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The Remanufacturing Industry and Its Development Strategy in China

Xu Binshi[1], Li Enzhong[1], Zheng Handong[1,2], Sang Fan[1], Shi Peijing[1]

1. National Key Laboratory for Remanufacturing, Army Academy of Armored Forces, Beijing 100072, China
2. School of Management, Hefei University of Technology, Hefei 230009, China

Abstract: The remanufacturing industry is an extension of the industrial chain in the manufacturing industry and plays an important role in advanced and green manufacturing. The *Made in China 2025* strategy proposes that China will "develop the remanufacturing industry vigorously, implement high-end remanufacturing, intelligent remanufacturing, and in-service remanufacturing." The remanufacturing industry in China is developing rapidly, and the remanufacturing pilot enterprises and number of types of remanufactured products are growing exponentially. Moreover, remanufacturing policies and regulations, basic theories, key technologies, and industrial standards are constantly innovated and completed. The future development of remanufacturing engineering in China is heading in a green, high-quality, high-efficiency, intelligent, and service-oriented direction and will focus on developing several key remanufacturing technologies, improving multiple supporting systems, and building many leading industries.
Keywords: green manufacturing; remanufacturing; development strategy

1 Introduction

The report of the 18th National Congress of the Communist Party of China highlights the "ecological civilization construction," emphasizing on "developing a recycling economy, improving the efficiency of resource recycling and utilization, building a green manufacturing system and following the path of ecological civilization." *Made in China 2025* proposes to adhere to the green development. The implementation of green manufacturing is conducive to the transformation and upgrading of key manufacturing initiatives [1]. Remanufacturing is the development and extension of green manufacturing for the entire lifecycle, which is crucial for the development of circular economy and efficient use of resources. The remanufacturing industry, dominated by electromechanical products, corresponds to the characteristics of a new type of industrialization such as "high technology content, good economic returns, low resource consumption, and less environmental pollution," and the development of remanufacturing industries is conducive to the formation of a new economic growth point. It will become a a major breakthrough in upgrading and transformation of the "Made in China" strategy [2,3].

Remanufacturing has garnered significant attention from government and corporate because of its significant economic, social, and environmental benefits. Premier Li Keqiang proposed the principle of "pushing forward the recycle and remanufacturing of waste materials and electromechanical products in an orderly manner, focusing on the quality control of remanufacturing, and perfecting the recycling logistics system for remanufacturing" [4]. *The 13th Five-Year Strategic Emerging Industry Development Plan* and *the 13th Five-Year Plan for Energy-Saving and Environmental Protection Industry* will, respectively, include remanufacturing in the national strategic emerging industries and energy-saving and environmental protection industries. In the new policy context, the remanufacturing industry will generate significant opportunities for development.

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Corresponding author: Xu Binshi, Army Academy of Armored Forces, Professor; Chinese Academy of Engineering, Academician. Major research field is remanufacturing engineering. E-mail: xubinshi@vip.sina.com
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2 Development of the green remanufacturing industry in China

The number of remanufacturing pilot enterprises and remanufacturing industry demonstration bases in China have been gradually increasing. In the meantime, the government promoted the certification of remanufacturing products and developed the "trade for another" policy [5]. In 2012, China proposed the implementation of the remanufacturing industrialization demonstration project for promoting the large-scale development of the remanufacturing industry by establishing the remanufacturing engineering (technology) research center, particularly some industrial agglomeration areas and major demonstration projects. The National Development and Reform Commission and the Ministry of Industry and Information Technology of the People's Republic of China have developed a pilot program for remanufacturing enterprises for identifying remanufactured products, market access requirements, quality control requirements, formulation of technical standards, circulation regulation, and construction of reverse logistics system experience.

