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Cycle time study of wing spar assembly on aircraft factory

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Abstract

Aircraft manufacturing processes require a high amount of time to carry out them owing to the large volume of various operations and the high utilization of manual labor. This paper focuses on cycle time study of aircraft assembly using a wing spar as a case of study. Through lean philosophy has been studied the current process and have been analyzed the obtained results. The overall goal was to find potential areas for productivity improvement and propose new solutions that would reduce significantly the cycle time. Results showed a 20% reduction in cycle time through application of lean philosophy, achieving 67% final saving if automation being applied. The study gives significant contribution to the overall goal, showing that. Is possible and necessary to bet for new techniques and technologies for manufacturing processes in aeronautical industry.

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Keywords: Cycle time; Lean manufacturing; Automation, Aircraft assembly;Value Stream Mapping;Aerospace;Wing spar

1. Introduction

Manufacturing processes in aerospace require a high amount of time to carry out them owing to the large volume of work and the high utilization of manual labor. That is why an accurate estimation and analysis of aircraft assembly times is important for process planning, cost control, reducing product development lead times and ultimately commercial success. Thus the implementation of effective methodologies allowing analyze processes time fast and accurately, is a significant challenge for manufacturers hoping to build and maintain a competitive advantage.

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Assemble an aircraft needs for around one third of total manufacturing cost [3]. Thus, Cycle Time Reduction (CTR) will be one of the major factors affecting the future of the civil aerospace industry [7] to successfully compete in the market, minimizing costs and passing a portion of those savings to customers.

Cycle time is an important aspect of process efficiency, defined as the total time it takes to complete a specific task from start to finish. Therefore, cycle time involves different elements that play a key role on it, see Fig 1. These elements, the relationship between them and the implications of these relationships, give clear vision of the subjects to be addressed and help to determine the methods and technologies applied as well as the terminology used to contextualize the field of study.

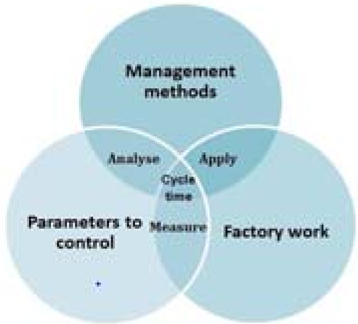

Fig. 1. Venn diagram for cycle time.

As can see in Fig. 1, cycle time involves different elements and actions for its development. For example: standardization and process optimization, development teams, time reductions, acceleration techniques, project complexity, information process, time to market, explicit goals, product design, launch and change philosophy, continuous improvement and manufacturing techniques. [8]. These concepts are intimately linked with the following concepts [9]:

- Product strategy
- Development process
- Team structure
- Supply chain

Although the literature cites many product development acceleration techniques, not many examples provide why and how these techniques are successful. Thus is key, look for management methods and new techniques that provide and improve manufacturing processes. One major cost driver is the manufacturing cost, in which assembly cycle time carries a big portion and provides necessary data for production planning and control [6]. Hence, an effective method to accurately estimate assembly cycle time is required to allow a better analysis of the process.

There are different approaches available nowadays to improve process performance. Lean philosophy offers a unique method that helps identify possible improvement areas on a production line [4]. The concept of lean is commonly known as a measure to reduce inventory and the number of hands involved in any process. It is also associated with continuous improvement, but the main theme in the lean concept is waste reduction. Lean is a useful tool that helps in reducing waste of time, material, effort and resources in an industry. The core approach of lean manufacturing is to produce a product in the shortest possible cycle time and streamline the flow of processes offering value to the customer through an ideal value added process that has zero waste [1].

Given the increase in demand in aeronautical sector, manufacturers are pushed to look for new concepts to stay in business amidst strong competition. Thus, the integration of lean philosophy and tools like Cause-Effect diagrams (Ishikawa diagram), histograms (Pareto diagram), Value Stream Maps (VSM) [10,11], brainstorming's or the Deming cycle (Plan, Do, Check, Act; PDCA) maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital [6].

In connection with the foregoing, the integration of new techniques provides a powerful tool, but once the process is improved through they, a new approach is needed. Looking to the machines used in aerospace and the integration man-machine, large dedicated machines are the common method for automation, striving to reduce costs and shorten lead times. These machines have enabling high accuracy in dynamic operations, such as drilling and the assembly of high quality products, however are expensive and lack flexibility [5].

Observing the prerequisites of trends in aircraft manufacture market, one can observe that there are clear indications that the automation for aircraft assembly requires flexibility to be profitable. That is why before deploying robots into production, all cost factors must be carefully studied and understood. However, industrial robots are key technology which is needed to implement a better cost-effective automation in an industry [5].

Until now, conservatism in the industry and high cost of technology did not help to bring new technologies to this sector. Also, historically the design of airframes was one hundred per cent focused on the performance of the aircraft and not at all on manufacturing considerations [2]. But aircraft manufacturers are being pushed by market to change for achieve their objectives and stay in the market.

This paper is based on the literature to discuss the application of new methodologies looking for results that contribute significantly to the overall goal of cycle time reduction trying to prove that a different approach is possible trough lean philosophy and the automation.

