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Scheduling and Planning Of Casting Operation in Cast Iron Foundry Using JIT

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ABSTRACT

There are several methods and strategies for production planning which are effectively implemented in the metal industry and in the automobile and machine tools industry in particular. However, small research has been published regarding scheduling in foundry operations. Therefore, the main aim of this paper is to develop a new mathematical model for scheduling foundry operations based on JIT (Just in Time) perception. The research strategy includes a review of available literature and combination of the developed mathematical model into a foundry for testing the model with true data. The planned model is successfully implemented into the ERP (Enterprise Resource Planning). The conclusions presented in this paper are based on the results of the tests carried out in the single foundry.

Keyword: *Cast Iron Production, Scheduling, Mathematical Models, JIT.*

1. INTRODUCTION

In today's economical industrial environments the main goal of a company is to earn a profit. Meeting customer needs completely and in time and offering them quality products is a must if the goal is to be reached. The other factors the existence of a best and valuable planning and scheduling system is a major way to achieve the necessary competitiveness and perform the given mission. But the planning and scheduling issues are very difficult because of the ever-varying needs of customers and the active constrains in dissimilar manufacturing fields, including the metal foundry. Therefore, research has been conducted designed at finding the solution to the problem. The timetable for the use of resourced and processes required by a business to produce goods or provide services. A typical business modifies its production schedule in response to large customer orders, to hold resource changes, to increase overall production efficiency.

The project carried out by about production system practices of cast iron foundries has selected that there is no widely accepted software system that has fundamentally solved the problem of generating pouring schedules for foundries. Therefore, there is a need to solve this problem by developing a new mathematical model and selecting software for pouring arrangement. The paper proposes a mathematical model to find a feasible pouring schedule based JIT (Just in Time) concept. The proposed model has implemented into the ERP (Enterprise Resource Planning) simulation software and apply for the furnace and pouring scheduling. Segment 1 of the paper gives a review of literature; segment 2 describes the problem and the mathematical model of pouring schedule. Segment 3 deals with the results of the model implementation into the ERP system. Segment 4 gives the result and conclusions.

2. LITERATURE REVIEW

In [1] to reduce energy consumption, iron and cast iron companies in Japan proposed and implemented new techniques such as continuous casting-hot charge rolling, continuous casting-direct hot charge rolling and continuous casting-hot direct rolling in the late 1970s. By the early 1980s, it was commonly believed, by the US iron and cast iron community, that the iron and cast iron industry in the 1980s would mainly rely on the new CC-HR production processes to improve productivity, reduce energy consumption, and maintain competitiveness in the market. The three new processes, CC-HCR, CC-DHCR, and CC-HDR, directly connect the SM, CC, and HRM at high temperature and form an integrated and synchronized production. Compared with the traditional cold charge process, the new process can reduce energy consumption, enhance product quality, increase production output, and shorten waiting times between production stages. In comparison with the cold charge process, planning and scheduling of CC-HCR, CC-DHCR, and CC-HDR not only needs to consider the increased constraints but also requires a high degree of real-time operation and dynamic adjustment capabilities.

Iron and cast iron industry is an important basic industry for any industrial economy providing the primary materials for construction, automobile, machinery and other industries. Despite this, planning and scheduling problems in iron and cast iron production have not drawn the as wide attention of the production and operations management researchers as many other industries such as metal cutting and electronics industries. However, the iron and cast iron industry is capital as well as energy intensive. The importance of effective planning and scheduling in this industry on cost and energy reduction and environment protection is by no means less than that in other industries.

In [2] A mixed integer programming (MIP) formulation of the problem is proposed but is impractical to solve in reasonable computing time for non-small instances. As a result, a faster relax-and-fix (RF) approach is developed that can also be used on a rolling horizon basis where only immediate-term schedules are implemented.

