PRODUCTION SCHEDULING FOR CONTINUOUS- DISCREET METALLURGICAL PROCESS

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Abstract

Article describes design of the model in terms of production scheduling continuously discrete manufacturing process. In terms of continuity, continuous changes in the chemical composition of sequences heats Al alloys, it is necessary to apply a specific approach. The production schedule is initially created for the workplace of a continuous nature, and it will create schedules for other devices and processes, as if it was applied the principle bottleneck.

Keywords: Production scheduling, continuous-discreet process, Al alloys

1. INTRODUCTION

Each company is original from the point of production processes. Application of standard enterprise information system (SAP, proAlpha, Baan, etc.) needs difficult adaptation especially for conditions of small or medium enterprises (SMEs) and the price of that system is relatively high. Therefore, the proposed model of capacity planning and scheduling is much more suitable for the conditions, requires and demands of SMEs [1, 2, 3]. Specifics of production processes of RS Ltd. are combinations of discrete and continuous processes and the fact that this small company is connected to a supply chain (KANBAN) with its mother company, which defines the level of some chosen products in the expedition warehouse by the end of a month [6].

For the above mentioned reason it had to be designed the new original production logistic system [1]. This system starts with order evidence, it includes the model of capacity planning, which respects KANBAN and model for production scheduling and operation evidence after the finishing of manufacturing [4, 5, 6]. Both models are created on the heuristic approach i.e. there were analyzed rules and limitations, which were applied to algorithms of the models. By this approach applied in the model there were included all activities, knowhow, experience, knowledge of the experts and people, who works in the company for a long time [2, 9, 10].

2. MANUFACTURING PROCESS ANALYSES FOR SCHEDULING MODEL DESIGN

The enterprise RS Ltd. is producer of stator and rotors for industrial ventilation and air conditioning system and is conformed to German mother company. The basic production process starts at cutting of dynamo plates and their welding or riveting (PP1), melting of aluminum alloys (PP2), its casting at molding presses (PP3), finishing (PP4) and surface treatment (PP5), see **Fig. 1**.

The file of recorded orders (FRO) is continuously actualized by adding new incoming orders, while planner can open the file anytime but on mentioned date he will receive the file through e-mail. By this step the actualization of this file is finished and it is ready for planner to create new production plans.

The capacity plan is created separately for these divisions:

1. For cutting (CNC machines) – section U1
2. For casting – section U2
3. For finishing (CNC machines) – section U3, however this is not detailed plan given to a supervisor but it is a list of products and due dates and delivery dates

