Formation of Work Plans and Schedules at Enterprises with Conveyor Assembly

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Abstract. The methods of constructing plans and schedules for the production of components and assembly of manufactured products from them on the conveyors of machine-building enterprises are considered. Work planning can be carried out both in the production of incoming orders for manufactured products, and in the production of products taking into account the current demand for it.

Keywords: modeling methods, planning, equipment, components, conveyor assembly, control algorithms, schedule theory.

1 Introduction

In recent years, the problems of creating methods for planning and formation of the schedule of work at industrial enterprises have bigger interest. Such interest is caused by the fact that successfully constructed plans and work schedules at enterprises can significantly reduce the time for manufacturing production programs and orders received [1].

In this regard, the idea arises to increase the efficiency of industrial enterprises by building beneficial plans and schedules for them.

Most of the scheduling methods [1-3] developed are designed for scheduling in production subdivisions and systems. The use of such methods for constructing work schedules at machine-building enterprises, which may include several production subdivision and systems, causes great difficulties. These difficulties are caused by the large dimension and complexity of scheduling tasks in enterprises.

Formation of plans and work schedules of the enterprise on the basis of the schedules for the manufacture of components in the divisions of enterprises also causes great difficulties. Such difficulties are associated with the fact that it is not clear how to determine the components that should be processed within one time interval in the same subdivisions of the enterprise. These components can be determined when there is already a work schedule in the enterprise, but without such a schedule, their choice can hardly be made.

Therefore, to construct work schedules at industrial enterprises, the development of special methods is required.

The article deals with the methods of forming coordinated plans and schedules of enterprises that include several production subdivisions that produce components for assembling from them on the company's conveyors of manufactured products. For enterprises of this type, on the basis of information aggregation methods, it is possible to create more effective algorithms for building coordinated work plans and schedules for all production subdivisions of enterprises.

2 Planning and scheduling tasks at enterprises

Let a machine-building enterprise be given, which includes several machining subdivisions for the manufacture of components parts, and conveyors for the assembly of issued products from them.

For any type of issues products, the composition of its details, components and assemblies, as well as the sizes of the batch of these products, is known. For any components of these products, a manufacturing technology is known, including the sequence and times of all operations performing for their manufacture on all equipment used for this.

Assembling of manufactured products can be carried out on one or several conveyors both from manufactured at the enterprise, and from components purchased on the side. On each conveyor only "their" products can be assembled. For each conveyor, its performance is known for the production of all types of products assembled on it, the number of work places during the assembly of any manufactured product, as well as the time and cost of readjustment the conveyor for the production of all batches of products which will be assembled on it.

Products are assembled on conveyors, usually in batches, the size of which is limited. Such restrictions are determined by the production capabilities of enterprises. The fact is that the manufacture of a large number of components can take considerable time, lead to large downtime of the conveyor in anticipation of their readiness, and will require the creation of large warehouses for their storage.

The assembly of any batch of products begins after delivery to each work place of conveyor of a certain number of sets of components, as a rule, the same number for all work places of conveyor.

In one of the tasks, it is required to build a work schedule at the enterprise, which will reduce the lead time for an order for the manufacture of a certain number of products of different types.

In another task, it is required to construct a work schedule at an enterprise that has one conveyor, on which L types of products are assembled sequentially. When assembling any batch of products, a certain part of it is sent to the warehouse in order to provide consumers with products of the required type stocked in the warehouse for the release of other products until its assembly will be resumed.

The volume of output and the value of stocked products should be determined in such a way that, in accordance with the existing demand for the product, increase profits from its sale, as well as reduce the cost of its storage and readjustment of the conveyor.

3 Principles of plans and work schedules formation at enterprises

As already noted above, plans and work schedules to improve the efficiency of the operation of enterprises should be built for all departments of the enterprise in such a way that they will be consistent with each other. For these purposes, an approach based on the use of information aggregation methods was proposed in [1].

The idea of aggregating information consists in forming such groups from the completing details of the manufactured batch of products, in which each detail of the group is received for its processing in the same order to the production subdivisions of the enterprise. At the same time, any detail of the group can be processed in each subdivision of the enterprise where it is processed, according to its "own" technological route.

