Optimization of Aircraft Part No-Return Manufacturing Process Based on Value Stream Analysis

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ABSTRACT: To target aircraft part manufacturing processes, this article analyzes the shortcomings of aircraft part “return” manufacturing process, and proposes the improvement solution of “no-return” manufacturing process optimization. By adopting measures, such as to cancel “returned” part hand-over, add work assignment to heat/surface treatment shop, add production schedule control by heat/surface treatment shop and improve part identification, etc., part fabrication cycle is reduced and part quality is improved. Based on the analysis and verification of value stream mapping before and after the improvement, the target of process optimization and restructuring is achieved.

1. Preface
As a tool for leaning manufacturing, Value Stream Mapping (VSM) plays a major role of making diagnosis on value creation process and becoming a planned tool for achieving leaning manufacturing[1]. VSM is widely applied by manufacturing enterprises to identify and eliminate inventory waste, transportation waste, and the waste resulting from improper process and waiting, reduce the non-value-added time during product manufacturing processes, continuously improve efficiency and reduce cost, so as to establish a more flexible and more efficient manufacturing system[2]. In addition, VSM also contains information process, which provides a better solution for information transferring and feedback[3]. As a discrete manufacturing enterprise organizing production per shop tasks, the aircraft manufacturing enterprise features complex internal management process, and great amount of waste caused by waiting, handling and inventory during material handover process. To eliminate the waste and non-value-added activities during aircraft part hand-over process, reduce manufacturing cost and improve production efficiency have always been the pursuit of an aircraft manufacturing enterprise.

Based on mind-set of lean manufacturing, this article analyzes and optimizes the aircraft part production and delivery process by means of VSM analysis, and establishes part “no-return” manufacturing process so as to improve production efficiency and achieve lean manufacturing of part fabrication.

2. Analysis of Current Situation
2.1. Current Situation of Production Organization
Aircraft manufacturing enterprise is a typical task-oriented enterprise. Its feature is that each task only uses part capacities and resources[4] of the enterprise, and that machine-group layout, also called “process focused” layout is adopted for manufacturing equipment arrangement. Equipment with the same or similar functions are arranged together as per space or administrative subordination
relationship to establish an production organization, so as to form various production shops of lathe shop, milling shop, heat treatment shop and surface treatment shop. As products are manufactured by different shops responsible for various processes, rather in by following the principle of “object-based” specialization on production line, a part needs to be repeatedly handed over among shops, particularly in cold and hot process shops. Aircraft parts are mainly formed and produced in cold process shop which is subject to schedule assessment, so heat treatment shop is not included in Work Assignment and is considered as in-process hop playing assisting and passive role during production. Furthermore, due to the characteristics of aircraft products, most cold-processed parts require heat and surface treatment. Therefore, a large number of parts have to be handed over from and to cold and hot process hops.

2.2. Current Situation of Production Process
After aircraft parts which have been machined and formed are handled to heat and surface treatment shop for heat treatment and surface treatment, detail part fabrication shop needs to take back the parts for identification, and final inspection, etc., and finally pack the parts and deliver them to assembly shop. The above repeated hand-over of parts is called “return” manufacturing process, as Figure 1 shows. Such repeated hand-over of parts restrains part fabrication efficiency, increases product cost, and is a typical waste.

3. Analysis on Shortcoming of “Return” Hand-Over
The “return” model for part manufacturing has been adapted to production organization featuring few types of aircraft parts and large batches. Production lines organized as per administration relations and in principles of process specialty facilitate specialized technical development, centralized equipment maintenance and internal administration management of an enterprise. However, as aircraft models and production capacity increase, newly built and reconstructed process lines break the original process line layout, and makes the shortcoming of “return” manufacturing model gradually exposed.

3.1. Great logistics and time cost
Due to the repeated part hand-over with no value added, the repeated warehousing, storage and recording activities prolong the cycle of part manufacturing and delivery and lowers the efficiency of production system. The initial statistics indicates that the inefficient hand-over time of certain specialized materials accounts for above 20% of the total hand-over time.

