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3D DIGITIZATION TECHNOLOGY - A NEW MECHATRONIC METHOD OF INTELLIGENT INTEGRATED DIMENSIONAL CONTROL OF COMPLEX COMPONENTS FROM AUTO INDUSTRY

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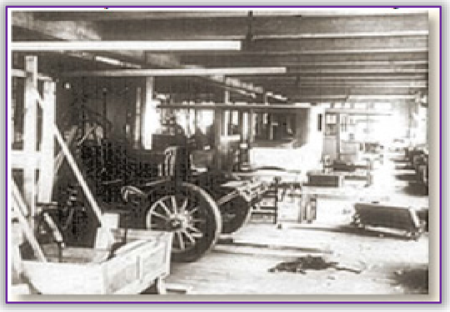
Abstract: The progressive replacement of traditional methods with high-tech (complex) intelligent mechatronic systems, technologies and equipment is one of the most important aspects of the production processes evolution in all industrial fields. Due to accelerated progress of technology transferred in multiple technological innovations, extremely favorable conditions have been created for the development of production and thus of the manufacturing technologies and intelligent control on the automatization way of all subsystems constituting technological processes. New intelligent mechatronic technologies of 3D integrated control offer an integrated portfolio of software solutions and measurable difference for an enhanced quality by accelerating the time needed to produce the components, while the costs of new products are considerably reduced, but also for product development, fundamentally oriented towards ensuring a high level of efficiency in manufacturing and integrated control by increasing the profitability and satisfaction of product delivery requirements.
Keywords: auto industry, mechatronics, 3D integrated control, laser scanning, digitization

INTRODUCTION

The invention of the automobile revolutionized the transportation of goods and people starting with the XX and XXI centuries, changing forever the way people live and conduct business, providing jobs for millions of people and generating a basis for a variety of related services. This represents at the moment 4% of European GDP and over 9% of employment in the manufacturing sector and establish itself as a key sector of the European and world economy.

Progressive replacement of traditional tools with intelligent technological equipment more complex and automated constitutes one of the most important aspects of development processes and production systems in all industrial fields [1]. New technologies for processing and assembly, coupled with the continued growth performance of computing systems and their integration in all industrial activities constituted the foundations for the development of automatic type flexible production system (FMS - Flexible Manufacturing System), or integrated production systems served by a global system of control or management (CIM - Computer Integrated Manufacturing).

Technological and economic developments due to the introduction of mass production have led to the concept of automation of production, everything starting with the introduction in 1920 by Henry Ford, the „transfer line" and „robot man" that serve with the imposed rhythm the automobile manufacturing process lines existing on the model Ford T.



a) Individual assembly of Ford automobiles (1903)

b) production lines Model Ford T (1925)
Figure 1: Comparison of automated assembly lines

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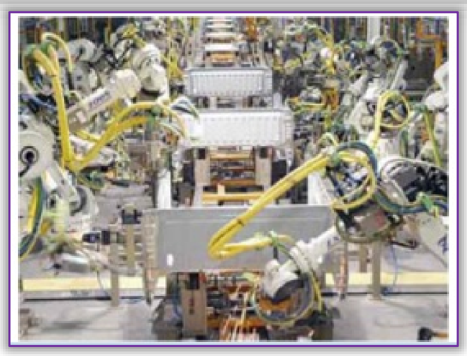


c) robotized assembly Michigan (2000)
Figure 1: Comparison of automated assembly lines

DIMENSIONAL CONTROL IN AUTO INDUSTRY

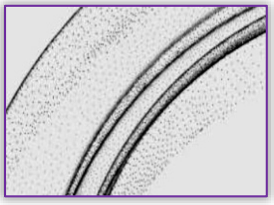
The first systematic technical and scientific preoccupations for quality have emerged with the increasing production of parts in the second half of the nineteenth century, developments taking place in several stages, with specific characteristics: the stage of inspection quality, quality control stage through various statistical methods, step by step quality assurance and total quality control stage. The control systems implemented in the automotive industry operates in compliance with requirements continuously updated on product quality, which they control [2]. For machinery construction, as in other industries, quality control is organized under four forms: before processing, after processing (passive), during processing (active) or integrated.