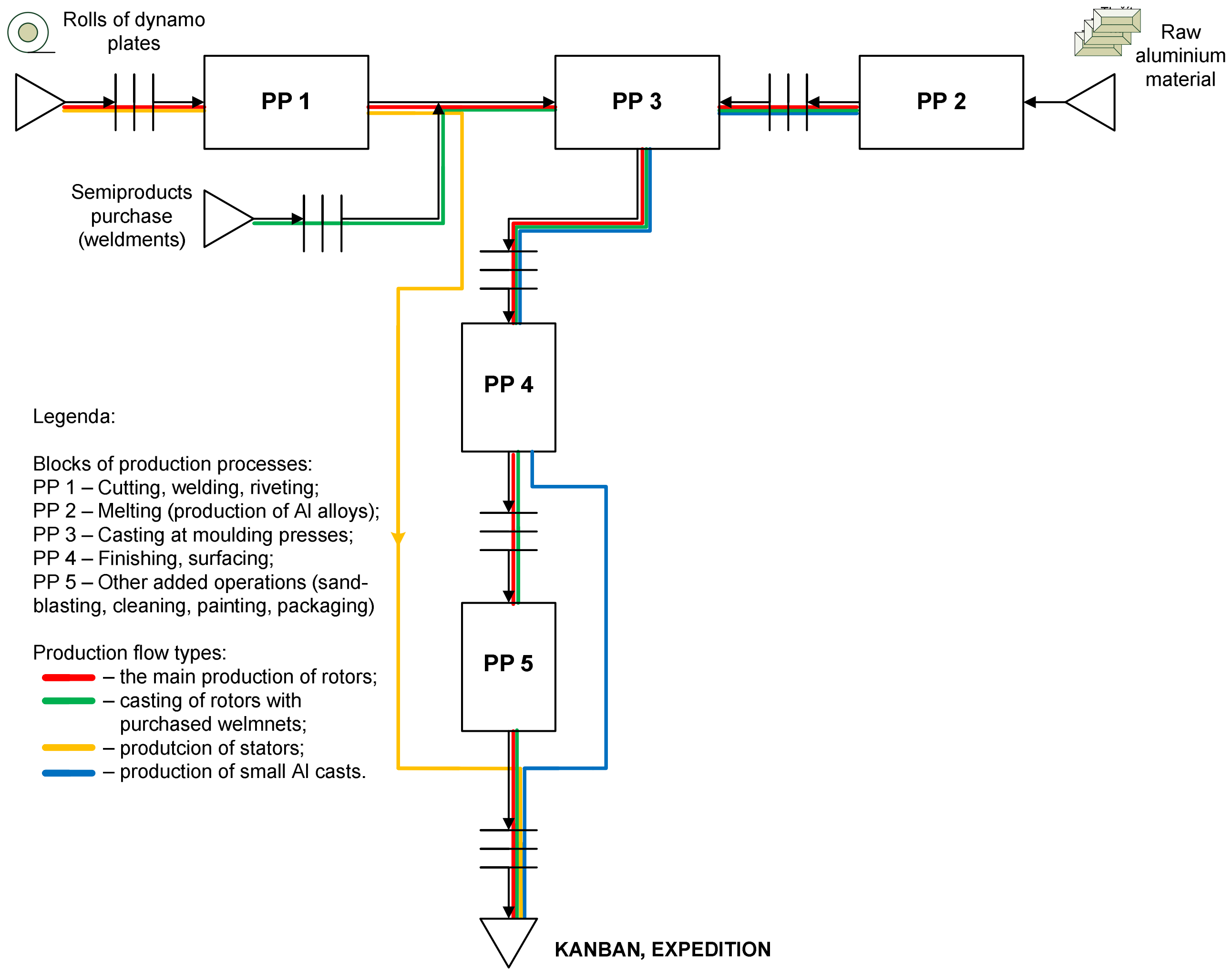

Fig. 1 Basic production processes and flows of RS Ltd. enterprise

2.1. PP1 – Cutting of shreds, riveting and welding

Shreds are cut at the same, two cutting presses L1 and L2. Presses are equivalent in speed and quality. Tact of the presses is 180-220 beats per minute. Cutting has enough reserve capacity. Scheduling strategy is to minimize the exchange of cutting forms, because replacing the forms takes about 8 hours (one whole shift). Replacing of the coil, the input item with which the presses are working, takes about 15 minutes. Minimizing of exchange of forms is achieved by creating families (family product - FP), i.e. product group, which varies only by a part of the same form, with the same strip width [1].

Riveting. The shreds are weighed and sheets are stacked manually, before riveting. Weighing accuracy is ± 1 of a shred. It is not possible to automate number of plates because of respecting the tolerance weight of shreds (the sheet thickness is varied). However it can be automated to a height of shred column. The riveting machines are the two, by side (not parallel), because they do not work from the same buffer. The servicing is individual considering the service processes and their relationship to the riveting operation. Riveting workplaces are specialized for large and small stators only.

Welding. It is similar operation as riveting, but the shred connection is got by welding of shred column at its perimeter. Welding rotor shreds is a bottleneck that is why it is possible to buy these weldments also from external suppliers.

