A Study of Complete Kit Oriented Aerospace Product Manufacturing Model

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Abstract. Theory model of Kit-Manufacturing is established to improve the efficiency of aerospace product manufacturing. The definition and algorithmic method of Key Routing and Standard Production Batch is provided. The Kit-Manufacturing coefficient for monitoring product manufacturing process is defined and an evaluation method for Kit-Manufacturing is provided. The precondition of achieving Kit-Manufacturing is introduced.

Introduction

In the manufacturing process of aerospace product, the feature of Multi-variety, small batch and changing BOM is marked. Because of the complexity of manufacturing process, the problems of overstocked finished parts, delivery delay and higher cost is prominent [1]. In order to reduce the finished parts stock and production cycle, a complete kit controlling model of the entire manufacturing process of aerospace is introduced.

In the model of traditional production control, which kit is generally limited to the kit of assembly cycle, different kind of parts is always uncompleted in assembling cycle, then production plan is adjusted. Kit-Manufacturing[2], which is supplement of MRPII [3,4] and turns 'kit oriented production control' into 'kit based production control', request the kit of parts is considered during job plan is being made and executed. Kit manufacturing is proposed to improve the available production management theories. Wang summed up concept of related papers, and summarized that dispatch study of oriented to kit manufacturing is still insufficiency [5].

Kit manufacturing refers to the dynamic kit during the process of production by controlling the production temps of all kinds of parts, to make all kinds of parts to start and accomplish manufacturing at the same time by scheduling the different temps of parts [6, 7].

Kit Manufacturing Model

Kit manufacturing model is mainly composed of key routing, standard production batch, kit coefficient and the evaluation method of kit manufacturing.

Key Routing and Standard Production Batch. To get real time kitting during the whole process of parts production, we split the plan quantity of their father part to get shorter production cycle.

In the production process of a general discrete manufacturing enterprise, manufacturing time only accounts for a small part of the whole production cycle. Besides the actual production time, we call the extra time preparation time of work center.

Construction and use of color / shades of gray:

Fig.1 Preparation time and production time of a part

Fig.2 Processes in a production cycle

As in Fig.1, tp_{ij} refers to the single production time of process j of part i , and TS_{ij} refers to the preparation time of the process. Set the batch quantity of part i as Q_i , then $TP_{ij} = Q_i \cdot tp_{ij}$. As in Fig.2, the whole production cycle TL_i of part i is compared of several preparation time and production time, so that $TL_i = \sum_{j=0}^J (TS_{ij} + TP_{ij})$. Several concepts are defined below before the kitting model is imported.

Economic batch quantity Q^E : Economic batch quantity refers to the production batch with the minimum cost. Generally, economic batch quantity is integer times of feed quantity, carrying quantity and assembly quantity.

Production batch Q^L : Production batch quantity is generally 1/ N of plan quantity.

Production period of part i in planed quantity: $TL_i = Q_i^P \cdot tp_i + TS_i$

N_i^L refers to the number of production batch: $N_i^L = Q_i^P / Q_i^L$

Production cycle of economic batch of part i : $TL_i^L = Q_i^L \cdot tp_i + TS_i$

Key routing: Key routing of a product refers to the longest routing of all parts. Set the planed quantity of component u' , the key routing is calculated as following:

Set variant; Set component is assembled by parts, Set=0, go to Step2, and traverse all parts;

If, then go to 4HStep3, or go to HStep6;

Set the assembly quantity of part i as, and process number as J . Set $j=0$, go to Step5 and traverse all J processes.

If, go to HStep5, or and go to 28H Step2;

Set production time of process j of part i as, preparation time as, then the whole production cycle of part I can be summarized as, if, then, set and go to 9H Step4;

is the key routing of part when plan quantity as.

Standard production refers to the kit manufacturing mode, where all parts are manufactured in appropriate quantity, to make all parts being dynamic kit.