- Passive control consists of verify the accuracy of parts after the whole batch was processed, in which case it is excluded the prevention of defective goods (hence the term „passive”) and may take place by universal or special means who can be automated and non-automated.
- Active control is conducted during the batch processing of parts and his aim is the conducting of technological process to avoid defective goods. Control can be performed during processing itself (without the removing of piece from work device) or immediately after processing, information about measurement being used in this case to regulate the technological system for the next batch of pieces.

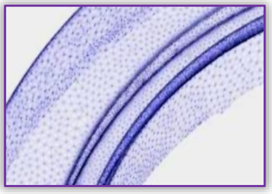
The most important factor in dimensional controlling is the precision of measuring equipment, the method and means of measuring, their choice being made according to two categories of indicators (factors): metrology indicators (graduated scale, the limits of measurement, power measurement) and economic indicators (cost control means), and the time for checking and adjusting device, instrument or machine measurement / control.

With the development of society, it was passed into a wider characterization of the quality through a growing number of operations that are part of the following categories [5]: obtain measurements and calibrations, recognition and identification of specific features, reading character or information code, detecting the presence of an object or a mark, comparing an object with a model or guide whit a machine or a robot.

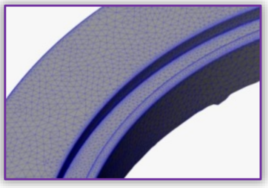
The modern methods for 3D measuring, checking or dimensional control for quality products can be: „with contact” (coordinate measuring machines - CMM), many of which are currently controlled by computer or CN); „without contact”, divided into two categories: optical and non-optical. The methods that are most commonly used for 3D dimensional control are with contact which in practice is generally used for lengths and diameters, the most representative equipment being the coordinate measuring machines (CMM). Optical systems are the most commonly used inspection methods without contact for product quality and relies on the technology use of microelectronics and computer processing of signals from sensors or transducers (computerized view, laser scanning, and photometry)[6].



a) 3D point cloud



b) 3D polygonal network (mesh)



c) resulting surface
Figure 2: 3D digitize process

3D scanning is the process of copying the digital information of a physical object (solid), his geometry, so it is known as digitization. „Digitizing” or „3D digitize” is a process that uses a digitizer probe with contact or without contact to capture the shape of objects and recreate them in a virtual workspace through a very dense network of points (xyz) as a 3D graphical representation. Dates that are collected under the form of points and the resulting file is called „point cloud” (Fig. 1). That „point cloud” type of information is then usually post-processed in a network of small polygons, which are called 3D polygonal network. The technologies used to build 3D scanning devices are multiple and each technology has its own limitations, costs, advantages and disadvantages [3]. The architectures of laser and video sensors used in the dimensional control without contact were developed as an alternative to replace the sensors (probes) with contact, where physical contact is not generally possible, in the super finished areas, rough high or where sharp edges are present. Total accuracy of a 3D acquisition system depends above all on the precision of the system probe used (contact or without contact) and the features of acquisition device for acquisition with contact or the structure of acquisition system for the ones without contact. This accuracy may vary from one micron to one millimetre depending on the system used and the acquisition speed may vary from several thousands to several points per second [7].

3D DIGITIZING TECHNOLOGY

The current stage of development of configurable intelligent systems is represented mainly by two functional solutions [9]:

- software solution;
- hardware solution.

Design and implementation of some intelligent mechatronic systems for installation and control of manufacturing lines in the automotive industry is a complex process that involves several steps.

