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USING SIMULATION OPTIMIZATION FOR PARTS RECOVERY AND SPARE PARTS INVENTORY MANAGEMENT IN POST PRODUCT LIFE CYCLE

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ABSTRACT

The parts recovered from discarded and end-of-life products can be used as a source of spare parts during post product life cycle. However, accurate determination of the final order quantity is complicated as it requires the prediction of spare parts demand for the post product life cycle. In this paper, the spare parts problem is solved using simulation. Simulation is chosen because of the stochastic and complex nature of the problem. A simulation model of the manufacturing system is first developed which is then integrated with a genetic algorithm to determine the optimal final order quantities for a number of critical spare parts.

INTRODUCTION

The success of companies in after sales service largely depend on the timely and cost effective supply of spare parts which are needed in the repair and maintenance of durable products. The acquisition of spare parts can be an extremely challenging task especially at the post product life cycle since the source of new spare parts is limited.

Placing a final order for spare parts at the end of product life cycle is a common approach to this problem. However, accurate determination of this final order quantity is a complicated issue since it requires the prediction of spare part demand for the post product life cycle. Prediction of demand is very difficult even when the failure rates are available and the number of installed bases is known, because a long term forecast over several years is needed and a number of intangible factors such as fashion and obsolescence must be considered. If the demand is overestimated during the post product cycle, excess parts have to be scrapped. Underestimation of demand results in opportunity cost and lost goodwill of the customers [1].

One possible solution to the above spare parts problem is that the recovered parts from the discarded and end-of-life (EOL) products can be used as a source of spare parts during post product life cycle because remanufacturing cost is much cheaper than cost of extra production [2]. However, the remanufacturing system is fraught with high degree of uncertainties in timing, quantity and quality of product returns. Thus a satisfactory decision model for the determination of final order quantities for spare parts during parts recovery and disassembly must have the ability of coping with many stochastic variables simultaneously.

CURRENT STATUS

In the literature, the most commonly used approaches to develop spare provisioning decision models are simulation and mathematical programming. Mathematical programming consists of the development of mathematical models based on techniques such as linear programming, dynamic programming and goal programming. Sherbrooke's [3] multi-echelon model for recoverable item control is the first application of mathematical programming in spare parts inventory management problem. After that study, many researchers studied various aspects of the spare parts management problem. The reader is referred to Kennedy et al.'s [4] paper for an overview of these studies. It is

noted that all these studies entail the use of simplified plants or systems models whose predictions may be of questionable realism and reliability.

The use of simulation in modeling the spare parts inventory management problem represents a popular alternative to mathematical programming since simulation has the ability of describing multivariate non-linear relationships which can be difficult to put in an explicit analytical form. However, simulation modeling is not an optimization technique. It is, therefore, necessary to integrate the simulation model with an optimization tool.

In recent years, metaheuristics such as genetic algorithms (GAs), simulated annealing, and tabu search have been extensively used along with simulation to enhance the efficiency of the search procedure. Among these guided search methods, simulation optimization via GAs is quite an active research area.

GAs are biologically inspired search procedures that have been used to solve different NP-hard problems [5], [6], [7]. Like other biologically inspired techniques (e.g. ant colony optimization, particle swarm optimization), they try to extract ideas from a natural system, in particular the natural evolution, in order to develop computational tools for solving engineering problems. They are used to search large, non-linear search spaces where expert knowledge is lacking or difficult to encode and where traditional optimization methods fall short.

There are successful applications of GA-based simulation optimization in scheduling, facility layout, assembly-line planning, supply-chain management, kanban systems, maintenance-policy selection, and spare parts inventory management.

METHODOLOGY

This study tries to determine the optimal order quantities for a number of critical spare parts. Reordering of spare parts during post product life cycle is not possible in the system considered. The only source of spare parts during this period is the parts harvested from the discarded and EOL products. Hence, the determination of the optimal order quantities for critical spare parts requires the simultaneous consideration of the demand for spare parts during post product life cycle and timing, quantity and quality of product returns.

In order to cope with these highly uncertain components of the problem, firstly, a detailed simulation model describing the manufacturing system with its spare parts inventory and remanufacturing related aspects is developed. Uncertainty in demand during post product life cycle, uncertain product returns and part recovery is included in this simulation model. Then, a GA is integrated with the simulation model for the optimization of final order quantities for critical spare parts.

While designing the GA, at first the final order quantities of critical spare parts is coded into chromosomes so as to perform the genetic operation. Each chromosome represents a possible configuration of final order quantities of critical spare parts. The GA process involves searching for the optimum final order quantities of critical spare parts. In our approach, the fitness of each chromosome is evaluated by the simulation model. According to the fitness results, the GA creates new alternative solutions. Thus, there is a two-way communication between the GA and the simulation model.

During this search process, a total annual cost (TAC) function is employed to evaluate the fitness of each alternative solution. This annual cost function involves the holding and shortage cost of spare parts and the costs associated with product recovery and remanufacturing.

Next, to further improve the performance of the GA developed, a set of experiments is performed to identify appropriate values for the GA parameters (i.e. the size of the population, the crossover probability, and the mutation probability).

CONCLUSION

Accurate determination of the final order quantity is a complicated issue because it requires the prediction of spare part demand for the post product life cycle. Moreover, the recovered parts from the discarded products can be used as a source of spare parts during post product life cycle. This stochastic and complex nature of the problem requires the use of simulation modeling. In this study, first, a simulation model of the manufacturing system is developed. Then a GA is integrated with the simulation model to determine the optimal final order quantities for a number of critical spare parts.

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