Such groups are considered as generalized details, production subdivisions of the enterprise, as generalized machines, and the task of constructing a work schedule at the enterprise, as the task of constructing a schedule for processing generalized details on generalized machines.

To build such a schedule, the processing time of each generalized part on all used generalized machines, i.e. the processing time of each group of parts in those production subdivisions of the enterprise where this group is processed.

These times can be determined using both traditional scheduling methods [4] and evaluation models [1, 5-7]. In Fig. 1 shows an example of a processing schedule for the i-th group of parts in the l-th production subdivision and T_{il} indicates the time of this processing.

Fig. 1.

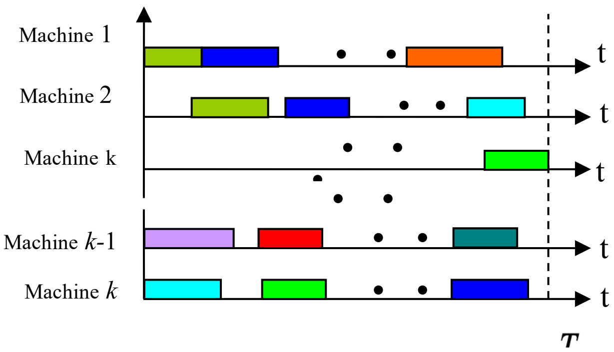

Fig. 2. Gantt chart representing the processing schedule of the i-th group of parts in the l-th production subdivision.

After determining the values T_{il} for all groups of component details and subdivisions of the enterprise, the traditional task of the theory of schedules actually arises, associated with the construction of a schedule for processing generalized parts in a production department that includes generalized machines. In [1], such a schedule for manufacturing groups of parts in the enterprise's subdivisions was called "wireframe".

Traditional “scheduling methods” [4] can be successfully used for constructing “wireframe” schedules, since the dimension of tasks during aggregation is significantly reduced. The "frame" schedule is consistent, i.e. the schedule for the manufacture of parts at the enterprise level, since the processing order of such groups in the enterprise divisions is determined using scheduling theory methods. As a rule, several such schedules are built, up to 15 - 25 and the best variant is selected from them. An example of such a schedule is shown in Fig. 2.

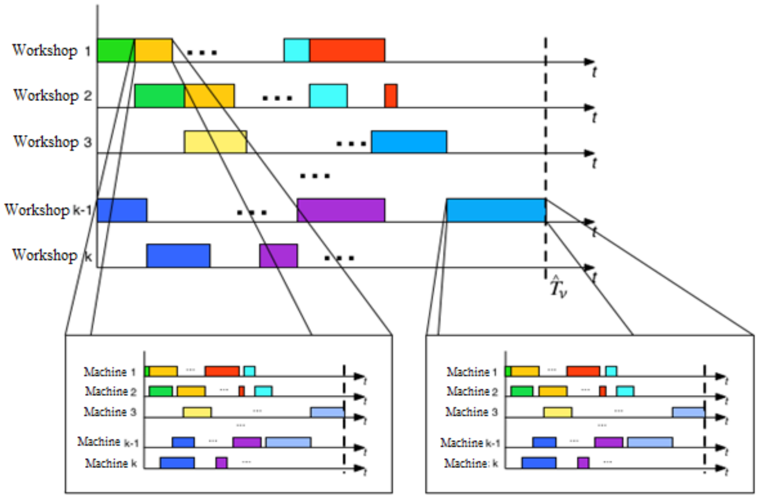

Fig. 3. A fragment of a “wireframe” schedule for processing groups of parts at the enterprise level.

This schedule, as can be seen from Fig. 2, has almost the same form as the schedule for processing parts in the subdivision shown in Fig. 1. However, in the Gantt chart, which represents the “wireframe” schedule, instead of machines on the ordinate axis, the production subdivisions of the enterprise (sections, workshops) are postponed, and instead of the part processing time on each abscissa axis, the processing times of groups of parts in the respective subdivisions are postponed.

