2004

Minimizing total setup cost for a metal casting company

Xue-Ming Yuan  
*Singapore Institute of Manufacturing Technology*

Hsien Hui Khoo  
*National University of Singapore*

Trevor A. Spedding  
*University of Wollongong*, spedding@uow.edu.au

Ian Bainbridge  
*University of Queensland*

David Taplin  
*University of Greenwich*

Follow this and additional works at: [https://ro.uow.edu.au/commpapers](https://ro.uow.edu.au/commpapers)  
Part of the [Business Commons](https://ro.uow.edu.au/commpapers), and the [Social and Behavioral Sciences Commons](https://ro.uow.edu.au/commpapers)

**Recommended Citation**  
Yuan, Xue-Ming; Khoo, Hsien Hui; Spedding, Trevor A.; Bainbridge, Ian; and Taplin, David: Minimizing total setup cost for a metal casting company 2004.  

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au
Minimizing total setup cost for a metal casting company

Abstract
The optimizing sequence of production for a set of customer orders - in order to minimize machine set-up time and costs - is one of the typical problems found in many manufacturing systems. In this paper, we develop a simulation model to capture a practical system of a metal casting company in Queensland, Australia, and optimize the production sequence for a set of customer orders. The method addressed in the paper can be applied to other optimization problems in manufacturing industry.

Disciplines
Business | Social and Behavioral Sciences

Publication Details

This conference paper is available at Research Online: https://ro.uow.edu.au/commpapers/751
MINIMIZING TOTAL SETUP COST FOR A METAL CASTING COMPANY

Xue-Ming Yuan
Singapore Institute of Manufacturing Technology
71 Nanyang Drive
SINGAPORE 638075

Hsien Hui Khoo
Department of Industrial and Systems Engineering
National University of Singapore
SINGAPORE 117576

Trevor A. Spedding
School of Engineering
University of Greenwich
Chatnam Maritime, ME 4 4TB, U. K.

Ian Bainbridge
Cooperative Centre for Cast Metals Manufacturing
University of Queensland
Queensland 4072, AUSTRALIA

David M.R. Taplin
School of Engineering
University of Greenwich
Chatnam Maritime, ME 4 4TB, U. K.

ABSTRACT

The optimizing sequence of production for a set of customer orders — in order to minimize machine set-up time and costs — is one of the typical problems found in many manufacturing systems. In this paper, we develop a simulation model to capture a practical system of a metal casting company in Queensland, Australia, and optimize the production sequence for a set of customer orders. The method addressed in the paper can be applied to other optimization problems in manufacturing industry.

1 INTRODUCTION

In a business and manufacturing environment, most companies face the pressure of rearranging and optimizing their production schedules and flow-lines in order to meet their customer orders. These concerns are considered simultaneously with the need to save cost and use material efficiently. The main objective is to satisfy customer demands with incurred costs as low as possible. In the past decades, such issue has received extensive attention. Computer simulation is widely used to represent manufacturing systems for the purpose of aiding decision support systems and strategies at the operational shop floor levels, e.g., Seliger et al (1986), and Garside (1988). Udo and Gupta (1994) use the simulation results to predict future output values based on various given input conditions. As a consequence, the cost, time and risks are reduced compared to experimenting with decision alternatives in real time systems. Shires (1988) integrates discrete event simulation into a decision support system at the operational planning and control levels of batch manufacturing, and presents how on-line short-term planning decisions are made. Rogers et al (1988) use knowledge-based to simulate and control automated manufacturing cells, and develop the knowledge-based system which can be applied to the control and scheduling of modular flexible machining cells.

This paper develops a simulation model for a metal production company based in Queensland, Australia. The cost concerns of the metal casting company focus on the extra time and energy spent in changing the set-up configurations in the manufacturing system. The need for changing the machine set-up is due to the various customer orders that vary in material type, make and dimension. The objective is to minimize the cumulative total cost incurred in changing of machine set-up. The simulation model is built to assess the set-up cost of every possible combination of the orders. The paper is organized as follows. The next section briefly describes the company’s manufacturing system, and introduces the problem on which the paper focuses. Section 3 builds a simulation model to assess the customer orders and performs a grid search for finding the best sequence of orders, which also results in the least total set-up cost. Finally, section 4 concludes the paper.
A pilot plant focuses on the production of small-sized aluminum alloy billets as feedstock to downstream processing industries. The billets production is in the range of 10 to 150 mm sizes and the material of the billet is aluminum mixed with various types of alloys. Within the casting process, there are three types of casting structures available, the conventional, thixomold and metal-matrix. The thixomold castings are developed to fill a marketing niche where the demand for weight reduction in material is sought. This type of light metal provides a sustainable and environmentally friendly solution to improving energy efficiency in the aerospace, electronics and automotive industry. The plant layout of the manufacturing department is shown in Figure 1.

