MEASUREMENT TECHNIQUES IN AERONAUTICS INDUSTRY

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Abstract: *Measurement techniques in the domain of aeronautics industry must ensure precision to the level of submilimeters. Measurement systems in this precision domain have an action range until 40-50m.*

The requirement that the used measurement method does not require direct contact with the object taken form measurement is fulfilled by measurement systems in industry, which presents also flexibility and portability advantages.

Within the framework of this paper, considerations will be presented regarding the used apparatus in this domain, which can ensure precision up to the level of microns, as are the followings: laser-tracker, precision laser scanner, measurement machines in coordinates.

1. Introduction

Determinants for the geometry of an airplane are the deviations of its parts. Knowing with precision these deviations, for which the tolerances are in the level of tenths of mm is an important requirement. Choosing the measurement system for determining these deviations is mainly depending on the precision of the system, on the number of points that must be measured, on the availability of the measured object and on the environmental conditions during the measurement.

2. Laser tracker

Laser Tracker system represents a specially developed measurement system for industrial applications, having at its base interferometer measurement of distances. Three-dimensional determination of the coordinates can take place both when the machine is in movement and when target points are static.

As brands (reflectors used at measurements) laser tracker has a variety of instruments for measurement:

- A Cat-eye reflector, „Cat-eye", which consists of two hemispheres of glass. The geometry of reflector ensures the parallelism between the incidence radius and the one that it reflects. "Cat-eye" reflector is used for areas of work greater than 2 m (fig 2.1).

- A triple concave mirror, made up of 3 mirrors placed in right angle. It is mainly used for high precision measurements in a work area less than 2 m.

- A central reflector called T-Probe, which is used for precise determination of hardly accessible coordinate points and which has as auxiliary instrument a bar calibrated by known dimensions and with its help the exact position of the measured points can be obtained in 3D system (fig 2.2)

Fig 2.1. „Cat-eye" Reflector

Fig 2.2. T-Probe Reflector

- another machine that is used together with the laser-tracker is a 3D scanner called T-Scan which determines the (X,Y,Z) position of the measured points with a precision of ±30μm at a distance from the laser tracker of max 9m (fig 2.3.).

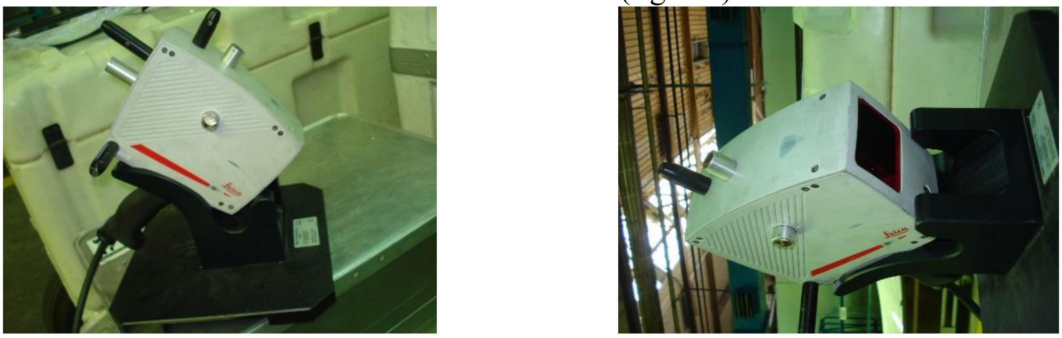

Fig 2.3. T-Scan Scanner

2.1 Characteristics of the laser tracker

Fig. 2.4. Laser-tracker Leica 840 with left T-Probe instruments and right T-Scan Scanner

Resolution of the laser tracker is ±0.0015 mm+0.006 mm/m

Measurement speed with T-Scan instrument is 3000 points/s at a distance smaller than 15 m.

Distance until it can be measured by using T-Probe instrument is up to 30m.

Maximum distance up to which it can make measurement is 40m using a reflector.

