3D INTEGRATED CONTROL OF COMPLEX COMPONENTS FROM AUTOMOTIVE INDUSTRY USING LASER SCANNING

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Abstract. *The creactivity of human being correlated with the requirements of permanent increase of the living standard, constitutes the basis of society development. In a perfect world or in an integrant production environment, the 3D measurement systems, by providing the quality control integrated in the production line would be able to measure all the necessary parameters in a single step, without errors and render the results in the same way to the manufacturing networks with computers, in formats useful for CNC machines control and processes management. Progressive replacement of traditional tools with intelligent technological equipment becoming more complex is one of the most important aspects of the development of production processes in all industrial fields. Because the automotive industry is one of the most important industries in the world, manufacturing systems engineering, control methods and techniques, and assurance of quality, present particular interest by the economic results, in particular the reduction of working time and production costs. Intelligent measurement and integrated dimensional control are needed to ensure the quality of the product or industrial manufacturing process.*

Keywords: 3D control, laser scanning, dimensional control

1. INTRODUCTION

The problem of intelligent measurement and integrated dimensional control is needed to ensure the quality of the product or of the industrial manufacturing process. This is required by the dimensional stability assurance in performing any intelligent industrial process. To assess the quality of the product or of the intelligent process, the mechatronics metrology is used as a process for measuring and verifying the macro and micro geometry of the work-piece surfaces. It encompasses all theoretical and practical aspects of measurements, tests and adjustments together with their precision and accuracy.

During the development of intelligent manufacturing techniques and technologies, with increasing demands for quality assurance, different high-tech mechatronic systems for measurement and intelligent dimensional control have been created, designed and developed, in evolutionary system. In this regard, specialized companies realized and developed new techniques, technologies and constructions on dimensional control systems integrating the new requirements of the development stage of society.

Along with the new scientific discoveries, the mechatronic systems for measurement and dimensional control on new principles of operation have been designed and manufactured, in integrated conception. Thus, mechatronic systems for ultra-precise, adaptronic and high-tech measurement and dimensional control were created. All these mechatronic systems have a wide application in measurement and control processes pre-process, in-process, post-process and integrated into the process.

Taking into account that the automobile industry is one of the most important industries in the world, the manufacturing systems engineering, control methods and techniques, and quality assurance present particular interest by the economic outcomes, especially the reduction of working time and of the production costs.

2. DIMENSIONAL CONTROL IN AUTOMOTIVE INDUSTRY

Traditionally, the products quality control in automotive industry is performed using manual methods of inspection and various statistical sampling procedures, which are generally time consuming, and require a precise activity. Often, this also assumes the transfer of parts or product from the production place in special arrangements, with consequences over the manufacturing time or with jams, sometimes on the production process.

The most important disadvantage of the traditional control is the fact that it is performed after the pieces have already been produced, and the number of scrapped pieces cannot be longer influenced. Therefore, additional costs are necessary to minimize the number of scraps or to adjust recoverable scraps.

In machines construction, as in other industrial fields, the quality control of products is organized under four forms: before processing, after processing (passive), during processing (active) or integrated [3].

3. 3D DIMENSIONAL CONTROL TECHNOLOGIES

3D scanning is the digital information copying process of the geometry of a physical object (solid), so it is known as digitization. "3D digitization" uses a contact or non-contact digitizing feeler to capture the objects form and recreate them in a virtual work space in a very dense network of points (xyz), in the form of 3D graphical representation. Data are collected in the form of "point cloud" and are typically post-processed in a network of small polygons (simple mode), which are called 3D polygonal network [6].

Modern methods of measurement, verification or 3D dimensional control can be: "with contact" (coordinates measuring machines (CMM), many of these are now computer controlled or CN); "contactless", divided into two categories: optical and non-optical.

Laser sensors and video-laser used in the dimensional control technologies have been developed as alternative to replace the sensors (feelers) with contact, where the physical contact is not possible, generally in the case of fine or gentle finished surfaces, super-finished or with large asperities, and for those with sharp edges [2].

