COMPUTER-AIDED QUALITY ASSURANCE IN A PRODUCTION LINE

Anne-Marie NIȚESCU, ***Lecturer univ. Dr. Ing., University of Petrosani***

Abstract: Today's advanced level of industrial production systems has been made possible by a veritable wave of technical progress, embodied in the introduction and expansion of electronic computing systems, information technology, electronics, robotics, and artificial intelligence.

Computer-aided process control is one of the most important methods considered for increasing productivity, and one of the tools it makes available to users is computer-aided quality assurance (CAQ). As its name suggests, this method involves the use of computer software at all stages of product quality testing, with the aim of improving the product and, in particular, increasing the efficiency of production activities.

The method involves the use of a preprocessing module equipped with 3D modeling functions, which allows users to construct the model's geometry or import it from an established program. The module includes a mesh generator that can generally operate in both automatic and parametric modes.

Key words: preprocessor module, electronic computing systems, 3D modeling facilities.

1.Introduction

The dynamic evolution of today's production processes, in all their aspects, has led to major changes in the approach to cutting-edge fields of science, advanced technology, and effective management methods. Increasing productivity is a goal that every company strives for from the earliest stages of development; thus, for manufacturing companies, an automated process management system is a true necessity because it offers numerous opportunities for growth. Driven by the desire to increase production volume and deliver finished products as quickly as possible, many entrepreneurs have viewed automation as the key to facilitating the coordination and synchronization of activities within the production process, generating benefits that cannot be matched by human operators alone.

Production methods and means are influenced by the presence of computers [1], robots, programmable logic controllers, numerical control systems, etc. This ongoing evolution has been primarily marked by the rapid development of computing technology, machining centers, group technologies, DNC systems, sensors, geometric modeling and graphical data processing techniques, simulation, diagnostic systems and techniques, high-level programming languages, and artificial intelligence.

The higher level achieved by today's industrial production systems, compared to traditional manufacturing systems, has been made possible by a veritable infusion of technological progress, embodied in the introduction and expansion of electronic computing systems, information technology, and electronics—which can also be referred to as the IoT (Internet of Things—a system composed of various interconnected devices with internet connectivity that can collect and transfer data via a wireless network without human intervention) and which facilitates the management of production lines with minimal human effort but with significant benefits: reduced operating costs, increased profits, and improved efficiency at every stage of the production process.

The technological modernization of production processes refers to the use of software and hardware to optimize them, from the planning stage through to the completion of the products. Technology makes a substantial contribution to the optimization of production processes, and as a result, the focus on improving the practical efficiency of production activities has led to the development of a market segment of professional IT solution providers dedicated to automating any production sector.

2.The Concept of a cybernetic system

Industrial production systems become cybernetic systems by integrating into their structure a control and self-regulating factor—typically of a human nature. These systems combine physical and computational processes to bridge the gap between the digital and the real worlds, enabling intelligent automation, real-time monitoring, and improved decision-making across all industrial sectors. This approach ensures optimal conditions for establishing a scientifically grounded framework for their management and organization.

Figure 1. System structure

The production process functions as a cybernetic system, the operation of which requires a set of inputs that undergo successive processing, ultimately becoming the system's outputs. A cybernetic system (figure 1) involves three elements: inputs, the processing of inputs, and outputs or results.

The products and services necessary for human existence are obtained through the production process, whose fundamental role is to combine existing resources, in accordance with certain quality standards, in order to produce the goods needed to satisfy customer needs.

Generally speaking, a production process consists of operations that can be grouped according to the activity they involve into: - technological operations; - control and quality operations; - transportation and storage operations.

3.Implementation of technology in production processes

Computer-Integrated Manufacturing (CIM) is an automated version of the general manufacturing process, in which each function is replaced by a set of automated technologies that can be found throughout the entire production flow or only at the stage level [4].

CIM is the manufacturing approach of using computers to control the entire production process and allows individual processes to exchange information with each part, beeing also known as flexible design and manufacturing.