2.2. PP2 – Production of Al alloys

Aluminum melting furnace produces 6 kinds of Al alloys for casting needs. The maximum batch is 450 kg per one melting. The melting capacity is 350 kg per hour (see **Fig. 2**). The criterion for effectiveness is to minimize of alloy changeovers and so called flushing melting and maximizing of melting batch (service times).

Fig. 2 Time sequence of formation of aluminum alloys

Minimizing of flushing melting requires minimization of number of alloy modifications needed for casting presses. It means that the planning of melting and their composition depends on the casting plan at injection molding machines. These plans of casting and melting are created by the interaction, taking into account the criteria of both production points. Minimum number of melting is 2 per shift, maximum 5, flushing melting takes at minimum 1 hour, its costs are inefficient costs (energy, metal loss, equipment depreciation, wages, loss of capacity). Because the melting furnace is the only one, it is a strategic device, by which the work of the whole company is influenced (see **Fig. 3**) [1, 5].

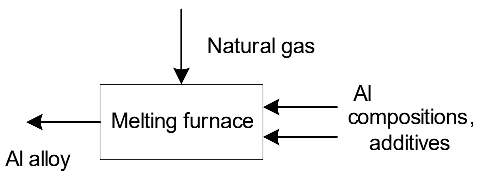

Fig. 3 Material flow of Al alloys creation

2.3. PP 3 – Casting

Casting of rotors and casting is carried out on five injection molding machines (see **Fig. 4**). Casting, in terms of process control, is a point, which combines the two flows – first flow of welded and riveted parts and second flow of Al alloys, cases and forms. It is optimal to cumulate such a number of units that will require n-times batches (melting) of the same alloy [11]. Scheduling has to also respect the size forms, contact force, speed, molding quality, environmental aspects [8]. It means that the injection molding machines are partly specialized in parts, i.e. not each assortment can be casted at each molding machine with normal (the same) efficiency.

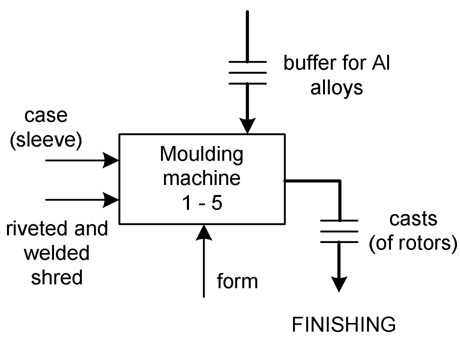

Fig. 4 Material flow of casting process

2.4. PP 4 – Finishing, surfacing

Currently, finishing of not controlled according to the operational plan of production, i.e., distribution of products to machines and workstations does not have its operational plan. Production manager assigns operational work to the machine workers according to the situation between the casting and surfacing. The surfacing (post-processing) follows the finishing at the machining shop. The machining shop has 5 computer numerical control (CNC) centers. Center 1 and 2 processes castings, the small orders are planned at center 3 because of its fast reconfiguration, centers 4 and 5 processes larger orders due to their long reconfiguration (about 4 hours). There is also a criterion of smoothness change of processes at “large” centers, which can shorten the configuration.

3. THE PRODUCTION SCHEDULING MODEL DESIGN

The dominant criterion is the continuity of changeovers in the casting process, as it was mentioned, because of the fixed relationship between the melting furnace and the casting injection molding presses. This criterion also plays a primary role at the creation of production schedules and all orders are cumulated first at this moment, at that place, where formed groups use the same or related aluminum alloy.

Other manufacturing operations are not fixed, they use a buffer and it allows some freedom to secondary and further cumulating. Mentioned freedom is given by the fact that cutting has sufficient capacity, capacity of welding can be added by purchasing of welded parts and in front of surfacing is also some sequence through the in-process production. Under these conditions there is defined progress of plans creation for each operation in the following order:

Schedule for press-molding has to respect the continuity of the chemical composition of Al alloys. Options transition among press-moldings without purification of the press are defined by "Transition matrix" (see **Fig. 6**). Followed by casting schedule creates a production schedule for induction furnace. From the schedule of casting is created schedule for welding (riveting), or purchase rotors and cutting schedule, as well as schedule for machining (see **Fig. 5**).