Generaly, the technology on which the optical 3D laser scanning process is based includes the following steps:

- The laser beam is projected onto the object;
- The object reflects the laser beam which is then collected by a digital sensor;
- The 3D spatial coordinate (X, Y, Z) of the point on the surface is calculated using algebraic equations;
- Location of the point in the coordinate system is stored as part of a point cloud which represents the physical part resulting in millions of points;
- These points, using techniques for creating 3D digital models (mesha) are used to create the 3D model of the measured part;
- Digital data are used for rapid engineering, rapid prototyping or inspection of the product.

4. INTELLIGENT MECHATRONIC SYSTEM WITH LASER FOR MEASUREMENT AND 3D INTEGRATED CONTROL

In the short term, the advanced mechatronic systems for measurement and integrated dimensional control achieved their goal, but in the long-term are needed new investments in other types of high-tech mechatronic systems to verify parts with a greater diversity. Therefore, it is necessary to create some high-tech mechatronic systems for measurement and integrated dimensional control with new higher features:

- modularity – so that it can easily adapt to new types of pieces that are intended to check;
- adaptability – at the new range of parts through the modules designed to their verification;
- intelligent – by the ability to signal, process and decide different situations and to report dimensional evolution of the piece [5].

Because the intelligent mechatronic system for 3D integrated control with laser from this project will be used in the production halls of the automotive industry environment and because the parts can have different shapes and complex surfaces, after the realized study and tests, the following hardware and software structure of the high precision adaptive laser scanning system is proposed (Figure 1).

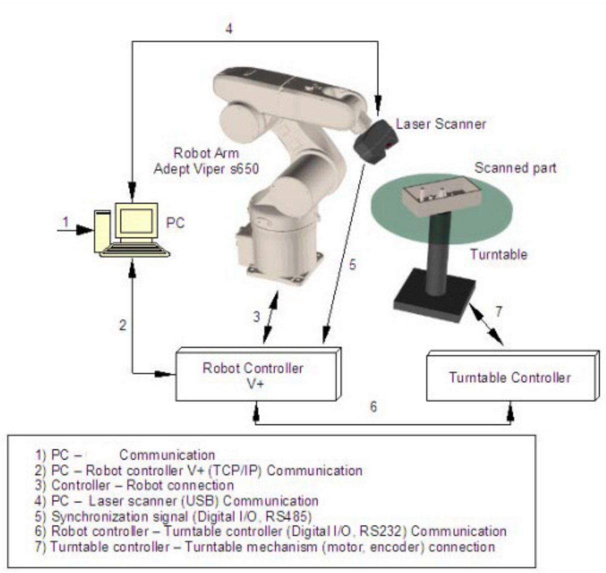

Fig. 1. Hardware and software structure of the laser scanning system and 3D processing of objects.

The proposed system for scanning, acquisition, alignment and inspection of data describing the 3D surfaces is composed of the following basic elements (Figure 2) [1]:

- Laser scanning device: acquisition system, hardware and software library with acquisition and initial processing functions (images improvement, alignment, eliminating points in excess, color combination).
- Robot arm vertical articulated or measurement arm (anthropomorphic) with 6 degrees of freedom – mechanical system, multitasking controller, guiding by the visual feedback from the control room (GVR), learning module, control software for robot motion, with GVR extension [4].
- Rotary table with precise positioning in the control loop of the movement and of the rotation speed.

The chosen laser scanning device is a Class II laser type of short distance, with triangulation, having two CMOS acquisition sensors. The optimum scanning distances are between 51 mm and 251 mm, the width of the scanning line can vary between 30 and 100 mm. The average measurement accuracy at point level has to be less than 10 µm. The acquisition ratio is between 50 and 500 frames per second, and the number of read points on a scanning line is equal to 500. This laser acquisition system interfaces with the PC using a USB standard port and has a RS485 digital signal, which can be used for synchronization with the robot controller.

The robot system used for sweeping the laser beam is a vertical articulated robot with 6 degrees of freedom. The repeatability of the robot arm movement will be about 0.01 mm. Displacement domains (6 axes, 6 pivots) 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°. Composed maximum speed at the top is 8200 mm/s.