From 2011 to 2016, the Ministry of Industry and Information Technology commissioned a third-party accreditation body for certifying the products of the applicants and released six batches of *Remanufactured Products Catalogs*. The catalog covers engineering machinery, electric motors, office equipment, petroleum machinery, machine tools, mining machinery, internal combustion engines, rail vehicles, auto parts, and other 10 categories of 137 types of products. At the end of 2016, China's remanufacturing pilot enterprises had already reached to 140, established five remanufacturing industry clusters, including Liuyang (Hunan), and three industrial demonstration bases, such as Shanghai Lingang. Among these 140 remanufacturing pilot enterprises, 62 are in East China accounting for 44%; 25 in Central China accounting for 18%; 15, 14, and 10 in North China, Northeast China, and South China, respectively; some in Southwest China and Northwest China. Among them, the largest share is by state-owned and private-owned enterprises that accounted for 40% of these pilot enterprises, followed by Sino-foreign joint ventures and wholly foreign-owned enterprises.

3 Opportunities and challenges in developing the green remanufacturing industry

3.1 Opportunities

3.1.1 The huge demand for the remanufacturing industry provides a strong impetus

Since the reform and opening up, China's economy and society have witnessed a rapid development, and the industrialization level has been continuously improved. In addition, industrial machinery and equipment have led to a period of rapid development. Since the beginning of the 21st century, the conventional industrial equipment has developed rapidly with many holdings. The number of high value-added equipment such as large ships, aircraft, and shield machines has rapidly increased. Moreover, a large number of mechanical equipment and electronic equipment reached the retirement peak. We considered only cars and machine tools: there are more than one million units of scrapped cars and machine tools every year; thus, the efficient recycling of used products is increasingly important; high value-added equipment performance gradually lagged behind, which required urgent upgrading. The conventional system of recycling–smelting–casting–manufacturing and recycling methods adopted for discarded electromechanical products is risky, because it does use the full value and causes huge waste of resources and energy with serious environmental pollution, which needs to be solved. Waste from electrical and mechanical products, which provides adequate "raw materials" for the remanufacturing industry, is processed in remanufacturing. However, it requires higher-scale requirements of the remanufacturing industry. A huge demand for the remanufacturing industry in China provides a strong driving force for its development.

3.1.2 The support of vigorous policy for the remanufacturing industry provides a strong assurance

Policy support is an important assurance for industrial development. In response to the increasingly grave problems of resources and environment, the Chinese government considers remanufacturing as a priority area for development and actively promotes the remanufacturing industry by formulating relevant policies and regulations. The implementation of *People's Republic of China Circular Economy Promotion Law* in January 2009 elucidates that the state supports enterprises to open exhibition, and then manufacturing, thus promoting the development of the remanufacturing industry into the legal track. At the implementation level, relevant state ministries and commissions have provided policy preferences in terms of finance, taxation, and markets for driving the overall development of China's remanufacturing industry through the key support to the domestic high-quality remanufacturing enterprises. Among them, the National Development and Reform Commission initiated organizing the work of "trade for another" for promoting the production and sales of remanufactured products and consumers' acceptance of remanufactured products. Under the guidance of the government departments, the policies and regulations on remanufacturing in China have been continuously improved, providing a strong assurance for the rapid development of remanufacturing.

3.1.3 The developing national major strategy has provided a wide scope for developing the remanufacturing industry

Since the 18th CPC National Congress, China's economy has entered an important transition period. China has successively launched major national strategies such as the "Silk Road Economic Belt" and "21st Century Maritime Silk Road". Building

the "Silk Road Economic Belt," and the "21st Century Maritime Silk Road" is an important strategic concept, which China has proposed under the constantly changing political, economic, and trade situations in the world, with the aim of strengthening China's cooperation with South Asia, ASEAN, West Asia, North Africa, etc. regional economic and trade ties to enhance China's strategic security. The implementation of the "Belt and Road Initiative" will greatly promote the infrastructure construction in the southwestern and southeastern coastal areas of China. Many mechanical and electrical products, including railways, highways, oil, shipping, and communications facilities, will lead to an extensive development, which provides a broad space for developing in-service remanufacturing, high-end remanufacturing, and intelligent remanufacturing in China.