Because the propagation characteristics of the laser beam are dependent by the environmental conditions, the system must be calibrated before each measurement, and air pressure and temperature parameters must be included in this process. It also must be taken into consideration that these values do not have to be modified during the measurement because it can systematically influence the precision of the measurement.

If the measured object is in a computer as 3D-CAD geometry, then deviations can be presented directly in the ONLINE module on the screen. The computer than calculates for each measured point the deviations from the projected model. In this way the user can recognize the direct zones in which the values are outside the tolerance range and can already check in detail these zones during the actual inspection.

With laser-tracker we are in a situation to determine, from a certain place, with high precision, the coordinates according to the polar method. Through high measurement frequency from tracking-module, surfaces can be digitalized in short period of time. On a frequency of 500 points/second, the user can make another pre-selection for not generating huge quantities of data. With offset reflectors measurements can be done on a defined R distance compared to the actual surface.

At laser-tracker Leica LTD 840, laser beam must not be interrupted during the measurement. This means a limitation in choosing the measured point.

The main characteristics of the laser tracker instrument are:

- does not need to be set;
- needs approximately 30 minutes to warm up before beginning of measurements
- Coordination system of the apparatus can be introduced in the airplanes system.
- the part prepared with 3D model can be overlapped and it can determine in real time the deviations without having the necessity for other measurements
- it can measure in a temperature interval between 0 and +40 ^{o}C (does not require acclimatization)
- For comparing the measured model with the one projected Poly Works 10.0 software was used.

2.2. Experimental determination with laser tracker. Atrape 200*

An application consists in verification of atrape coordinates (* support that is mounted on the machine with the reason to fix the piece in order for processing) fig.2.5 and fig.2.6 (3D position of this) in reference with the airplane's coordinate system and the rectification of these data in case in which these do not correspond. This verification consists of scanning with T-Scan instrument the surface of the piece that is going to be processed. Atrape is a TIV (tool and Instrument of fixation and verification) which is mounted on the work bench of a cutter and on which the boring of the surfaces is done.

Work stages:

After the apparatus is in optimal working conditions (heating) the laser tracking coordinate system is brought in the coordinate system of the airplane through aligning three known coordinate points (with the help of the T-Prod instrument) located on the edges of the atrape (fig.2.6). After this process the active surface is scanned from a single position (precursory stripes of approximately 10 cm were divided for scanning uniformly and not to have overlapping of point clouds). In case in which the laser tracker loses visual contact with the device T-Scan retakes the measurement from the alignment of the coordinate systems.

After measurements several point clouds were obtained, which partially overlap. Through the mesh type surface creations the scanned surface is obtained. This surface is checked one more time for deviations in different areas with known coordinates with the help of the T-Prod instrument.

Deviations from the theoretic profile must be between ±0.25mm. If there are areas that pass this tolerance level, point coordinates must be modified that define the alignment plan.

After correcting the alignment coordinate plans, the site surface is located within the tolerance values, the processed profile measurements are resumes fig.2.7 with measurement in real time of the deviations from the form in well defined known coordinate points. In case in which the profile is not within the ± 1mm tolerance value the recovery process will be launched.

Fig 2.5.Laser tracker in measuring position.Atrape mounted on a cutter.Plates with coordinate in the system of the airplane which is on atrape

