

Progress of remanufacturing engineering and future technology expectation

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Abstract After development for decades, abroad remanufacturing has formed a complete industrial system. At present, the research emphases are on marking logistics management and market cultivation theory of remanufacturing products, and so on. The Chinese remanufacturing starts fairly late. After 10 years of development, it formed a remanufacturing mode with Chinese characteristics that is sustained by high-tech industries, using the surface engineering technology to restore the size and improve properties, and combining manufacturing, study and research together. The remanufacturing mode is not only circular but also economic. With the development of science and technology, future remanufacturing technology will break the previous limits, explore and understand the limits of micro machining. It will carry out the waste product remanufacturing in the micro-nano scale, and extend the remanufacturing industry to a more broad space.

Keywords Sustainable development · Remanufacturing industry · Surface engineering · Micro–nano machining

1 Introduction

The development of modern science and technology brings human society into industrialization which makes economy develop rapidly and physical quality of life improve greatly. However, the more humans enjoy the material

civilization, the more they feel the environment which they must rely on gets worse. The environment pollution is severe, and ecological balance has been disrupted. Natural resources are wasted seriously, which have resulted in shortage of resources that support the human society and economic to develop rapidly [1, 2]. To protect the environment, build a circular economy to maintain the sustainable economic and social development has become a common concern topic of the whole world [3]. Manufacturing industry is not only the pillar industry of the national economy, but also the major source of environmental pollution, which consumes and wastes a lot of resources. In order to solve the shortage and waste of resources and to reduce the harm of a lot of failure and discarded products to human, the international has set off a green wave to make full use of resources and reduce environment pollution since the 1980s. It proposes the concept of “green manufacturing” and new ways of thinking. Under the situation, the remanufacturing project as a new research field arises [4]. It has formed remanufacturing industry in foreign countries, which is the best method to solve the waste of resources, the pollution of environment and the retrofit of used equipments.

2 Development history of the foreign remanufacturing industry

In the 1950s or earlier, driven by interests, the European and American corporations started recycling used products, and then the early remanufacturing industry formed [5]. In the late 1970s, the Massachusetts Institute of Technology began research on the recycling of waste products. In the 1980s, the United States officially advocated renovation or regeneration of waste products, and called it “remanufacturing”, while the Japanese proposed the concept of “renewable

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plant technology". In 1992, the Russian scholars proposed the idea to establish "the committee of repair heat treatment technology" to the International Heat Treatment Committee [6]. The World Bank funded the final report of "Remanufacturing: the experience of the United States and the revelation to developing countries". The final report described the United States remanufacturing enterprises and experience, analyzed remanufacturing application prospects of some third world countries. It promoted the development of the remanufacturing industry. In the United States, Canada, the European Union and other developed countries, the remanufacturing of used mechanical and electrical products has several decades of development history. From technical standards, production technology, processing equipments, recycling of used products, to the remanufactured product sales and after-sales service, the remanufacturing industry has formed a complete industrial system [7]. The remanufactured product range has covered the auto parts, machine tools, construction machinery, railway equipments, medical equipments, and some electronic products.

The global remanufacturing output had more than one hundred billion dollars in 2005. Remanufacturing industry in the United States was the largest, and its output reached 75 billion dollars. The automotive and construction machinery remanufacturing accounted for more than 2/3, and the output reached about 50 billion dollars. Japan had also strengthened the construction machinery remanufacturing. Till 2008, 58 % of the construction machinery remanufacturing was used by the Japanese domestic users, and 34 % were exported to foreign countries. The remaining 8 % sold as accessories after dismantling. Till 2004, Volkswagen had been remanufacturing 7.48 million automobile engines and 2.4 million transmissions. The ratio of the company sold remanufactured engines and accessories to the new machine was 9:1 [8].

Remanufacturing can not only save a huge social wealth, but also significantly improve the combat effectiveness of the military equipments. The United States military absorbs a large number of advanced scientific and technological achievements by remanufacturing, thus improves the tactical and technical performance of existing weapons and equipments. Remanufacturing provides excellent application and test opportunities to these advanced technologies. Improvement of the equipment performance of the United States military accompanies with the equipment remanufacturing. The remanufacturing project research has attracted the attention of the American policy-making departments. The defense manufacturing industry committee in and after 2010 which belongs to the United States National Research Council, had formulated the framework of the defense industry remanufacturing technology about 2010. It proposed the strategy to achieve the future required manufacturing capabilities, and took performance upgrades, life extension technology and remanufacturing

