

IDENTIFICATION OF THE FLOWCHART FOR MANUFACTURING AND INSPECTION OF INDUSTRIAL SPARE PARTS

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ABSTRACT

In the actual development of technologies and related devices, it is important to develop the manufacturing processes considering the integration of the main factors concerning the technological steps, inspection steps, and reaction plan in the case of non-conforming parts. To optimize the manufacturing steps, the flowcharts should give a theoretical overview of the production and inspection processes and the correlation between them. In the present paper, the application of a tool used in the automotive industry is proposed for sampling in the case of a fastening lug. During the development phase, activities for identifying manufacturing steps and the related inspection methods were determined. Also, the reaction plan was identified in the case of a non-conforming part that resulted from processing. In the development phase of a product, one of the most important jobs of a process designer is to integrate, in a suitable manner, in the same flowchart, the main requirements regarding the products process, inspection, and cost saving. The defined flowchart was implemented in the case of an industrial spare part used in fixing devices, by considering two different variants. A comparison between the results obtained was made. Both proposed alternatives were validated, so they can be used in practice.

KEYWORDS: manufacturing flowchart, non-conforming spare parts, technological steps, inspection steps, reaction plan, integration.

1. INTRODUCTION

In modern industrial engineering, the use of flowcharts or more precisely, technological flowcharts, is fundamental to the design, optimization, and control of the manufacturing processes [1], [2].

The technological flowchart provides a structured, visual representation of the sequential and parallel operations that the raw material (or set of inputs) undergoes to become a finished product [3]. Such diagrams facilitate clarity in process understanding, enable the identification of bottlenecks, and optimization of resources, including time, energy, materials, and labor [4]. They also

support risk management, quality assurance, and compliance with standards [5].

The technological flowchart is one of the most valuable tools for analyzing and illustrating industrial processes. It offers a graphical representation of all operations, sub-operations, and control points involved in production, by showing their logical and temporal sequencing [6]. Through such schematic representation, engineers and technologists can easily identify critical stages, potential bottlenecks, and opportunities for improvement [7]. Moreover, a well-designed flowchart contributes to better coordination among production departments, clearer communication of technological requirements, and improved

decision-making concerning the process optimization and automation [8].

The use of process flowcharts, work instructions, and technological documentation ensures consistency and traceability throughout production. These documents define the sequence of operations, the required equipment, the process parameters, and quality checkpoints. As noted by Lasi et al. [9], standardization supports Lean Manufacturing and facilitates the implementation of Industry 4.0 principles, where physical processes are interconnected with digital networks for adaptive and intelligent production control [10].

Generally speaking, a technological flowchart is composed of several fundamental stages: material preparation, forming or shaping operations, heat or surface treatments, assembly, quality control, and packaging. Each step is represented by standardized symbols connected by directional arrows indicating the process flow. According to Shao et al. [11], such diagrams enhance the understanding of complex production systems and facilitate communication between engineers, operators, and managers, leading to improved decision-making and process optimization [12].

This paper presents the development of a technological flowchart for processing an industrial product, emphasizing the logical organization of operations, the interdependence of technological stages, and the optimization of production parameters. By clearly defining each step within the process, the study aims to facilitate a better understanding of material flow, equipment utilization, and operational efficiency. The proposed approach can be adopted in various industrial sectors, contributing to the enhancement of productivity and sustainability in manufacturing systems.

The paper is structured into five sections. Following this introduction, section II describes the manufacturing process for the fastening lug part. Section III identifies the decision points associated with the processes and activities involved in its production.

Section IV presents a case study, namely the proposed technological process flowchart used for manufacturing the fastening lug. Finally, section V presents the paper's conclusions.

2. IDENTIFYING THE MANUFACTURING PROCESSES OF THE FASTENING LUG PART

The manufacturing technology of an industrial product refers to the systematic transformation of raw materials into finished goods through a sequence of well-defined and controlled processes. Each production stage, from material preparation to finishing, plays a critical role in achieving the required physical, chemical, and mechanical properties of the final product. The design and control of these processes require the integration of technological expertise, engineering principles, and quality management systems to ensure efficiency, safety, and sustainability.

This chapter presents the technological process for manufacturing the fastening lug part by using cutting operations. The technological process was designed based on the products' geometry and functionality. All operations included in the technological process were standardized, and a technical time norm was established for the complete machining of the part using the designed technology.

The fastening lug is an essential component used in clamping mechanisms to secure parts or assemblies in a defined position, ensuring the stability and proper functioning of the overall assembly (see Figure 1 and Figure 2).