3.1.4 The ever-changing new technological breakthroughs provide important support for the development of the remanufacturing industry

Since the beginning of the new century, the rapid development of computer technology has created many high and new technologies, such as "Internet plus," Big Data, and cloud computing, and accelerated the breakthroughs in high-tech fields, such as artificial intelligence, nanotechnology, and additive manufacturing (3D printing). The Internet technology provides the basis for strengthening the planning of the remanufacturing system and perfecting the remanufacturing of reverse logistics system, and is expected to solve the technical problems of reverse logistics of waste electromechanical products' recycling. Big Data and cloud computing technologies provide handy tools for the health monitoring and life assessment of remanufactured products, thus driving a breakthrough in these products. Technologies such as artificial intelligence, nanotechnology, and 3D printing additive manufacturing further improve the production efficiency of the remanufacturing industry and ensure the quality of the remanufactured products. The advent of a series of high-tech technologies provides an important support to improve the remanufacturing industry chain, enrich the means of remanufacturing, and enhance the quality of the remanufactured products.

3.2 Challenges

3.2.1 The overall size of China's remanufacturing industry and its backward development environment

Compared with the developed countries, the remanufacturing industry of China is in the initial stage of development. The industrial scale is less than 100 billion yuan and the number of large-scale remanufacturing enterprises is small. The independent R&D capability and production capacity of the remanufacturing technology of enterprises are lagging. Remanufacturing industries in developed countries, such as Europe and the United States, have formed a comprehensive manufacturing system and market environment with large industries. In the United States, the scale of its domestic remanufacturing industry has reached over hundreds of billions of U.S. dollars. Some world-renowned large-scale manufacturing enterprises have set up their remanufacturing production lines. In addition, remanufacturing companies in the United States have invested heavily in R&D to match their domestic remanufacturing needs.

3.2.2 The imperfect supporting policies and regulations and industrial chain in the remanufacturing industry

First, all localities lacked the overall consideration about the remanufacturing industry development. When formulating the industrial structure development plan, relevant departments did not consider the demand for remanufacturing for the sustainable development of the manufacturing industry. The progress and direction of remanufacturing development are different. Local governments and enterprises between the development plan do not converge, resulting in conflicts. Second, the lack of market access and evaluation mechanisms led to substandard refurbished products posing as remanufactured products into the after-sales service market, which affected the formal remanufactured product sales and prevented the real remanufacturers from exposing to a market competitive advantage, leading to market turmoil. Third, the remanufacturing standard is not comprehensive. Owing to the lack of relevant standards and norms, most enterprises fail to establish the corresponding quality control system in the key parts of the old parts testing and remanufacturing the blank repair. Consequently, the quality of the remanufactured products lacks scientific guarantee [6].

3.2.3 Technological development is difficult to meet the diversified needs of the remanufactured products

There are many types of mechanical and electrical products, with varied service conditions and different damage situations; remanufacturing technology has high requirements; thus, remanufacturing is needed to make recovery and performance improvement of mechanical and electrical products. A significant progress has been observed in the remanufacturing technology in China, particularly in automation and intelligent remanufacturing technology. However, the studies on the remanufacturing technology in China mainly focus on the research and development of scientific research institutions with the government investment and of scientific research institutions. Weak ability and lack of effective R&D results based on customer needs make it difficult for enterprises to meet the diversified needs of the remanufactured products in the market.

3.2.4 All sectors of society, particularly users, are not highly accredited with remanufactured products

At the social level, remanufacturing as a new concept is not yet widely recognized by the consumers and society. Many domestic consumers are skeptical to accept and use remanufactured products. Some even regard remanufactured products as

"second-hand products." This is attributed to the current lack of positive publicity on remanufacturing and long-term consumer attitudes. In addition, owing to the lack of market cultivation, the sales channels for remanufactured products are not yet fully established, thereby affecting the enterprises involved in remanufacturing [6].