Typically, such a distribution of component parts into groups produced extremely rare usually when the production of these types of parts masters at the enterprise and is adjusted only after the inclusion of new components in the production program or when the composition of the equipment of production equipment changes.

The processing times of each group of parts in the production subdivisions of the enterprise can be calculated independently of each other in any sequence. Therefore, on multiprocessor computing tools, you can organize parallel calculations of these times. This makes it possible to significantly reduce the calculation time, which was confirmed by the results of computational experiments [2].

Here it is useful to note some features related to the construction of "wireframe" schedules, which can reduce the time of there building.

From the results of computational experiments, it is known that the existing methods of building schedules quickly and well build work schedules when processing 30-60 types of parts in a production subdivision that has 30-70 units of equipment. Each part is usually processed in such a subdivision on 5 to 12 types of machines.

This information is useful when forming groups of components parts and subdivisions of the enterprise, which can be considered as "generalized machines" for processing these groups.

If the group of parts being formed contains more than 80 types of parts, then it is advisable to divide such a group into smaller groups, each of which does not exceed the above boundaries, so as not to miss the opportunity to quickly build work schedules for processing groups of parts.

If the number of equipment units in a subdivision of an enterprise turns out to be more than 70 -90 units, then it is convenient to divide such a subdivision into several subdivisions in the calculations, the number of equipment in which does not exceed the above boundaries.

If the number of formed groups of parts turns out to be very large, then their number in many cases can be reduced by attaching parts, which are not processed in all subdivisions of the enterprise, to groups that have similar fragments of routes.

In addition, it is advisable to note that the processing of components by such groups in the subdivisions of enterprises makes it possible to more efficiently organize the transportation of parts between divisions than with traditional processing. The fact is that after the completion of the processing of each group in any subdivision, all processed parts can only go to two places.

One of such places is a subdivision, in which processing of all parts of the group that are not completely made, will continue, since each group of parts is sent to the subdivisions for processing along one known route.

Another place for transportation of the group parts, the processing of which is completed in this subdivision, is the warehouse, where the finished parts for assembly are stored.

4 Schedules at enterprises with conveyor assembly of products

The constructed examples showed that the order of processing of components and, to a large extent, the total production time of products depends on the order of assembly of batches of products. The "wireframe" schedule for the manufacture of components intended for the assembly of any batch of products, in turn, can be considered as a "frame" for the manufacture of components for this batch in the production subdivisions of the enterprise.

An example of such a "frame" for the manufacture of components for each batch of products has the form similar to the "frame" schedule shown in Fig. 2, where the manufacturing time of this "frame" of components is indicated by $\hat{T}_v$. The assembly time of any batch of products can be determined by knowing its size, the number of jobs on the conveyor and its productivity.

In this case, knowing the times of manufacturing the “frames” of components and the assembly times of batches of products from them, it is possible to construct a time-optimized “frame” assembly schedule for several batches of various products, if we consider the manufacturing time of the “frame” of components for assembling the ith batch of products through A_i as the processing time of the ith detail on the first machine, and the assembly time of this batch of products on the conveyor through B_i as the processing time of the ith detail on the second machine, then this problem turns out to be similar to Johnson's [4] (see Fig. 3).

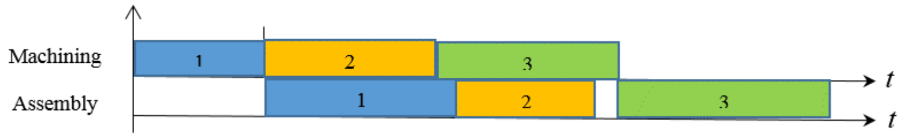

Fig. 4. Gantt chart of the "frame" schedule for the manufacture of components and assembly of products from them.

The assembly sequence of a batch of products and, accordingly, the manufacture of components for this can be determined using the results of the following theorem, which is similar to Johnson's theorem [3].

Theorem 1. Let several batches of products of various types be assembled on a conveyor, the assembly of each of which begins after the manufacture of all components for this batch of products.

