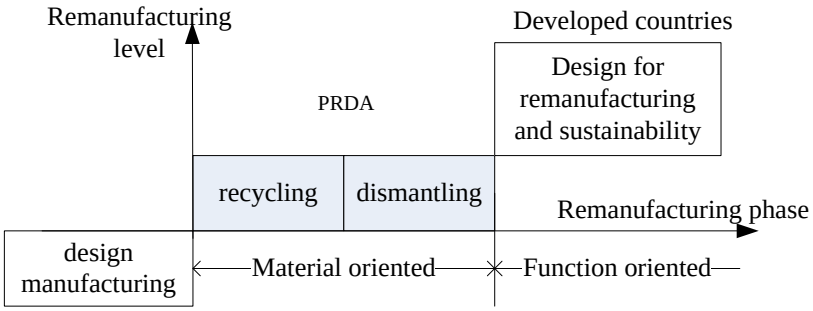

Fig.3 The tendency of remanufacturing

4.2 Suggestions: Breaking through from mechanical OEM

Since detailed specifications for a discrete remanufactured product has not yet been laid down in China, remanufactured products are regarded as inferior to new products. Although remanufactured product has the price advantage over new products, it is difficult to convince customers the remanufactured products quality. Our suggestion is remanufacturing engineering in PRDA should be firstly implemented in mechanical industry. And a proactive approach for OEM to implement remanufacturing engineering is directly oriented to end user's end product. This would benefit both remanufactures and customers. For OEM remanufactures, this kind would help them to accumulate experience of remanufacturing and free from the problem of customer's less attractiveness of remanufactured products. For customers, this kind would help them to get a remanufactured product with superior quality and performance, but at a lower price. The collaboration of OEM and end-user is critical for both sides. Since the remanufacturing engineering is driven by government and society, and since resource exhausting and energy consuming make cost increase rapidly, manufacturer should be proactive rather than reactive to take part in the manufacturing engineering.

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