In the system, molten aluminum metal and alloy are first mixed in the furnace. The molten material then flows to the casting operation and is processed into billets of various sizes. The feedstock production system in Figure 1 depicts a system that runs continuously to meet various customer orders. Within the furnace itself, there are about 100 alloy types to be selected from to mix with the aluminum metal. At the casting stage, there are three types of casting structures available for selection: conventional, thixomold, and metal-matrix. The billet sizes may range from 10 mm to 150 mm in diameter size. Statistically, the alloy types from customer orders follow the uniform distribution on the interval [1, 100], and the diameter sizes from customer orders follow the uniform distribution on the interval [10, 150].

Due to different customers wanting different sizes and types of products, extra costs are incurred where there is a huge variability in orders. For our system, there are the following three changes: (a) change of alloys, (b) change of structure types and (c) change of sizes of products.

(a) The change of alloys incurs extra time for changing the material in the machine. This happens after the furnace activity. Apart from the change of set-up, the alloy material has to be removed from the chambers, producing scrap metal which will be sent for remelting. Moreover, energy is spent in moving material around whenever the material is consumed inefficiently in the process. The estimated cost for the change in alloy set-up is $41.68.

(b) The change of machine types occurs at the casting stage. The estimated cost for the change in structure set-up is $18.51.

(c) The change of casting or product sizes also occurs at the casting stage. The estimated cost for the change in diameter set-up is $9.25.

The beginning process of producing the first order usually requires no changes in set-up. However, for the sake of further investigation, it is assumed here that the entire manufacturing process begins with an initial set-up of Alloy Type 1, Conventional Structure and Diameter Size 10. We use a sample of five orders to illustrate the problem here. The set of orders, A, B, C, D and E, are presented in Table 1. These five orders are the actual orders received in

Figure 1: Layout of the Manufacturing Department
Yuan, Khoo, Spedding, Bainbridge, and Taplin

a particular day, which is the approximate number of orders that are expected to receive on a daily basis. The costs incurred for set-up changes of material, machine structure and diameter size are defined as costs X, Y and Z, respectively. The set-up costs are incurred after the processing of every order, except for order D where the diameter matches that of order C, which is 15 mm. Figure 2 shows the cumulative total costs incurred whenever the change of set-up is required in the processing of the next order. The total set-up cost incurred at the end of the five orders for the first case is $337.95.

In the next set of sequences shown in Table 2, orders A and B are switched. This re-sequence of orders results in a matching pair of material type, orders A and C, and a matching pair of diameter selection, orders C and D. Since the set-up of the machine structure is initially the conventional type, Conv, no change of set-up is required for the casting machine for the processing of the first order, B. The cumulative costs for the second sequence of orders are shown in Figure 3. The total set-up cost incurred at the end of the five orders for the second case is $277.76.

Without doubt the higher extra set-up costs result in a higher total operational cost. The interesting problem is to find the optimal sequence of order sequence so as to minimize the total machine setup cost. For the above practical system, since the number of the orders is small, we can obtain the optimal sequence of the orders through permutation based on simulation. Next section will use simulation to obtain the optimal sequence of the given orders by permutation.

<table>
<thead>
<tr>
<th>Order</th>
<th>Material Type</th>
<th>Machine Type</th>
<th>Diameter (mm)</th>
<th>Cost X Incurred</th>
<th>Cost Y Incurred</th>
<th>Cost Z Incurred</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50</td>
<td>MM</td>
<td>25</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>33</td>
<td>Conv</td>
<td>30</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>Thix</td>
<td>15</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>MM</td>
<td>15</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>E</td>
<td>25</td>
<td>Conv</td>
<td>25</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 2: Second Sequence of Orders

In this section, we develop a simulation model to capture the manufacturing system. Through the simulation model, we calculate the total setup costs for all the possible sequences, and then obtain the optimal sequence with minimal total setup cost. Similar studies of sequencing orders or jobs for minimizing costs in the production stream are conducted by Vickson (1980) and Van Wassenhove and Baker (1980), where all the data used are known and fixed, and all the uncontrollable factors such as machine breakdowns are eliminated.

The simulation model shown in Figure 4 is developed to represent the manufacturing system in Figure 1. Each activity block in the model contains the necessary time and cost that capture the actual situation in the manufacturing system. The three set-up costs, X, Y and Z costs, are executed in the model whenever alloy type, structure type or diameter size of the following orders do not match. The model can generate any range of orders that may be keyed in through option menus shown in Figure 5. The alloy type
of each order is generated according to the uniform distribution on the interval [1, 100], and the diameter size of each order is generated according to the uniform distribution on the interval [10, 150]. During the simulation run, the user may continue to key in as many orders as required, or select the "end of orders" option shown in Figure 6.

Here we use the sample case presented in Section 2 as an illustration of our simulation results. For the five orders received in the particular day, the number of the total possible sequences is 5! = 120. A total of 120 simulation runs are performed to investigate every possible sequence combination of the five sample orders. The order sequences and their corresponding total set-up costs are displayed in Figure 7.

