Int. J. Production Economics 147 (2014) 94–107

Contents lists available at ScienceDirect

Int. J. Production Economics

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

Systematic simulation based approach for the identification and implementation of a scheduling rule in the aircraft engine maintenance

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ARTICLE INFO

Article history:
Received 1 December 2011
Accepted 25 October 2012
Available online 7 November 2012

Keywords:
Aircraft engine maintenance
Scheduling rules
Production planning and control
Simulation

ABSTRACT

In the current situation of fluctuating demands and market driven turbulences, new part manufactures have to deal with many turbulence factors. Companies operating in the MRO (maintenance, repair and overhaul) sector have to additionally deal with major variations of work load and work contents. In addition, the operational processes of the maintenance contractors are strongly affected by the influence of the customers. The delivery date of the corresponding order is highly influenced by the customer. Besides the information about the actual work load is only completely known when the inspection is completed. Since the planning of the maintenance event and the maintenance operation are hard to handle, the focus of the approach presented in this paper is set on improving the maintenance operation by finding suitable scheduling rules for the job-shop operation of the maintenance. We hypothesize that the use of scheduling rules can improve the maintenance operation. The main question which is answered in this paper is the question if an improvement of the logistical targets of the maintenance system can be accomplished with the use of decentralized scheduling rules. As part of the examination, a systematic simulation based approach for the identification of scheduling rules is defined. Due to the need of different studies, a simulation model is developed. With this model, the different simulation studies can easily be accomplished. The simulation results show an influence of the decentralized scheduling before each of the machine tools. The best results were achieved by the combinations of FIFO/Slack and ESD/Slack with an influence on the target values on-time delivery, work in progress, the throughput, the performance and the throughput time.

Further on a tool for the implementation of the identified scheduling rule in a decentralized shop control is described. Besides the validation of the tool in an aircraft engine company is made. The application of a Slack rule during a period with increased workload of 36% showed a nearly constant on-time delivery.

1. Introduction

Today's economic markets are incredibly turbulent. This turbulent environment can be determined by the technology, the internationalization of markets and the permanent change in supply and demand (Westkämper and Zahn, 2009). These factors directly influence the processes of new part manufacturers. Not only are the processes of new part manufacturers affected, the companies operating in the MRO sector are also heavily influenced by these increasing turbulences. These MRO companies are further influenced by order variations, whether in the amount or labour content, due to changes triggered by the customer. The dilemma for an aircraft engine maintenance company is that they have to cope with the coordination of the removal strategies of a multitude of separate customers, unscheduled engine removals (UER's) and the thread of OEM's (original equipment manufacturers) searching to cover their development costs with profits generated on the aftermarket (Reményi et al., 2011a). At the same time they must also contend with low and predictable costs and guaranteed turnaround times becoming more and more important to the customer (Reményi et al., 2011a).

Therefore, the maintenance procedures have to be constantly improved. One way to increase the aircraft availability and improve maintenance and support efficiency is by speeding up the turnaround time for scheduled and unscheduled maintenance (Candell et al., 2009). To speed up, or reduce the turnaround time, is especially in the MRO market a challenging mission (Reményi et al., 2011a). The majority of MRO companies are organized in a job-shop

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http://dx.doi.org/10.1016/j.ijpe.2012.10.022

production, which is defined in the study by Reményi and Staudacher (2011). For the control of the job-shop operation, many approaches concerning the scheduling of the orders can be found in the literature. For a suitable scheduling appropriate sequencing (priority) rules are required. Therefore, the focus of the presented paper is set on the identification of suitable scheduling rules for the aircraft engine maintenance with a simulation model. In addition, the simulation based selected scheduling rule is implemented in a decentralized job-shop control.

As many decisions are made on the shop floor level the decentralized approach of a control tool is appropriate (Reményi et al., 2011a). Axsäter (1982) points out that the possibilities of decentralizing production planning tasks depend to a large extent on the organizational structure of the production system. Since the maintenance process is predominantly organized as job-shop, information is needed at the different local operation areas. Köhler (1993) adds that for the support of decentral decision-making, central systems are not suitable. Referring to the job-shop structure of a maintenance company the development of a decentral control tool is necessary.

This paper aims to explain the maintenance process in the aircraft engine maintenance, define its existing challenges and review earlier literature. The simulation model and its input and output values are described, along with its results using the variance analysis calculation. The scheduling rule defined by the simulation is implemented in a decentralized job-shop control. The validiation of the control tool and the scheduling rule is made by the implementation in a maintenance company.

