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WASTE REDUCTION AND PRODUCTIVITY IMPROVEMENT IN THE MANUFACTURING PROCESS OF ELECTRONIC BOARDS

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Abstract: *This paper presents a solution for optimizing the conformal coating process of electronic boards used in the aerospace industry by applying Lean Manufacturing principles and tools. The primary objective was to identify and reduce time and resource losses, directly impacting productivity and process efficiency. To identify and diagnose the root causes of waste, specific Lean Manufacturing tools were employed, including process flow analysis, Value Stream Mapping (VSM). The study highlights the types of waste identified according to the TIMWOOD framework such as waiting time and inefficient transportation and proposes practical solutions, such as increasing the capacity of the transport device and eliminating waiting times between protective coating applications. The results demonstrate a significant reduction in operation time and an increase in the number of boards processed simultaneously, leading to enhanced productivity and a 59% reduction in waste*

Keywords: *Lean Manufacturing, Value Stream Mapping, Kaizen, Manufacturing, Waste.).*

1. INTRODUCTION

Lean Manufacturing has become an essential approach in the aerospace industry, addressing the sector’s rigorous requirements for high quality products, cost efficiency, and the reduction of operational and delivery lead times. Originally developed for the automotive sector, Lean principles have been successfully adapted to aerospace manufacturing, demonstrating significant potential for improving process efficiency and minimizing waste. The core philosophy of Lean Manufacturing focuses on the systematic elimination of waste broadly defined as any activity that does not add value to the product alongside continuous improvement (Kaizen), just-in-time delivery, and enhanced process control. These principles are supported by fundamental quality management theories, including those of Deming and Juran, as well as by modern methodologies such as Six Sigma [1], [2], [3].

In aerospace manufacturing, waste manifests in various forms, particularly over production, unnecessary motion, waiting times, and excessive processing. Studies have identified unnecessary movement and waiting as the primary sources of inefficiency, often caused by inadequate facilities, non-optimized workflows, and operator related challenges. Tools such as Value Stream Mapping (VSM) and waste identification checklists are essential for diagnosing these issues, enabling the development of targeted lean action plans that enhance operational performance and promote a culture of continuous learning and improvement within aerospace organizations [4],[5],[6].

The implementation of Lean Manufacturing in aerospace production represents a strategic necessity for enhancing competitiveness and sustainability. By combining lean principles with advanced Industry 4.0 technologies, aerospace manufacturers can achieve superior operational performance, reduce environment-mental impact, and adapt to the continuously evolving market demands. At present, both the automotive and aerospace industries face major challenges related to increasing competitiveness, reducing costs, and improving product quality. The key challenges include the difficulty in changing the factory layout, lack of plant specific manufacturing strategies, lack of

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benchmarking between manufacturing plants, and the non-existence of a culture of learning through experimentation [7], [14-17].

In the specific manufacturing process of electronic boards, the application of Lean tools such as Value Stream Mapping (VSM) technique enables the identification and elimination of waste within the production flow. For instance, VSM provides comprehensive visualization of the entire process, highlighting both value-added and non-value-added activities, such as areas with idle time or excessive inventory, and root cause analysis techniques enable the resolution of recurring issues that negatively impact quality and productivity [4].

The concrete application of lean methodologies in aerospace component manufacturing has demonstrated significant improvements in productivity and quality using tools such as 5S, Kaizen, and Just-In-Time [8], [9].

It is also important to note that the implementation of lean is not without challenges, as suppliers in the aerospace industry face cultural barriers and resistance to change, which can be overcome through appropriate training strategies and employee engagement [10].

The adoption of lean practices significantly contributes to the sustainable performance of companies by optimizing resource utilization and reducing environmental impact aspects that are increasingly important in the current context of sustainable development [11].

Improvement and optimization solutions for identifying dysfunctions within the production system and balancing production lines can also be achieved through modeling and simulation software. These tools highlight bottlenecks in the manufacturing flow while simultaneously providing valuable information for decision makers in managing the production process [12], [13].

