QUALITY OF MEASURING THE STEEL STRUCTURE OF THE WORKING MACHINE CABIN WITH 3D MEASURING DEVICES

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ABSTRACT
Quality control is one of the most important factors in any organization, especially in production organizations. The accuracy or doubt of the obtained results cannot be questioned at any time. Appropriate measuring instruments must be used to achieve the desired results. The paper presents the measurement and control on geometrically complex steel structure of the working machine cabin using a 3D measuring device or a measuring arm of the FaroArm Quantum type. The presented measurement results show the justification of using the measuring arm which is reflected in the quality, reliability and accuracy in relation to conventional measuring systems. In order for a new product to meet quality and find its place in the world market, organizations must strive to introduce TQM.

Keywords: quality control, 3D measurement, measuring arm, measurement accuracy, TQM.

1. INTRODUCTION
Today, when the market places more strict requirements for higher product quality, the use of modern measuring devices for measurement and control is almost inevitable. The measurement provides accurate information and data on the actual dimensions of the product, based on which the compliance of these data with the requirements of the technical documentation defined by the designer during product development is checked. With the increasing complexity of product geometry, the requirements for the volume of information on product dimensions increase as well, and therefore new measurement procedures and new types of measuring devices are introduced [1].
Classic measuring devices that enable measurement in one dimension cannot meet the requirement of measuring the tolerance of shapes, which are increasingly defined in design drawings. In addition, classic measuring devices do not allow automation of the measuring process, so more and more organizations are considering replacing classic devices with newer, more modern measuring devices.
The development of engineering and technical sciences also required the appropriate development of measurement methods and instruments, and supplementary equipment used for measurement [1].
The use of 3D measuring devices for measurement and control is becoming an indispensable part of the production process. The advantages of such measuring and control devices are

numerous compared to conventional measurement methods. 3D portable measuring devices, known as measuring hands, are portable coordinate measuring machines, which determine and record the location in 3D space via a probe. The modern 3D portable measuring devices have the ability to upgrade a 3D laser scanner, which allows more accurate position analysis.
In order to show the measurement and control in this paper, a measuring arm of the FaroArm Quantum type was used, showing its advantages in relation to conventional measurement and control methods.

2. MEASUREMENT AND CONTROL

Measurement and quality control are important segments in every production and represent one of the key points in the process model of quality management. It is one of the activities for all improvements of measured dimensions and shapes and is part of the Deming circle.
Production measurements, as part of the activities that connect the measurement functions with the product manufacturing process, is a modern approach to measurement. Production measurements enable the production process to take place without downtime and to produce a product with the desired characteristics. Industrial production requires frequent measurements and controls performed for the purpose of automatic process control. Product quality control cannot be perceived without measurement as a condition for the sale [3].
The control provides information on whether a dimension of the measured object is within or outside the tolerance limits. The results of control help make decisions about whether a product is accurate or non-compliant. Based on the results, the stability of the process or the need for correction of process management is determined, which ultimately serve to decide what to do and how to proceed [1].
Product quality assurance can also be achieved outside the production line by implementing TQM (Total Quality Management) or total quality management and error prevention in the planned area. TQM is especially important for production systems, because the overall approach to quality management helps achieve exactly the product that customers want [2].

3. QUALITY OF MEASUREMENT WITH 3D DEVICES

In addition to the development of technology, the measuring technology with the help of 3D devices has also evolved, which makes measurement easier, more precise and more accurate. One of the leading manufacturers of portable measuring devices is Faro, which has been developing 3D portable devices for solving dimensional metrological problems for the past 30 years. Faro portable measuring devices (measuring hands) enable precise 3D measurement and recording, CAD comparison and dimensional analysis of parts and complex structures within the production process. The devices are also used for inspection of components and assemblies, and production planning and quality control [6].
Namely, with quality training, the measuring arm operator can measure the position and analyze the obtained results in a short period of time. Due to the small dimensions and low weight of the device itself, it is possible to transfer the device to the positions that are still being processed, in order to avoid the need to reposition it in the machining center if there is a need for finishing [4].
The advantage is also reflected in the simple measurement of complex parts such as bodies and cabins, oval-shaped casings, turbine blades, etc. Faro has developed 3D measurement technologies and quality control software in order to integrate with the existing production and assembly systems, and production tools and technology [6].

3.1. Measuring arm FaroArm Quantum

3D measuring arms, also known as articulated arms, are portable coordinate measuring devices, manually guided, which determine and record the position of the probe or tentacles in 3D space and display the results through dedicated software.