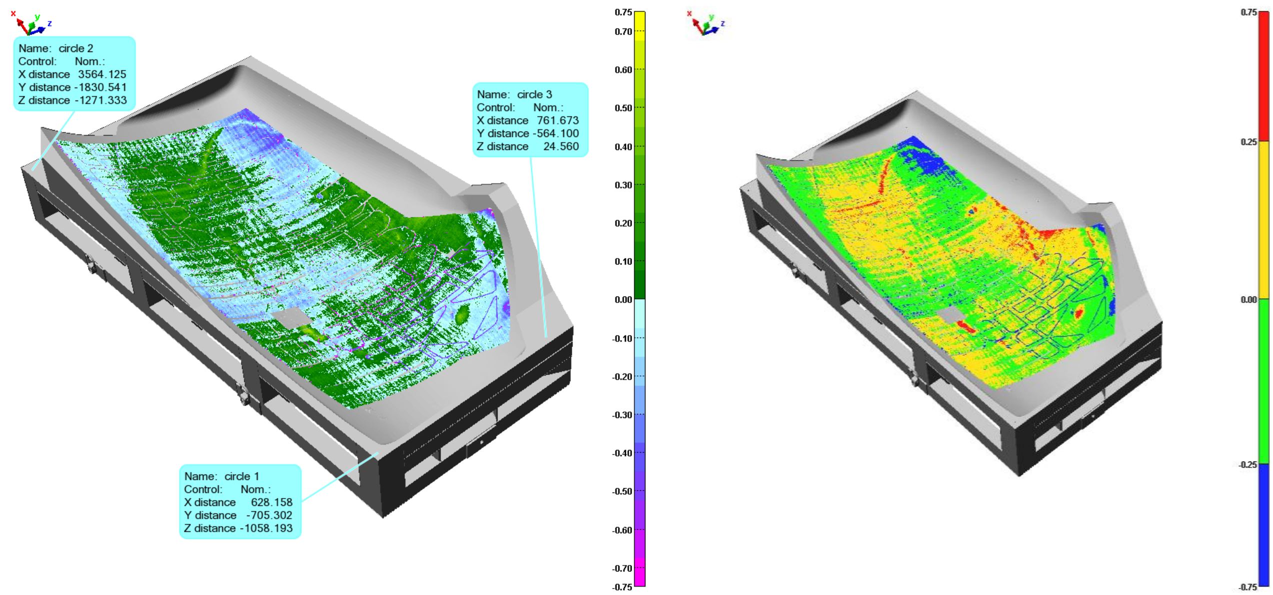

Fig. 2.6. Representation of alignment plan of the atrape and the result of the measurements

Table 2.1 with measured points and deviations of these from the projected model.

Table Type	Data to Reference (Data Point)
Cmp Object(s)	ATRAPA-200, atrapa 200-2
Ref	PL_1_00_00_ED_A_280308_
Cmp Dist	0.750000
HiTol +	0.250000
HiTol -	-0.250000
Err Dir	Shortest Distance
#Points	1283582
Mean	-0.014986
StdDev	0.152101
RMS Error	0.152838
Max Error	0.728363
Min Error	-0.749979
Pts within +/-(1 * StdDev)	986784 (76.877364%)
Pts within +/-(2 * StdDev)	1219313 (94.992996%)
Pts within +/-(3 * StdDev)	1258035 (98.009710%)
Pts within +/-(4 * StdDev)	1275315 (99.355943%)
Pts within +/-(5 * StdDev)	1283582 (100.000000%)
#Pts Out of HiTol	101895 (7.938332%)
Surface Out of HiTol	7.708495%