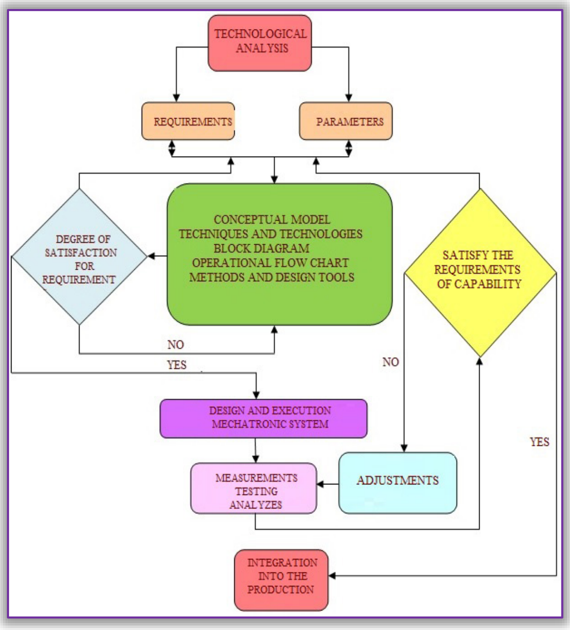


Figure 3: Design and implementation of mechatronic systems

Because intelligent mechatronic systems for 3D integrated control are used both on the production lines and in metrological laboratories and because the parts can have different shapes and complex surfaces an adaptive intelligent mechatronic system generally has the following configuration as in figure 4 [9].

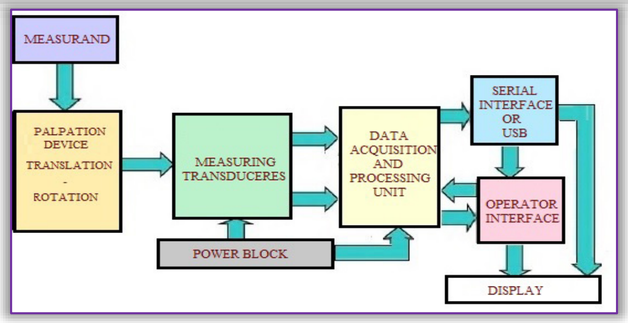


Figure 4: Schematic diagram of a measurement intelligent mechatronic system

Based on this design methodology and general configuration was developed an intelligent mechatronic system for bimodal dimensional control by laser scanning for parts and complex families of parts in automotive industry. It is composed of:

- Laser scanning device (scanner laser probe): acquisition system, hardware and software library with acquisition and primary processing functions (image improvement, alignment, excess points elimination, colour combination). Chosen scanning system is a Class II laser scanner type of short distance (because we want the highest possible accuracy - required for complex parts), with triangulation, having two CMOS acquisition sensors [8]. The optimal scanning distances are between 51 mm and 251 mm, the width of the scanning line may vary between 30 and 100 mm, this being of the cross type. Average accuracy of control at point level is 1-2 µm. This acquisition rate is between 50 and 500 frames per second and the number of points read on a scanning line is equal to 500. This laser acquisition system interfaces with the PC using a standard USB port and has a digital signal RS485 that can be used to synchronize with the robot controller.
- Articulated vertical robotic arm or measurement arm (anthropomorphic) with 6 degrees of freedom – mechanical system, multitasking controller, guidance by visual feedback from the control room (GVR), learning module, driving software for moving robot with GVR extension. The robot system used for scanning the laser is a vertical articulated robot with six degrees of freedom [4]. Repeatability of the robot arm movement is about 0.01 mm. Areas of movement (6 axes, 6 rotation joints) of the robot system are: axis (joint) 1: ± 170°, axis (joint) 2: -170°, + 45°, axis (joint) 3: -29°, +256°, axis (joint) 4: ± 190°, axis (joint) 5: ± 120°, axis (joint) 6: ± 360°. Maximum speed composed at peak is 4400 mm.
- Rotary table with precise positioning in regulation loop of the displacement and rotation

speed. The rotary table is driven as external motion axis by the controller of the robot arm and table motion is synchronized with the movement of the robot, in other words, the robot has added an additional degree of freedom (the 7th). The use of the rotary table is necessary because the robot arm cannot reach behind the object without causing a collision or without changing its position.

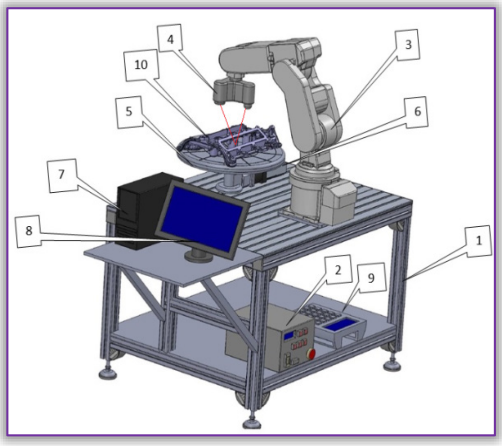


Figure 5: Hardware and software structure of the laser scanning system
1 - table; 2 - controller; 3 - robotic arm (6 degrees of freedom); 4 - laser scanning system; 5 - table positioning piece (rotary); 6 - control axis for the table; 7 - PC; 8 - Display; 9 - manual control and teaching device (teaching pendant); 10 - measured piece.