Some or all of the following subsystems may be found in a CIM operation:

-CAD (computer-aided design)

-CAE (computer-aided engineering)

-CAM (computer-aided manufacturing)

-CAPP (computer-aided process planning)

-CAQ (computer-aided quality assurance)

-PPC (production planning and control)

-ERP (enterprise resource planning)

4.Computer-aided quality method

One of the most effective tools considered for increasing productivity is Computer-Aided Quality (CAQ)—a subsystem designed to optimize quality control and engineering calculations using electronic computing methods. This method analyzes and evaluates the quality of designs using computer-aided techniques to calculate the product’s operational, functional, and manufacturing parameters [2]. In terms of solution synthesis, the main benefit of CAQ lies in the product’s technological feasibility; in terms of analysis and evaluation, CAQ is used to analyze the quality of the product design. Based on the information obtained, the product design is iterated through the initial stages of the design process until the optimal solution is found.

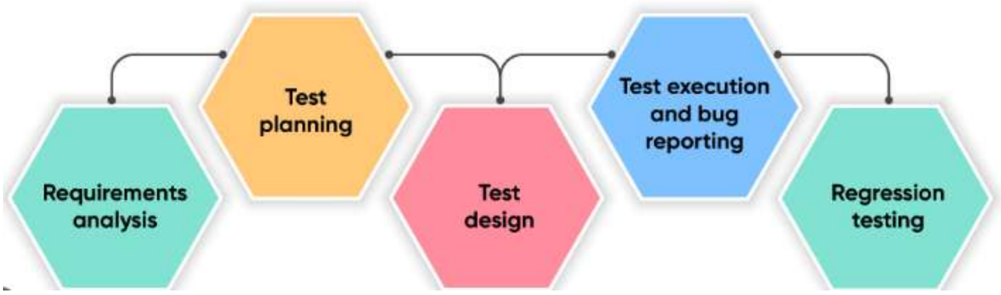

Figure 2. Quality control process

Quality control (figure 2), an essential step in the production workflow, is the process of monitoring how products and services are produced in accordance with design requirements throughout the entire manufacturing process, which includes design, production, installation, and service activities [5]. In quality inspection, the conformity of products and services is assessed through measurements, testing, or comparison with a standard. Even if the inspection process takes place in several stages (upon receipt of raw materials, at certain stages of manufacturing and assembly, upon delivery, etc.), the inspection stage (figure 2) does not imply that defect prevention mechanisms are in place throughout the entire quality system.

In a business environment where quality is viewed as a driver of development, a company’s success and survival depend on adapting to changes that involve a variety of aspects—both in terms of the means of achieving quality and in the “cost-benefit” relationship, which remains vital. The quality of a product is the extent to which it is useful in all its technical-functional, psycho-sensory, and economic aspects, such that it satisfies the needs for which it was created and complies with the limitations imposed by the general interests of society.

Quality assurance is the fundamental value of the concept of “quality assurance,” which is to prevent defects from occurring, so a systematic approach to processes—starting with suppliers of raw materials and ending with procedures for resolving issues that arise both during and after quality assurance—gives the customer confidence that the stated quality requirements will be met.

For a long time, research has focused on increasing productivity by improving the performance of machine tools, but the results have not confirmed a substantial increase in productivity.

Quality improvement is based on feedback from product sales and maintenance services; in developing and managing the quality assurance process, databases containing catalogs of specifications, errors, measuring instruments, etc., are utilized.

The CAQ method includes:

• effective quality control management;

• internal audits of activities;

• assessment of sales levels;

• attributes of competitors' products and activities;

• statistical control of process stages;

• quality documentation, etc.

While the concept of "computer-aided quality" is sometimes used interchangeably with "quality management system," CAQ software sometimes refers to a subset of functions that include advanced product quality planning, continuous quality improvement throughout the product lifecycle, and ensuring quality control during production.

In its broadest sense, computer-assisted quality consists of:

- Quality planning software for the product design and engineering phases.

- Quality assurance software for the procurement of raw materials, components, or complex assemblies from suppliers.

- Quality control software for managing quality data during product manufacturing.