3.2. Quality Issues of part scratches, etc.
As parts are handed over repeatedly, large components might be scratched, or damaged, etc., which causes unnecessary quality loss, and small parts might be lost. The statistics shows that 20% of parts
might be scratched or damaged to certain extent during the hand-over process and 10.6% scraped parts are caused by surface quality issue.

3.3. Insufficient proactive planning in heat and surface treatment shops
In “return” part manufacturing model, heat and surface treatment shops do not take the major responsibilities of part delivery schedule, and they won’t push part fabrication during the whole manufacturing process, which is not good for production balancing.

4. Analysis on Value Stream Brought By “Return” Hand-Over
Fabrication of sheet metal parts for certain commercial aircraft is taken as an example for value stream analysis. A detail fabrication shop receives a work order of 2 batches every month, with each batch containing 11 pieces of parts, 30-day continuous operation per month and 7 effective operation hours per day. The whole manufacturing process consists of 11 operations to be accomplished by 3 operation units. The manufacturing process related information prior to the improvement is shown in Table 1.

| Table 1 Summary of Manufacturing Data |
|--------------------------------------|
| Shop                                 | S/N | Operation Description | Cycle (minute) |
| Sheet Metal Shop                     | 1   | Blanking              | 5              |
|                                      | 2   | NC milling            | 400            |
|                                      | 3   | Trimming              | 90             |
|                                      | 4   | Forming               | 110            |
|                                      | 5   | Inspection            | 30             |
|                                      | 6   | Inspection            | 30             |
| Physical & Chemical Test Dept.       | 7   | Physical and chemical test | 420         |
| Sheet Metal Shop                     | 8   | Trimming              | 70             |
| Heat / Surface Treatment Shop        | 9   | Heat and surface treatment | 750         |
| Sheet Metal Shop                     | 10  | Coding and packaging  | 45             |
|                                      | 11  | Delivery to Assembly Shop | 20            |
| In Total                             |     |                       | 1970           |

Current VSM is to be made:
With the collected manufacturing data and special symbols of VSM, and in accordance with the method for mapping value stream, the following VSM is made for sheet metal part fabrication process to highlight the waste and non-value added steps within the whole process[5].
Calculation of value stream assessment indicators:

1. Value-added time AT: the time bringing value addition to products

\[ AT = \sum_{i=0}^{n} CT_i \]  

where: \( CT_i \) refers to the operation cycle time in No. \( i \) work station.

2. Non-value added time UT: the time bringing no value addition during manufacturing, such as handling, waiting time.

\[ UT = \sum_{i=1}^{n} CT_{i+1} \]  

where: \( CT_{i+1} \) refers to the delivery cycle from No. \( i \) work station to No. \( i+1 \) work station

3. Value addition ratio I: the percentage of value added time and manufacturing cycle time.

\[ I = \frac{AT}{AT + UT} \times 100\% \]  

Put the data above into formula (1), (2) and (3) and obtain AT=1970 minutes, UT=21500 minutes, I=8.4%, where value addition ratio is low and non-value added time is long, which indicates that huge waste in production lines. Therefore, analysis and improvement shall be made in an all-round way so as to reduce product manufacturing cycle and improve manufacturing fluency.

5. Establishment and Effect Analysis of “No-Return” Process

In order to solve the problem of waste, adopt ECRS techniques and 5W1H techniques for industrial engineering process analysis, and raise the process improvement scheme for part manufacturing
processes “no-return”.

5.1. Connotation of Part Manufacturing “No-Return” Process Improvement
Without change on current organization structure, reduce part hand-over procedure as possible, i.e. part manufacturing shop shall complete all the operations such as processing, forming, etc., deliver to heat/surface treatment shop, and after completing heat/surface treatment, if it does not require that the parts must be returned to the part manufacturing shop for previous operation to complete the subsequent work on process technique basis, the parts will not be returned. Heat/Surface treatment shop shall complete the residual work such as process lug removal (lugs for anodizing in surface treatment shop), part identification, inspection, packing and hand-over. Heat/Surface treatment shop shall be changed from the original operation coordination shop to main responsible shop for “no-return” part delivery. It shall be responsible for directly delivering the parts to assembly and other user shops, and to achieve “no-return”.