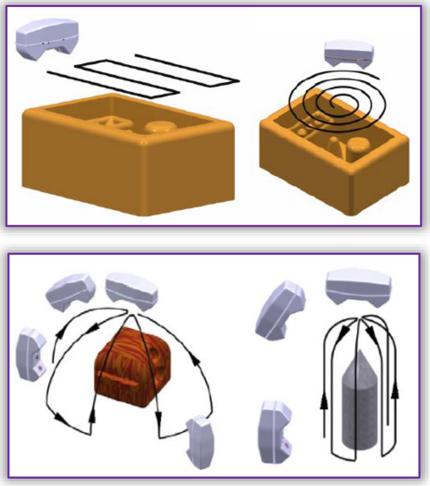


Figure 6: Scanning models

Synchronizing the three components of the scanning system - robotic arm, rotary table and laser scanning device - is essential for the operation at high-speed operation without sacrificing the scanning accuracy. Control of complex parts can be achieved both by the 2D artificial vision system (optical camera) that can provide an accuracy of the measurement up to 0.017 mm and, if the quality requirements are of high precision or require complex measurements (conical features, profiles or other critical dimensions) by the 3D laser scanning system composed of the vertical articulated robotic arm, the scanning tool and the rotary table. This solution provides the flexibility and adaptability of the system to a variety of parts and complex family parts in the automotive industry.

The scanning time estimated for a simple surface will vary according to the chosen control devices:

a) Quick scan, with a resolution of 0.7-0.9 μm, 2500 mm²/s, with a forward speed of 50 mm/s and an acquisition rate of 50 frames/second, a 50 x 50 mm² surface will be scanned in 1-5 seconds.
b) Accurate scanning, with a resolution of 0.3-0.5 μm, 375 mm²/s, with a forward speed of 7.5 mm/s and an acquisition rate of 150 frames/second, a 50 x 50 mm² surface will be scanned in 10-20 seconds.
c) Ultra-accurate scanning, with a resolution of 0.1-0.2 μm, 175 mm²/s, with a forward speed of 2.5 mm/s and an acquisition rate of 350 frames/second, a 50 x 50 mm² surface will be scanned in 1-5 min.

Scanning and digitizing software is the solution for transforming the 3D scanning data into parametric CAD models. Generally, it enables the transformation of 'point cloud' obtained from scanning the piece and its transformation into the CAD model by the mesh NURBS (Non-Uniform Rational B-spline) process that allows the creation of smooth surfaces and curves.

After the tests conducted in laboratory on the developed prototype resulted that the 3D integrated control technology is effectively realized in two stages:

» proper scanning and digitization step;
» transfer and dimensional control step.

Scanning and digitizing stage comprises the following sub-stages:

» stage of preparation and positioning piece;
» stage of providing scanning trajectories;
» stage of scanning and digitization in real time;
» stage of finishing the information obtained (removing isolated areas);
» stage of effective realization of the 3D model.

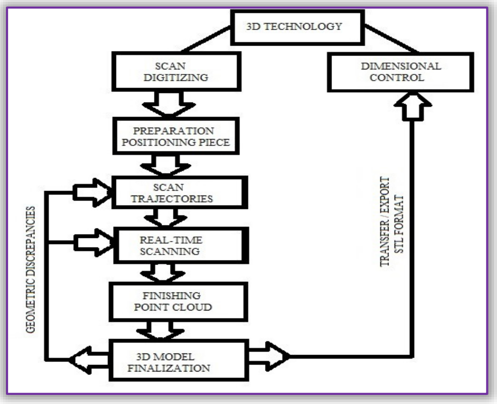


Figure 7: Block diagram of the 3D integrated control technology stages

With the help of the dimensional control software used, respectively VX Model and Solid Works [10] (AutoCAD, Catia V5 or other special measurement software) was developed integrated control itself for the scanned part for a range of geometric dimensions. The obtained results were compared with the original dimensions or those of the other measuring devices.