2. Methodology

In this paper, it was selected as a case study the cycle time of a wing spar assembly. The methodology was carried in two phases. The first stage was to diagnose the framework as it existed through the application of a value stream mapping (VSM) [10,11] and then analyze the methods and practices for cycle time reduction through the application of Lean Manufacturing [1,4]. When the first stage was completed, the second was improve and redesign a new and automated assembly process, following the improved process as starting point. However, estimate the cycle time is not intuitive [8], especially for the new automated processes because cycle time depends on various process parameters, such as robot motion speed or moving distance [5].

The wing of a modern aircraft is made up of the main central wing box plus the leading and trailing edge as it can be seen in the example, Fig 2.

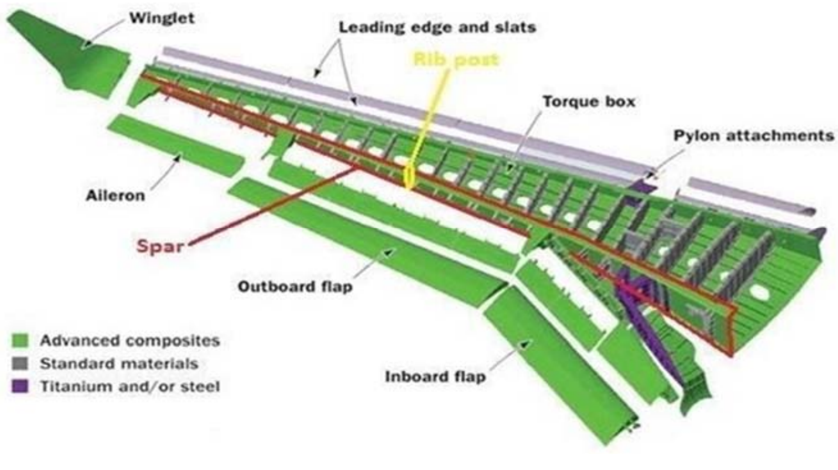

Fig. 2. Venn diagram for cycle time.

As shows Fig 2, a wing box is made up of three major components, the ribs, the longitudinal spars and the skin panels, that are strengthened with rows of stringers attached by thousands of rivets and bolts. The spar is the main element of the study in this project, in that was developed the study of assembly cycle time. The rib post is one of the elements of the spar assembly.

Aircraft assemblies can be summarized into three main phases:

1. Pre-assembly
2. Drill
3. Assembly

Regarding to the above, aircraft assembly tooling is employed for holding the aircraft parts in space during assembly. Fixtures position and hold parts during assembly, jigs also guide cutting tools. The assembly process is basically carried out by drilling holes followed by fastening. In the case of study, wing spar assembly, Fig 3 shows the build sequence summarized

Fig. 3. Wing spar build sequence.

2.1. Lean application

Once the VSM analysis was carried out and the build sequence was identified, the analysis can be done. Focused on cycle time the problem statement was:

- What operations require more time?
- What areas/operations need improvement?
- What are the causes of the above questions?

Looking to the build sequence (Fig 3) and to the questions done was observed that the most time-consuming operations was drill and measure & shim consuming 68% of the total cycle time. This reflects a high impact in the hole process and highlights the operations that need improvement. These processes may contribute to waste generation [1,4] one of the most critical principles lean manufacturing. Hence, is needed to focus on the causes that produce the actual cycle time (see Fig 4) to analyze and reduce it if possible.

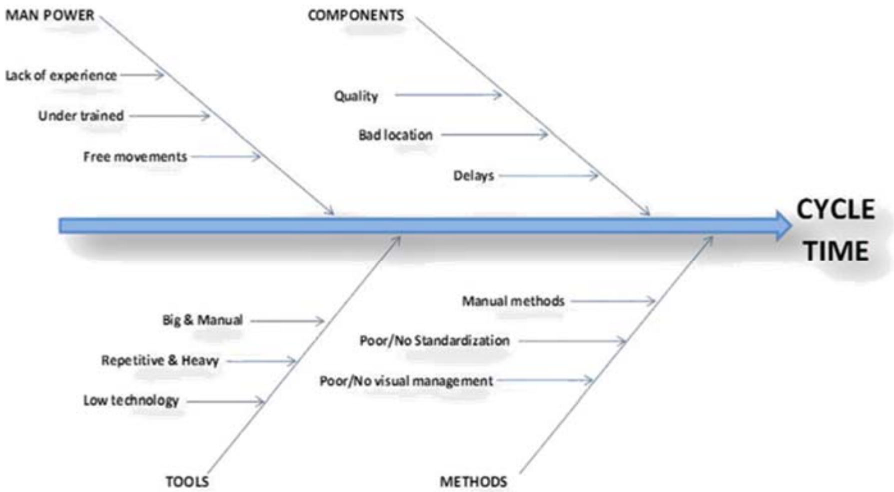

Fig. 4. Assembly process cause-effect diagram.

