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LIFECYCLE EXTENSION FOR INDUSTRIAL EQUIPMENT

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Abstract: *The product life cycle extension is an important concept of how to utilize a ready-made good with a less possible harm to nature. In our case it helps to decrease consumer's expanses, need in recycling and utilization, energy consumption and material usage. In more wide range it pushes producer to find new sustainable solutions for their product lines and improve products liability. In order to satisfy both aspects of product lifecycle: economic and ecological - the end of life strategies will be described in this paper.*
Keywords: remanufacturing, product lifecycle extension, take-back approach, End-of-Life strategies.

1. INTRODUCTION

There are a lot of new ideas for the new methodologies of sustainable development exist that have not been put on the table yet. Unstable economic situation in many countries prepare us to face major changes in the near future. Manufacturers try to adopt their products for the new consumer requirements and further develop its business. At the same time government puts more strict regulations and policies regarding manufacturing and utilization processes and their consequences.
In this paper the new life cycle extension approach and possible ways to implement it in practice will be considered. According to research the combination of remanufacturing and take-back approaches can be used for industrial equipment life cycle extension.

2. PRODUCT LIFE CYCLE AND END OF LIFE STRATEGIES

The life cycle of product refers to the sequence of interrelated steps of a product from the acquisition of raw materials for manufacturing to the disposal of the used product, i.e. its end-of-life (EoL). At the end-of-life, the product can be either disposed off, or still used to extend its life cycle (see Fig. 1).

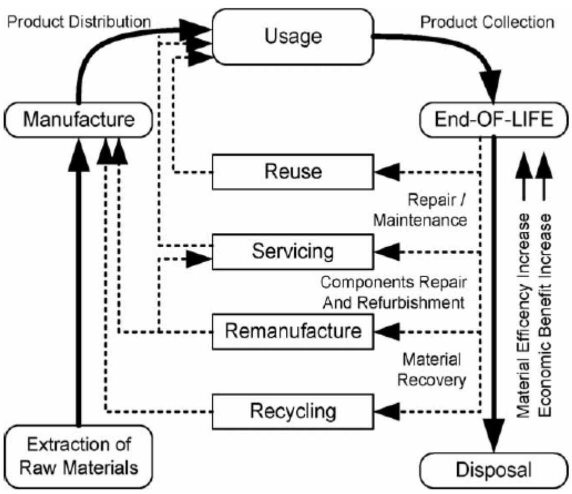

Fig. 1. Product life cycle [1]

According to our previous researches after product reaches its end-of-life stage, it should not be wasted, but should be proceeded in one of the next ways:

- *Reuse* (direct reuse, reuse after minor repairs, indirect reuse);
- *Servicing* (reconditioning, repairing, product service systems);
- *Remanufacturing* (remanufacturing of product, components and demanufacturing (parts reuse or ("cannibalization");

- *Recycling* (with or without prior disassembly);
- *Disposal* (incineration, landfill).

It is becoming more common nowadays, that original equipment manufacturers (OEM) financially and organizationally are responsible for the take-back of their products when they reach the end of their life cycle (EoL). The best EoL approach for industrial equipment life cycle prolonging is corporation of take-back approach with remanufacturing concept. This method is widely used in industry all over the world.

3. PRODUCT REMANUFACTURING

Remanufacturing means that a product is reprocessed or upgraded in an industrial process [2]. During this process, the core (used product or its component) passes through a number of remanufacturing operations, e.g., inspection, disassembly, part reprocessing, reassembly, and testing, to ensure it meets the desired product standards [3].

The business concept of remanufacturing is based on the idea that resources that were used in the manufacturing of the product are reused, thereby making remanufacturing advantageous. The reused resources consist of the material in the product, energy, machine time, labour and other costs that have been accumulated in the new production process [4]. From an environmental perspective, it is still important to consider the impact of prolonging the life of products with obsolete or polluting technologies.