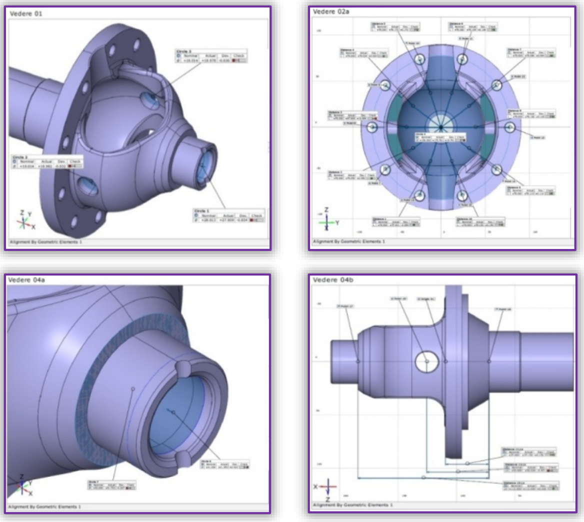
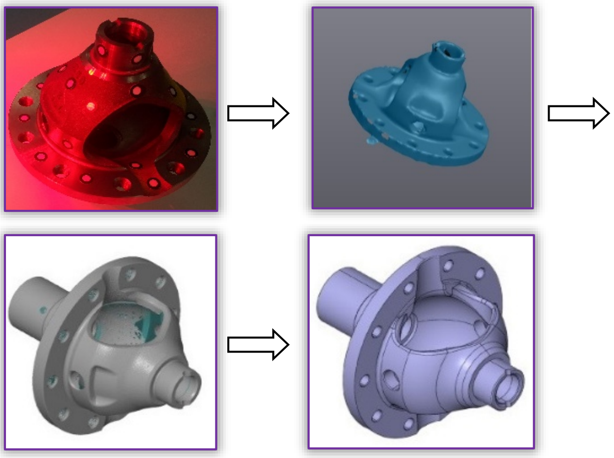


Figure 8: Different types of measurements realized with the 3D integrated control system.

After carrying out the 3D scanning operation, data resulting from all scanning devices are inserted into digitization software and, using markers localization tools and by combining them, it can be realized a single image with a much improved quality. The whole quality control process of the 3D parts can be automated. Specification of minimum and maximum tolerances accepted, in which the set points of the inspected surface must be, and of the threshold value, allows the display of points with different colours depending on the results of measurements, points with a lower tolerance than the threshold value being displayed with a different colour dots with a higher value.



a) real piece, b) digitized piece (intermediate stage)
c) digitized piece (final stage), d) 3D model.
Figure 9: Stages of 3D scanning

CONCLUSIONS

The importance which 3D scanning technology has it and its accuracy is dictated by the tracked application type in such that typically applications do not require a very high tolerance (± 0.3mm), can be use a variety of control techniques without contact to achieving their results, but because the auto industry requires a high degree of accuracy, we can only use certain types of mechatronic systems for integrated 3D control with laser being required a fairly high level of data quality (number of points and space control), the permissible tolerances in most cases is between ± 0.01mm ± and 0.001mm.

3D scanning and rapid prototyping techniques plays an important role in reverse engineering techniques in the automotive industry, even if such a procedure does not necessarily mean physical realization of the prototype. Using this type of 3D integrated mechatronic system for dimensional control presented, a prototype piece can be realized, controlled and approved very easily and quickly, all in one day. The resulting data can be accessible to a large number of equipment or prototyping, production or quality control.

Once a product has been produced in its physical form, it can be scanned and the resulting data compared with the geometry models and the deviations (errors) from the initial geometric model can be determined precisely if it does not have a virtual model. Another advantage that is not so obvious is that once the object is in electronic format, complex ideas can be applied easily and accurately, the manufacturing processes can take place in several branches of the same company in different locations around the world, the contribution of design and manufacture compartments can be carried out on the same pattern and at the same time.

After taking some tests on the prototype achieved based on the virtual model presented, on a number of complex parts and families of complex parts in the automotive industry, revealed that the dimensional inspection error depends on the scan resolution used and the type of scan used (trajectories, forward speed, complexity, method of preparation part, etc.), the inaccuracy of measurement being approximate in calculations equal to ± 0.7 + L / 300.

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