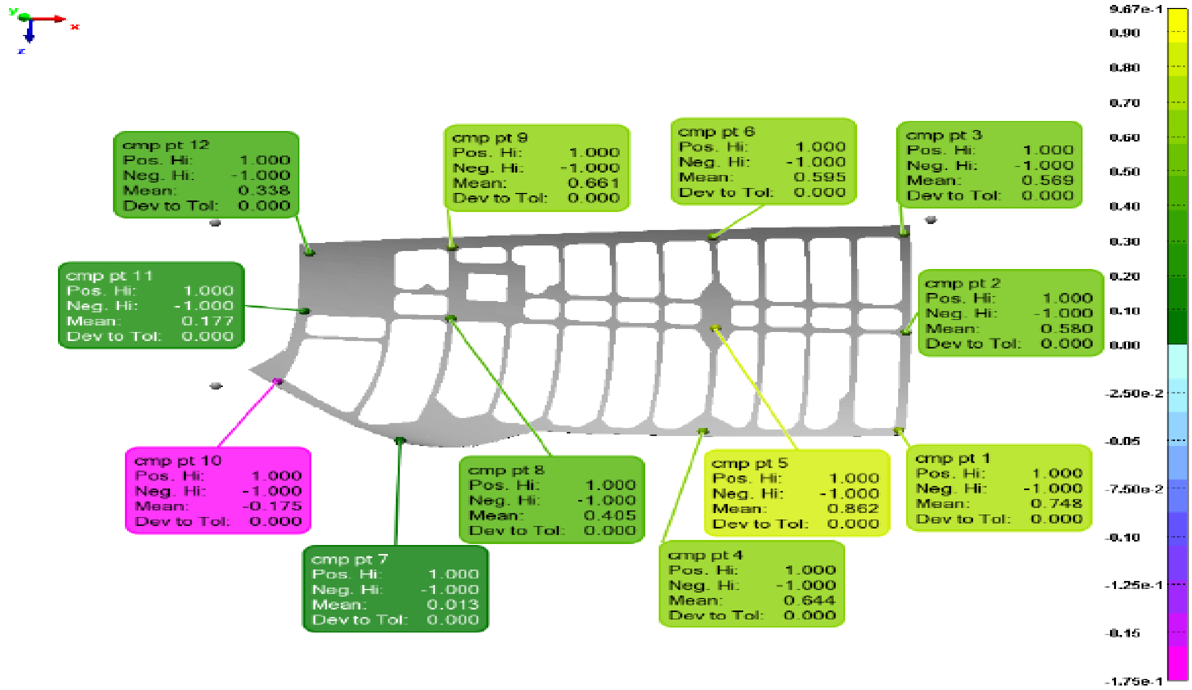

Fig.2.7 Verification of the processed wrapping in areas with known coordinates

3. Laser Scanning

Laser Scanning is a new geodesic technique, through which the geometry of a structure can be completely measured without the help of a reflective environment, with high precision and increased speed. The results of the measurements are represented by a (considerable) variety of points, named in the specialty literature point clouds.

Each delivered point cloud by the laser scanner contains a number of considerable points that are affected by huge errors. If the final product is represented by this point cloud, the precision of the measurements cannot be guaranteed on the same level with the measurements done with conventional measuring instruments.

As error sources that affect the result of the ground laser scanner measurement there are four categories: instrumental errors; errors due to the form and nature of the scanned object; errors due to the environment in which the scanning is done; methodological errors.

Attenuation or elimination of the effect of these errors depends, in most of the part, by a careful individual calibration of each type of instrument and the precaution measurements that needs to be considered at their usage.

2.1. Scanning techniques in the aeronautic industry for a block.

The scanned piece is a block on which profiles called necessary rail rods are pulled to the bracing of the airplane’s fuselage. (fig.3.4)

Within the research done on the 3D scan, an ATHOS III type laser scanner was used with support for camera of 400mm, manufactured by GOM company. (fig.3.1)

Technical data:

- Scanned volume is L=547mm, I=434mm, H=418mmm
- Number of scanned points is approximately 5.000.000 at a resolution of 2448x2050 pixels
- Measurement precision is from 0.003 mm
- Operating temperature from +5 la +40^{o} C
- Maximum operating distance from the central unit

- Processing software is GOM Inspect V7.5

Fig.3.1 ATHOS III Scanner

Fig 3.2 Marker types

Scanning stages:

- In the first stage of the scanned piece there are no markers (fig.3.2) in order to be visible at least four on a scan after the piece is covered with a layer of dust with the purpose of anti-reflexion.
- The second stage consists of fixing the scanner so it can focuses on both piece measurement rooms (fig. 3.3).

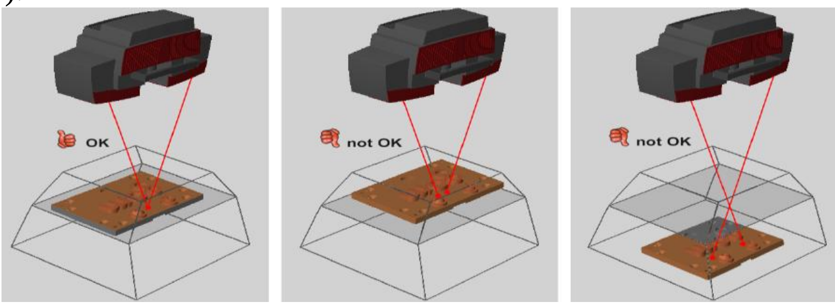

Fig.3.3 Fixing the scanner

- The third stage consists of scanning the piece from several positions in order for the model to be scanned completely (fig.3.5).

