

Ming-zhou Liu, Cong-hu Liu, Mao-gen Ge, Yuan Zhang, Qing-hua Zhu

# Remanufacturing in Industry 4.0

**Abstract** Using the theory of human blood circulation system, the authors explore the importance of remanufacturing in Industry 4.0. In this paper, they draw analogies between smart factory and human heart, between smart products and blood, and, between product function and nutrition and oxygen in the blood. Remanufacturing is analogous to the ingestion of oxygen and nutrition in lesser circulation or systemic circulation. Remanufacturing well supports recycling production, which is significant in realizing intelligent industry. Furthermore, this paper discusses the development direction of remanufacturing engineering in Industry 4.0 ages.

**Keywords:** remanufacturing, Industry 4.0, sustainable development

## 1 Industry 4.0

With the dramatic development of technology, the contradiction between human's mushrooming requirement for material and the limitation of environment and resources becomes increasingly intense. Facing the complicated and competitive global environment, manufacturing industry has suffered a lot and all governments have worked on it. Under the background that many developed economic entities, including America, have carried out reindustrialization strategy, the vision of future manufacturing industry is portrayed by German researchers with the concept of Industry 4.0 (Industrie 4.0 Working Group, 2013). Industry 4.0 is the fourth industrial revolution led by intelligent manufacturing. Through applying the Internet, Internet of things and Internet of services, in manufacturing industry, the physical world and the virtual world are connected by

Information Communication Technology (ICT) and Cyber-Physical System (CPS), which makes conventional manufacturing industry transform to intelligent manufacturing industry.

The project of Industry 4.0 holds three themes. The first is smart factories. It lays emphasis on research of intellectualized manufacturing system and process and makes a network of distributed manufacturing facility come true. The second is smart production. It includes production logistics management of entire enterprise, man-machine interaction and the application of 3D technology in industrial processes. This project focuses on drawing the attention of the middle and small-sized enterprises, trying to make them the users and beneficiaries of the new smart production technology. Meanwhile, they would be the creators and providers of advanced industrial production technology. The last one is smart logistics. In the process of smart logistics, logistics resources are integrated by the Internet, Internet of things and Internet of services. This method could give full play to the efficiency of logistics resource suppliers. Furthermore, the demand side could acquire service matched so as to receive logistics support as soon as possible. The three themes make Industry 4.0 a smart, efficient, green industry.

## 2 Industrial 4.0 thinking based on bionics

Comparing production with human blood circulation, the authors found an interesting phenomenon. Smart production, just like oxygen and nutrition entering the blood during lesser circulation and systemic circulation in human blood circulation, can transform original raw materials and recycled products to original components and remanufactured products respectively, through advanced production-manufacturing technology, as shown in *Figure 1*.

The smart factory, as the heart in the body, offers smart production system and provides networked, distributed manufacturing facilities. The smart factory is the key point of the whole production system, which is specializing in manufacturing smart products.

The smart product, like the blood in the body, is the

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Ming-zhou Liu (✉), Cong-hu Liu, Mao-gen Ge, Yuan Zhang  
Hefei University of Technology, Hefei 230009, China  
Email: liumingzhou0551@163.com

Qing-hua Zhu  
Shanghai Jiao Tong University, Shanghai 200030, China

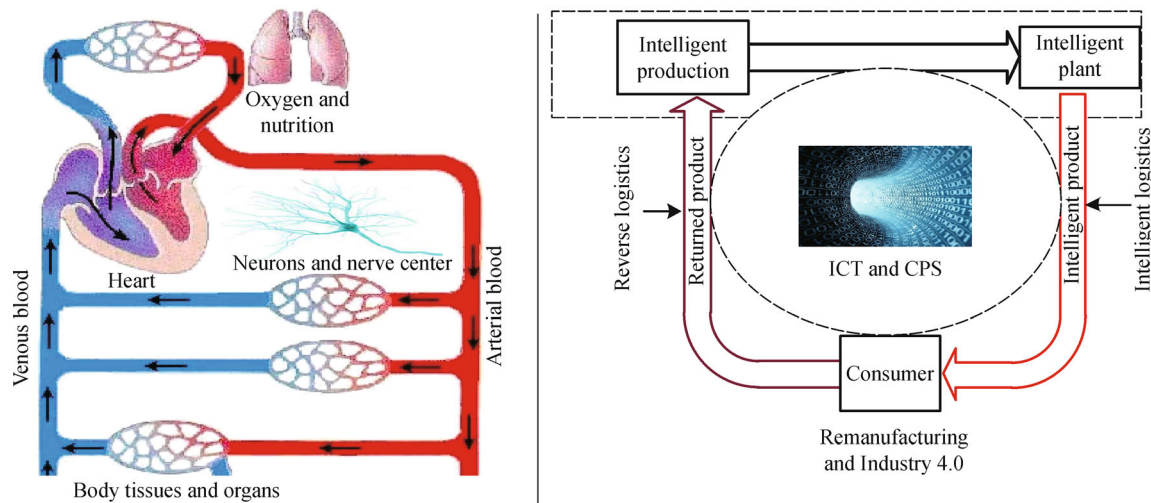


Figure 1. Comparison between Industry 4.0 and blood circulation system.

output of the smart factory. The smart product is equipped with personal information during integral supply chain and life cycle, could autonomously monitor product life cycle. Product features are just like the oxygen and nutrition in artery. Once new products are used, they will be regarded as the old and discarded ones. As the blood in vena, recycled products have functions transformed into use value, and functions recovered through remanufacturing.