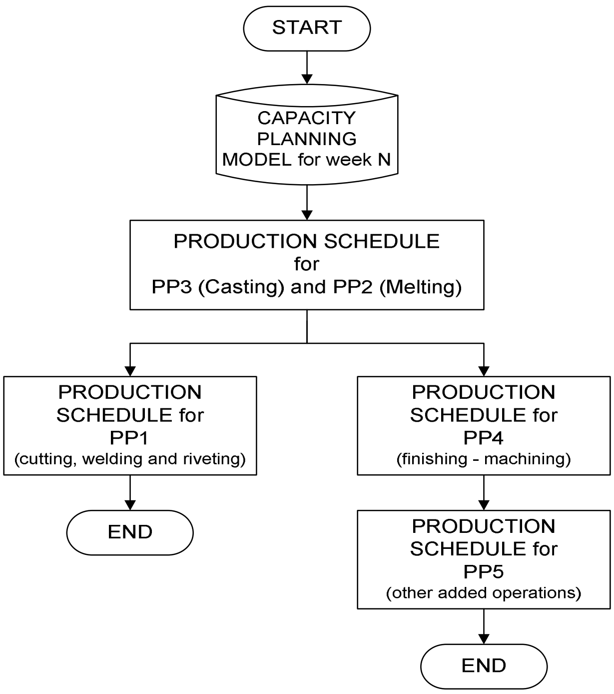

Fig. 5 The sequence of the production scheduling models creation

Further cumulating orders and generation of the sequence – the sequence of casting, production of alloys, cutting and welding, and finally the order castings are respected in particular schedule. The schedules are prepared for one week, on days.

The rules for creating of models of scheduling:

1. **Creation of daily schedule at molding presses**. There are some certain rules for all products which are produced on molding presses: not that each product is suitable to produce at any machine. The existing technological rules determine for which of a product is suitable certain molding press. Although ultimately any product can be produced at any molding press, but with a different efficiency. The main product should always be produced on the main technology, so at the most appropriate molding press.

If it is not possible to provide in terms of overlapping operations, then a product can be produced at an alternative technology.

2. **The daily schedule for the production of alloys**. The daily plan is given mainly in accordance with casting requirements for molding presses and the alloy transition matrix. The biggest challenge is to ensure the continuous operation of the molding machines, but which are fed from the only one furnace and thus one and the same alloy. Therefore it is necessary to cumulate the first contract for molding presses.
3. **The daily schedule of cutting, welding and riveting**. Each workplace is doubled, it means that there are two cutting machines, two welding machines and two riveting equipment. Plan for welding and welded parts is derived from plan of casting. Bought welded parts are ordered one week in advance for which a supplier is able to deliver them. The supplier is contractually bound to RS Ltd. company with an assortment, which is managed by the Supply Chain Management. There are two riveting machines, where stators are riveted. The first is for small stators, the second for big stators, while there is a conjunction of middle dimensions that can riveted on both machines [7]. The plan of cutting is derived from plans of welding and riveting on the basis of cumulating the orders.
4. **The daily schedule of surfacing**. There are five machining CNC centers available. The first two centers are intended purely for castings and other three machining centers are designed for rotors that come directly from the casting. The newest CNC machine is determined for orders with a small number of products, because it is reconfigured fast. It is planned to include this CNC machine to produce the largest rotors in the future. Here again, any rotor can be processed on each machine, but there is optimal assignment of the rotors to the individual machines, i.e. specialization. To minimize setup times (configuration) of a machine it has to be minimized the change of rotors size. The larger is dimension jump, the longer time is needed for adjustment of machines. Another important fact to be calculated when daily plans reparation for surfacing that there is only one operator for two CNC machines in one shift. The daily plans are not created for subsequent operations such as washing, painting, packaging etc., there are only calculations of the total time of these operations and the finish time of the production is moved forward about this calculated time.
5. **The daily schedule for finishing.** Finishing in the current planning is not included i.e. finishing does not receive plan. There is only plan for casting and then subsequent operations of finishing are derived (known is only assortment, due date and quantity). Finishing is essentially used to as a time fulfilling, i.e. as a flexible reserve for the replenishment of stock levels.