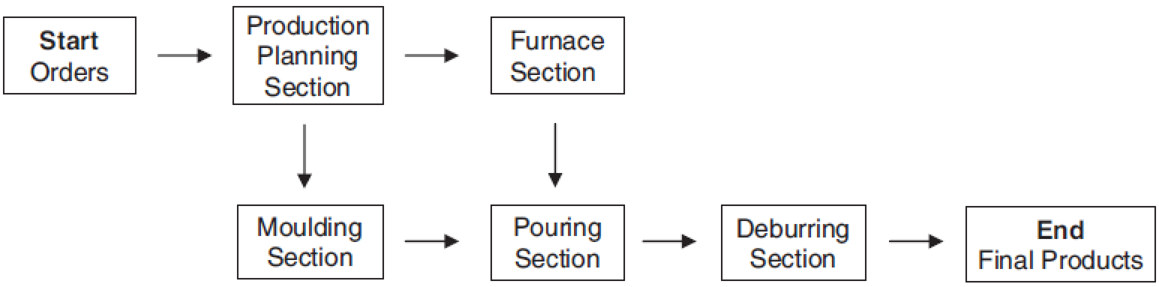
In [3] foundry which has only one furnace and several molding machines producing a known demand for different types of items which can be made of different alloys. There are two important and linked decision levels in this foundry: what alloys should be produced in the furnace in each period, and the quantity of items to be produced in each molding machine. Two different cases are highlighted here: a single alloy can produce all the item, and different alloys are needed to produce the items. After the alloy is defined by the design, one is faced with one of the most classical optimization problems, known as the diet or mix problem. This problem consists of determining the amounts of each raw material to be used so that the design-specified values of carbon, manganese, etc. are met at minimal costs. The furnace is then fed with the calculated quantities of raw material to produce a given type of alloy, based on its capacity per hour. The liquid alloy is poured out, after which the furnace is fed again to produce a new (or the same) type of alloy. A new type of alloy, in fact, is only allowed when there is a change in shift, defining a 6-hour period in the daytime or a 5-hour period at night.

In [4] the decision to provide multiple products/services on common resources results in the need for changeover and setup activities. Setup activities due to changeovers represent costly disruptions to production/service processes. Therefore, setup reduction is an important feature of the continuous improvement program of any manufacturing/service organization. It is even more critical if an organization expects to respond to changes in shortened lead times, smaller lot sizes, and higher quality standards. Every scheduler should understand the principles of setup reduction and be able to recognize the potential improvements. Setup time, in general, can be defined as the time required to prepare the necessary resource (e.g., machines, people) to perform a task (e.g., job, operation). The setup cost is the cost to set up any resource used prior to the execution of a task.

In [5] several production environments require simultaneous planning of sizing and scheduling of sequences of production lots. Integration of sequencing decisions in lot sizing and scheduling problems has received an increased attention from the research community due to its inherent applicability to real-world problems. A two-dimensional classification framework is proposed to survey and classify the main modeling approaches to integrate sequencing decisions in discrete time lot sizing and scheduling models. The Asymmetric Traveling Salesman Problem can be an important source of ideas to develop more efficient models and methods to this problem.

In [6] Teaching-learning-based enhancement (TLBO) algorithm is an atypical nature-inspired algorithm that mimics the teaching and acquirements process. A bigger adaptation of TLBO algorithm (I-TLBO) is advised to enhance the achievement of aboriginal TLBO by accomplishing an antithesis amid corruption and analysis ability. Encouraged by the abstraction of the actual population, two new phases, namely self-feedback acquirements date as able-bodied as change and bisect phase, are alien in I-TLBO algorithm. In self-feedback acquirements phase, an abecedarian can aces up his after-effect based on the actual adeptness if his present accompaniment is bigger than the actual state. In adapt and crossover phase, the learners amend their positions with anticipation based on the new citizenry acquired by the crossover and change operations amid present citizenry and actual population. The architecture of self-feedback acquirements appearance seeks the advancement of acceptable corruption adeptness while the addition of the change and cantankerous over appearance aims at the advance of analysis adeptness in aboriginal TLBO. The adeptness of proposed I-TLBO algorithm is activated on some criterion functions and a combinatorial enhancement botheration of calefaction alleviative in branch industry. The allusive after-effects with some added bigger TLBO algorithms and archetypal algorithms appearance that I-TLBO algorithm has cogent advantages due to the antithesis amid corruption and analysis ability. In aboriginal years, the enhancement problems are mainly apparent by authentic algebraic methods, such as acceptable exact methods, activating programming, accidental searches, acclivity methods and planning algorithms.

3. FOUNDRY OPERATIONS



The main activities in a small market-driven foundry. Clients randomly and spontaneously submit orders specifying the item type, quantity and, alloy. The Production Planning department negotiates due dates with the client, often agreeing on unachievable dates that result in delivery delays and the possible loss of future orders from the client. Thus the minimization of delays is one of the principal concerns of the foundry company. The Production Planning department specifies which items should be produced during the next few days, advises the Moulding section which molds to prepare in advance, and determines the specific alloys to be melted. The scheduling is guided by due dates in the following days as well as by delayed orders. Excessive changes of alloys are undesirable, and so setups are considered in the model. The manufacturing system has the following characteristics and assumptions:

• An alloy is generally used in several products, but a product is made from just one alloy.
• The output weight of an alloy is equal to the total gross weight of the products in which the alloy is used.
• A product cannot be manufactured in a given time period unless the alloy which it is made from is also processed in that period. Processed alloys cannot be held over to the next period.
• In each time period, only one alloy can be processed on the furnace.
• A setup changeover from one alloy to another consumes capacity time in a manner that is independent of the sequence in which the alloys are processed.
• All products have a demand over a planning horizon that would be met if capacity were sufficient. However, delays will occur if capacity is tight, and so backlogs must be represented in the model.
• The objective is to schedule lot sizes and to sequence setups in order to minimize a penalty-weighted sum of product backlogs, finished inventories and setup changeovers.

