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Remanufacturing of mobile phones—capacity, program and facility adaptation planning

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Abstract

Successful remanufacturing of mobile phones must meet the challenges of continuously falling prices for new phone models, short life cycles, disassembly of unfriendly designs and prohibiting transport, labor and machining costs in high-wage countries. A generic remanufacturing plan for mobile phones is developed. For the planning of remanufacturing capacities and production programs, a linear optimization model is introduced. To support the planner in the periodic adaptation of an existing remanufacturing facility under quickly changing product, process, and market constraints, discrete-event simulation is applied. Uncertainties regarding quantity and conditions of mobile phones, reliability of capacities, processing times, and demand are considered. The simulation model is generated by an algorithm using results from the linear optimization approach.

Keywords: Mobile phone remanufacturing; Production program planning; Linear optimization; Discrete-event simulation

1. Introduction

Today, the remanufacturing of expensive, long-living investment goods, e.g. machine tools, jet fans, military equipment or automobile engines, is extended to a large number of consumer goods with short life cycles and relatively low values. Reuse is an alternative to material recycling to comply with recovery rates and quantities as well as special treatment requirements as prescribed by European legislation with the directive on Waste of Electrical and Electronic Equipment (WEEE) [1,2].

Some remanufacturing cases are widely known, e.g. the remanufacturing of single use cameras (Eastman Kodak and Fuji Film), toner cartridges (Xerox), photocopiers (Fuji Xerox, Australia, Netherlands and UK), commercial cleaning equipment (Electrolux) and brand name computers (IBM, France, Germany, USA; HP, Australia). Remanufacturers are OEMs themselves who have integrated new distribution models such as leasing or "pay per use" with remanufacturing strategies [3]. Other remanufacturing practices, e.g. for washing machines (ENVIE, France), personal computers (ReUse network, Germany), accumulators (teldeon, Germany), cordless phones, car stereos, FM radios (Topp Companies, USA) and mobile phones (ReCellular, USA; Greener Solutions, UK) are less popular, due to the fact that OEMs are not involved. Products are not sold through regular retail channels established by OEMs.

Market studies regarding offer and demand for mobile phones with GSM standard [1,4,5] show the worldwide potential for mobile phone remanufacturing. The studies revealed that with a total quantity of over 200 Mio. unutilized mobile phones, Europe can serve as a supply market. Demand markets can be found in Asia and Latin America, e.g., China and Brasil, where market penetration is as low as 20% and—in the case of Brasil—where the old TDMA mobile communication standard is currently replaced by the GSM standard. By means of low-cost remanufactured phones, one

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cannot only serve communication demands of lower income classes in those regions, but it is possible to recycle phones complying with WEEE requirements and thus provide services for OEMs within the scope of the directive.

In order to evolve mobile phone remanufacturing into a profitable business segment, it is necessary to provide remanufacturers with efficient planning methods and tools, capable to deal with the special procurement, remanufacturing and distribution processes. The tools and methods should allow the efficient reconfiguration of remanufacturing facilities considering fast-changing product, process, and market conditions. The most frequently changing input parameters are the type and quantity of mobile phones offered at the market. In Western Europe, with the average replacement cycle of phones being less than 18 months and more than 100 new phone models every year it is feasible to assume that the remanufacturing program requires adaptation several times during a year [5]. In this paper, an approach is presented to support the remanufacturing program planning under the above-stated framework. The remanufacturing program and required capacities are determined by means of combinatorial optimization. Based on the results, the planner is enabled to adapt and evaluate the existing remanufacturing facility using discrete-event simulation.

2. Constraints for planning of mobile phone remanufacturing

In the following, the process chain of mobile phone remanufacturing is analyzed to identify aspects that need to be considered in the planning of a remanufacturing facility. The procurement of phones can be realized in cooperation with OEMs, e.g. by acquisition of overproduction, or in cooperation with net providers, supermarkets or other private and public organizations who have frequent and close contact with phone users, in so-called take backs. Experience has shown that consumers are willing to either turn in their used phones as a charitable donation or trade them in for benefits such as free phone minutes [6,4]. An effective and efficient take back of mobile phones is an essential element of the remanufacturing process chain. Legislation has a strong influence on why and how take back is and will be organized for different product classes. Yet, in many cases, take back is accomplished without any pressure being built up by governments. This is the case if profits expected from selling remanufactured products or recycled material can compensate the costs for take back, inspection, testing, refurbishment and redistribution of products. Using retail channels for product take back is an adequate approach to utilize existing logistics capacities, and address known customers to replace their used products. The lower the take back costs in relation to the residual value of the product, the higher are the chances for voluntary take back without the need for legal regulations. If the residual value is either low or not known to the user, and weight and volume permit

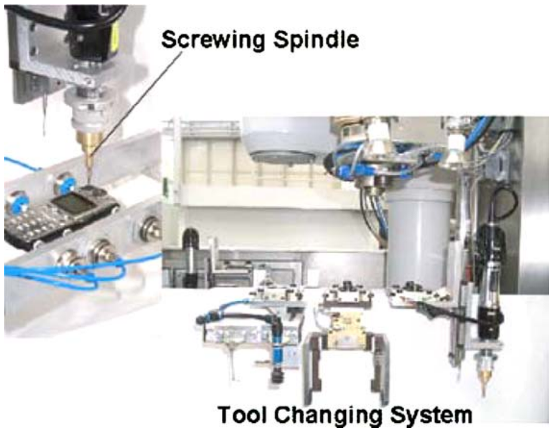

Fig. 1. Automated disassembly of mobile phones [11].

disposal together with domestic waste, the risk of incorrect disposal of the product is relatively high. For these types of products, it is necessary to implement a take back offering some benefit to the user. In take backs, the variability regarding quantity, model and condition of returned mobile phones is high. Identification and pre-sorting of phones at collection points can reduce volume and model diversity of phones sent to the remanufacturing facility.

After the take back, phones need to be separated, e.g. from chargers or earphones, and identified. Experience of remanufacturers shows that about 70% of phones recovered in Europe and the USA are considered beyond economic reuse, i.e. that either remanufacturing costs are too high or demand is too low for these phones, and they are consequently sent to material recycling [6,4]. The remaining phones need to be tested to determine optical or functional faults that can be ascribed to the main elements housing, printed circuit board (PCB), display, microphone and speaker. The combination of faults results in different process times for disassembly and reassembly. Replacement components are supplied either by external procurement or internal retrieval of components from used phones.

Efficient disassembly is a prerequisite for the remanufacturing of phones with functional faults. The disassembly process of none-flip (candy bar) mobile phones can be automated, making use of a flexible disassembly cell developed within the Collaborative Research Center 281 “Disassembly Factories” [7,8] depicted in Fig. 1. The hybrid system is characterized by the integration of manual and automated operations. In this system, the only manual operation is the removal of the main battery. For the automated operations, a 4-axis Scara robot was applied. A flexible gripper is used to pick cell phones independent of length and width. It places the phone in a flexible clamping device. Pneumatic cylinders are used to form the specific shape of the phone, thus being able to grip independent of the provided phone geometry. The clamping device attached to a pivot arm ensures the time efficient removal of non-ridged part, such as the key