2. RESEARCH METHODOLOGY

Due to the extended production time, the delivery of products to the client could not be completed within the expected timeframe. Consequently, the production process was reviewed with the objective of optimization. To this end, the data was consolidated and analyzed together with the management team using lean manufacturing tools (VSM/MUDA).

Starting from the analysis of the manufacturing process of electronic boards intended for the aerospace industry designed to deliver high performance under conditions of vibration, moisture, and extreme temperature variations the following types of lean manufacturing waste were identified: transportation, waiting time, and over processing. To eliminate these types of waste, Value Stream Mapping (VSM) was conducted, through which the time associated with each type of waste was identified.

The data collection method from the production line was implemented from the decision to initiate the improvement project, using a Lean Manufacturing specific tool, referred to as the TIMWOOD diagram: T – Transportation: Unnecessary movement of materials or products; I – Inventory: Excess raw materials, work in progress, or finished goods; M – Motion: Unnecessary movement of people or equipment; W – Waiting: Idle time when resources are not being used; O – Overproduction: Making more than is needed or too soon; O – Overprocessing: Doing more work or using more components than necessary; D – Defects: Efforts caused by rework, scrap, or inspection.

The collected data (operator interview and company database) was consolidated, and the allocation of non-value-added (NVA) activities corresponding to each TIMWOOD loss was tracked.

3. IMPLEMENTATION STEPS

3.1 Measurement and Analysis

To measure and analyze the manufacturing process, a Value Stream Map (VSM) was created to identify both value-adding activities and waste in the application of a protective material layer on a single board. Each board requires the application of four layers of protective coating to meet the customer's specifications regarding the required thickness. In this case, a transport device with four slots (one for each board) was used.