4. SCHEDULING TECHNIQUES

4.1 JIT (Just In Time)

Attack fundamental problems: JIT maintains there is little point in making major problems such as capacity bottlenecks or poor quality vendors. It is far better to solve these fundamental problems and avoid a fire fighting style of management.
Eliminate waste: Waste is any activity that does not add value. Samples of such activities are inspection, transport, and inventory. JIT stresses that these activities need to be eliminated to improve the overall operation of the company.

Strive for Simplicity: Any approach that is adopted should be simple if it is to be effective. Previous approaches to manufacturing management have been based on complex management of a complex manufacturing system. By contrast, JIT implementation simplifies the flow of materials and then superimposes simple control.

Devise systems to identify problems: In order to solve fundamental problems, they need to be identified. A JIT implementation will include mechanisms that will bring problems to the fore. Examples of these mechanisms are statistical quality control (SQC), which monitors the manufacturing process and draws attention to any defect-producing trend.

4.2 Hierarchical Algorithm

A hierarchical production planning and scheduling system are developed that integrates planning decisions into a unified and consistent framework**.** A three-tiered approach is used to address long-term inventory control, short-term production planning, and daily scheduling tasks. A product grouping scheme introduces uniformity into the solution process and simplifies overall model complexity [7]. The first level in this system addresses the long-term aspect of production
Planning. It determines monthly production quantities for stock items *so* as to minimize inventory holding costs over a period of twelve months. The second level subproblem focuses on the assignment of products to production lines using a product grouping procedure to indirectly minimize sequence dependent changeover times. This short-term planning model operates over a period of one month and maximizes productivity through preferential product line assignments on a number of non-identical production lines**.** The third level subproblem, the sequencing subproblem, seeks the job orderings of minimum changeover time for each production line on a weekly basis.

Most production planning and scheduling models focus on only long-term, short-term, or daily planning. Few provide a formal link between these planning tasks which differ in goals, production units, and time horizon. Long-term planning is typically implemented by high-level management in general terms over an extended time horizon. On the other hand, short-term planning is done at a lower, very detailed level on a more frequent basis**.** Typically, long-term plans are made in such general terms that they provide little useful information upon which a scheduler may base operational decisions; As a result, short-term operations may at times be inconsistent with long-term goals. Thus, establishing a formal link between long-term and short-term planning procedures would serve to maintain consistency [9].

Protection planning in a typical manufacturing organization is a sequence of complex decisions. The complexity depends on a number of factors such as a number of products, product complexity, internal and external constraints, and the length of the planning horizon. During the last two decades, hierarchical production planning methods have been used for solving such large production planning problems. The main idea in HPP is to decompose large problems into smaller subproblems, solve individual subproblems, and then link the results in a coordinated manner. To coordinate, decisions obtained at the higher levels impose constraints on the lower level decisions, and the decisions are often made on a rolling horizon basis [8].

5. PROBLEM DEFINITION

- Due to improper scheduling lead time required for pouring operation is observed to be very high.
- The pouring operation in the automated line and the semi-automated line are optimal.
- But there is a manual line of mold preparation where a lump sum of time, say, 9 to 14 minutes, is wasted as these three lines are not properly scheduled.
- This is our area of focus, where we intend to fix the schedule for the operation based on selected model and algorithm.
- Lead time in pouring operation is high.
- It increases casting operation time.

The problem found mathematically using hierarchical algorithm and the scheduling was developed based on JIT(Just In Time)[9]. The following notation is used:

Indices

$a = 1,\ldots, A$	Alloys
$c = 1,\ldots, C$	Charges
$f = 1,\ldots, F$	Furnaces
$i = 1,\ldots, I$	Items
$J=1,\ldots, J$	Operations
$l = 1,\ldots, L$	production lines
$m = 1,\ldots, M$	Moulds
$o = 1,\ldots, O$	production orders
$t = 1,\ldots, T$	Periods

