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A Study and Analysis of Issues in Disassembly Process for Environmentally Conscious Manufacturing

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Abstract—*The historic cause of Environmental Conscious Manufacturing (ECM) is that during the industrial revolution, environmental issues were not addressed when designing and manufacturing products. The focus has been on Economic Conscious Manufacturing and not on Environmental Conscious Manufacturing. ECM may be approached through 3 R's i.e. Reduce, Reuse and Recycle. The thrust of this paper is on Disassembly (issues in disassembly process) as the first and essential requirement for Product Recovery which in turn is the first logical step to these 3 R's. Disassembly has got special relevance as it provides ease in repair and maintenance operations, retrieval of components and material for reuse and recycle, exclusion of hazardous materials when products are discarded, aids in designing better products and a convenient assembly. However, the disassembly process creates an inconvenient working environment due to many issues. Some of the major issues in disassembly process are related to the variety of incoming products for disassembly, quality of returned products, types of defect in the returned products, irretrievability of components, and layout of disassembly system.*

Keywords*: Environmentally Conscious Manufacturing; ECM; Product Life Cycle; Disassembly; Issues in disassembly; Product Recovery.*

1. INTRODUCTION

The historic cause of Environmental Conscious Manufacturing (ECM) is that during the industrial revolution, environmental issues were not addressed when designing and manufacturing products. The focus has been on Economic Conscious Manufacturing and not on Environmental Conscious Manufacturing. It is a well recognized fact that our environment has limited resources, i.e. the materials we convert into products, energy, water and air supply and the places where we dispose of old products, are limited. Our society uses these resources to improve the living standard. Current manufacturing activities have caused the degradation of the environment, the depletion of resources at an accelerated rate, global warming, and affected the quality of life. New technologies, the short life cycle of products consumed more resources that hinder sustainable growth. However, we also need to provide for a sustainable environment for the next generation [1]. To this end, we need to identify the extent of the problem and take remedial action.

Today's high- tech society requires thousands of different products which ultimately result in billions of tons of materials discarded, most of which end up in landfills. Various environmental problems as a result of unplanned manufacturing activity that needs an urgent attention and remedial action are the ever increasing consumption of limited natural resources, the amount of waste generated, the decreasing number of landfill sites and the increasing level of pollution. ECM is mainly driven by the escalating deterioration of the environment. Rules of thumb for ECM include improving efficiency and productivity through efficient energy and materials use, substituting more abundant and environmentally preferable materials for those that are rare or environmentally problematic, as well as recycling and reusing products at the ends of their lives. Thus, ECM may be approached through 3 R's i.e. Reduce, Reuse and Recycle. The thrust of this paper is on Disassembly as the first and essential requirement for Product Recovery which in turn is the first logical step to these 3 R's. Product recovery aims to minimize the amount of waste sent to landfills by recovering materials and parts from old or outdated products by means of recycling and remanufacturing (including reuse of parts and products) [1-3].

ECM has a variety of definitions [1-3]:

(a) Environmentally conscious manufacturing (ECM) is concerned with developing methods for manufacturing new products from conceptual design to final delivery and ultimately to the end-of-life (EOL) disposal such that the environmental standards and requirements are satisfied.

(b) Environmentally conscious manufacturing (ECM) is a new way of thinking about manufacturing which focuses on the most efficient and productive use of raw materials and natural resources, and minimizes the adverse impacts on workers and the natural environment. In its most advanced form, a product's entire life cycle is considered, from design, raw material and natural resource use to end use and disposal.

(c) Environment Conscious Manufacturing (ECM) is defined as a set of tools and techniques required for the manufacture of new products as per environmental standards and regulations. It involves developing manufacturing methods responsible for the whole life cycle of the product i.e. from the conceptual design to production to final delivery and finally to end-of-life disposal or recycling or re-manufacture.

It could be concluded from these definitions:

(i) ECM involves both Environmentally Conscious Product Design and Environmentally Conscious Process Design.

(ii) The main objective of ECM is to obtain a product whose manufacture, use, and disposal have the least environmental impact, and to achieve this end ECM has product’s life cycle approach.

2. PRODUCT LIFE CYCLE

The various phases or stages of a product’s life cycle [1] include Pre-production; Production; Distribution; Use; and End of Useful Life. All these five major phases of a product’s physical life cycle calls for specific and multi-pronged strategies for tackling the issue of environmental deterioration and damage.

Pre-production phase involves the preparation and procurement of raw-materials and components required for the production processes and end product.

Production phase builds upon the pre-production phase and involves the transformation of materials, production of components, product assembly and finishing.

After the successful completion of the Production, the Distribution phase begins that involves the packaging and transportation of the end-product.

As soon as the product is shipped and received by the customer, Use of the product begins till the end of its useful life and during its useful life there may be requirement of servicing and spare parts.

At the end of useful life, the various choices may be recycle, reuse, disassembly, remanufacture or simply disposal as waste.

Thus, it is required to develop and implement environmental strategies for each phase of a Product’s Life Cycle. These strategies may be categorized as Resource-Reduction Strategies, Useful-Life Extension Strategies, and End-of-Life Strategies. Understanding and implementing the end-of-life strategies for the product is critical since one of the largest impacts on the environment occurs at this stage. The objective of the End-of-life strategies is to further harness the value of the various resources used for the manufacture of a product after the useful-life extension strategies fail to deliver. At the end of useful life, the product shall be such that it facilitates recycle, disassembly, re-use and upon disposal shall have low environmental impact.

Disassembly has recently gained a lot of attention in the literature due to its role in product recovery. Disassembly is the first crucial step in product recovery. Product recovery aims to minimize the amount of waste sent to landfills by recovering materials and parts from old or outdated products by means of recycling and remanufacturing (including reuse of parts and products) [2-4].

