Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 17 (2014) 14 – 19

www.elsevier.com/locate/procedia

Variety Management in Manufacturing. Proceedings of the 47th CIRP Conference on Manufacturing Systems

De-Manufacturing Systems

Marcello Colledani[a,b], Giacomo Copani[b], Tullio Tolio[b,]*

[a]*Politecnico di Milano, Department of Mechanical Engineering, Via la Masa 1, Milan, 20157, Italy*
[b]*ITIA-CNR Institute of Industrial Technologies and Automation, Via Bassini 15, Milano, 20133, Italy*

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000. *E-mail address:* tullio.tolio@itia.cnr.it

Abstract

De-Manufacturing Systems allow implementing optimized End-Of-Life strategies and are necessary to support a sustainable and competitive Manufacturing/De-Manufacturing integrated paradigm. However, available technologies, management methods and business models present several limitations that make landfill and, at a lower extent, materials recycling, the most diffused End-Of-Life practices. To overcome these limitations, this paper proposes an integrated multi-disciplinary research framework addressing single technologies improvement, system integration and business model coherency. The main challenges and research opportunities are presented that can boost the development of sustainable De-manufacturing Systems at industrial level.

Selection and peer-review under responsibility of the International Scientific Committee of "The 47th CIRP Conference on Manufacturing Systems" in the person of the Conference Chair Professor Hoda ElMaraghy"

Keywords: De-Manufacturing Systems; Sustainability; Key-Metals;

1. Introduction and challenges

Manufacturing is a fundamental pillar of modern society, significantly contributing to employment and welfare. Manufacturing is necessary to keep high value-added knowledge and competences in high-wage countries, which are key competitive factors of advanced economies. It is an indispensable element of the innovation chain: manufacturing enables technological innovations to be applied in goods and services, making new products affordable and accessible to a multitude of consumers, thus increasing societal and economic benefits. However, recently, concerns have been raised on the energy and resource efficiency of manufacturing operations. As a matter of fact, manufacturing absorbs a significant fraction of the produced energy and materials. For example, it is responsible for the consumption of more than one third of the primary energy produced [1]. For these reasons, it is of paramount importance to propose new paradigms for sustainable and competitive manufacturing.

Within this scope, on the one hand, it is necessary to develop processes, technologies and methods decreasing the energy and material consumptions of manufacturing activities [2]. On the other hand, End-Of-Life (EOL) processes must be viewed under an integrated Manufacturing/De-Manufacturing perspective, thus supporting the reduction of primary raw materials consumed during the manufacturing operations.

De-Manufacturing can be defined as the "break down of a product into its individual parts with the goal of reusing and remanufacturing parts, or recycling the remainder of the components" [3]. A De-Manufacturing strategy should find the right mix between (i) product remanufacturing and re-use, (ii) sub-assemblies and components re-use within manufacturing, (iii) material recycling and recovery, (iv) incineration and (v) waste disposal in landfills [4] to maximize the residual value of end-of-life products and to minimize the environmental impact.

In order to push the establishment of structured De-Manufacturing operations, different countries are pursuing this issue through regulations. For example, in Europe the regulation fixes recycling targets for Waste Electrical and Electronic Equipment (WEEE) and End of Life Vehicles (ELVs) – EU Directives 2012/19/EU and 2000/53/EC. These regulations, however, are targeted to specific manufactured products (for example, many industrial products such as

Selection and peer-review under responsibility of the International Scientific Committee of "The 47th CIRP Conference on Manufacturing Systems" in the person of the Conference Chair Professor Hoda ElMaraghy"
doi:10.1016/j.procir.2014.04.075

machine tools, robots, trains, etc., are not included in this legislation). In addition, regulations set a normative framework to organize EOL tasks, but the overall performance depends on the quality and efficiency of the De-Manufacturing Systems. Nowadays, available technologies, management methods and business models constitute serious barriers to the development of successful De-Manufacturing systems. In fact, for many high-tech products, the only available end-of-life treatments are open-loop recycling of materials, to be sold in the secondary raw material market, or landfilling. These businesses are well-established but less favorable in terms of recovery of value added to manufacturing [3] [4]. They are traditionally conducted with massive use of manual operations and with poor support of advanced technology and automation.