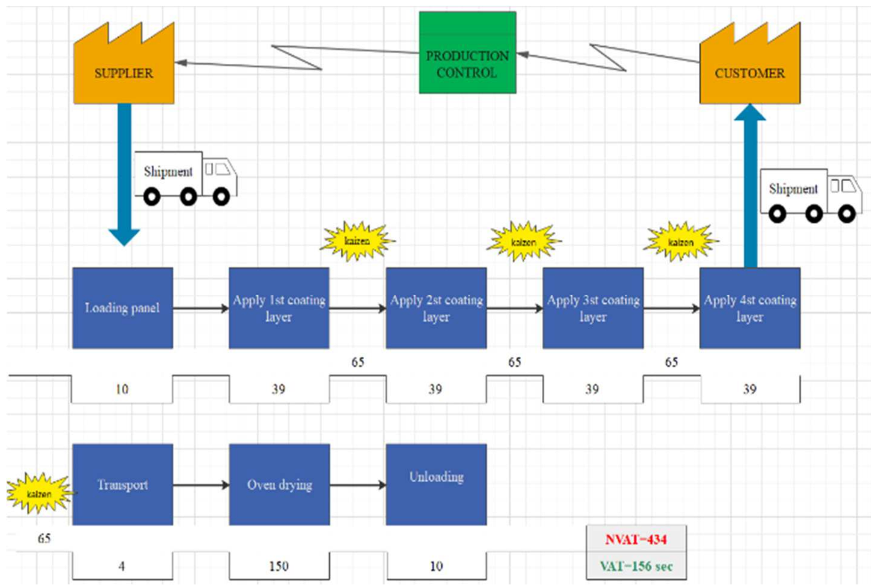

Fig. 1. VSM before improvement

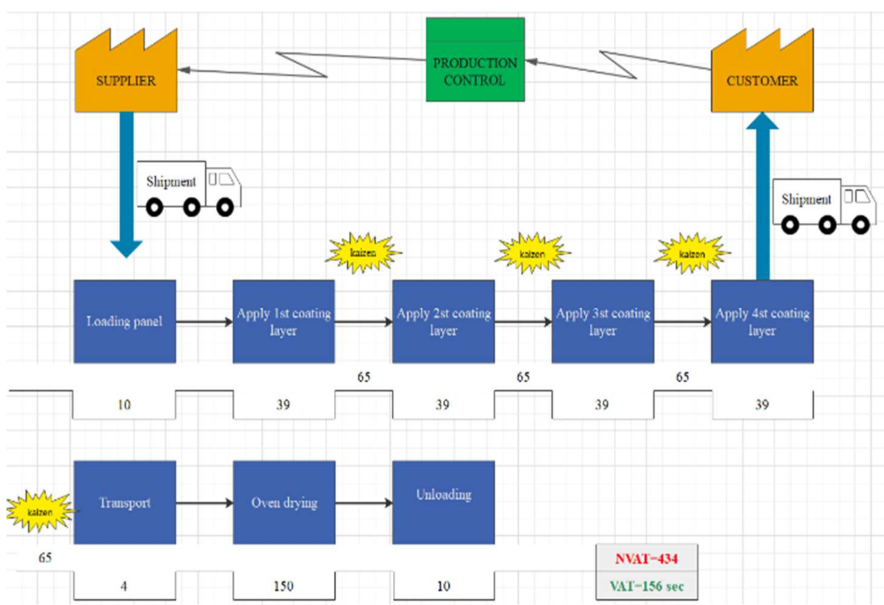

Fig. 2. VSM after improvement

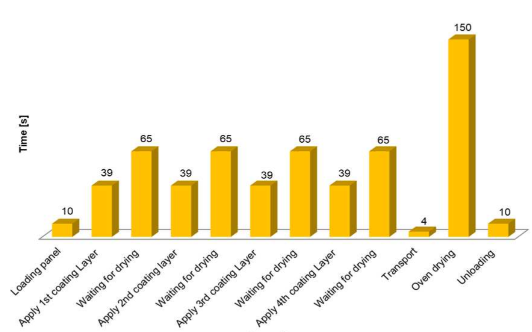

Fig. 3. Processing times distributed by operations before the improvement

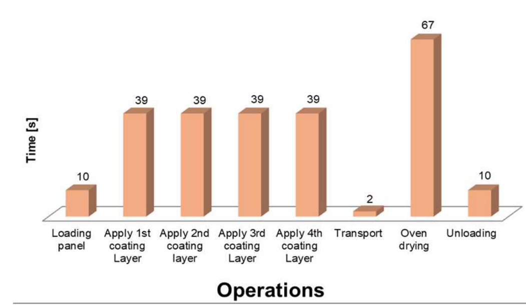

Fig. 4. Processing times distributed by operations after improvement

According to the VSM shown in Figure 1, the Non-Value-Added Time (NVAT) is 434 seconds, while the Value-Added Time (VAT) is 156 seconds for the application of a single layer of material on one board. Additionally, improvement opportunities (Kaizen) can be observed, particularly related to the drying times between the applied layers.

3.2 Improvement

Following the identification of waste presented in the initial VSM (Figure 1), a future state Value Stream Map was developed to reflect the improvements. To eliminate the waiting times associated with the drying of the four protective layers, the number of transport slots increased from 4 to 9 in total. This change led to an increase in production capacity by converting waiting time into processing time.

4. RESULTS AND DISCUSSION

Following the analysis of the production process, the processing times are presented for each operation on a single board, both before the improvement (as shown in Figure 1) and after the implemented changes (Figure 2). According to the chart, it was found that the application of material on a single board (out of the four boards on the transport device) accounts for 71% of the total time allocated to processing one board. This percentage represents value adding activities, while non-value-adding activities such as transportation, drying, and unloading account for 29%.

Figure 2 presents the processing times after the implemented changes and improvements. According to the chart below, the time required for material application using the transport device with 9 slots was reduced by 68% (from 417.4 seconds to 157.1 seconds). This improvement contributed to a reduction in transport time to the oven, enabling the drying of 9 boards within the same time previously required to dry only 4 boards.

5. CONCLUSIONS

In conclusion, replacing the transport device (from 4 to 9 slots) contributed not only to the reduction of time associated with value-adding activities but also to the auxiliary times within the production process (as shown in Figure 3).

The replacement of the transport device led to an increase in production capacity from 39 boards per day to 94 boards per day, representing a 59% increase.