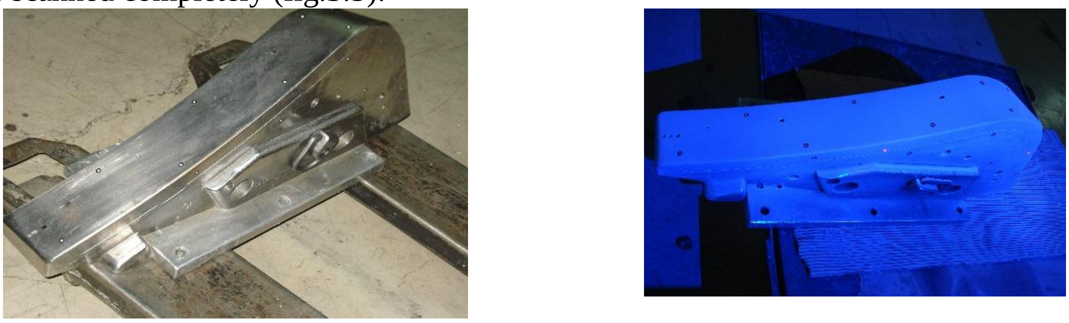

Fig. 3.4. Sample

Fig. 3.5 Sample scanning

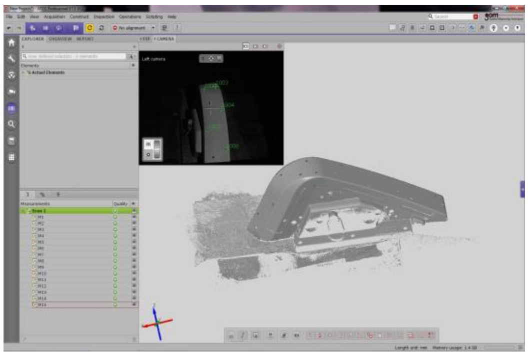

Fig. 3.6. Recognizing markers

As a result of the scanning it can be observed that the markers are recognized automatically by the processing software fig 3.6.
- The fourth stage consists of processing the point clouds obtained after the scanning.
The processing software permits the introduction of the projected model and the alignment of surface meshes resulted after the scanning. This alienation is done after two planes, three points, etc. In our case the alignment was done after two airplanes fig 3.7. and fig. 3.8.

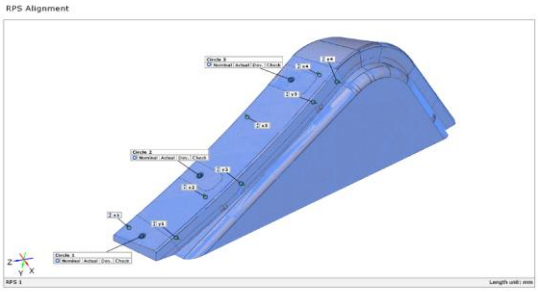

Fig 3.7. Alignment plans for scanned piece

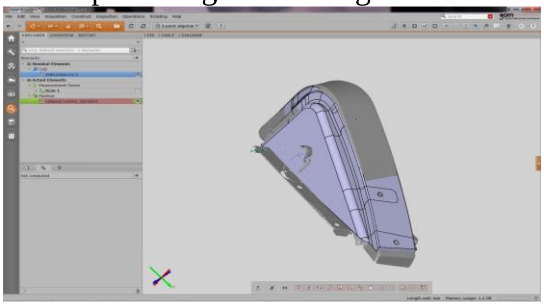

Fig 3.8. Aligned sample and mesh surface

After alignment the deviations between the surface of the projected piece and the one realized was obtained and also the position of the fixation holes of the sample (fig. 3.9. and fig. 3.10.).