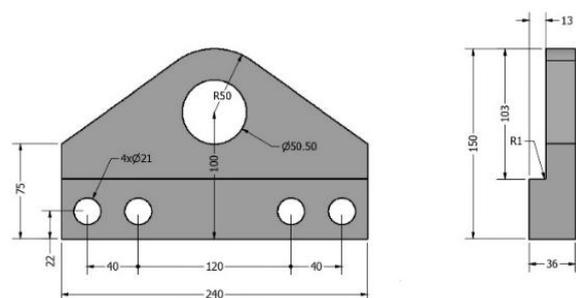


Fig.1. 2D representation of the Fastening Lug Industrial Spare Part

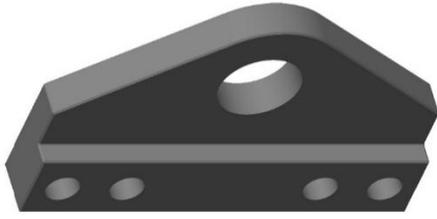


Fig.2. 3D representation of the Fastening Lug Industrial Spare Part

The part functional-constructive analysis aims to highlight the role of each component surface in fulfilling the part's main function.

The primary task of the part is to ensure the clamping and fixing of another part or assembly, while also allowing disassembly when necessary. Additionally, the fastening lug must withstand mechanical stresses such as tension, compression, or corrosion, depending on the operating environment.

The main body of the part provides a mounting point for fasteners (bolts, nuts, etc.). The attachment holes allow the insertion of these fasteners. The shape of the part ensures compatibility with both the fasteners and the other components of an assembly.

The technological process for part manufacturing is established by using the analog method, as detailed in the manufacturing process described in the table below, and the allocated inspection steps and characteristics to be inspected.

To carry out the manufacturing activities identified in the technological itinerary, the following equipment is selected:

- A profile-cutting machine,
- A milling machine, and
- A drilling machine.

To perform the inspection activities defined in the technological itinerary, the following categories of equipment are used:

- The calipers and micrometers for general dimensional verification,
- A laboratory coordinate measuring machine - CMM, for the accurate evaluation of chamfers and radius, and
- A roughness tester for assessing the surface finish quality.

Table 1. Manufacturing activities and associated inspections

Process step	Inspected issues
<ul style="list-style-type: none"> • Raw material receiving 	<ol style="list-style-type: none"> 1. Length 2. Weight 3. Quality and delivery documents
<ul style="list-style-type: none"> • Cutting 	<ol style="list-style-type: none"> 1. Length 2. Weight
<ul style="list-style-type: none"> • Milling 	<ol style="list-style-type: none"> 1. General aspect 2. Dimensions, including laboratory measurements 3. Roughness
<ul style="list-style-type: none"> • Drilling 	<ol style="list-style-type: none"> 1. General aspect 2. Diameters 3. Roughness
<ul style="list-style-type: none"> • Packaging 	<ol style="list-style-type: none"> 1. General aspect
<ul style="list-style-type: none"> • Storage 	<ol style="list-style-type: none"> 1. General aspect
<ul style="list-style-type: none"> • Delivery 	<ol style="list-style-type: none"> 1. General aspect

3. IDENTIFICATION OF THE DECISION POINTS

In the case of manufacturing the fastening lug part, quality control activities are essential not only for verifying dimensional accuracy but also for assessing the stability and repeatability of the production process.

Technological quality control plays a fundamental role in ensuring the reliability, durability, and functional performance of industrial components.

In this chapter, the decision points are identified for processes and activities related to the manufacturing of the fastening lug part. The decision points to be used in each production step are identified to ensure the validation of the product parameters.

The technological quality control applied to the fastening lug part serves not only to validate product compliance but also to support continuous process optimization, risks analysis, and to reduce the probability of occurring defects, and to improve the detection of potential defects. By systematically analyzing measurement results

and identifying areas where precision can be improved, manufacturers can enhance both product reliability and overall production efficiency. Consequently, quality control is an essential mechanism for maintaining high standards in industrial manufacturing, ensuring long-term process stability and increasing confidence in process capability.

4. CASE STUDY: THE PROCESS FLOWCHART TO PRODUCE THE FASTENING LUG PART

The technological flowchart represents a central instrument in the development phases of product manufacturing processes and associated inspection activities, including some decision points. It provides a structured and formal representation of the sequences of technological operations, material transformations, and decision-making nodes involved in the manufacturing activities of a dedicated product or for a family of similar products.