FaroArm Quantum provides unparalleled possibilities for detailed surface shape measurement and raises the criteria in portable measurement with revolutionary measuring hands [6]. This measuring arm utilizes a new technology that uses a point inside its housing for the origin of the coordinate system, which significantly shortens the time of installation and start of work, because with similar devices it is necessary to determine the area of the coordinate system and its origin. With the help of the measuring arm, the data on the measured dimensions can be obtained in several ways. The first way to obtain dimensions is by using tentacles with ceramic balls of different dimensions. Another way to obtain results is by 3D scanning, which has the same base of point selection. The product must first be scanned with a laser scanner, and the results are subsequently processed by comparing the obtained model with a 3D model from one of the CAD tools [6].

The FaroArm measuring arm is a new innovative measuring device, which entails the need for a certain amount of knowledge required for data handling and processing, and thus the price. The training of the user of the measuring arm lasts for a longer period, with the precondition of computer knowledge and basic knowledge of one of the CAD programs. Figure 1 shows the FaroArm Quantum measuring arm used to collect and display data for the purpose of this paper.

Figure 1 Measuring arm FaroArm Quantum type [6]

3.2. Example of working machine cabin measurement

To show the procedure and measurement results in this paper, a measuring arm of the FaroArm Quantum type with round tentacles was used as part of the data processing driver. The measurement was performed on the steel structure of the working machine cabin in the production organization of Krupa Kabine d.o.o. Bosanska Krupa.

It is important to note that a detailed measurement and control of a single cabin takes a lot of time (16-20 hours), depending on the type of cabin or the number of positions from which it is composed. Therefore, the periodic measurement of the cabin is performed according to a predetermined measurement plan at the annual level, which is defined on the basis of the annual number of manufactured cabins. The measurement cabin is taken by the method of random sampling in daily production.

As the production capacities are up to several units of product per shift, and the control must be performed continuously, the measurement of each cabin would not be possible. Therefore, special attention is paid to preventive control, which includes measurement and control of welding patterns (Figure 2).

Figure 2 Welding pattern

Figure 3 Display of measurement with measuring arm FaroArm Quantum

In this example, the measurement was performed at only one position of the cabin, i.e. the right side of the air conditioning filter or the position of the M6 threaded sleeves with the help of a 3D measuring arm Faro Arm Quantum with a ceramic ball tentacle with a diameter of 3 mm (Figure 3). Lenovo laptop was used to connect the measuring arm to the software and data transfer.

3.3. Display of measurement results

Figures 4 and 5 show the interface of the software setting of the coordinate system starting point and the 3D display of the measurement report for the measured position of the cabin (right side of the air conditioning filter).

The coordinates of the M6 threaded sleeve of position mark 15 to 19, and the spatial or longitudinal measures from the coordinate system starting point to the center of the M6 threaded sleeve of position mark 55 to 64 were measured [7]. The position of the threaded sleeve is defined from the coordinate system starting point defined by the 3D model, and not from the measuring arm starting point [7].

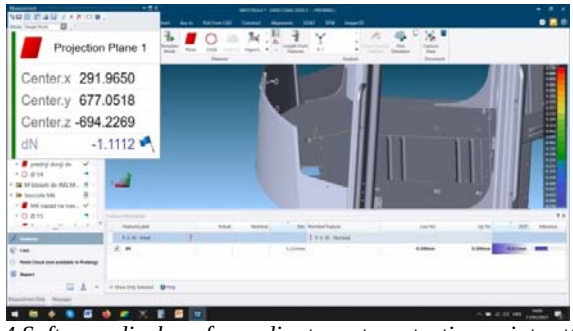

Figure 4 Software display of coordinate system starting point setting [7]

In this measurement, the z-axis is excluded because all threaded sleeves are in one H-plane so that the 3D report does not contain coordinates along the z-axis. The measuring arm is also placed in the position defined from the coordinate system starting point of the 3D model.

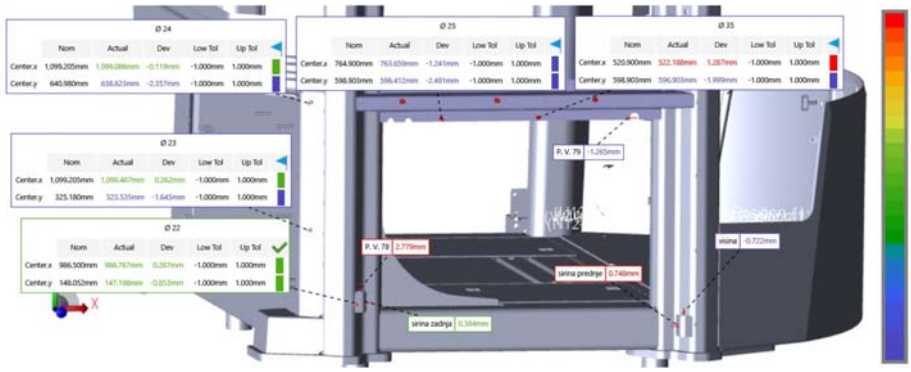

Figure 5 Software display of 3D measuring report [7]

Table 1 shows the measurement results in the plane for the x and y coordinates of the M6 threaded sleeves used for mounting the air conditioning filter on the side of the cabin, measuring point marks 15 to 19.

