CIRP Journal of Manufacturing Science and Technology 2 (2009) 13–20

Contents lists available at ScienceDirect

CIRP Journal of Manufacturing Science and Technology

journal homepage: www.elsevier.com/locate/cirpj

Process planning for IT-equipment remanufacturing

Sebastian Kernbaum, Steffen Heyer *, Stylianos Chiotellis, Günther Seliger

Institute for Machine Tools and Factory Management, Technical University Berlin, Berlin, Germany

ARTICLE INFO

Article history:
Available online 21 August 2009

Keywords:
Remanufacturing
Process planning
Mathematical programming

ABSTRACT

We present an approach for the design, evaluation and implementation of remanufacturing processes in a given facility. Based on the description of the market situation and involved actors, a planning method is derived. Data acquisition procedures for product, process and facility are described. A mixed integer program is developed for optimization of a remanufacturing process and evaluation of its economic viability. Additionally, the paper describes the technical implementation, the software workflow and example application on the product category Flat Screen Monitors.

1. Introduction

Reuse and Remanufacturing of Waste Electrical and Electronic Equipment (WEEE) are a matter of current concern, driven by economic, ecologic, social and legislative factors. The potential that lies in the reuse and remanufacturing of IT-equipment is not fully exploited yet. Only a few specific products have been considered – e.g. mobile telephones [1–4] – and not all treatment opportunities available are applied. Moreover the financial uncertainties concerning product quantities, types and conditions that are long associated with remanufacturing processes limit the entrance of new actors into the sector. Although planning decisions highly influence the efficiency of a production system carrying out remanufacturing operations, decision support and planning tools, which are standard in assembly industries, are seldom available and applied. The need for such tools is evident. Based on a market analysis and the identification of actors that are aiming to extend their operations by establishing remanufacturing processes as value adding processes, an integrated planning system is presented in this paper.

2. Actors involved and task definition

Actors involved in closed-loop-economy and their relation is given in Fig. 1, not considering legal aspects. The actors vary in access to product and material condition, amount and information's about these. The following are identified as capable to extend their operations with remanufacturing oriented value adding processes: OEM's, suppliers, maintenance shops, existing remanufacturing companies, and partly recycling companies.

These actors have in common the access to functional or non-functional products and components that are valuable enough to justify their upgrade, through some remanufacturing treatment, to a marketable state or condition.

The same actors differ in their specific knowledge on the product itself, the products status and condition as well as their operational capability to bring it to a valuable condition. They also differ in available equipment, processes and capacities, i.e. in remanufacturing capabilities. This raises the following questions for each specific actor:

- To what extent do I incorporate remanufacturing activities in my existing facility/facilities?
- Which specific remanufacturing processes am I able to carry out?
- How much investment is needed in order to offer high quality remanufacturing?
- What are my specific costs and revenues once the remanufacturing processes are operational?

To answer these questions in a suitable manner, a three step planning approach has been developed, implemented in a software tool and applied to the example of flat screen monitors remanufacturing.

3. Planning method

The proposed approach involves three steps: the data analysis, the process design phase and the remanufacturing process optimization of the remanufacturing tasks phase.

3.1. Data acquisition

The product and facility relevant data that are required for the proposed planning approach are determined and acquired.

Data regarding the product need include the product structure, i.e. components and component groups, joining elements and techniques, disassembly sequences, material ratios etc. and end-

* Corresponding author.
E-mail address: sheyer@mf.tu-berlin.de (S. Heyer).