Disassembly is defined as the methodical extraction of valuable parts or subassemblies and materials from discarded products through a series of operations. After disassembly, the reusable parts or the subassemblies are cleaned, refurbished, tested, and directed to the part or the subassembly inventory for remanufacturing operations. The recyclable materials can be sold to raw-material suppliers, while the residuals are sent to landfills [5].

Disassembly may be a partial disassembly or complete disassembly. A product is said to be partially disassembled if it has not been fully disintegrated into all its basic components, and if disintegrated into all its basic components, then it is called complete disassembly. A product is to be partially disassembled or completely disassembled depends on the demand of its various components for recycle or reuse. Although, disassembly seems to be reversed sequence of assembly, it is quite different especially in case of complex products. Disassembly has got special relevance as it provides ease in repair and maintenance operations, retrieval of components and material for reuse and recycle, exclusion of hazardous materials when products are discarded, aids in designing better products and a convenient assembly [6].

3. ISSUES IN DISASSEMBLY

Major issues in disassembly process are related to the variety of incoming products for disassembly, quality of returned products, types of defect in the returned products, irretrievability of components, and layout of disassembly system [2].

The issue of the variety of products to be handled on a disassembly system and the layout of the disassembly system or disassembly line is interrelated. If the number of different products handled by a disassembly line or system is large and also the different products belong to different “families of parts”, the disassembly system has to be very flexible and this flexibility shall result in the loss of efficiency in the disassembly process. This flexibility is required to accommodate the varying sequence of disassembly process and the varying shape, size, other specifications, and nature of the components/products for disassembly. This issue will also cause balancing problem of the disassembly line or issue of task sharing time on stand alone workstations. As the number grows of different products to be disassembled on a disassembly line, it is difficult to balance the line and results in an un-paced line which is an indicator of the loss of efficiency in the disassembly process [2,5,6]. This issue may be handled by designing the disassembly system or disassembly line for a "family of parts" and restricting the disassembly process only for the various products belonging to this "family of parts". This sorting of different products may be done using "Group Technology".

The other issue in the disassembly process lies on account of the quality of the incoming products. There exists a large variation in the quality of products to be disassembled i.e. from functional to non-functional products and from good shape to damaged and accidental products. This variability in the quality of products for disassembly causes a negative impact on the efficiency of the disassembly system and generally a trade-off exists between the two. In order to handle and restrict this variability, an understanding and analysis of the defects in the products is required. A product or its constituent component may experience a physical defect and/or functional defect. A product or its constituent component is said to be physically faulty if its geometrical specifications like shape and size gets altered from its original one. This physical alteration may be caused due to any accident or hostile operating conditions and may also cause functional defect. A functional defect in a product is said to happen if it does not perform the function or operate as per its design. The functional defects are generally caused due to out-of-range manoeuvre or operating or ageing of the product. This loss of functionally may also be due to physical damage to the product. Moreover, a physical damage to a component of a product may cause a physical damage and/or functional loss to other associated components of the product, and the vice-versa is also true i.e. a functional defect in a component of a product may cause physical damage and/or functional loss to other related components of the product. Thus, a product or its constituent components may have a physical defect or functional defect or both. A priori knowledge of the nature of defects facilitates the disassembly of the demanded component from the product and has a significant bearing on the efficiency of the overall disassembly process.

Physical defects and damaged fasteners are two major obstacles that guide the whole disassembly process. These obstacles may alter the disassembly sequence or may cause unnecessary delay or may even bring the whole disassembly process to a halt. Thus, the size of these obstacles govern whether the components or parts of a product could be disassembled or not, and if could be disassembled then which components and the time required for their retrieval. These obstacles may not just cause further physical damage and/or functional damage to the component being disassembled but also to other related or coupled components of the product, and are a source of concern for the safety of the workers, tools, equipments and machinery involved in the disassembly process.

Physical defects (including damaged fasteners) and sometimes functional defects presents a lot of operational constraints and loss of efficiency on the disassembly process for meeting out the demand for the recovery of the product and the implementation of ECM. These operational constraints are mainly on account of physical defects (including damaged fasteners) and precedence relationships or sequence to be followed for the retrieval of components in a product. Irrespective of the demand of the component, a product could be disassembled to retrieve its particular component in a limited sequence of operations. Thus, these defects cause a great variation in the disassembly task times and may cause the following situations [2-4,6] in the disassembly environment:

(a) Inability to complete one or a few of the disassembly tasks assigned to a particular workstation.

(b) Inability to complete all the disassembly tasks assigned to a particular workstation.

(c) A Change in the disassembly sequence.

(d) Non-initiation of the disassembly process on account of non-completion of the very first step in the disassembly process.

Moreover, sometimes there are situations which demand the use of special tools, jigs and fixtures to initiate or complete the disassembly task or process. These situations may also warrant that one or more components need to be damaged or destroyed for the retrieval of the demanded component from the product.

Overall, these situations cause an inconvenient working environment and loss of efficiency in the disassembly process.

4. DISCUSSION

Major issues in disassembly process are related to the variety of incoming products for disassembly, quality of returned products, types of defect in the returned products, irretrievability of components, and layout of disassembly system. The issue of the variety of products to be handled on a disassembly system and the layout of the disassembly system or disassembly line is interrelated. This issue may be handled by designing the disassembly system or disassembly line for a "family of parts" and restricting the disassembly process only for the various products belonging to this "family of parts". This sorting of different products may be done using "Group Technology".

The other issue in the disassembly process lies on account of the quality of the incoming products. A priori knowledge of the nature of defects physical defect and/or functional defect) facilitates the disassembly of the demanded component from the product and has a significant bearing on the efficiency of the overall disassembly process. Physical defects and damaged fasteners are two major obstacles that guide the whole disassembly process.

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