In JIT production mode, planed completion time of all parts should be at the same time. If planed completion time is t_R , the standard production batch can be calculated as follow.

Step1.Set the key routing of component as TL_S , planed production quantity as. Set component is assembled by parts and=0, then go to Step2 and traverse all I parts.

Step2.If, go to Step3, or go to Step4;

Step3.Set economic production batch of part i as. The production cycle could be obtained as and the number of production batch could be obtained as. If, then set, $i=i+1$ and go to 3HStep2;

Step4.Get the number of standard production batch of component as:

Step5.If, then go to 33 Step6, or go to Step9;

Step6.The following steps should be done of part i :

a)Standard number of production batch $N_i^{LS} = \min(N_i^L, N^{LS})$,

b)Standard production batch $Q_i^L = Q_i^P / N_i^{LS}$,

c) $k=0$ and go to Step2;

Step2.If $k < N_i^{LS}$, then go to ~~tp~~ or set $i = i + 1$ and go to ~~tp~~

Step3.For the k -th production cycle of part I , related parameters of plan production cycle could be obtained.

- a) Plan production cycle as $TL_i^{LS} = Q_i^L \cdot tp_i + TS_i = (Q_i^P / N_i^{LS}) \cdot tp_i + TS_i$,
- b) Planed completion time as $t^K - (N_i^{LS} - k - 1) \cdot TLS / N_i^{LS}$,
- c) Planed begin time as $t^K - (N_i^{LS} - k - 1) \cdot TLS / N_i^{LS} - TL_i^{LS}$,
- d) Set $k = k + 1$ and go to Step2.

The result is evaluated.

Kit coefficient. The quantity of parts could be assembled of a component is up to the minimum quantity of completed parts. For example, component p is composed of x_1, x_3, x_4 and x_5 , which quantity is 2,4,6,8 and 10. The completion quantity of p at the moment of t can be expressed as $Q_p^F(t) = \{Q_1^F, Q_2^F, Q_3^F, Q_4^F, Q_5^F\}$.

Tab.1 Quantity of parts of component p at different moment

Moment	completed quantity	Surplus of Assembling
t_1	{2,0,0,0,0}	{2,0,0,0,0}
t_2	{2,4,6,8,0}	{2,4,6,8,0}
t_3	{4,8,12,16,20}	{0,0,0,0,0}
t_4	{5,8,12,16,20}	{1,0,0,0,0}

Completion rate of part i : $F_i = (Q_i^F / Q_i^P) \times 100\%$, where Q_i^F is the completion quantity of part i . The maximum completion rate can be expressed as $F^{\max} = \max_i \{F_i\}$. And the kit coefficient of part i is $S_i = F_i / F^{\max}$. The completion rate and kit coefficient of component p at different moment is listed in Tab.2.

Tab.2 The completion rate and kit coefficient of component p at different moment

Time	Plan quantity	completed quantity	completed rate	Kitting coefficient
t_1		{2,0,0,0,0}	{0.2, 0, 0, 0, 0}	{2,0,0,0,0}
t_2		{2,4,6,8,0}	{0.2, 0.2, 0.2, 0.2, 0}	{1,1,1,1,0}
t_3	{10,20,30,40,50}	{1,2,3,4,5}	{0.1, 0.1, 0.1, 0.1, 0.1}	{1,1,1,1,1}
t_4		{4,8,12,16,20}	{0.4, 0.4, 0.4, 0.4, 0.4}	{1,1,1,1,1}
t_5		{5,8,12,16,20}	{0.5, 0.4, 0.4, 0.4, 0.4}	{1,0.8,0.8, 0.8, 0.8}

Evaluation of Kit Manufacturing

The target state of kit manufacturing is that completion rate of every part keeps pace which each other and kit coefficient is equal to 1.

