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Combining in-house pooling and sequencing for product regeneration by means of event-driven simulation

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Abstract

The condition of complex products in the transport industry, such as train couplings or aircraft turbines, is not exactly determinable before their disassembly and diagnosis in a maintenance plant. Thus, planning and control of their regeneration is impeded since work plans and spare part demand result at short notice. This paper presents a novel method, which combines a planning approach, the in-house pooling of components, and a controlling approach, the sequencing of components, by means of event-driven simulation. Thereby, mean cycle time, mean tardiness and on-time delivery can be optimized under the consideration of the volatile conditions.

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Keywords: Simulation; Production planning and control; Sequencing

1. Introduction

The rising complexity and value of products used in transport industry, e.g. train couplings or aircraft turbines, increase the importance of their regeneration [1]. However, the condition of the products is in many cases not determinable during their operation. Hence, their regeneration takes place in maintenance sites at defined intervals of time or mileage. The unknown condition of components before their disassembly and inspection in the site leads to dynamic work plans, uncertain processing times and lumpy spare part demand. Consequently, the regeneration planning and control (RPC) is impeded and result in fluctuating cycle times. Since the majority of German regeneration companies define the reliability of their services as their main goal, harmonizing cycle times and improving on-time delivery as well as mean tardiness has to be considered in particular [1,2].

Maintenance sites are organized as job shop productions, because they have to handle a wide range of products and a high rate of variants [3]. However, the material flows of different products' individual components share the same buffer in front of the reassembly [4]. At this convergence point, the production material flow (repaired components) and the stock material flow (spare parts) merge to one, see Fig. 1.

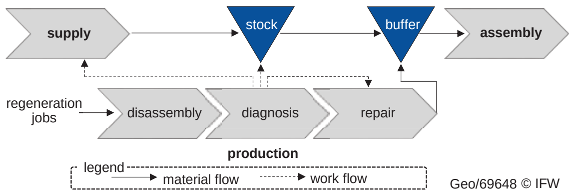

Fig. 1. Schematic procedure of a regeneration process.

Because the assembly only starts when the last component of a job arrives, cycle time, job tardiness and on-time delivery as well as the waiting work in progress (WIP) are primarily defined by this point in time. In particular, at the date required three categories of WIP are distinguished:

- completed WIP (assembly started on time)
- partial completed WIP (components waiting at the buffer)
- not supplied WIP (needed components, which have not arrived yet at the buffer)

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The value of waiting WIP over a period under review, e.g. one year, is in the following referred to as distorted WIP. The higher the distorted WIP the more capital commitment costs for the regeneration company occur due to not completed assemblies. Thus, there is a need for RPC methods, which synchronize the provision of components to the assembly on time. In doing so, the service performance is increased and the distorted WIP reduced [4].

Based on the investigations of [5,6] it emerged, that the planning method "pooling" and the control method "sequencing" have a strong influence on the performance of regeneration companies. Thereby, the dynamic and stochastic dependencies among the consecutive regeneration steps, e.g. between the diagnosis and the repair process, have to be considered for an optimal coordination of the material flow. Prior research led to simulation-based pooling and sequencing approaches using the event-driven simulation [4,6]. However, the combination of these methods has not been investigated yet.

This paper illustrates the state-of-the-art of pooling and sequencing. Afterwards, the method of combined in-house pooling and sequencing is introduced. The method is implemented and tested in an event-driven simulation of a real case scenario, the regeneration of train couplings.

2. State of knowledge

The following section presents the difference between external product pooling and in-house component pooling as well as the results of previous simulation studies on sequencing in the field of product regeneration.

2.1. Disposition of pool-inventory

Research on the disposition of pool inventory has been carried out in the economic literature, particularly for the aircraft industry, since the end of 1960 [7]. The idea is, that worn out products are regenerated in maintenance sites and directly supplied to external warehouses (pools) following the make-to-stock principle. The pools provide the stocked products to decentral locations for temporary storage or directly to their points of use. Thus, short transport and delivery times are realized. On the other hand, additional inventories are built up and particular attention must be devoted to the emerging inventory and transport costs [8, 9]. Since the pools are located outside of the regeneration sites and store completely regenerated products, this method is defined as external product pooling [7]. External pooling approaches consider the regeneration process as a "black box" and approximate cycle times via exponential or Poisson distributions. Furthermore, infinite repair capacities are assumed and dynamic as well as stochastic cause-effect relationships in the site neglected [8,9,10]. Hence, in [4] a simulation-based approach is developed, which transfers the idea of external product pooling to the pooling of components in a regeneration site (in-house), see Fig. 2.

Components of products that regularly induce delays to the start of assembly, e.g. because of long processing times, are systematically identified by means of the event-driven simulation and added to the pool (pool-components). As a result, they are supplied to the assembly on time.

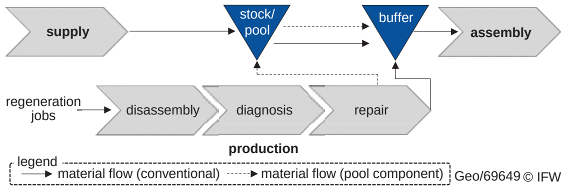

Fig. 2: In-house pooling of components at the product regeneration.

The regeneration process is not affected since repaired pool-components fill the pool after their regeneration to create a closed circuit. Mean cycle time, mean tardiness and on-time delivery are greatly improved. The benefits have to be contrasted with the initial acquisition and stock costs. Because of this optimization problem, Georgiadis et al. [4] introduces a method to determine pool configurations under economic aspects (suitable components, optimal stock-sizes).

2.2. Sequencing

Sequencing rules are used to determine the priority of a job or component at waiting queues in the production. Table 1 describes five rules, which are frequently tested at assembly job shops and repair shops. Assembly job shops are characterized by a job shop production with convergent material flow to an assembly, but do not consider a disassembly or diagnosis. These specific regeneration steps are considered in repair shops.

Table 1: Sequencing rules tested in assembly job shops and repair shops.

Rule	Full Rule Name	Description
RAND	Random	A random job or random component is processed first.
FIFO	First-In, First-Out	The job or component which arrives first at the work station is processed first.
SPT	Shortest Processing Time	The job or component with the shortest operation processing time is processed first.
EDD	Earliest Due Date	The job or component with the earliest due date is processed first.
JST	Job Slack Time	The job or component with minimum slack is processed first.

Sequencing at assembly job shops has been well studied over the last decades [11]. In contrast, sequencing in repair shops has not received the same attention.

Guide et al. [12] investigate the influence of the rules FIFO, SPT and EDD in repair shops with different utilization level, number of machines and product complexity. They identified that the utilization level of machines and the complexity level of products have a strong influence on the impact of sequencing in repair shops. The best results concerning mean tardiness and on-time delivery were achieved by the EDD rule. However, at various settings, the improvement of the mean cycle time was better by using FIFO and SPT. Reményi et al. [2] tested the impact of the