Then, with the simultaneous availability of all works, the “frame” schedule, which minimizes the total production time of all products, is such that the assembly of j-th product batch precedes assembly ($j+1$)-th product batch, if

$$\min\left(A_j, B_{j+1}\right) \le \min\left(A_{j+1}, B_j\right) \quad \text{and} \quad A_{j+1} \ne B_{j+1}. \tag{1}$$

If $A_{j+1} = B_{j+1}$ and there is k ($k = 1,...,n$) subsequent work on the manufacture of batches of products for which equalities are also satisfied $A_{j+k+1} = B_{j+k+1}$, then for these works, besides fulfilling the conditions $\min\left(A_{j+k}, B_{j+k+1}\right) \le \min\left(A_{j+k+1}, B_{j+k}\right)$min for all k ($k = 0,1,...,n$), the condition must also be fulfilled $\min\left(A_j, B_{j+n+1}\right) \le \min\left(A_{j+n+1}, B_j\right)$, where across $j+n+1$ the first job following the job is indicated $j+n$, for this $A_{j+n+1} \ne B_{j+n+1}$.

Let us consider the principles and methods of constructing plans and schedules of work at enterprises with conveyor assembly of products, when various types of products can be sequentially assembled on one conveyor, the volumes of output of each type of product are determined by the demand for them r_i ($i = 1,...,L$). Let us denote by $\tilde{C}_{si}$ financial, and by τ_i time costs of preparation and readjustment of the conveyor for assembling of i -th products ($i = 1,...,L$).

In the task, it is necessary to determine the volume of production of each type of product in such a way that there are no surpluses and shortages of manufactured products in the warehouse, and the number of changeovers of the conveyor from the production of one product to another during the planned period would be as small as possible

To ensure consistent production of types of L products and their availability in the warehouse, it is proposed to make the times between the start of adjacent releases of products of each type t_s identical and determine them, in accordance with [8], using the following ratio:

$$t_s = \max\left\{ \sqrt{\frac{2\sum_{i=1}^{L} \tilde{C}_{si}}{\sum_{i=1}^{L} C_i \bar{r}_i \left(1 - \frac{\bar{r}_i}{p_i}\right)}}, \frac{\sum_{i=1}^{L} \tau_i}{1 - \sum_{i=1}^{L} \frac{\bar{r}_i}{p_i}} \right\} \quad (1)$$

where $\bar{r}_i$ value of average demand for products of the i -th type ($i = 1,...,L$) during the planning interval T .

Value q_i and $\tilde{q}_i$ denoting the number of products in the production batch and the number of products from this batch, which is sent to the warehouse, are determined using the ratios (3), (4).

$$q_i = (p_i - \bar{r}_i)t_{li}, \text{ i=1,…,L} \quad (2)$$

$$\tilde{q}_i = \bar{r}_i t_s = p_i t_{li}, \text{ i=1,…,L} \quad (3)$$

Calculation of work schedules at such enterprises in conditions of random demand $\bar{r}_i$ (i = 1,…, L) after determining the values $\tilde{q}_i$ (i = 1,…, L) can be made in accordance with the scheme described in the previous paragraph.

In the conditions of the traditional processing of components, when the parts after processing in one production subdivision arrive to continue processing in different subdivisions, it is very difficult to organize efficient transportation of parts.

In this work, the processing of components is proposed to be carried out in groups, which are processed in the production subdivisions of the enterprise in the same order. This allows you not only to build work schedules at the enterprise level, but also to organize the efficient transportation of parts between production subdivisions and build a schedule for their transportation.

5 Conclusion

The ideas of forming groups of components, which are created in accordance with the principles described above, have proven to be very productive. This allows:

- to offer another organization of the manufacture of components parts, when their processing is carried out in groups, which are formed according to the principles described above;
- to develop building schedules methods for processing components at the enterprise level;
- to organize efficient delivery of component parts between production subdivisions;
- more effectively manage inter-shop vehicles of the enterprise;
- drill down into the "wireframe" schedules at the enterprise level to the processing schedules for individual parts on all the equipment used.

The developed methods of constructing work schedules for enterprises with conveyor assembly of manufactured products can be used to create algorithms for selecting equipment for the modernization of such enterprises. The efficiency of scheduling methods can be improved by parallelizing the calculations performed.

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