From the results shown in Figure 7, we can obtain the minimum total set-up cost is $249.99 and the correspond-
However, unless every possible sequence of orders is generated, the model does not automatically enable the user to find the minimum cost. Therefore, the simulation model is most suitable for performing various scenario analyses. The model presents a method for assessing customer orders and highlights the cost consequences linking to the inefficient time spent in the change of set-up for the machines in the manufacturing department. The model may be expanded to include the concerns of more sustainable issues such as the efficient use of energy and material and the cost and re-melting of scrap metal. This type of simulation and modeling development encompasses the use of a systems approach where the interacting factors of a system under investigation is facilitated to provide a framework for considering all its objectives, methods and possible outcomes (Chestnut 1967).

The user input conditions have considered the initial set-up of all three Alloy Type, Structure Type and Diameter Size. As presented in the previous sections, the results of the minimal set-up costs are based on the initial set-up conditions of Alloy Type 1, Conventional Structure Type and Diameter Size 10. Given any other initial conditions, the output of the simulation may differ in value and best order sequence. Future research work along this direction will focus on mathematically modeling problems of optimizing sequences of production based on a generic setting of customers and developing feasible and efficient algorithms for optimizing the sequences of production.

REFERENCES


AUTHOR BIOGRAPHIES

XUE-MING YUAN is Associate Professor and Senior Fellow in Singapore Institute of Manufacturing Technology. He received his B.Sc. degree from Department of Systems Engineering and Applied Mathematics, National University of Defense Technology, both M.Sc. and Ph.D. degrees in Operations Research from Chinese Academy of Sciences. He has been an Associate Professor of Chinese Academy of Sciences, and held the appointments in INRIA, Hong Kong University of Science and Technology, Nanyang Technological University, and Singapore Institute of Manufacturing Technology. He has published a number of papers in the international journals including IEEE Trans. Automatic Control, European J. of Operational Research, OR Spektrum, Annals of Operations Research, J. Appl. Prob., Stochastic Models, etc. His current research interests include logistics networks optimization and planning, integrated supply chain optimization and management, production planning and scheduling, business process re-engineering, stochastic models and algorithms, and e-commerce fulfillment. He is a member of INFORMS and College of Simulation, INFORMS. His e-mail address is <xmyuan@SIMTech.a-star.edu.sg>.

HSIEN HUI KHOO is a Research Fellow and PhD student in the Department of Industrial and Systems Engineering in the National University of Singapore (NUS). She received her M. Eng (2000) and B. Eng (1998) in Mechanical Engineering from the Nanyang Technological University. While pursuing her Master's degree, she was involved in some research area concerning sustainable manufacturing in aluminium and die cast production in Queensland, Australia. Her research interests spans from simulation modeling and sustainable development to clean technologies and industrial process ecology. Her e-mail address is <isekhh@nus.edu.sg>.

TREVOR A. SPEDDING is the Medway Chair of Manufacturing Engineering at the Medway School of Engineering at the University of Greenwich. Before joining the University he was Associate Professor in the School of Mechanical and Production Engineering at Nanyang Technological University (NTU) in Singapore. Trevor has a Honors Degree in Mathematics and Statistics and obtained a PhD for research concerned with the statistical characterization of engineering processes. Trevor’s research interests and publications are in areas including, the application of statistics and artificial intelligence techniques to manufacturing, the simulation and modeling of manufacturing systems and supply chains, quality engineering and multimedia based teaching techniques. He is chartered engineer and statistician and has worked as a consultant and conducted short courses for several prominent companies in the UK, Europe, USA and Singapore. His e-mail address is <t.a.spedding@greenwich.ac.uk>.

IAN BAINBRIDGE is a Research Officer in Cooperative Research Centre for Cast Metals Manufacturing (CAST), University of Queensland. He has degrees in Metallurgy and Commerce from University of Melbourne. He is presently completing a PhD in Metallurgy at the University of Queensland. He has been involved in aluminum industry and research over 40 years with technical and managerial positions in production. He was a member of management team that built and operated a major aluminum smelter in Australia. He has been operating own consulting business to the aluminum industry more ten years. His primary technical interest is in solidification and hence casting and the cathodes. His e-mail address is <i.bainbridge@cast.crc.org.au>.

DAVID M. R. TAPLIN is presently a visiting Professor of Industrial Process Ecology at the Medway School of Engineering, Intelligent Systems Centre, University of Greenwich, England. In 1997 he was appointed as Professor of Sustainable Manufacturing at Nanyang Technological University, Singapore. Later he became a Professorial Associate in the Faculty of Technology at Brunel from (1998-2002). He was also a Dean of Central Queensland University (CQU) in Australia. At CQU he established the School of Industrial Ecology and Built Environment (SIEBE), the new initiatives in Process Engineering and Light Metals (PELM) and in Sustainable Product Integrated Engineering (SPINE), respectively. At that time he was appointed CQU Honorary Professor of Industrial Ecology and Adjunct Professor of Asset Sustainability at Queensland University of Technology. His e-mail address is <D.Taplin@greenwich.ac.uk>.