For remanufacturing to be successful, Thierry et al. [5] highlight the need to gain information on future market needs of remanufactured products, and match this to information on the magnitude of return flows. One of the major issues impacting remanufacturing is in the difficulty of obtaining used products (cores) that are suitable for remanufacturing. As not all products can be reused or serviced after reaching its end-of-use or end-of-life there seems to be an option to follow between remanufacturing and recycling, depending on the product's condition. The suitability of a product for remanufacturing depends on many aspects of the product configuration, such as:

a. design of product;
b. value of remanufactured products;
c. cost of remanufacturing relative to cost of other alternatives for dealing with EoL products e.g. recycling;
d. transportation distances and costs;
e. demand for remanufactured products;
f. frequency of product returns;
g. volume of product returns;
h. condition of product returns;

By providing customers with remanufactured products, companies can provide the same level of service using fewer resources. In this way, remanufacturing can reduce the resource intensity and increase the eco-efficiency of product systems.

3.1. Upgrading as part of remanufacturing

Actual tendency is so that the rapid rate of technological change in many industries, poses another major challenge to remanufacturers. In some cases, for example electrical industries, product life span is decreasing, creating a technological pull away from the environmental principles of longevity, reuse and resource productivity [6,7]. For these products, upgrading will become crucial to ensuring the continued viability of remanufacturing, and to ensure that remanufacturing does not merely prolong the life of an inefficient and obsolete product.

Upgrading products to the latest standard is one possible solution for increasing the potential remanufacturing volumes for the product remanufacturing case, using for example modular design strategies [2].

Upgrading products to the latest technical solution is a viable option when expanding

the lifetime of a product. The possibilities to do so are limited according to the upgrading cost it generates, but also according to the level of technology of the core to be upgraded. If the fundamental technology of a product is changed completely in the new product (product class level), the possibilities to remanufacture are low. If instead of the changes in technology are minor and concentrated only to specific modules/components (product model level) in the product, the potential for upgrading is greater. To summarize, upgrading products can be a very effective strategy for matching supply and demand and increasing remanufacturing volumes.
Looking deeper into Östlin et al. research [2] is possible to estimate the potential remanufacturing volumes for a product with and without upgrading.
As it is shown on Fig. 2, the upgrading process during remanufacturing or other related processes can significantly higher remanufacturing volumes.

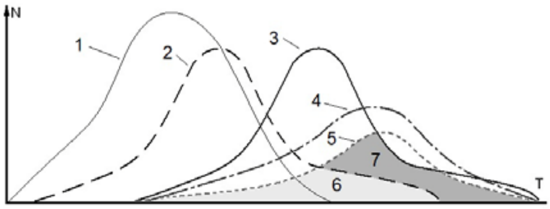

Fig. 2. New products demand, disposal distribution, potential remanufacturing volumes with and without upgrading.

In figure 2 curve 1 – production distribution of new products, demand on market; curve 2 – possible demand for remanufactured cores/products; curve 3 – possible demand for remanufactured cores/products with upgrades; curve 4– disposal distribution; curve 5 – disposal distribution of the products/cores suitable for remanufacturing; zone 6 – potential remanufacturing volumes; 7 zone – potential remanufacturing volumes added to 6 zone, when products are remanufactured with upgrade(s).

Moreover, demand for remanufactured products with upgrades (3) could be even higher then demand for remanufactured products without upgrades (2).

4. TAKE BACK APPROACH

Krikke et al. [4] describe commercial returns as another category connected to the process of sales. Reasons for the returns include a) problems with products under warranty, b) product recall or commercial return, c) end-of-use products and d) end-of-life products.
According to Östlin et al. [8] there are seven different kinds of take-back relationships with suppliers/end-users that have different characteristics for the ability to control the rate and timing of the returns of used products/components. Those are: 1) ownership-based (e.g. leasing, rental), 2) service-contracts, 3) credit based, 4) deposit-based, 5) direct-order, 6) buy-back, and 7) voluntary-based relationships.
Goals of Product take-back:

- shift waste management costs to producers;
- reduce volume of waste generated;
- increase use of recycled materials;
- producers are made responsible to collect and recycle end-of-life products;
- waste management costs are shifted to those most capable of reducing EoL costs by changing designs for recyclability, longevity, reduced toxicity, and limited volume of waste generated;
- EoL costs reflected in product prices – consumers can make more informed decisions.