5.Example of implementing CAQ method in a production flow

Throughout all phases of the product's production cycle, computer-aided quality method (figure 3) helps optimize processes, ensure consistent quality, and provide comprehensive documentation of a product's quality history.

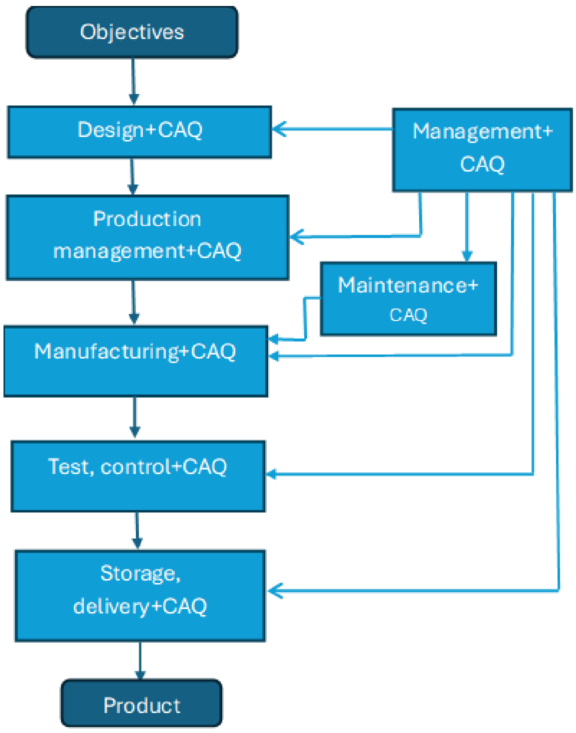

Figure 3. CAQ method

The CAQ method aims to incorporate the use of computer software into all stages of a product's production, with the goal of improving the product and, in particular, streamlining production activities.

The tool aims to:

• increase productivity;

• reduce production costs;

• ensure that product delivery deadlines are met;

• improve the quality of the product and the activities performed during the production process;

• improve the flexibility of production systems, etc.

The software programs currently used for this structural analysis are:

– ANSYS;
– SolidWorks;
– CATIA.
– Autodesk
– Robot Structural
– Analysis Professional

In general, the preprocessing and postprocessing modules are accessible through the same user interface, though they can also be used separately, without the processing modules (figure 4).