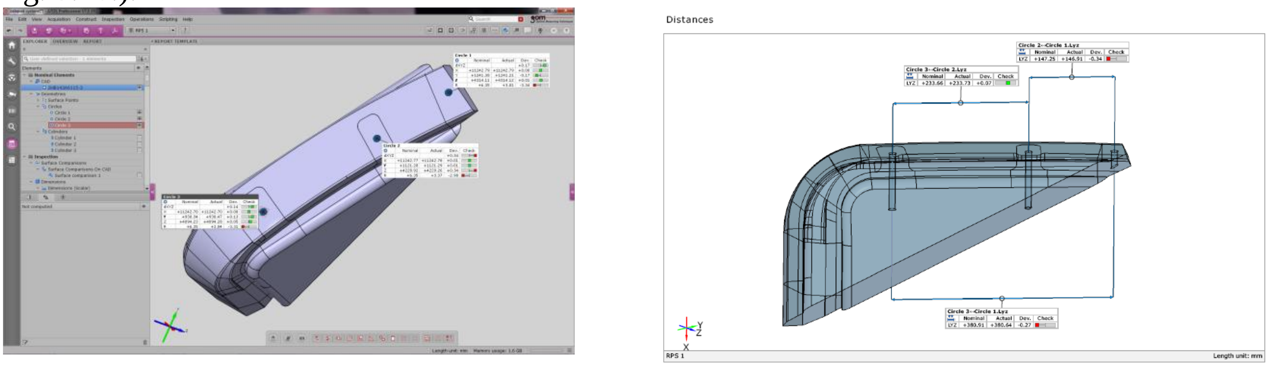

Fig.3.9. Position of the sample fixation hole and the deviations of these from the project

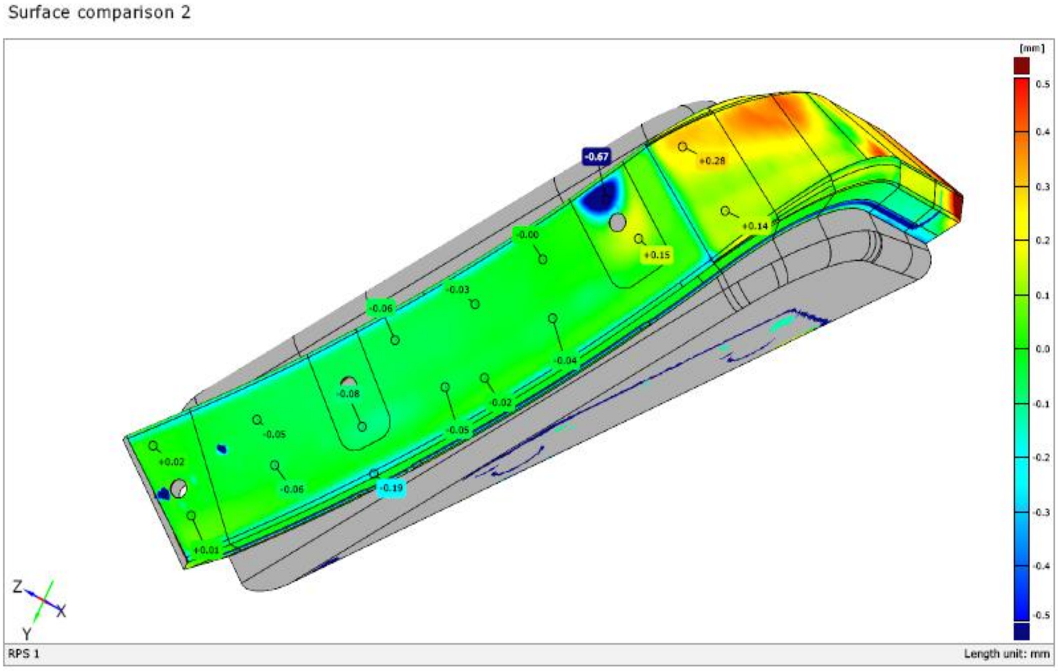

Fig.3.10. Deviations of the samples' active surface from the projected model

4. Verification techniques using the coordinate measurement machine for a sample (same from the scanning)

Different construction type coordinate measurement apparatus is used in aeronautic industry and in the astronautic industry for a very long time. Coordinate measurement machines can be three different types by basic construction (fig 4.1):