In order to boost De-Manufacturing as a new competitive paradigm it is important to define the conditions for a profitable sustainable business. This implies the solution of technological, economic and social issues that, in turn, pose significant multi-disciplinary research challenges. This paper formulates the concept of De-Manufacturing Systems, provides example of the potential impact of these solutions in a growing sector, the mechatronic component industry, and sets the framework for future research in this area.

2. De-Manufacturing systems

A De-Manufacturing System can be defined as the set of resources (human and technological), organization, IT infrastructure and associated business model to enable product De-Manufacturing (Fig. 1).

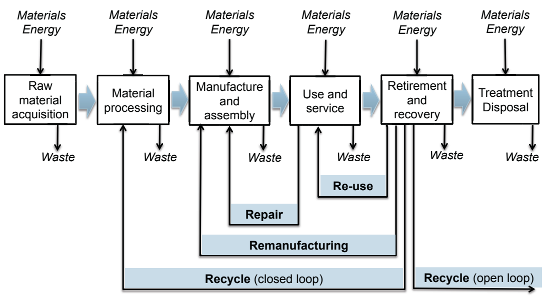

Figure 1 – Products and materials Life Cycle

De-manufacturing processes typically include disassembly, remanufacturing, recycling and recovery processes. Disassembly is generally the first step of the process. It is usually performed with the scope of isolating (i) hazardous components that cannot enter the recycling flow, (ii) re-usable parts with high residual value, (iii) parts that need to go through a dedicated recycling process chain. Manual disassembly is typically implemented at the state of the art.

Remanufacturing entails renovating used parts or components so that they can perform their function similar to new ones. Remanufacturing generally consists in dismantling the used units into their components, inspecting these components, repairing defective components or replacing them with new ones, reassembling the units, readjusting as necessary and submitting them to the final quality test, that usually the same used for new manufactured parts. Remanufacturing is recognized to be the most beneficial end-of-life treatment. It preserves more or less 85% of the initial value, while recycling preserves almost 7.5% of initial value. Remanufacturing processes use 20-25% of the energy needed to manufacture the same product. The cost of remanufacturing can be between 45% and 65% less than the manufacturing cost. Remanufactured components are traditionally not re-used in the manufacturing process to be assembled in new products, although their quality could support this model. Remanufactured components are typically sold in the aftermarket as spare parts. For example, in the automotive industry, of the total gross profit of the car manufacturer, the new car sells contributes to the 18%, the service generates 14% while the spare parts market generates 39%.

Recycling is mainly performed by mechanical processes or by thermal processes. Mechanical recycling systems are multi-stage systems including size-reduction and separation technologies. The scope of size-reduction technologies is to (i) reduce the size of the particles in favor of downstream separation processes, (ii) liberate inhomogeneous particles thus increasing the quality of the separation process. The scope of separation stages is to split a mixed input stream into two or more output streams in which the concentration of target materials is greater than in the input stream. In recycling industry, mechanical separation is performed by a series of separation stages involving different separation technologies that classify materials on the basis of their properties. A separation process creates an environment in which particles with a high value of the property move differently from those with a low value of the property. Under ideal separation conditions, the inspection will be perfectly accurate and the material flow will be correctly classified. However, in the real world, random disturbances cause ”contamination” of the output flows, where materials are wrongly classified. Thermal recycling processes are typically based on pyrolysis. This process enables to separate organic from non-organic fractions. However, although improvements have been proposed in the last years, pyrolysis generates serious environmental concerns due to the energy required for the process and the need for emissions treatment plants. For some materials, recycling processes enable to reach target grades that are comparable to market requirements (copper, aluminum). Otherwise, recovery processes need to be implemented.

Recovery processes make use of chemical reactions to separate the target materials at very high grade levels. They are typically performed in batches. One of the most advanced technology is this field is hydro-metallurgical processes [15]. These processes have recently been proved to be more sustainable than traditional metallurgical recovery processes.

Nowadays, there are several limitations that prevent companies from implementing a successful De-Manufacturing System. First, the inefficiency of disassembly processes was pointed out as one of the major limitations. The low productivity and the high labor cost of manual disassembly in high-wage countries are not compatible with the residual value of many disassembled products. An extreme