Fig 4 shows four levers: Man power, components, tools and methods whit their implications that contribute to actual cycle time. Below are analyzed these levers:

- Methods: the analysis showed that the process was 98% manual, had poor standardization and bad visual management. This contributes directly to the value added in the operation, showing that process was adding value only 47% of the assembly time.
- Man power: as a consequence of poor standardization the operators have freedom of movements in work station, also it was identified in some cases under trained operators and lack of experience.
- Components: not all the responsibility falls on the operators, sometimes operators have lead time due to problems with components and lack of standardization, quality, bad location of parts in the border line and delays in component supply push up cycle time.
- Tool analysis: process showed low technology, big and manual tools and repetitive operations.

After process analysis many things come to light. The analysis has shown different wastes as over processing, unnecessary motion and waiting among others. Now, it is clear that the process needs changes to reduce current cycle time eliminating waste [4,8]. The proposed solutions were framed in two different ways and suppose to apply:

- Lean manufacturing
- Automation

Doing this, the proposed solutions pretended to achieve:

- Process standardization
- Process total control and high efficiency on its development
- Reduce lead time and waste
- Reduce the cycle time and improve assembly process
- Improve man power efficiency and reduce health costs

If a process or a product was not designed through a Lean philosophy, after it will be difficult to adapt to this philosophy [4]. Is for that this first steps in change the model are the most important to acquire in the future the highest development. To have success is necessary involving all areas of the company/factory. To do that, is needed to apply a series of methodologies that will have a direct impact in current process development. Fig 5 shows these methodologies.

Fig. 5. Just in Time (JIT) methodologies.

Regarding to current process standardization and pull flow process are the most important to apply because there is where the process shows its weakness and are the main contributors to current cycle time. Improving them the assembly evolves and therefore can be achieved the expected results.

2.2. Automation application

When lean manufacturing methodology was applied and fully adopted the process is ready to the next step, automation. Through lean philosophy were identified and improved the actions, but were observed that process can be improved to a next level, to do that automation looks the option. The key was to achieve the maximum cycle time reduction as well as high accuracy and quality.

In connection with the foregoing, all off build sequence steps are susceptible of automation, but it should be applied only where it makes sense and where several of the following will result: higher output, better quality, reduced scrap and rework improvements in workspace safety and fewer required people [5]. Therefore, the main questions are:

- What areas/operations needed improvement?
- What kind of automation needed to apply?
- What kind of technology?

As noted in lean application, current process has two operations that consume the 67% of total cycle time. Also regarding the questions above, is needed to focus on the operations that need more manual labor and can be easily automated avoiding reworks and operations that do not add value.

In the case of the study, a part of the most time consumers (drill and measure & shim) the parts load operations also consumed high amount of time.

The market offers a wide range of technologies to apply automation. The current process is 98% manual and drill operations are developed by operators with drill machines. Therefore, current process does not have any kind of automation implemented. The proposal methodology was to use a robot for locate the parts and scan the gaps between the spar and the parts, and a parallel kinematic machine (PKM) for drill and fettle the parts for reduce/eliminate the gaps between the spar and the parts.

The following section discuss the results obtained after the application of the proposed methodologies.

3. Results

After analysis of the assembly process, were proposed two different methodologies: apply lean manufacturing and automation. Applying them was pretended to improve the disadvantages of the current assembly process, reducing the cycle time.

Through Lean manufacturing and applying its techniques, as standardization, the control of the process was improved and therefore one can know exactly the quantity of parts needed in each step. Doing that was possible to achieve the following results:

- Reduce intermediate stock
- Increase process control
- Operators know every moment what they have to do
- Reduce the variability of the process and therefore is easier to identify the problems that can arise

Applying Lean manufacturing, can be achieved a 20% of cycle time reduction in current process. This reduction of cycle time seems inadequate but serves as a starting point to transform the process to a Lean philosophy while working in the development of the automated cell. Thus, when the automated cell is ready to take to the practice in the factory, the elements involved in the assembly are improved by facilitating the integration of this new system.

Through the automation was achieved a maximum reduction in cycle time, as well as high precision and quality in the assembly process. The methodology to develop the automated cell was based in the application of easy and clear ideas, facilitating visual management and improving the process to the highest level to reduce the cycle time to the minimum.

Combining the use of industrial robots and PKM, the assembly process was transformed to a new assembly process achieving a 67% of cycle time reduction. This solution looks ambitious and supposes a big change in the manufacturing process and in the factory culture. The main contributions of this solution are:

- Increase of added value of the assembly process
- Reduction of non-value added operations
- Increase the efficiency of man power and head count reduction
- Facilitate visual management of the process
- Improve quality of the assembly process.

4. Conclusions

Following the study carried out in this paper, it is demonstrated that, despite the conservatism of the aviation industry and the high cost of technology it is both possible and necessary to implement new cutting-edge methodologies breaking the tradition of this industry. Historically this sector evolved only in the use of materials, being the progress on new manufacturing processes and technologies very low.

This means that now the aeronautical industry given the growing demand and competitiveness of the sector, seeks solutions to stay or enter the market. Betting on automation and lean manufacturing, aeronautical companies have a powerful tool to drive the change in manufacturing processes for the next ten or twenty years, being more competitive and efficient to achieve future improvements and company objectives.

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