1755-5817/$ – see front matter © 2009 CIRP.
doi:10.1016/j.cirpj.2009.07.003

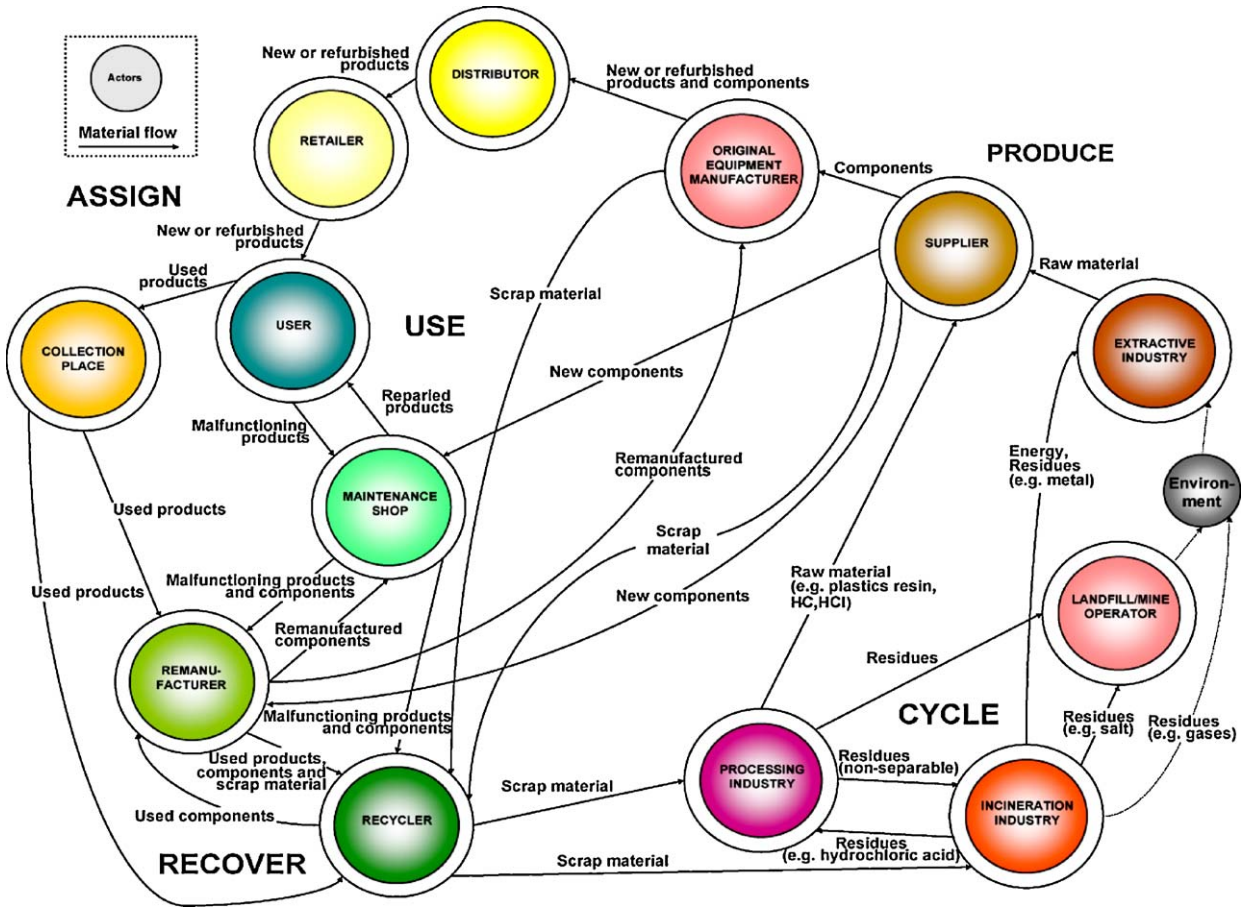

Fig. 1. Complexity in remanufacturing [6].

of-life data (disassembly times and costs and recycling quota). For ease of system integration, product models are developed using the commercially available software system ProdTect [7]. ProdTect is a software tool which supports the development of ecologically sound products by providing information related to a product's treatment and recycling at an early product development stage [8]. In the ProdTect product model input module, the product structural information is composed of:

- Parts information, such as material composition, disassembly movement, dimension, shape, accessibility.
- Connection information composed of the different joining elements in the product.
- Priorities information, which gives an order of the parts inside the product. A part is prior to another if it needs to be dismantled to get access to the other.

ProdTect calculates technical, economic and ecological parameters. The resulting data, such as disassembly times and sequence, can then be utilised for the planning of the end-of-life processes for a product [9]. An overview of the software tool ProdTect is given in Fig. 2.

Product accompanying information were analyzed and prepared for being used for the proposed planning approach.

The next step involves acquiring data regarding the resource and capacity planning of the given facility. Such data include the available installed capacity, the actual job schedule and the inventory levels and can be acquired from the ERP (Enterprise Resource Planning) system of the facility. Facility accompanying data were analyzed and prepared for application in the proposed planning approach in accordance to the VDI 3633 guideline ([10], Fig. 3).

3.2. Process design

The second planning step is the development of the process model. The process model design determines all possible sequences and types of remanufacturing steps that are required in order to process a batch of incoming products, e.g. testing, cleaning, disassembly, reassembly from a specific product type, e.g. flat screen monitors. The sequence is derived by conducting trial runs on a number of sample products. A graphical user interface (GUI) has been developed in order to assist the planner to visualize the developed remanufacturing process in the form of a network. This network acts as the interface of the database that contains the product, process and facility information.

Fig. 4 gives an overview of the structure in the example of a typical remanufacturing process. Products entering are first examined according to product relevant testing criteria. Based on these tests, a list of failures can be documented for each specific product. These lists of failures need to be treated to bring the product back to a valuable condition—they therefore create specific "remanufacturing paths" for each single product in the overall designed process network.

Based on results of preliminary tests, treatment decisions are made: if the amount of failures exceeds a threshold of acceptable failures in the designed process, the product is sent to material recovery processes. In the case where a product is in a condition to be sold to customers, only cleaning and packaging operations need to be carried out. If failures are worth to be treated, the product is