Table 1 Display of measurement results in a plane with 3D measuring hand FaroArm Quantum [7]

Name of position	M6 threaded sleeves									
Mark of the measuring point	15		16		17		18		19	
Nominal values x,y (mm)	x	y	x	y	x	y	x	y	x	y
	874,20	647,57	634,20	647,57	386,70	647,57	124,20	638,58	124,20	456,73
Allowed deviations (mm)	+1,00	+1,00	+1,00	+1,00	+1,00	+1,00	+1,00	+1,00	+1,00	+1,00
	-1,00	-1,00	-1,00	-1,00	-1,00	-1,00	-1,00	-1,00	-1,00	-1,00
Measured values (mm) for cabin type KM 1544	874,12	**645,58**	634,86	**645,24**	387,56	**645,01**	124,92	**635,42**	125,03	**453,94**

Table 2 shows the measurements results in space, i.e. the longitudinal measurements from the coordinate system starting point to the center of the M6 threaded sleeve, position marks 55 to 64 for four cabins.

Table 2 Display of measurement results in space with a 3D measuring hand FaroArm Quantum [7]

Name of position		M6 threaded sleeves									
Mark of the measuring point		55	56	57	58	59	60	61	62	63	64
Nominal value (mm)		89,80	9,00	190,80	377,00	539,30	558,30	738,20	750,00	112,30	53,10
Allowed deviations (mm)		+1,50	+2,00	+2,00	+2,00	+3,00	+2,00	+3,00	+2,00	+2,00	+3,00
		-1,50	-2,00	-2,00	-2,00	-3,00	-2,00	-3,00	-2,00	-2,00	-3,00
Measured values (mm) for cabin type	KM 1544	**93,40**	9,00	190,70	376,70	**535,80**	558,20	739,60	750,00	111,10	55,10
	KM 1616	**93,30**	9,20	192,10	377,10	536,30	558,20	739,50	749,00	111,50	53,70
	KM 1659	**92,40**	9,40	191,00	376,90	**535,90**	557,90	739,90	749,60	111,00	53,50
	KM 1730	**93,00**	9,30	190,80	376,80	537,20	558,00	735,60	**747,70**	112,60	54,50

The results shown in Table 1, where the measurement was performed in the plane for x and y coordinates of one cabin type KM 1544 for five measuring points, and Table 2, where the measurement was performed in space for four cabins type KM 1544, KM 1616, KM 1659 and KM 1730 for ten measuring points indicate that there are deviations from the nominal value, i.e. deviations outside the allowed limits. The displayed measurement values show how accurate and reliable measurement results can be obtained with 3D measuring devices, in this case with a FaroArm Quantum measuring arm, even in the case of a very complex geometry of the working machine cabin.

It is important to note that for all measured positions whose results go beyond the allowed deviations, the measurement report is submitted to the quality control service. The quality control service undertakes activities related to resolving non-compliance in coordination with the designers. The designers give the order for the correction, and then re-measure and control the tools for making the welding pattern. After the corrections have been made on the welding pattern, the completely new cabin made with the new pattern must be measured and controlled. For a cabin with a negative measurement report or non-compliant measures that are outside the allowed deviations, permission for use is required from the customer or designer, or otherwise a new replacement part of the cabin is made for which non-compliance has been determined.

4. CONCLUSION

The paper presents an example of measuring and quality control on a steel structure of a working machine cabin with a complex geometry using a 3D measuring arm of the FaroArm Quantum type. 3D measuring devices, although more expensive than conventional measuring and control devices, ultimately reduce the cost of the product itself because human factor errors in reading control values in a conventional way are excluded. The accuracy and reliability of the results is at a high level. The control time is much shorter, as there is no need to set up and center the cabin, excluding the centering errors as well. Given the complex geometry of the cabin, in the end it is possible to transfer all the coordinates to a CAD program and, if necessary, simply construct a cabin, which would conventionally take much more time, including new costs. The characteristics of such portable measuring devices are great ease of handling, small dimensions, device mobility and high accuracy at shorter lengths of measurement and control, while various software packages specific to various areas of industry allow users to effectively use and present their results.

By applying the mentioned 3D measuring devices, the organization creates a good basis for the introduction of TQM as a methodological multi-layered concept for long-term sustainable business success and achieving organizational excellence.

5. REFERENCES

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