CPS and ICT, like the neurons and nerve center in the body, can integrate all information from production, sale, leaving-factory logistics to service; can carry on dynamic management on enterprise's production data; and realize digitized end-to-end integration based on ICT.

The consumer is like the tissue and organ in the body. Through the tissue and organ, oxygen and nutrition are assimilated, and carbon dioxide, excreta are discharged. Then, in a similar way, smart product turns into recycled product after consumer usage.

Smart logistics is in charge of transmitting intellectual products and recycled products, like the artery and vena in the body. The reverse logistics is the process that delivers recycled products.

In brief, the overall goal of Industry 4.0 is to use information interaction of high-tech and intelligent decision-making technique comprehensively, making high-efficient, green cycle of energy and substance, and achieving sustainable development of manufacturing.

### 3 Role of remanufacturing in Industry 4.0

The content of oxygen and nutrition in the blood can be provided by means of lesser circulation or systemic circulation, making blood regain vitality so as to maintain body requirements. Human blood circulation is an important physiologic link to maintain body sustenance.

Remanufacturing is an indispensable process in Industry 4.0, and recycled product could regain performance via recovery technology.

To a large extent, the condition of individual's health depends on the original blood quantity instead of the reimport blood quantity. If the former blood quantity is greater than the latter for someone, his health would be worrying. Blood regains oxygen and nutrition through lesser circulation, and moves in circles. Therefore, human beings should strengthen its systemic circulation and hold adequate oxygen by its circulation perpetually if they are supposed to have strong bodies.

In the same way, for sustainable development, manufacturing industry should adjust the proportion of remanufacturing in entire manufacturing industry instead of pursuing original manufacturing absolutely. Remanufacturing is the reverse cycle of Industry 4.0. It is an industry that contains disassembly cleanout and recovery, which put remanufactured products into use to prolong their services.

The dynamic degree and sustainable capacity of remanufacturing industry lie on the share of remanufacturing in Industry 4.0. The higher proportion of remanufacturing is, the less energy and resource consumption for an equal output. In the future, it is a great challenge for manufacturing industry to meet the endless material needs and to reduce resource consumption. In Industry 4.0, the importance of remanufacturing will be more prominent, remanufacturing is the key to keep the substantial development of Industry 4.0.

### 4 Developmental direction of remanufacturing

An expedite blood circulation is the primary criterion to resist diseases. Similarly, remanufacturing is indispensable

in satisfying the abundant demand for material in the resource shortage age. It is undeniable that remanufacturing takes mushrooming importance in industry, and has been playing a crucial role in maintaining the substantial development of manufacturing (Xu, Dong, Zhu, & Shi, 2012).

The main research direction of remanufacturing is as follows:

(1) Intelligent disassembly. Based on CPS which are like the neurons and nerve center in the body, the companies could track, retrospect and monitor the products in services to ascertain the forming process of recycled products concerning the pollution layer and metamorphic layer. With the assistance of ICT, the manufacturers could dismantle the returned products with minimum damage.

(2) Nondestructive cleaning. The manufacturers could facilitate the greening, harmless nondestructive cleaning process with the techniques which adopt pollution-free and tractable cleaning materials.

(3) Remanufacturing process. Remanufacturing process is analogous to lesser circulation. On the basis of representing the full life cycle of each recycled part accurately, an efficient, greening remanufacturing processing technique could be designed and developed. Furthermore, through using real-time monitoring and optimal control in remanufacturing process, the manufacturers could recover or promote the performance of the remanufactured parts.

(4) Remanufacturing assembly technology. Facing the personalized and diversified demand of the consumers, based on the uncertainty of the coating layer and modified layer of the remanufactured parts, it is necessary to conduct researches on remanufacturing assembly technology (Liu, Liu, & Zhu, 2014). The research is the core precondition to ensure that the quality of the remanufactured products is not lower than that of the original ones.

(5) Active remanufacturing. With studies of the life cycle that consists of the original life cycle and the regenerative life cycle, with the goal of exercising optimum function and optimum performance, and under the criterion of high-

quality, high-efficient, energy-saving, materials-saving, environmental protection and minimum life cycle, it is necessary to encourage an initiative for remanufacturing engineering during the original life cycle of the products.

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## 5 Conclusions

With the rapid development of economy, the contradiction has become increasingly violent between economic growth and environmental issues. The over-exploitation of the natural resources and unrecoverable alteration of the environment have caused many serious issues such as ecological destruction, waste or shortage of resources, and pollution. A principal challenge to the development of future remanufacturing is the gap between limited resources, fragile ecosystem and everlasting material needs of mankind. In the ages of Industry 4.0, remanufacturing ought to be the key measure to fulfill sustainable development of manufacturing industry. Remanufacturing is related with the subsistence and continuation of human beings.

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