Production scheduling determines the order of products, volumes to days and changeovers for particular machines based on capacity plan for the week N and week N+1.

The procedure starts at the section U2 – Casting

1. The arrangement of orders by chemical composition, according to the number of products, the possibility of transition by transition matrix (see **Fig. 6**).
2. Derivation of orders for components requiring a maximum of two batches.
3. The order with the purest alloy is selected and it is assigned to the molding press – to the main technology for the certain product, a second batch, if it exists, is assigned to the alternate technology, if there is any.
4. The other product of the same alloy is taken, if exists, and it is assigned to the main technology, if not occupied (and the procedure is repeated from the step 3).
5. The other product with different alloy is taken, on which is the best transition and it is assigned to previously (in step 3, 4) not occupied molding press.
6. This cycle is repeated until all products are assigned from plan capacity for N+1 week.
7. When assigning a product to the molding press, it will reduce the capacity of the operating time required for a given order. If the capacity of the molding press runs out or there is no such order, which the capacity uses, the molding press is not further taken.

8. The plan of melting and the order of molding press supplies are calculated on the basis of this procedure.
9. The sequence of orders (and number of pieces of products) for individual molding presses are created, from which daily and shift plans are calculated.

	DIN 226	DIN 231	DIN 230	D 106	S 106	D 165
DIN 226	Y	Y	N	Y	Y	Y
DIN 231	Y	Y	N	Y	Y	Y
DIN 230	Y	Y	Y	Y	Y	Y
D 106	N	N	N	Y	Y	Y
S 106	N	N	N	Y	Y	Y
D 165	N	N	N	Y	Y	Y

Fig. 6 The transition matrix for furnace and presses

The scheduling model for the section U1

Orders casted in week N+1 are produced at U1 in the week N. It is determined the order of cutting at the cutting machines L1 and L2 based on the capacity plan for a week N for U1 and schedule for the section U2 for the week N+1 as follows:

The volume of orders cumulated in FP (family product) and individual orders are split into approximately two equal volumes:

- 2 by ½ of the number of pieces (whole orders) for riveting
- 2 by ½ of the number of pieces (whole orders) for welding

The rules at cutting are:

- To cut large size shreds at L1 for the riveting workplace NR1 – specialized in larger stators and weldments – workplace NR1
- To cut small size shreds at L2 for the riveting workplace NR2 and welding workplace NR2
- To determine order of cutting according to FP, from the most wide to the narrowest or vice versa

The order of riveting, as it is the last operation, is not important. The order of welding is determined from the order of pressing. The order of the welding NR1 and NR2 is according to the sequence of the cutting.

The scheduling model for the section U3

There are five CNC centers O1 – O5. Orders casted in week N+1 are processed on the section U3 in the week N+2 as followed:

The products are divided into:

O1, O2 – small casts
O3 – small rotors (approximately 1/3 of week volume)
O4 – middle sized rotors (approximately 1/3 of week volume)
O5 – big rotors (approximately 1/3 of week volume)

The order of production to CNC machining centers is determined according to the criteria: from the minimum dimension to the maximum in even weeks and from maximum to minimum in odd weeks. Thereby it is achieved minimizing the number of changeovers. Or it is determined to assign those products (orders), which are the earliest due date to have enough time for finishing [1, 3].

4. CONCLUSION

The paper described the special approach to production scheduling problem solution, in the case when dominant production operation is continues and sequence of product of this operation is important from economic point of view. In this case don't applied push or pull strategy, but strategy similar "bottle neck". This approach was successful applied by authors in the project for RS Slovakia in the year 2013.

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