2. Review of the literature

The literature being reviewed concentrates on prior research in aircraft engine and aircraft maintenance, decentralized production planning and control, job-shop control through scheduling rules, and systematic approaches for the identification of scheduling rules.

Literature concerning aircraft engine maintenance frequently concerns the diagnosis of the engine's condition, known as Condition Based Maintenance (CBM). Articles published by Jessop et al. (2008) and Rajamani et al. (2004) are exemplarily for the description of a CBM system. Kleeman and Lamont (2005) produce another approach to scheduling problems using a multi-objective evolutionary algorithm to solve scheduling problems. With using a simulation model, described by Gatland et al. (1997), the capacity problems during a maintenance event are objectively solved. Guide (1993) developed a simulation model which should prove that the application of a synchronous manufacturing is applicable in a maintenance company. Some interesting research concerning the use of scheduling rules in the aircraft engine maintenance and pooling of spare parts is discussed in Scudder (1984) and Hausman and Scudder (1982).

Research focused on aircraft maintenance is found in the following published papers. The simulation of a job-shop with the objective to find an optimized layout is best found in Leemis et al. (1990). Cobb (1995) describes the application of a simulation model for the aircraft component maintenance. The optimization of line maintenance planning, which is described as short inspections of aircraft between arrival and departure at an airport, is best represented by the simulation model described by Gupta et al. (2003). The influence of resource availability on the throughput in the aircraft component maintenance is examined by the simulation model developed by Harvey et al. (1992). Other reserach topics include the material requirement planning, as described by Ghobbar and Friend (2004), and the spare part pooling, examined by Kilpi and Vepsäläinen (2004). The manpower and capacity planning in the aircraft maintenance is described by Yan et al. (2004) and Dijkstra et al. (1991).

There are numerous literatures focusing on decentralized production planning and control. Wiendahl and Garlichs (1994) are examplary in using Decision Support System (DSS) for the decentral production scheduling of an assembly system. A genetic algorithm is used for the scheduling. Wiendahl and Ahrens (1997) demonstrate an agent-based approach for the control of a production system. Rohloff (1993) considers the decentralized production planning by the development of an object-oriented information system. Scholz-Reiter and Hamann (2008) examine the behavior of a learning production control through the application of the neural networks theory.

The need for a decentralized planning and control approach is widely discussed. Wiendahl and Garlichs (1994) mention that in many companies responsibility for detailed planning and order implementation has already been transfered to the production area. Rohloff (1993) states that due to the deficiencies of today's production planning and control systems (PPC) and modern organizational production processes trends, it is evident that only a decentralized approach is able to cope with the changing requirements of production planning and control. Wiendahl and Ahrens (1997) observe that control functions are being more and more decentralized due to the growing complexity. Mey (1999) discusses that diffusing production processes with high control effort offer better approaches to decentralization. This diffusing nature is a characteristic of the maintenance process. The reviewed articles offer approaches to a decentralized control that are appropriate to cope with the unstable economic market. According to Teunis (2003) the decentralization of production systems can take place on three levels:

- on site level,
- on production level,
- on job-shop level.

Reviews of sequencing methods for job-shops are best described by Ramasesh (1990) and Sisson (1959). MacCarthy and Liu (1993) declare that the utilization of classical scheduling theory in most production environments is minimal. Furthermore effective scheduling software is essential in complex manufacturing environments (MacCarthy and Liu 1993). The application and the analysis of scheduling rules in different production environments have been already widely discussed in the recent years. A good classification of scheduling rules is made by Ramasesh (1990). The classification is hereby made in four groups:

- according to the dependence on the time in the shop (static, dynamic)
- according to the dependence on the state of the shop (dependant, independent)
- according to the structure of the rules (simple, combinatorial, truncated, weighted index, heuristic)
- according to the information context of the rules (arrival time, processing time, due-date information, cost or value-added) (Ramasesh, 1990).

In further publications especially the temporal and informational dependence of scheduling rules are discussed. Panwalker and Iskander (1977) and Gere (1966) explain these in great detail. However the practical application and the effect of scheduling rules are regarded critical by Wiendahl and Lüssenhop (1987) and Lödding (2008a). Therefore a systematic approach for the identification of scheduling rules is needed.

The systematic approach for the identification of a scheduling rule in the MRO industry with the processes disassembly, repair and assembly has not been systematically analyzed. Some work