The role of the flowchart is to ensure a comprehensive approach to the manufacturing process, to enable process optimization at all stages, from the acquisition of raw materials to the final standardization, performance evaluation, and quality assurance.

The technological flowchart plays a critical role in modern industrial processes by offering a clear, structured representation of the production stages. Its implementation brings multiple advantages across operational, managerial, and sustainability domains, as follows:

- *Communication improvement*, by presenting a unified and visual overview of the process. The flowchart facilitates effective communication among engineers, operators, and management.
- *Enhanced quality assurance*, by allowing the identification of key control points and testing procedures, thereby supporting the obtainment of consistent product quality.
- *Support for sustainability* - the chart highlights process stages where waste generation or energy loss may occur, enabling targeted, specific interventions to increase resource efficiency.

- *Basis for continuous improvement* because the technological flowchart underpins the application of methodologies such as Lean Manufacturing and Six Sigma fostering, both as issues of a culture process optimization ongoing.
- *Effective support* to achieve a good understanding of the manufacturing processes and their correlation with the inspection activities.

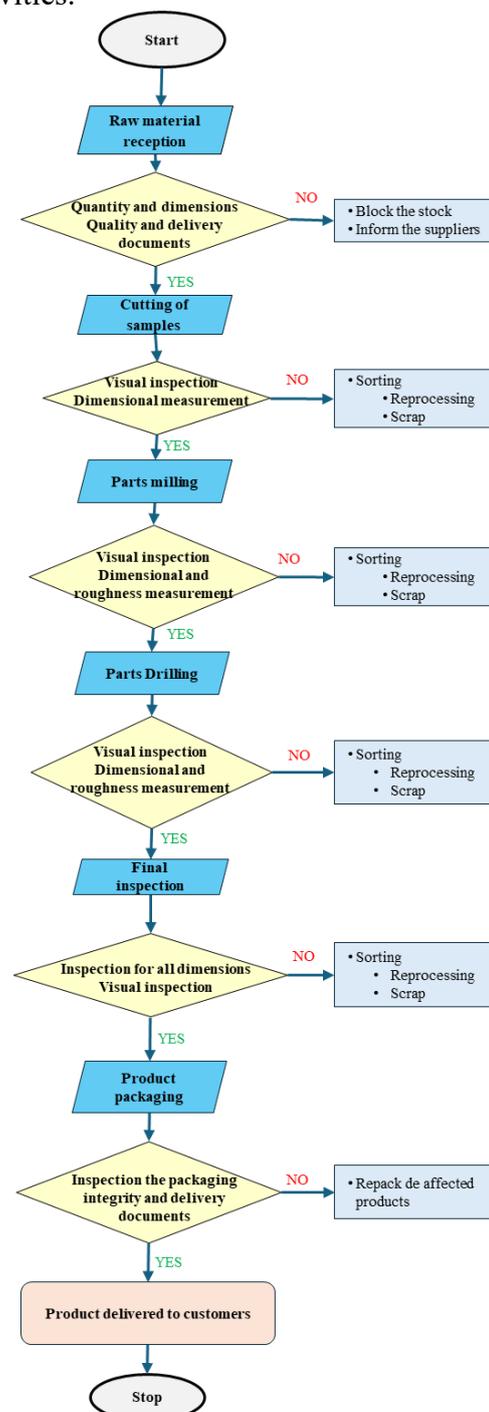


Fig. 3. Process flowchart to produce the fastening lug part

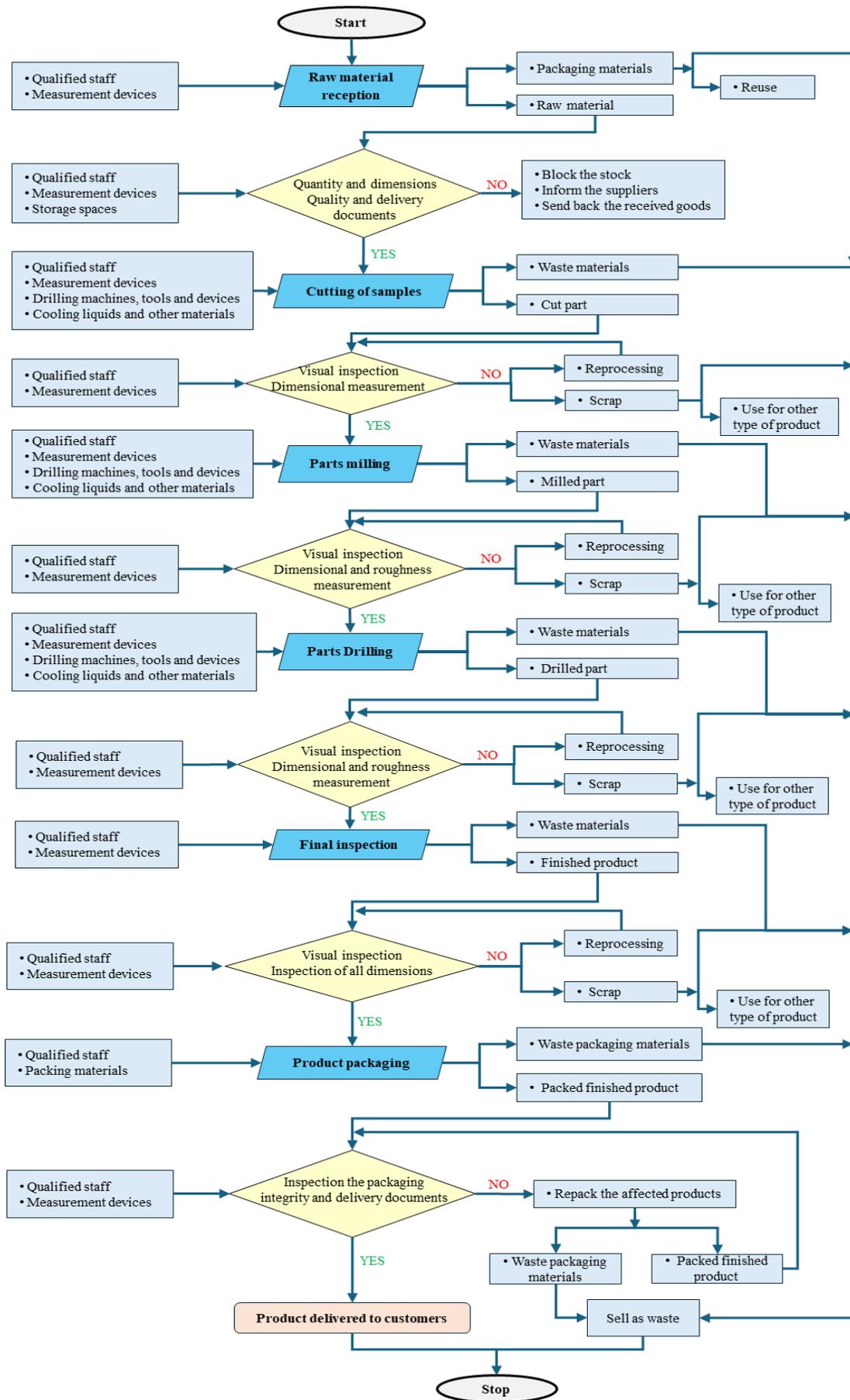


Fig. 4. The comprehensive process flowchart to produce the fastening lug part

The integration of a technological flowchart into industrial operations not only enhances transparency and compliance processes but also contributes to strategic decision-making and operational excellence.

Figure 3 presents the technological process flowchart associated with the production of the fastening lug part.