technology of the weapon systems as the important research area in current and future defense manufacturing [9]. The defensive weapons research department of Boston University specializes in cost savings data of remanufacturing products, such as aerospace planes, runner weapons systems and military equipment. Longbow AH-64D is a new kind of helicopter which is the remanufacturing product of AH-64A. After remanufacturing, the battlefield survivability, information exchange ability, and navigate ability of the aircraft increases. AH-64D can attack 4 times target numbers at the same time than the AH-64A and its survivability increase by 7.2 times than the AH-64A. At present, it has become the strongest and most advanced helicopter on active duty in the United States. Target acquisition capability of the remanufacturing M1A1D tanks increases 70 %, shortens the fire time and improves accuracy. Furthermore, the target detection and identification distance also increases by 30 %, which can provide better damage performance and reduce the possibility of mis-hits. The Bradley M2/M3 chariot of the United States army upgrades to A3 type after remanufacturing. It integrates car monitoring, diagnostics/prognostics subsystem the Army Technical Architecture (ATA) command and control software program group, can fully co-operate with the Abu Donald M1A1D-type M1A2SEP-type battle tanks, and other "XXI digital platforms" military forces. The F-14D fighter is obtained by the remanufacturing of F-14A, and it can simultaneously track 24 targets and attack six of them, the radar height ranges from 24 m to 24,000 m. It has monopulse angle tracking, digital scan control, target recognition, and air strike evaluation capacity [10].

3 Overseas research status of remanufacturing industry

Foreign remanufacturing model is based on the pieces and size repair methods to restore the size of the parts. Research is focused on the analysis of full life cycle, the aging of product parts or the changes in the physical and mechanical properties. Information is used in recovery or remanufacturing used products successfully. To study and develop advanced remanufacturing technologies, surface cleaning technologies and waste minimization technologies which have the better economic and environmental effects are used well. The performance or aging characteristics of the remanufacturing products are measured and the remaining life of the products is predicted using advanced diagnostic techniques and tools [11]. Through the accumulation of such basic research works, industrial countries have laid a solid foundation for the remanufacturing industry sustainable development. At the moment, foreign remanufacturing project research has progressed to the macroscopically integral research, such as management

model, market cultivation, certification and the social and economic benefits.

Margatete [12] has studied whether the product recovery system and repair industry can be applied in the automotive parts remanufacturing, he believes that the remanufacturing products recycling has formed a closed loop industrial processing. Due to the lack of knowledge of other industries, these industries are not able to remanufacture products of other industries, this restricts the development of the remanufacturing [13–14]. Johan believes that if the remanufacturing products want to be recognized and purchased by consumers, it must obtain accurate market information of remanufactured products, it must accurately grasp the reverse logistics information [15]. The internal relationships in theory of the demand for new products or remanufacturing products are shown in Fig. 1. Due to the insufficient awareness of consumer to remanufacturing product, the market demand of the remanufacturing products is low, and the price is another important factor which affects the remanufacturing products. For example, compared with a new product, remanufacturing product's price is lower, this is due to the traditional understanding of consumers, the price of an old product certainly cannot be compared with a new product. But with the extension of time, consumers reduce interest in new products. Due to the lower price, the remanufacturing products have stronger competition. Lu and Nathalie [16] describe a clear remanufacturing system network, the remanufacturing network (RMN), as is shown in Fig. 2. The system assumes that there are four kinds of participants: consumers, logistics nodes, remanufacturing centers and producer. As consumers, they have two roles: buying new products and using the olds. The recycling center in the middle just recycles old products and does some necessary processing like cleaning, disassembly, and inspection, then returns old products to the remanufacturing

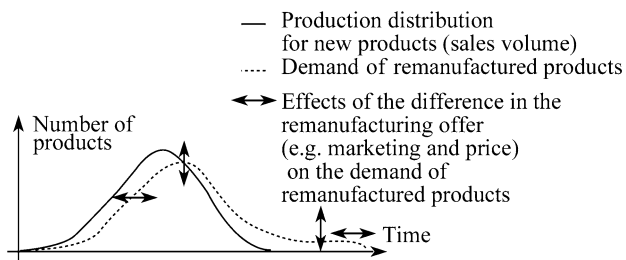


Fig. 1 Internal relationships of the demand of new products or remanufactured products [15]

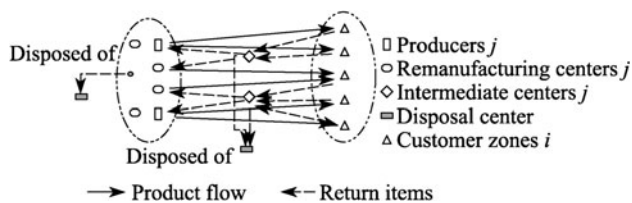


Fig. 2 Location problem of a remanufacturing system [16]

centers. The remanufacturing center receives the products which can be remanufactured from the recycling center. As parts of the product flow line, producers and manufacturing center are responsible for the production of the products that consumers need. In Fig. 2, we can see two processes: one is the inverse process that the old products come from the consumer through the recycling center and then flow to the remanufacturing center; another is new products from the remanufacturing center or producers directly flow to consumers.