1. in console; 2. portal type; 3. pod type;

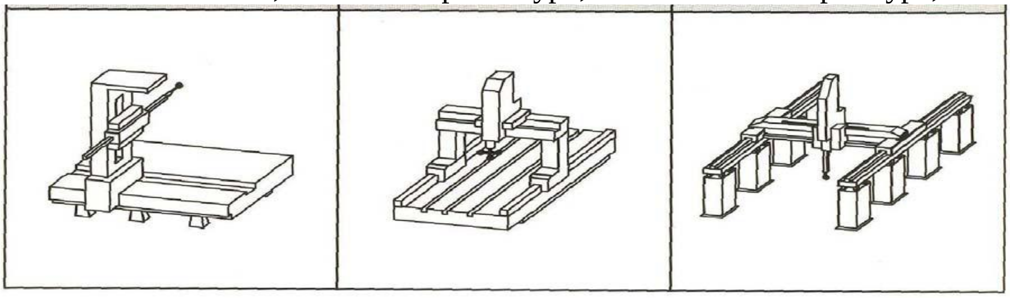

Fig. 4.1 Type of coordinate measurement machines

When we need to test with precision, construction components or heavy machines up to tons, pieces with more meters in dimension, then the bridge type of measuring devices fit the best, which are designed especially for high volumes.

In industrial production, coordinate measurement technique has found a stable place. Today, there is no piece of which dimension cannot be measured with machines of measuring coordinates.

Main advantages of the coordinate measuring machines are:
- measures dimensions, form and position of all the geometrical elements;
- reduces measurement time to a fraction of the time used with other machines;
- it is very flexibly adapted to changing of the dimensions and the type of the piece;
- can replace calibers and monoscope measuring devices;
- stages of the measuring process are registered (positions that are followed by the indicator) which in case there is an inspection for the same type of piece this will be done with minimal supervision on behalf of the operator, which leads to a better productivity.

Coordinate measurement machines (DEA – Digital Electronic Automation) fig 4.1 used in our case is a bridge type and has the following characteristics:

Dimensions of the measured piece on the three axes are:

Axe X 12590mm (length); Axe Y 1830mm (width); Axe Z 970 mm (height)

Precision of measurements 0.002m; Work temperature $(20\pm1)^{o}$ C; Humidity (60 ± 5)%

The checked piece is a sample (the same used at scanning) on which several profiles is pulled that are necessary to brace the airplane's fuselage (fig. 3.4).

Stages of verification measurements:

After launching the measuring machine and the initiation of it, the format of the projected 3D model is imported from CATIA/CAD in program of measurement that is installed on the computer after which the piece will be positioned on the measuring table so its orientation and position will ease furthermore the inspection process.

Having the piece positioned on the table of the machine, the usable indicators must be selected, these indicators are defined and calibrated in which the surface of the piece can be identified that contributes to the alignment for defining the new coordinate system of the piece in reference to the global one. Defining the new coordinate system is based on three chosen plates with the help of which it is precisely positioned.

The procedure for defining measurement surface, in case in which we have the CATIA/CAD model, is different from the one where we don't have this information. The element underlines this difference, it is the way in which we define surfaces and namely through selecting them directly from the CATIA/CAD model. In this way, the introduced model in the computing program defines the surface that need to be analyzed, this changing its color to yellow for an easier identification (fig.4.3).

Once the measurement surface is established, the points that will be touched are defined with the help of the mouse through a network that is in the established zone, in which the distance between 2 successive points presents the measurement step, method of realizing the measurement being completely automatic in all stages.