Set u' as parent component of part i , then completion rate of u' is $F_{u'}' = \min_i \{F_i\}$ and kit coefficient of u' is $S_{u'}' = \min_i \{S_i\}$. Set q_i^c as the assembly quantity of part i in u' , then $Q_{u'}^F = \min_i (Q_i^F / q_i^c)$.

Completion rate of a component, which is defined as the weighted average completion rate of all

parts, is $F = \sum_{i=0}^I TR_i \cdot F_i / \sum_{i=0}^I TR_i$. And kit coefficient of a component is defined as the weighted

average kit coefficient of all parts, is $S = \sum_{i=0}^I TR_i \cdot S_i / \sum_{i=0}^I TR_i$. Set the start time and completion time of

k -th production cycle of part i as t_i^k and t_i^{k+1} . Set completion rate of part i as

$$F_i(tx) = \begin{cases} 0, & t_i^k \leq tx < t_i^{k+1} \\ (tx - t_i^k) / TL_i^{LS}, & t_i^k \leq tx < t_i^{k+1} \\ 1, & t_i^{k+1} \leq tx \leq t_i^{k+1} \end{cases}, \text{ then the average kit coefficient of part } i \text{ is}$$

$$\overline{S_i^k} = \frac{1}{TL^{LS}} \int_{t_i^k}^{t_i^{k+1}} \frac{F_i(tx)}{F^{\max}(tx)} dx. \text{ The completion curve of different parts is different, so } F^{\max}(tx) \text{ equals}$$

to different $F^{\max}(tx)$ curve in different domain of tx . As in Fig.3b, the kit coefficient of Part2 could be obtained as:

$$S_2(tx) = \begin{cases} \frac{(k / N^{LS})}{(x / 100)} = \frac{100k}{N^{LS} \cdot tx}, & 100k < N^{LS} \cdot tx \leq 100k + 20 \\ -\frac{200k + 100}{3N^{LS} \cdot tx} + \frac{5}{3}, & 100k + 20 < N^{LS} \cdot tx \leq 100k + 50 \\ \frac{(x - 40k - 20) / 60N^{LS}}{(x - 40k - 20) / 60N^{LS}} = 1, & 100k + 50 < N^{LS} \cdot tx \leq 100k + 80 \\ 1 / 1 = 1, & 100k + 50 < N^{LS} \cdot tx \leq 100k + 80 \end{cases}$$

$S_0(tx)$ and $S_1(tx)$ could be obtained by the same method.

The average kit coefficient of part i could be obtained as

$$\overline{S_i} = \frac{1}{TLS} \cdot \sum_{k=0}^{N^{LS}} (\overline{S_i^k} \cdot TL^{LS}) = \frac{1}{TLS} \cdot \sum_{k=0}^{N^{LS}} \left(\frac{\int_{t_i^k}^{t_i^{k+1}} S_i(tx) dx}{TLS / N^{LS}} \cdot TLS / N^{LS} \right) = \frac{1}{N^{LS}} \cdot \sum_{k=0}^{N^{LS}} \left(\frac{\int_{t_i^k}^{t_i^{k+1}} S_i(tx) dx}{TLS / N^{LS}} \right).$$

$$\text{So that } \overline{S_2} = \frac{1}{N^{LS}} \cdot \sum_{k=0}^{N^{LS}} \left[1 - \left(k \ln \frac{100k}{100k + 20} + \frac{2k + 1}{3} \ln \frac{100k + 50}{100k + 20} \right) \right].$$

Since $f(k) = 1 - \left(k \ln \frac{100k}{100k + 20} + \frac{2k + 1}{3} \ln \frac{100k + 50}{100k + 20} \right)$ is an increasing function, so that the average

kit coefficient $\overline{S_i^k}$ is also an increasing function of k . And kit coefficient $\overline{S_2}$ could be increased with the increase of N^{LS} .

Fig.3 Diagram of kit manufacturing evaluation.

In kit manufacturing mode, methods such as standard production batch calculation and monitoring of kit coefficient should be used to optimize the whole production process.

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