The manufacturing process begins with the reception and verification of raw materials, followed by cutting, milling, and drilling operations. Each stage is subjected to visual and dimensional inspections, compliant parts proceed to final inspection, then packaging, and are ultimately delivered to customers, while non-compliant parts are either reprocessed or scrapped.

The defined flowchart, depicted in Figure 3, is applicable to the logistics and manufacturing activities of the product, fastening lug, and associated technologies. The proposed flowchart helps process engineers and quality-dedicated staff to:

- Identify, design, and assure the suitable measurement methods and techniques.
- To find the critical parameters and the requested inspections/measurements.
- Investigate the product quality along the entire process flow.

If a more detailed analysis of the manufacturing process is intended, then the more comprehensive process flowchart, presented in Figure 4, can be used.

5. CONCLUSIONS

The technological flowchart is a key tool for organizing, visualizing, and optimizing industrial production processes.

The flowchart also strengthens quality assurance and risk control, ensuring compliance with international industrial standards.

By establishing a detailed technological scheme, this research provides a foundation for further improvements in industrial process management, productivity enhancement, and sustainable manufacturing practices.

The proposed methodology can be adapted and applied across various industrial sectors,

serving as a reference model for process design, optimization, and innovation in modern production systems.

Moreover, the development of the proposed technological flowchart creates a bridge between theory and practice and constitutes a framework for innovation, transparency, and continuous improvement in manufacturing.

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