$did_{,o}$ delivery date for an item I and order o
K_i tardiness of item I [day]
$k_{l,f}$ utilization factor of furnace f on production line l
$K_l^R{}_{,f,t}$ available capacity of furnace f in a day t [hours]
$K_l^{cap}{}_{,f}$ capacity of furnace on production line per hour [kg/hour]
$_{a,t}$ number of charges for alloy a
N_m^R available quantity of molds type m [pieces]
n_s^h number of hours in shift s
$_{s,t}$ number of shifts in a day
$o^{h\ the}$ number of overtime hours
Pr(i) priority of item i
$q_{i,c}$ quantity of items i from one charge [pieces]
$q_{i,o}$ quantity of items i per production order o [pieces]
$q_{i,t}$ quantity of produced items i and period t[pieces]
$q^n{}_{i,t}$ ordered quantity of item i[pieces]
$q^z{}_{i,t}$ inventory of item i in period t[pieces]
Q_{raw} total quantity of cast iron [kg]
Q_l quantity of cast iron for line l [kg]
$Q_{l,f,c}$ quantity of cast iron for charge in furnace f on line l[kg]
$t_{i,j}$ processing time of operation j of item i [hours]
$t_{l,f,c}$ processing time of charge c in furnace f on production line l[hours]
tm_m time of assuring necessary quantity of mould type m
$tp_{l,f,c}$ start time of processing charge c in furnace f on production line l
$tz_{i,o}$ finish time of item i on production order o

Mathematical model formulated as follows:

$$H = \sum_i K_i$$

Minimized Tardinass of pouring time,

$$K_i = \begin{cases} 0 & if \quad dd_{i,o} \geq tz_{i,o} \\ tz_{i,o} - dd_{i,o} & otherwise \end{cases}$$

Tardiness,

$$\sum_a n_{a,t} \cdot Q_{l,f,c} \leq K^R_{l,f,t} \cdot K^{cap}_{l,f}$$

The total quantity of alloy for period t is equal or less than the available furnace capacity.

$$K^R_{l,f,t} = \left[\sum_s \delta_{s,t} \cdot n^h_s + o^h \right] \cdot k_{l,f}$$

Available capacity of the furnace on the production line.

$$\sum_l Q_l \leq Q_{raw}$$

Consumption of total required quantity of melted cast iron for all production line,

$$g \neq i, \ \Pr(g) \geq \Pr(i)$$

The starting of pouring item from charge c in production line,

$$\sum_j t_{i,j} + t_{l,f,c,i} \leq dd_{i,o} - tp_{l,f,c,i}$$

Sum of the charge processing time in the furnace and subsequent operation time is less than or equal to the processing time in the furnace.