5.2. Part “No-Return” Process Improvement Scheme
1) Cancel the “return” process in heat/surface treatment shop
After heat/surface treatment is completed in heat/surface treatment shop, for parts that only require accessory work to be completed such as packing, identification, and finished-part inspection in the shop, the process for returning the parts to manufacturing shop should be fully canceled. These accessory work should be transferred to heat/surface treatment shop, and then the shop should deliver the parts to assembly shop. Move the bench worker in part manufacturing shop to heat/surface treatment shop. Meanwhile, cancel the repetitive work of part receipt inspection.

2) Add process work assignment for heat/surface treatment shop
General principle for process work assignment change: heat/surface treatment shop is between the original manufacturing shop and assembly shop.

3) Add production plan control in heat/surface treatment shop
Add production plan assessment milestone for heat/surface treatment shop. It has been changed from in-process coordination shop to delivery shop. This could pull the production schedule in downstream part manufacturing shop, and guarantee the part delivery milestone.

4) Improve part identification control
a. It is not allowed for bulk storage during part hand-over. Parts shall be packed with polythene bag in uniform specification or tied with protective tape to reduce part sorting time.
b. There shall be paper of Part Identification Control Card and with the part. Identify the part bar code to reduce the recording time for part handover.
c. For easily-confused parts with similar shape, one-to-one attach part ID tag. Individually pack and handover the parts to reduce the distinguishing time.
d. For part hand-over, perform as per the attached sketch page showing part shape to avoid part confusion.

5) Technical condition controlled as per sectional responsibilities
Fabrication shop shall be responsible for the correctness of conditions such as structure size, geometry, etc. before parts delivered to heat/surface treatment shop. After heat/surface treatment shop receives the parts, it shall be responsible for the consistency of part identification and physical parts during subsequent production and hand-over, as well as part surface quality condition.

![Figure 3 Chart of Part “No-Return” Manufacturing Process](image-url)
6. Implementation Effect of “No-Return” Process Improvement

6.1. Optimize Part Manufacturing and Delivery Process; Reduce Part Delivery Cycle
Optimize logistics paths, and reduce part hand-over times. Learning from VSM analysis, hand-over distance has been reduced by 3120 meters, await time for shop-to-shop transfer has been reduced by 10380 minutes. Unemployed Time (UT)(Non Value-Added Time) has been reduced from 21500 minutes to 11120 minutes, the value-added ratio has been increased to 14.9%.

![Figure 4 VSM of Part “No-Return” Manufacturing Process](image)

Since production cycle has been reduced, the turnout has been increased from 22 parts for 2 batches each month to 42 parts for 3.9 batches each month. The production capacity has been increased by 91%.

6.2. Reduce the Damage Probability and Reduce Quality Loss
Reduce unnecessary part hand-over and handling activities, effectively solve the problems of part damage and lost. Inspection pass rate for parts delivered by sheet metal shop has been increased from 85% to 92%. Waste loss has been reduced by over 500 thousand RMB each year.

6.3. Optimize Production Plan Assessment Management
As per part “no-return” production method, production plan will be unified arranged. Delivery assessment milestone and production tact shall be set for surface treatment shop, which shall be responsible for arranging the production plan according to the urgency level of the part. It could pull the production schedule in downstream part manufacturing shop, and guarantee the part delivery milestone.

7. Conclusion
This text takes aircraft parts manufacturing processes as example, applying VSM to analyze, finding out non-value-added sectors, optimizing processes, systematically combing and solving the technical
and management problems such as long path of part hand-over, nonstandard identification, and delivery schedule responsibilities not clear, etc. The process optimization result has been fully incorporated into part manufacturing processes. It has demonstrated the feasibility for analyzing aircraft part manufacturing processes by using VSM technique, and optimization with lean production, which is worth the relevant enterprises in the industry to promote and adopt.

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