The result of the inspection (deviations) are analyzed in real time and are shown in the computers screen at each measured point of the piece through comparing the projected model. Exporting of data from the coordinate measurement machine's control program was done in a file in text format.

The software that operates the coordinate measurement machine does not permit modification of the coordinates (translation and rotations) and for this the projected model is transferred from the airplane's coordinate system to the machine's local coordinate measurement system through alignment of them after three work planes on the position in which the piece it is fixed for inspection.

Fig.4.2. Measurement machine in different stages of inspection.

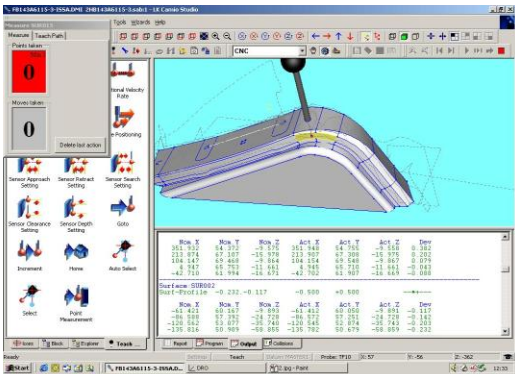

Fig.4.3. Surface for which inspection is needed

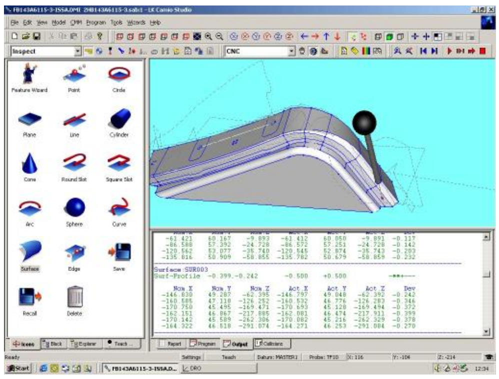

Fig.4.4 Software that operates the measurement machines in different stages of the inspection

The file is exported in text format

Surface:SUR002

Surf-Profile -0.237,-0.114 -0.500 +0.500 --*+---

Nom.X	Nom.Y	Nom.Z	Act.X	Act.Y	Act.Z	Dev
-61.421	60.167	-9.893	-61.414	60.053	-9.892	-0.114
-86.588	57.392	-24.728	-86.571	57.248	-24.728	-0.145
-135.816	50.909	-58.855	-135.782	50.674	-58.858	-0.237

5. Conclusions

Measurement systems in the industry, in the context of contemporary development and technology modernization, have a huge advantage in comparison with traditional measurement systems. Permanent quality control of the finished products and the progressive automatization will enforce the industry and the construction domain to use modern measurement systems, which come from the engineering measurement domain, of industry measurement techniques. This is applied in the most divers branches, of international standards, which obligates the companies from this profile to assume their own quality manual, capable to put in practice according to the requests.

Measuring is a process in which the measured volume is quantitatively compared to a reference volume of the same type. From the results of a measurement the following conclusions can be obtained:

- quality of the measured object, for example if the piece is in conformity or not, or if it can be corrected;
- parameters of the processing, for example if the process is adequate, the status of the machine tool, modification of processing parameters and tools can be adjusted;
- capacity of the supplier to manufacture products with the required characteristics according to the necessities.

Laser tracker has the advantage that permits bringing the own coordinate work system in the coordinate system of the airplane, in comparison with other coordinate measurement machines where the software does not permits the modification of the coordinates (translation or rotations) and this is why the projected model must be brought from the airplane's coordinate system in the local coordinate system of the measurement machine. Another advantage of the laser tracker is that it can be transported and can operate on a higher interval of temperature (0, +40^{o}C); they do not require acclimatization as the other DEA type coordinate measurement machines (that functions between 20±1^{o}C).

Today, measurement systems in the industry offer a variety of usage possibilities, in different branches of the industry, construction or other domains from the actual activity.

6. Bibliography:

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Useful websites:

www.leica-geosystems.com *www.innovmetric.com* *www.gom.com*