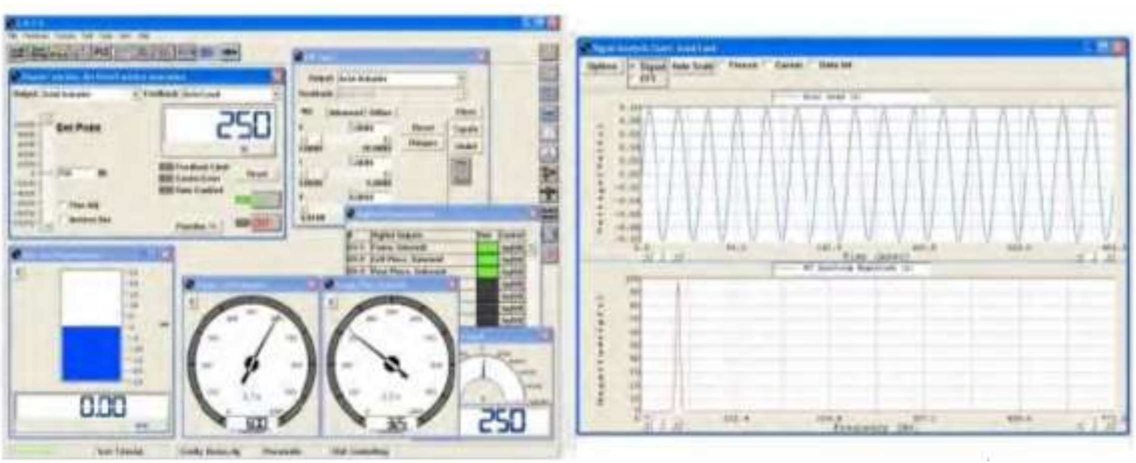

Figure 4. Example of a testing software interface

The preprocessor module, equipped with 3D modeling capabilities, allows users to build the model geometry or import it from another established program, and includes a mesh generator that can generally operate in both automatic and parametric modes. High-performance generators enable additional operations such as, for example, connecting meshes composed of incompatible elements and local mesh optimization. For selecting model materials, the preprocessors contain databases covering a wide range of materials, with the option to customize them according to user preferences. The selection of the finite element type used in the analysis is based on a library that includes both general-purpose elements for 1D, 2D, and 3D analysis, as well as special elements such as Spring, Gap, Radiation Link, etc. The preprocessor module also includes functions for defining loads and displacement constraints corresponding to the respective model.

The processor module contains the numerical calculation programs that actually perform the finite element analysis [3]. Users can select the type of analysis to be performed: under static conditions, under dynamic conditions, for materials with linear or nonlinear behavior, and for the analysis of thermal, electrical, and magnetic fields, etc. Running these programs automatically executes the steps of the finite element analysis without any user intervention;

the user may receive a series of messages regarding the progress of the process. These high-performance modules also offer the possibility of customizing the analysis, providing the user with a series of modifiable subroutines using the programming language employed by the manufacturer in developing the module; this allows for analyses based on models different from those included in the package.

The post-processor module allows the user to make use of the results obtained from the finite element analysis. These results can be presented graphically, as a color-coded map superimposed on the model's geometric shape, or numerically, as lists of data related to the analyzed event or process. High-performance modules allow users to display the deformed shape of the model, manipulate it graphically, view an animated representation of the model's behavior, and save the results in appropriate formats for future use.

As an example, we used this method in the production process for a lighting product, specifically Forvia's Slimline headlight (figure 5). Forvia Romania stands out in the manufacture of lighting systems and lamps for motor vehicles, a field in which it has established itself on the Romanian market. Even though there are a large number of competing companies, Forvia manages to meet the demands of the automotive market through the quality of its products and short production lead times, thanks to its high-tech equipment and qualified staff.

Forvia headlights were the company's first products—and they have remained an important part of the company's identity throughout its development and technological progress.

In a system such as that of the Slimline headlight, component requirements are interrelated, determined by the production volume of the finished product and its structure. The breakdown of the finished product by components is specified in the form of a structure diagram, which can be represented graphically as shown in figure 6.

Figure 5. Slimline Headlight

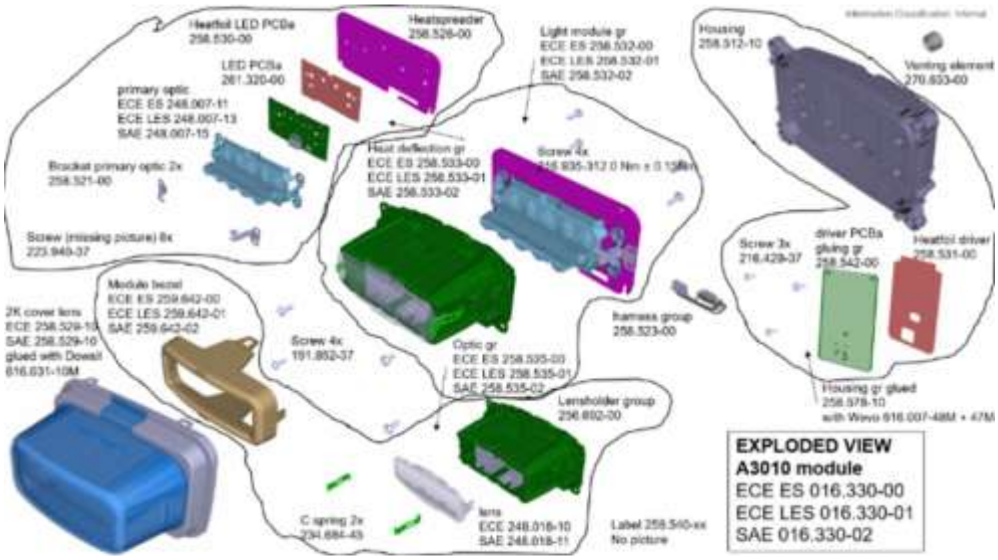

Figure 6. Product structure by component

Using the analysis modules of specialized software (including SolidWorks) for the product under analysis, the following steps are performed:

1. Creating the geometric model or importing it in a format supported by the finite element analysis software.

2. Determine the type of analysis to be performed.

3. Define the material properties of the geometric model.

4. Discretize the geometric model using the functions provided by the software. It is possible to edit certain areas of the finite element mesh automatically or manually.