After analyzing the data and the equipment configuration, we realized that the waiting time could be transformed into productive time by creating a new design with optimal locations, thereby maximizing machine loading."

By modifying the transport device, we achieved the following benefits:

- Elimination of waiting time between lacquer layers;
- Conversion of waiting time into production time;
- Consolidation of the transport of multiple boards within the same time unit;
- Achievement of a more linear process in terms of production times.

According to the chart in Figure 5, the processing times distributed by operations before and after improvement are presented.

Figure 5 provides a clear and effective visualization of the outcomes achieved through the implementation of improvements at each stage of the manufacturing process. The analysis concentrated on those operations that were the primary sources of waste and extended processing times.

The application of multi-layer lacquer and the drying of boards in the oven represented substantial challenges in identifying technical solutions to enhance productivity.

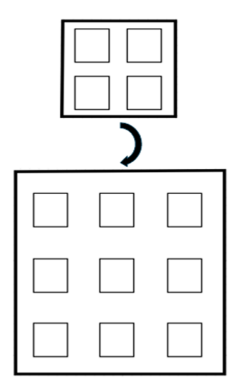

Fig. 5. Tool Redesign: Conversion from 4 to 9 Locations

Process Step	Initial [s]	Actual [s]	Difference [s]	Improvement [%]
Loading panel	10	10	0	0
Apply 1st coating layer	39	39	0	0
Waiting for drying	65	0	-65	100%
Apply 2nd coating layer	39	39	0	0
Waiting for drying	65	0	-65	100%
Apply 3rd coating layer	39	39	0	0
Waiting for drying	65	0	-65	100%
Apply 4th coating layer	39	39	0	0
Waiting for drying	65	0	-65	100%
Transport	4	2	-2	50%
Oven drying	150	67	-83	55%
Unloading	10	10	0	0
TOTAL	580	235	-345	59%

Fig. 6. Process Time Improvement – Before vs. After

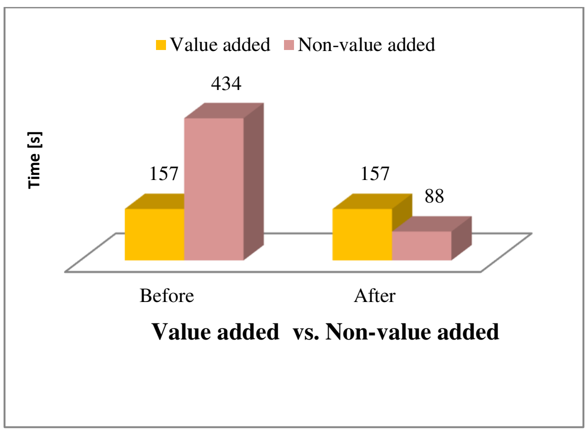

Fig. 7. Comparison of value added vs. non-value added

The adoption of Lean methodologies enabled the achievement of these improvements through systematic data collection, comprehensive analysis, identification of optimal solutions, and rigorous application of the chosen methods. Similar results have been supported by the work of [18-21].

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Reducerea pierderilor și îmbunătățirea productivității în procesul de fabricație al plăcilor electronice

Această lucrare prezintă o soluție pentru optimizarea procesului de acoperire conformală a plăcilor electronice utilizate în industria aerospațială, prin aplicarea principiilor și instrumentelor Lean Manufacturing. Obiectivul principal a fost identificarea și reducerea pierderilor de timp și resurse, care influențează direct productivitatea și eficiența procesului. Pentru a identifica și diagnostica cauzele fundamentale ale pierderilor, au fost utilizate instrumente specifice Lean Manufacturing, inclusiv analiza fluxului de proces, Value Stream Mapping (VSM). Studiul evidențiază tipurile de pierderi identificate conform cadrului TIMWOOD cum ar fi timpul de așteptare și transportul ineficient și propune soluții practice, precum creșterea capacității dispozitivului de transport și eliminarea timpilor de așteptare între aplicările stratului de protecție. Rezultatele demonstrează o reducere semnificativă a timpului de operare și o creștere a numărului de plăci procesate simultan, conducând la o productivitate îmbunătățită cu 59%

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