Multiple Criteria Lot-Sizing in a Foundry Using Evolutionary Algorithms

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Abstract. The paper describes the application of multiobjective evolutionary algorithms in multicriteria optimization of operational production plans in a foundry, which produces iron castings and uses hand molding machines. A mathematical model that maximizes utilization of the bottleneck machines and minimizes backlogged production is presented. The model includes all the constraints resulting from the limited capacities of furnaces and machine lines, limited resources, customers requirements and the requirements of the manufacturing process itself. Test problems based on real production data were used for evaluation of the different evolutionary algorithm variants. Finally, the plans were calculated for a nine week rolling planning horizon and compared to real historical data.

1 Introduction

One of the authors has been working for a Polish foundry to develop the software which would help to improve shop production planning process. A weekly task for the planners at the operational level is to say how many castings for which orders will be produced on molding machines during all working shifts. The planning process is done manually with a little support of spreadsheets and basic MRPII/ERP (Material/Enterprise Resource Planning) related tools. It is a common practice not only in this particular foundry. The survey conducted by Van Voorhis and Peters [10] has shown that also in the USA only a few foundries used specialized software to assist the planning and scheduling process while the majority of them did it manually.

The production in small and medium iron foundries is often done in short series so the planners must take into consideration many orders, each for a different product. In the considered foundry there were about 100–200 active orders a week for 10 to 500 castings of various weight and iron grade.

The castings manufacturing process itself can be divided into following steps: designing a pattern, preparing molding sand and cores, making molds, melting and pouring hot iron and finally finishing operations. The patterns are prepared in a separated pattern shop and once they are made they can be used many times. If a casting requires cores, they are made in a core shop. Cores usually can be prepared earlier, even a few days before they are put in a mold. Next molding sand is compacted around a

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pattern in a flask thus creating a mold. Then hot iron, melted in electric furnaces is poured into the flasks, which are left to solidify. After several hours the castings are taken from the molds and they undergo cleaning and finishing operations in a dressing shop.

Operations for the pattern shop are planned independently of the main production process. Operations for the core shop and the dressing shop can be planned easily on the basis of a molding plan unless the plan includes an enormous number of castings which require many cores or a lot of time to be finished. This situation is very rare in the foundry so it will not be considered in the optimization model.

Thus a priority for the planners is to prepare an appropriate molding plan connected with a pouring schedule for the furnaces. These plans must be coordinated as melted iron cannot wait too long to be poured, and also the room for the molds waiting for pouring is limited. While building the plan many technological and organizational constraints have to be taken into consideration. The most significant are:

- capacities of furnaces and molding machines,
- the number, desired delivery date and cast iron grade of ordered castings,
- the number of different castings which can be produced during one shift (setup times are included in forming times),
- the number of flasks of various size available during a working shift,
- the minimum batch size a customer can accept.

The data for the optimization model can be collected nearly automatically from the existing production control system.

2 Mathematical Model

A mathematical model was formulated on the basis of the classical discrete capacitated lot-sizing problem with single level and multi item production on parallel machines. A similar approach can be found in Santos-Mezo et al. paper [8], which discusses a lot-sizing problem in an automated foundry. The model proposed in this paper, however differs in two main points. A commonly used minimization of an artificially built sum cost function has been replaced by two objective functions indicated directly by the planners. Another modification is that the equality constraint balancing inventory and demand has been changed into an inequality constraint.

The following symbols are used:

Decision variables:

x_{ijtz} – number of castings planned for order i to be manufactured on machine j during day t and shift z,

v_{htz} – number of heats of grade h during day t and shift z.

Data:

τ – week for which the plan is created,

k – number of working days in a week,

m_j – number of working shifts for machines type j,

n_j – number of active orders for machines type j,

C_P – daily melting capacity of the furnaces [kg],

W – weight of single heat [kg],