Foreign remanufacturing industry has developed maturely, its technical research also fully expands in the last century. Now, the theoretical studies in foreign remanufacturing are mainly concentrated on distribution management and market cultivation.

4 Remanufacturing development in China

Since 1999, we have vigorously publicized and deeply studied remanufacturing project [17, 18]. During the last 10 years, the only existed several remanufacturing companies in China experienced difficulty in carrying out the work until they got the wide recognition and strong support from the national government agencies, industries and the community. The remanufacturing companies, such as Sinotruk Jinan Fuqiang Power Co., Ltd. (Sino-British Joint Venture), the manufacturing plant of Shanghai Volkswagen (Sino-German Joint Venture), Baike (Changshu) Motor Co., Ltd. (HongKong invested), Guangzhou Huadu Worldwide Automatic Transmission Co., Ltd. (Investments of overseas Chinese) and so on, are carrying out the remanufacturing processing in the heavy-duty truck engines, car engines, vehicle motors as well as the car gearbox and other areas, respectively. The remanufacturing products accord to the international standards and meet the requirements of remanufacturing. It can be said that they are the first group of remanufacturing companies in China. However, their development is extremely difficult due to various reasons, such as policy, technology and so on [19]. Until 2008, the National Development and Reform Commission (NDRC) appointed 14 companies as the first batch of auto parts remanufacturing industry points, including the above-mentioned companies, and the remanufacturing industry in China gets the official national recognition and policy support. In the end of 2009, Premier Wen made important instructions on remanufacturing and said the remanufacturing industry was very important. In 2010, the National Development and Reform Commission and other 11 ministries jointly issued “suggestions on promoting development of remanufacturing industry”, and bred remanufacturing industry as new economic growth point. In 2011, the state issued “the 12th Five-Year Plan for National Economic and Social Development”, and it required to “promote remanufacturing industry development; develop and apply

remanufacturing key technology, and promote the circular economic mode” in the next 5 years. In 2012, the National Development and Reform Commission began to start the second batch of national remanufacturing industry pilot. Above legal provisions as well as the spirit of the instructions of the Party and state leaders, injects powerful force to the remanufacturing development. It can be said that China has entered a new stage that promotes the remanufacturing industry as the core content of national goals, the remanufacturing development in China has shown unprecedented good momentum. It can be said that China has formed a remanufacturing mode with Chinese characteristics that is sustained by high-tech industries, using the surface engineering technology to restore the size and improve properties, and combining manufacturing, study and research together.

The remanufacturing technology in China depends on surface engineering technology to develop [20]. In order to restore or change the material surface morphology, chemical composition, structure and stress state are applied. To obtain the required system engineering [21], the surface coatings and modification technologies are used to repair the corrosion, wear and damage parts or materials. Through several years of research and practice, according to the standard that remanufacturing products characteristics and quality of performance should be not worse than the new products, our laboratory has innovated a number of independent remanufacturing technologies with Chinese characteristics, such as automated nano-particle composite brush plating technology, nano less mount intelligent self-repairing additive technology, automated high velocity arc spraying technology, automated micro-plasma cladding technology, remanufacturing nondestructive testing assessment techniques and equipments. These technologies are well adapted to the needs of the development of circular economy in China. Energy saving, materials saving, reducing pollution play an extremely important role in the healthy development of the remanufacturing industry.

5 Future prospects of remanufacturing technology

Based on accumulation of the existing technology, the study of the matter structures will enable mankind to the era of regulating of molecules, atoms, and electrons. It promotes machining accuracy from micro-scale to nano-scale and makes the human understanding of the nature and transformation to a new deeper level. Nowadays, the worldwide are starting to compete to establish new integration methods and technologies to adapt to nano-scale. Physical substance of traditional manufacturing and remanufacturing is using connection defects between the atoms, molecules, or crystal for processing, while the nano-processing is taking an atom or molecule on the device

surface as a direct object to be processed. It can be said that the physical substance of the nano-scale processing is to cut off the bonding between atoms or molecules, remove or add atoms or molecules. The various material combination is in the form of covalent bonds, metal bonds, ionic bonds, and so on, and it is difficult to cut the bonding between the atoms, the traditional processing methods are not practical [22, 23]. Thus, countries all over the world are studying and innovating the nano-scale processing and manufacturing technologies, such as a variety of nano cutting and nano welding technologies based on electronics, optics, magnetics and mechanics. The breakthroughs of these technologies will bring a profound revolution to remanufacturing industry, and change the understanding of matter and energy structure. By decomposing, regulating and synthesizing molecules, atoms and other microscopic structures, it will complete the combination of new material and energy. At the same time, combining with the existing macro restructuring technologies, it makes the remanufacturing parts which are mainly used products reach zero scrap rate, completely realizes the full recycling of resources. This will open a new application field of the existing remanufacturing.

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