5. CASE STUDY

The combination of remanufacturing method and take-back approach is used for industrial equipment lifecycle extension. In general, these machines are heavy, complicated, multi-core and expensive. Design rather conservative then ‘green’.

Cost of remanufactured industrial products is rather high as collection of them is quite complicated and transportation is expensive due to the weight. Value of remanufactured industrial products is really cheaper then new one. Because of that demand for remanufactured industrial products is big. The real problem is the willingness of a customer to return industrial product to OEM. Almost in 90% cases customer would prefer to resale or dispose an obsolete industrial equipment, rather to send it to OEM or recycle it. So the manufacturer is losing an option to receive his product to cannibalize its parts or remanufacture it. Solution could be in proper motivation of a customer to give-back industrial product via reverse logistics or other network.

If to speak about material handling equipment (electric stackers and pallet trucks) the customers normally return the leased equipment after 5 years been in long-term-rental to distributor and receive the new ones. It is the usual practice, what is used at least for last decade. In 2005 – 2009 one interesting project between two BT Industries distributors (now Toyota Material Handling Group) has taken place. The scheme was next (Fig. 3):

a. Swedish distributor collected used warehouse trucks (electric stackers and electric pallet trucks) from its customers;
b. Then the used machines were diagnosed and sorted according to product families;
c. After that the used equipment was sent to Latvia with needed set of spare parts;
d. When Latvian distributor received the machines, they were forwarded to work stations, where the remanufacturing process had been provided;
e. The condition of used material handling equipment after remanufacturing process was “as new”.

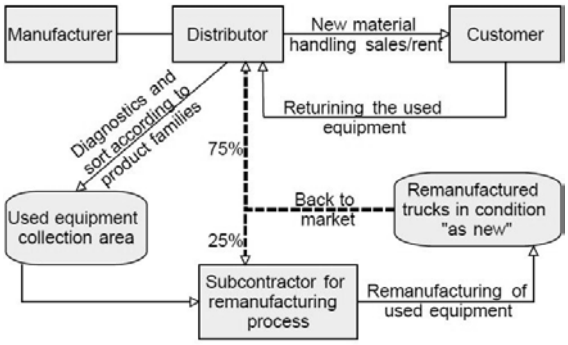

Fig. 3. Framework for remanufacturing system of material handling equipment

The remanufacturing system discussed here can be conceptualized into a framework as shown in Fig. 3. The products returned to the disassembly centre are revised, classified and organized by the disposal and remanufacturing strategy. Returned products which are of good quality for remanufacturing can be disassembled and processed until they become parts and/or components. Remanufacturing process generally involves total disassembly and extensive inspection of all parts and modules. When the product has been disassembled, parts/components are cleaned and tested. Just like assembly lines, which are used to assemble components into a final product which has high volume, disassembly lines are essential to transform the discarded products to parts/components.

To minimize the total costs of the system, the distributor must decide on the number of products to be disassembled and the parts to be purchased from suppliers.

Transportation costs of products =

$$\sum_i\sum_n\sum_p t_i \cdot x_{inp} \cdot b_{np} + \sum_i\sum_m\sum_p t_i \cdot x_{imp} \cdot b_{mp} \quad (1)$$

Disassembly cost = $\sum_i\sum_p b_i \cdot s_i . d_{ip} \cdot TD_i$ (2)

Disposal costs= $\sum_i (1-b_i) \cdot s_i \cdot DC_i \cdot TD_i$ (3)

Collection costs = $\sum_i s_i \cdot CC_i \cdot TD_i$ (4)

Purchasing costs= $PC \cdot \sum_k Q_k$ (5)

Where, i product; l distribution centre; n collection centre; p disassembly centre; t_i transportation cost of one unit of product i per mile; x_{inp} quantity of product i shipped to disassembly centre p from collection centre n; x_{imp} quantity of product i shipped to disassembly centre p from customer; b_{np} the distance between collection centre n and disassembly centre p; b_{mp} the distance between customer and disassembly centre p; s_i returned fraction of the demand from customer for product i; b_i fraction of returned product i satisfying the quality specifications for remanufacturing; d_{ip} disassembly cost per unit of product i in disassembly centre p; TD_i total demand of product i; DC_i disposal cost per unit of product i; CCi collection cost per unit of product i; PC purchasing cost per unit of component; Q_k number of units of component purchased from an external supplier to manufacturer k.