At the enterprise level, the concepts of remanufacturing, manufacturing, and maintenance are unclear. In addition, the concepts and relationship of remanufacturing, manufacturing, and maintenance are not clear yet. Some enterprises remanufacture directly by copying the manufacturing mode, such as simply repair. This type of misleading caused inaccurate positioning and goals in guiding the practice of production. Second, enterprises cannot effectively handle the relationship between new product production and old product remanufacturing, and just simply copy foreign technology without analyzing factors such as situations of the old products, and sales channels. Instead, they should develop remanufacturing with Chinese characteristics based on mature technologies Third, some enterprises lack remanufacturing professionals, technical personnel, equipment, remanufacturing market cultivation, and other basic conditions, which makes it hard to [6].

4 The development trend of the green remanufacturing industry

In recent years, the rapid development of the remanufacturing industry and remanufacturing of key technologies have made important breakthroughs in research and development, gradually formed to life assessment technology, composite surface engineering technology, nano-surface technology, and automated surface technology, which can be used as the core remanufacturing of the key technology group. In the upcoming 15 years, under the dual promotion of policy support and market development, the remanufacturing industry is predicted to develop in the five directions of "green, high quality, high efficiency, intelligence, and service" [6].

4.1 Green

The discarded electromechanical products is the core of remanufacturing spare parts. It requires less energy and resource requirements with less environmental impact for the production of rough blanks, preparation of thinner wear-resistant, corrosion-resistant, anti-fatigue surface coatings on the surface of damaged parts, with resources and environmental benefits. Compared with the manufacturing of new products, remanufacturing, recycling, dismantling, and cleaning processes will produce waste water, waste gas, off scum, and other wastes; the national environmental standards should be strictly followed to promote green production.

4.2 High quality

The future of the remanufacturing technology will reflect the characteristics of high quality, including advanced remanufacturing design technology, remanufacturing of blank life assessment technology, composite surface engineering technology, and intelligent remanufacturing technology. In addition, high-quality technology group will be applied in large-scale research and development. Furthermore, remanufactured products and services will be of high quality and reliable. The remanufacturing industry is a full process-oriented industry from the technical, product, and service dimensions, which aims to achieve high-quality development.

4.3 Efficient

The efficiency of remanufacturing is mainly reflected in technology and industry services. In the area of dismantling technology, the automatic depth-dismantling equipment will significantly improve the efficiency of remanufacturing disassembly; in the aspect of cleaning, the cleaning equipment based on the technologies of ultrasonic, laser, ultraviolet, and high-speed jet can significantly improve the cleaning efficiency of the remanufactured blank. In the forming process, the flexible remanufacturing equipment based on computer control and robot operation can quickly generate remanufacturing reparation programs according to the damage types and characteristics of remanufactured blanks for obtaining high-efficiency remanufacturing [7,8]. In addition, owing to the rapid development of information technology and communication technology, remanufacturing industry services have become more efficient. In the eras of Internet of Things, cloud computing, and Big Data, remanufacturing can provide customers with fast and efficient product solutions, reduce customer time costs, significantly improve product remanufacturing rate, and maximize product efficiency.

4.4 Intelligent

Intelligent remanufacturing is based on the product lifecycle design and management as a guide, integrates the Internet, Big Data, and other new-generation information technology with links such as remanufacturing recycling, production, sales, management, and service, and performs analysis, planning, control, and decision-making through man-machine integration, man-machine interaction and other integrated approaches. In the key remanufacturing process, intelligent remanufacturing technology which is as the core, and Netcom interconnection, which is the support can effectively improve product quality, reduce production energy consumption, and enhance remanufacturing efficiency. It is of great significance for promoting remanufacturing industry upgrading.

