A Review of Manufacturing Teams

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Abstract
This paper is presents a method of calendar that means scheduling for manufacturing teams, when the average orders effectiveness function is used as the superiority criterion. The method is based on the perception of "production intensity", which is a dynamic parameter of construction process. Applied software package allows scheduling for medium quantity of jobs. The result of software application is the team load on the planning horizon. The computed plan may be corrected and recalculated in interactive mode. Present load of every team is taken into account at each recalculation. The method may be used for any amalgamation of complex and specialized teams.

Keywords: *Scheduling, Production intensity, Order utility.*

I. INTRODUCTION

The current methods of production planning consider each division of an enterprise, for which the schedule is developed, as the "working center". This paper relates to development for working centers, which are production teams. The production teams are controlled for assembly of compound machines, apparatus repair or transfer to a new place and so on. Every production team consists of regular or temporary staff, affecting a joint job and having joint conscientiousness for their results. Team members may have the same or dissimilar professions. Accordingly, there are specialized or complex teams. Each job may comprise some tasks of various types that require personnel of appropriate professions. Depending on compliance between task types and professions of team workers, a complex team may perform all tasks of a job or its part only. A dedicated team may only perform a task corresponding to its profile.

The main advantage of using teams as functioning centers is associated with great flexibility inherent in such systems. Two types of elasticity are possible in scheduling. Routing suppleness is possibility to choose among two or more working centers to carry out a given operation. According to the categorization (Blackburn & Millen, 1986) this type of flexibility is associated with hardware flexibility. The other type of flexibility named as sequencing flexibility is coupled with software flexibility. This type of flexibility makes it promising to change the sequence of operations within the job. The possibility to appoint one of available complex teams when scheduling for any job relates to routing flexibility of scheduling. At the same time, the sequence of operations desired for a job may be changed by harmony of team members, depending on such factors as worker's load, availability of facilities, etc.

Scheduling for teams is a complicated problem as it is often hard for a manager to establish the load level of each worker and probable completion dates of the team tasks. The only possible version of production planning here is the amalgamation of tasks scheduling for all teams within a planning period and the daily plan, which is elaborate by the team itself. Because for completion of a specific planned job several teams of various specializations may be engaged, sequence of their work may only be directly unwavering by team leaders and may vary depending on the situation. If production teams are considered as "machines", then according to the classification of planning problems, the set of production teams with non-determined sequence of their use may be unwavering as Open Shop. At the same time, possibility to several teams for a given operation provides the flexibility of such machine set. Consequently, we may suggest that scheduling for the set of construction teams is associated with the Flexible Open Shop problem.

II. LITERATURE REVIEW

As far as the author knows, there is only one article, which is committed to scheduling for technical structure of Flexible Open Shop type. In the paper by Witkowski et al. (2011) the problem of this type is measured, when all jobs at the instant of planning are available. In this paper the makespan *C*max is painstaking as a criterion. The criterion *C*max has been used in mainly other studies on Open Shop Scheduling problem. Gonzalez and Sahni (1976) elaborated the exact algorithm for this problem, when preemption is achievable. Bai and Tang (2013) consider the task with the given release dates. In the book (Gupta et al., 2013) a number of algorithms were studied for scheduling at two operation stages with the criterion *C*max. Shabtai and Kaspi (2006) researched the Open Shop Scheduling problem with the criterion *C*max when job duration may vary. In a few papers other criteria are used. Brasel et al. (2008) designed some heuristic algorithms for the Open Shop Scheduling problem with the criterion of mean flow time *F*.

Liaw (2005) studied this problem for the case of synopsis tardiness minimization Σ*Ti*, Naderi et al. (2011) used the criterion of summary of period minimization Σ*Ci*. The significant version of the Open Shop Scheduling problem relates to a task of synchronized Open Shop Scheduling. The latter may be considered as a variant of the classical Open Shop model, in which operations belonging to the same job may be processed concomitantly on several machines. Ng et al. (2003) studied this problem for the criterion of weighted tardy jobs number Σ*wiUi*.

III. MAIN PROBLEM DEFINITIONS AND UTILITY FUNCTIONS

Let us assume that it is compulsory to perform *n* various jobs at the facility of scheduling (enterprise, vessel, building, etc.) for a certain stage of time after the planned start. The planning horizon of the working project is usually equal to a certain reporting period, for example, a month or a week. When a vessel or a building is constructed, the horizon may be determined for the reporting period, or to the entire period of construction. Let us suppose each job may be performed by one or several production teams, and their number is equal to *M*. Each job *i* comprise several tasks (operations) and has to be completed on due date *di*.

A. Assumptions

a) Within this arrangement the sequence of tasks (operations) that belong to the same job to be performed was not taken into account. In general, these tasks may be executed in any sequence.
b) The priority coefficient can be resolute for each job.
c) Liberate date is known for every job.
d) Each job can be executed by any number of production teams simultaneously.
e) Process time of a job as a whole and process time of every task belonging to a job is known and deterministic.
f) The review duration of job completion is assigned normatively.
g) Each job has one task of a certain type as the main one.
h) In the inauguration, for every production team it is known what a job is being performed, and when this work will be completed.