The rotary table is controlled as external movement axis by the controller of the robot arm, and the motion of the table is synchronized with the movement of the robot. In other words, the robot has added a supplementary degree of freedom (the 7^{th}). 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.

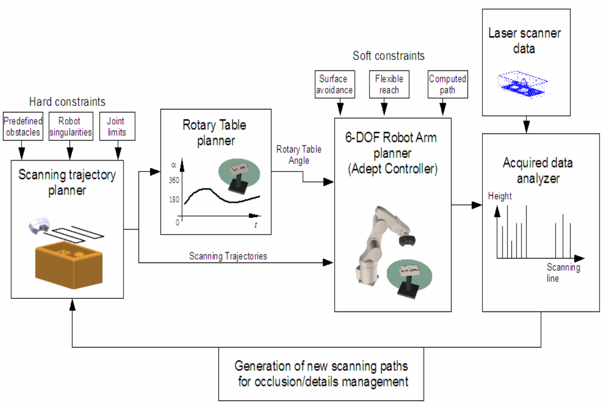

Fig. 2. Planning based on motion constraints during the constituted process of scanning up

Softwares that will allow permanent knowing of scanner position, softwares for creating scan pathways and a graphical interface software running on PC will be used in order to integrate the scanning device with robotic arm. Because we want to realize an as accurately device and that can read at every 1 millisecond the position of the robot system, the acquisition rate of the device will be that of the scanning device [9]. Measurement accuracy is of the order of microns, whereas both the scanning device and the articulated arm will be high precision devices.

Inspection of processed parts is implicitly realized by the 2D artificial sight system (optical camera) that can provide a measurement accuracy of up to 0.005 mm according to choice. If the quality requirements are of high precision or complex measurements are necessary, the proposed solution is represented by the 3D scanning system consisting of the robot arm vertical articulated, the scanning device and the rotary table. This solution offers the flexibility and adaptability of the quality control system and a precision of the microns order.

The scanning device being mounted on the robot arm flange (the gripper), it is considered that the scanned object can be bounded by a vertical cylinder, having the diameter and the maximum height specified as follows:

- for complete scan from above, the maximum height of the piece is 600 mm and the maximum diameter of the piece is 750 mm;
- for scan from lateral, the maximum height is of 700 mm and the maximum diameter is 500 mm;
- for combined scanning, from lateral and from above, the maximum height is 500 mm and the maximum diameter is 600 mm.

The scanning time estimated for a simple surface will vary depending on the chosen devices. Realization of the dimensional control is a very complex process, and in order to obtain maximum efficiency it is necessary the use of a measuring program. This program realizes the connection and communication between the user, the measuring device and the measuring in coordinates [8].

More softwares have been developed for the proposed constructive solution:

- software for the corelation and integration of the scanner with the robotic arm;
- trajectories generator software;
- software for the rotary table positioning in the scanning process;
- software for graphical interface with the user;
- scanning and digitizing software.

5. CONCLUSIONS

The importance that the 3D scanning and its accuracy have are dictated by the sought application. Because the automotive industry requires a high degree of accuracy, we can use only certain types of mechatronic systems of 3D integrated control with laser. A fairly high threshold of the data quality is neccesary, the tolerances accepted in most cases being between ± 0.001 mm and ± 0.01 mm. The 3D scanning techniques and those of rapid prototyping play an important role in the reverse engineering techniques in the automotive industry, even if such a procedure does not necessarily assume physical realization of the prototype. Using the presented mechatronic system of 3D integrated control with laser, a prototype can be made and approved, followed by realizing a mold that can be made quickly and easily, all these in one day.

The scanned data can be transferred to any CAD file format and accessible to a large number of equipment. After a product has been made physically, it can be scanned and the resulting data can be compared with the geometric patterns and deviations up against the initial geometric model can be precisely determined [7]. Another advantage is that once the object is in electronic format the complex ideas can be applied easily and accurately. Thus, the manufacturing processes can be developed in several branch establishements of the same company in different locations around the globe.

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