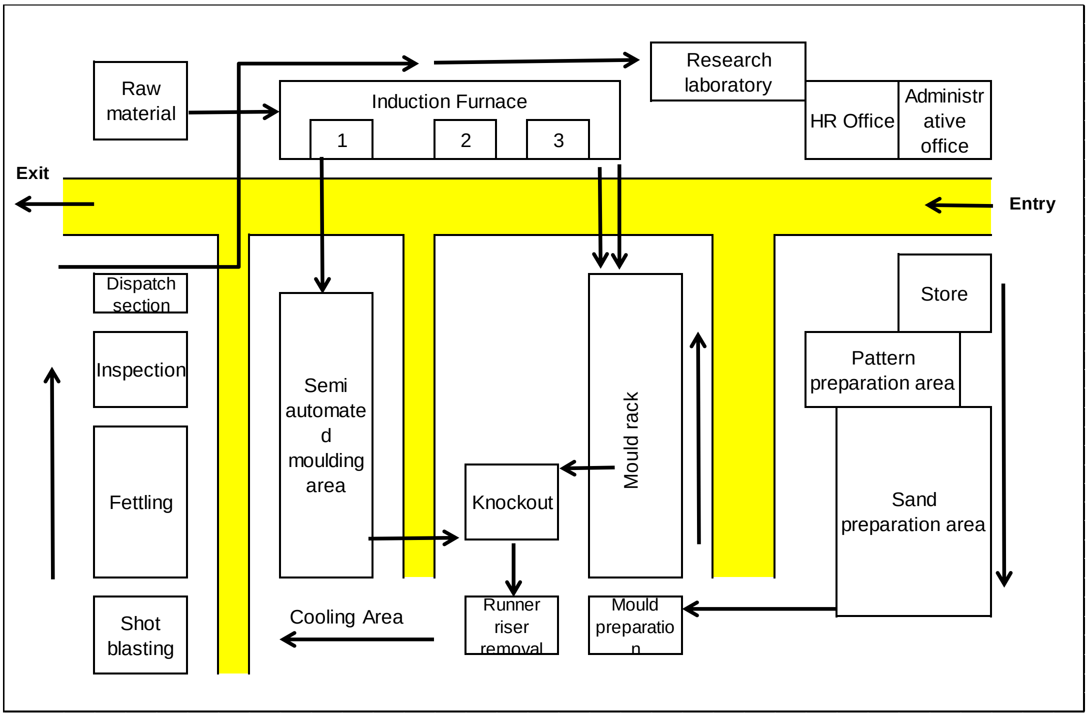


Fig.2 Technological Scheme of Cast Iron Foundry

6. IMPLEMENTATION OF JIT IN SCHEDULING

The problem was well analyzed, it found that improper scheduling in pouring operation in cast iron foundry by using the hierarchal algorithm, the tardiness were calculated based on this tardiness of time the proper scheduling were created based on JIT concept in Fig.3.

FURNACE	MANUAL	SEMI AUTOMATIC	COMPLETELY AUTOMATIC
1F1	0	1	1,1,1
1F2	1,1	1	1
1F3	1	1,1	1
2F1	1,1	1	1
2F2	0	1,1	1,1
2F3	1,1	1	1
3F1	1	1	1,1
3F2	1	1,1	1
3F3	1	1,1	1
4F1	1,1	1	1,1
4F2	1	1,1	1
4F3	1,1	1	1
5F1	1	1	1,1
5F2	1,1	1	1
5F3	1	1,1	1
6F1	0	1,1	1,1
6F2	1,1	1	1
6F3	1	1,1	1
7F1	1,1	1	1
7F2	1	1,1	1
7F3	1,1	1	1

Fig.3 Scheduling Procedure

Bottlenecks as analytical capacities are defined. Each operation is authentic in the appearance of its continuance and capacity. The abstruse operations for assembly of casting products. After creating orders the next assignment is to actuate the assembly adjustment (production band and abundance from one allegation are automatically offered) and the basal plan. By the alternative of the amount of accusing the basal plan of that day is determined.

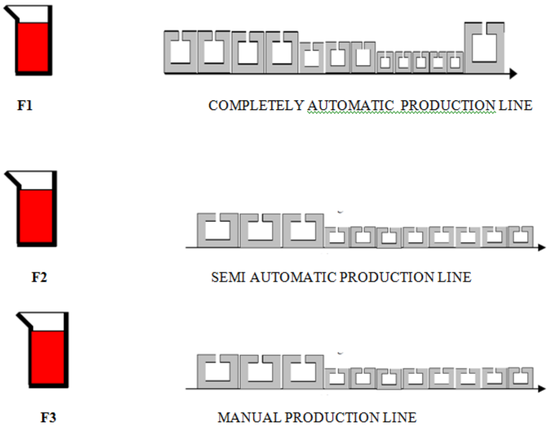


Fig.4 Schematic Diagram of Productive System

Detailed scheduling with the dates, accouterment and hours of the cloudburst operations alpha times for every assembly adjustment is bent afterward the basal plan has been generated. Afterwards the alternative of the time and assembly line, the arrangement offers all assembly orders planned for that day anniversary day contains three shifts. Afterwards, the alternative of assembly adjustment is performed and the action of scheduling starts.

An accurate assignment of the arrangement is the rescheduling that solves: priority changes for the ahead generated plan of pouring, changes acquired by abnormal scheduling in the cloudburst operations.

According to the ahead appear analysis on branch operations scheduling the authors accept assured that in a lot of cases the foundries agenda operations manually and that alone a few of them use software to abetment in Scheduling. Thus the development of the operations scheduling archetypal for the accomplish of casting articles renders the present analysis aboriginal and of ample automated Significance. So the JIT adjustment can be acclimated not alone in the assembly of car locations but as well as cloudburst processes. The algebraic scheduling archetypal has been auspiciously activated to the foundry, and it has decidedly bigger the start-up action and the scheduling of boiler operations. It is as well an arrangement for the bigger ecology of acquired results.

7. CONCLUSION

The capital ambition of this cardboard was to advance a new algebraic archetypal for scheduling branch operations based on the JIT (Just in Time) concept. An ample accomplishment was fabricated to hotlink bookish analysis with industry requirements in adjustment to accomplish this goal. The advisers as well showed that the JIT and OPT concepts, originally developed for detached production, can be activated by the Combination of the action - detached production, such as the assembly of casting products. In this cardboard, an algebraic archetypal is proposed to acquisition an achievable cloudburst schedule. The use of this algebraic archetypal for scheduling the operations of a branch reduces the time bare for breeding cloudburst schedules and enables the ascendancy of tardiness. The advantage of the proposed archetypal and algorithm in allegory with added algorithms is in its multi-stage access to planning and scheduling.

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