The mathematical approach was adopted for used material handling unit price for remanufacturing from Neslihan Özgün Demirel et al. [9] article.

The whole project was provided with non-monetary operations. As a result the remanufactured trucks were divided as follows:

- 50% returned to distributor in Sweden;
- 25% were sent or stored according to Swedish distributor wish (customers in Europe, Russia);
- 25% left at subcontractor warehouse as payment for work.

The volume of this project was 700 – 800 remanufactured trucks per year. This project was successful because of two main reasons:

a. Difference in salary between Sweden and Latvia;
b. Serious amount of work in Sweden. They did not have enough time and human resources for this project at that time.

When the economic crisis begins the project has been stopped. Undoubtedly, the project can be easily activated again in maximum volume when the needed capacity of work appears. Such scenario works when the customer returns the forklifts from long-term-rental after 5 years of use. What to do with the client, who has bought the material handling equipment without any loan or leasing? The new possible formulation of take-back approach in industrial world is offered in this paper. The new idea is to stimulate the used equipment take-back after up to ten years being in operation. It must be very interesting for the big companies with stable plans and financial situation. On the other hand, this approach could be useful for the clients, who need to change or upgrade equipment they use, because of requirements change. The new treatment of this approach can be very useful in these cases. Our aim is to prolong useful lifetime of industrial equipment by combining EoL approaches and sales/marketing possibilities.

Let's say that in normal way industrial product is bought for price X, have a useful life of N years, and have a descending value $V \rightarrow 0$ from customer's point of view and descending value $W \rightarrow 0$ from manufacturer's point of view, starting from the point when this product was produced/ purchased. In normal situation when product reaches its end of life (N), V is ≈ 0, (but $W \neq 0$), product is disposed. All material work and energy that embedded into this product is wasted. In the paper is proposed approach to motivate customer return disposed equipment to distributor. It might be denoted that the market price for one industrial product is $X+10\%$ which is comparatively higher than normal price. But it can be also proposed that when the product reaches its EoL, and if it is returned to distributor (producer), last one refunds *30%* of the price of the product ($X+20\%$). So even if V is almost $= 0$, W is not 0, and the product has a potential value for its manufacturer (as remanufacturing option is available; cores/ parts to be cannibalized). Even more, using this scheme, distributor gains *20%* more at the early stage of production, but have to refund customer *10%* after receiving an old product. But this *10%* is covered by all other benefits: smaller reverse logistics costs, motivation to return products for value-added activities, greater cash-flow, predictability of returns, stable product returns as a source for remanufacturing, and control of the distributor over the greatest part of its old products.

5. CONCLUSIONS

Considering age, material quality and other conditions, different products requires different approaches when it comes to end-of-life context. Industrial products differ from consumer products in terms of cost, useful life, handling and disposal. In order to extend a lifecycle, for any type of product there is always a reuse or service options near the end-of-use point and recycle or dispose options near the end-of-life point. Many types of industrial equipment have an opportunity to be remanufactured or demanufactured for parts by OEM – which is the most efficient way to prolong product's or part's lifecycle. This will save money, material, cores, energy, lover emissions and landfill. Moreover, right motivation of the customer to give back an obsolete product will offer an opportunity to forecast future remanufacturing volumes and create a new stable market. So even if product is old and consumer want to get rid of it, OEM still have an interest in it, in its parts that could be cannibalized, in opportunity to upgrade and remanufacture it. No doubt this is beneficial for both sides.

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