5. Apply boundary conditions and displacement constraints (fixed joints, supports, etc.).

6. Apply loads—specifically, the forces, moments, and pressures acting on the model.

7. Run the finite element analysis.

8. Visualizing the results—as a color-coded map superimposed on the geometric model, in vector form, or in cross-section—and interpreting them.

9. If necessary, the discretization of the geometric model can be repeated. One can opt for a finer discretization of the entire geometric model or just a portion of it considered critical.

10. The results of running the analysis, using different discretization methods and analysis options, should show a trend toward the results converging on a common value.

Testing of the analyzed manufacturing process was carried out in the following steps:

1. The heat sink label was scanned

2. The module was connected to the leakage test

3. The module's functions were tested according to the test instructions, using the OK/NOK markers

4. The module was connected to the EOL test

5. The module's functions were tested according to the test instructions, using the OK/NOK markings.

6. The automatic vent was checked.

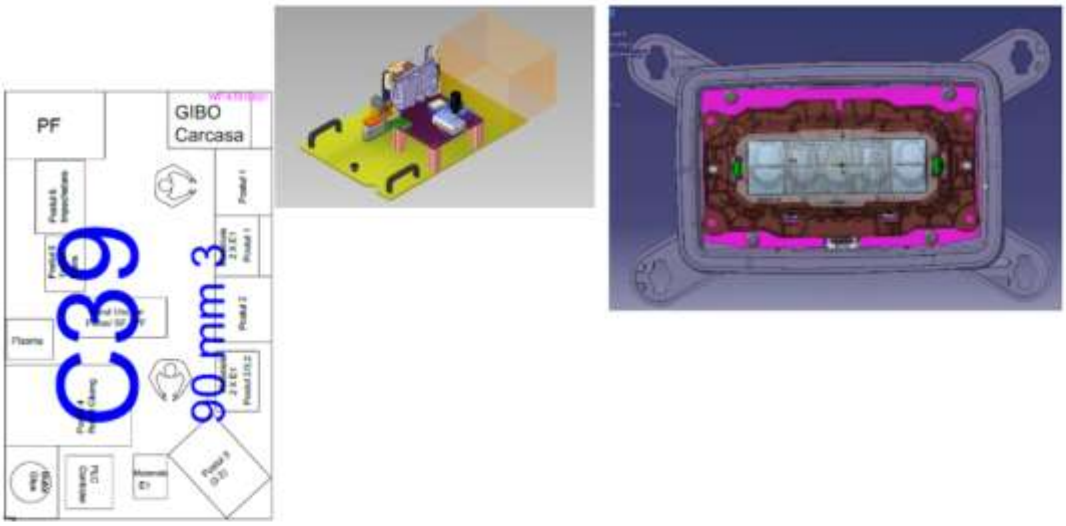

Figure 7. Product Test

Conclusions

The automation of production processes offers various other advantages, as the data entered or collected through technological applications makes it possible to estimate the time required to fulfill production orders, determine the quantities consumed and produced, ensure compliance with specific quality standards, and view key performance indicators based on a history of previous operations.

In conclusion, the implementation of automation systems is beneficial for any company that manages or owns production facilities, as software solutions facilitate the optimization of the journey from concept to finished product, offering a high degree of flexibility in adapting to the needs of each individual business.

We can state unequivocally that in the future, there will be growing interest in integrating computer vision systems into production processes with the aim of minimizing human operator intervention, optimizing operational efficiency, and reducing production costs.

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