4.5 Service

Machinery manufacturing enterprises in developed countries have already shifted from manufacturing to service-oriented manufacturing. While focusing on the development of product design and manufacturing technologies, development of supporting technologies for manufacturing services is emphasized. Advanced service model has accrued higher profits than product production and sales. In the future, China's equipment manufacturing industry is likely to shift from manufacturing to service-oriented manufacturing. Service-oriented manufacturing technology will likely be an important part of the mechanical engineering technology. The mechanical engineering technology, which serves the second half of the product, will attract more attention and invest more manpower and capital. A batch of new mechanical engineering technologies are likely to emerge and prompt the emergence of a new format of the machinery industry.

5 Green remanufacturing industry development strategy

5.1 Recent development strategy

This industry will focus on further promoting the application of the remanufacturing technology and equipment, enhancing the remanufacturing capabilities of enterprises, and encouraging the integration of production, study and research, and continue to promote and apply a batch of core remanufacturing technologies and equipment in remanufacturing enterprises. Moreover, accelerating the R&D and application of remanufactured complete sets of equipment and encouraging capable enterprises to explore the construction of automated remanufacturing product lines is essential. Support the establishment of specialized recycling of old pieces, cleaning, spare parts manufacturing, parts testing, and remanufacturing products sales enterprises. Encourage third-party logistics enterprises and professional testing organizations to conduct remanufacturing-related businesses, give attention to the advantages of specialized enterprises, explore old-for-releasing, financial leasing, rental repurchase, and other old parts recycling mode, and establish a stable reverse recovery logistics system for old parts. Remanufacturing products need to expand sales channels [9]. For precision and complex complete equipment, key components are mainly remanufactured by contract outsourcing; collaborative manufacturing in the industrial chain, which is developed rapidly, could reduce the cost.

5.2 Medium-term development strategy

Establish and improve the standard system of remanufacturing and product certification system [10]. Based on the common basic remanufacturing, product remanufacturing design, remanufactured parts quality, and remanufacturing technology standards, the key components and parts of remanufacturing products are clearly defined, re-evaluation standards of the remanufactured products are established, and the remanufactured product labels are unified. The requirements of the use of remanufacturing standards should be based on the establishment of remanufactured product certification system. For gearboxes, copiers, medical equipment, and other technical difficulties, which rely on importing, the government should encourage the original manufacturing enterprises to remanufacture in the country or apply the original authorized model for remanufacturing, thus exploring the original manufacturer, overhaul, remanufacturing plant's business alliance model. Remanufacturing is performed in high-end equipment such as aviation, rail transit, and offshore engineering equipment. Many key equipment and components such as aero-engines, gas turbines, shield machines, and heavy-duty mining trucks are remanufactured. The government should encourage relevant cooperation units to study the application of intelligent and informative means in remanufacturing.

5.3 Long-term development strategy

Explore bioengineering, simulation techniques, and 3D printing technology in remanufacturing applications. Encourage enterprises to use the simulation technology, performance evaluation technology, online condition monitoring, and fault diagnosis technology for remanufacturing. In addition, enterprises are encouraged to adopt intelligent control system, real-time communication technology, and system coordination technology to manage remanufacturing production [11]. Focus on the role of the Internet in the reverse logistics recycling system platform, the process of complex remanufactured products, the establishment of re-manufacturing of public information services and trading platform, and remanufactured product information traceability system. Support the participation of Internet companies in the recycle, logistics, pricing, and sales of remanufactured e-commerce systems and support industry associations and key enterprises to explore innovative business models and sales models based on Internet information sharing and business collaboration. Attempt to achieve remanufacturing rate reaching 80%, develop world-class remanufacturing enterprises and industrial parks, and form industrial agglomeration effect.

6 Conclusions

China has explored and formed a self-remanufacturing industry model "based on high-tech as a support, take surface resurfacing technology for restoring its size and improving performance, in the means of combining production, study, and research, which is both circular and economical" [4,12]. Remanufacturing is considered a national strategic emerging industry and energy-saving and environmental protection industry

because of its significant economic, environmental, and social benefits. It has received considerable attention from the government and enterprises and will surely achieve leapfrog development in the future.

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