B. Notation

Indices
i = 1, 2 …n Index of order (job)
l = 1, 2 …J Index of operation execution tree level
m = 1, 2…M Index of specific production team in team list
j = 1, 2… S Index of task (operation) type
z = 1, 2…Z l Index of decision tree node on level *l.*

Premeditated teams load for the subsequent seven weeks is shown in Table 1. In this case we can see that during the first and the second weeks the team load is not more than 100%; in the third week all teams are overloaded, in next weeks there are load oscillations. The computed plan solution commonly ensures timeliness of jobs achievement, but it is not optimal, and may be significantly improved. For this purpose, it is compulsory to analyze the list of jobs, which are planned for the teams on the scheduling horizon. In Table 1the fragment of the team timetable for jobs execution in the following 3 weeks is shown. Information in Table shows that the team 3 is the most congested team, which on the third week has the load of 161%. Studying the list of jobs for the team 3 in the third week, we can suggest that this load could be less, if execution of the job 22 was postponed to the next week.

	A	B	C	D	E	F	G	H
13								
14			Weekly teams load in % of throughput					
15	Weeks	1	2	3	4	5	6	7
16	Team 1:	72	83	112	62	146	136	28
17	Team 2:	76	86	100	112	121	49	0
18	Team 3:	96	76	161	65	125	76	9
19	Team 4:	52	95	128	58	142	85	16
20	Team 5:	50	28	112	78	138	98	10

Table 1.Planned Teams Load

	A	B	C	D	E	F	G	H
21								
22			Weekly jobs list					
23	Weeks	1		2			3	
24	Team 1:	2, 8		2, 8, 10			10, 26, 20	
25	Team 2:	1, 2, 7, 5		2, 7, 11, 12, 9			11, 12, 20, 24, 30	
26	Team 3:	4, 8, 6		8, 14, 19, 17, 13, 15		14, 19, 17, 13, 15, 22		
27	Team 4:	7, 3		7, 12, 19, 13, 15		12, 19, 13, 15, 18, 24		
28	Team 5:	3, 5, 6		11, 12, 14		11, 12, 14, 26, 18, 30, 22		

Table 2.Fragment of Jobs List Scheduled for Teams

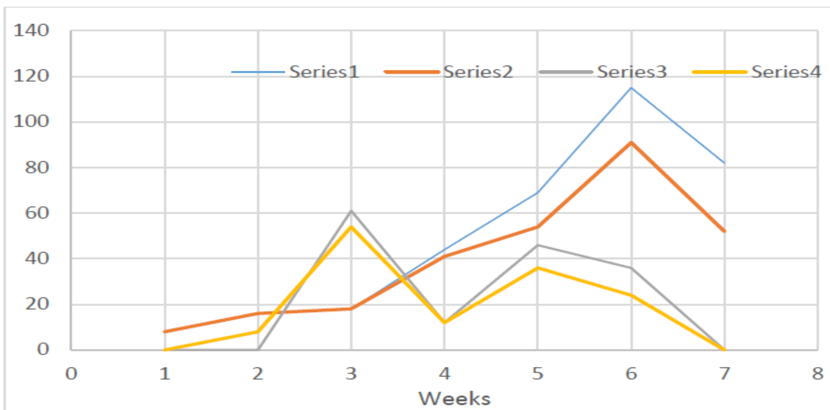

Fig. 1. Jobs Tardiness and Highest Team Overload

The plan perfection achieved by amendment is shown on the diagrams in Fig. 1. The diagrams show the summary slowness for all planned jobs in hours, and the overload of the most charged teams as percentage on the planning horizon. Thin lines refer to the preliminary planning solution, thick lines relate to the corrected solution. As it follows from Fig. 1, the adjustment diminishes both the jobs tardiness and the most team overload, appreciably. Though, it is impracticable to eliminate unevenness absolutely using only the scheduling process. Therefore, for timely jobs completion we have to change the team structure or duration of working time.

1) Synopsis weekly jobs tardiness according initial schedule in hours.

2) Summary weekly jobs tardiness according corrected schedule in hours.

3) Overload of the stimulating team according to initial schedule as percentage.

4) Overload of the charged team according to corrected schedule as percentage.

IV. CONCLUSION

Results above substantiate that the approach to invention teams scheduling, which is based on application of order utility functions, produces a reasonable schedule. The problem solution, which uses the “greedy” algorithm, is able to create the search tree starting from the initial system state. The program in VBA language for MS Excel was planned, and the example of its application for scheduling was made. The calculated schedule may be enhanced in interactive mode, if a certain job is overdue to the next week. Scheduling is a regular process that repeats with certain, but not always constant frequency. For this purpose it is opportune to use new MS Excel sheets, where information from previous sheets may be contained. By varying or inserting new data, the user may correct the previous plan or design a new one. Analyzing a set of calculated schedules, one may detect efficient deviations of teams load and optimize professional team structures. In observe various additional constraints may be compulsory for scheduling. For example, often it is needed to take into account hopelessness of job execution in a certain time interval. In the nearest future it is designed to elaborate some solutions for such problems.

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