APPLICATION OF LASER-TRACKER IN THE AERONAUTICS INDUSTRY

Corneliu MOTOTOLEA PhD. Eng.- Tehnical University of Civil Engineering Bucharest, e-mail: cadconsultmcs@yahoo.com

Abstract: *In this paper will be presented the application of the laser-tracker, which is used in the aeronautics industry for the quality control of the subassemblies that are used in the assembly of the aircrafts.*

Keywords: *laser-tracker, aeronautics industry, millimeter measurements, quality control.*

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. The laser-tracker.

Laser-Tracker system represents a polar measurement system, especially developed for industrial application. The properties of the interferometer, which was established in the industry for quite some time, were enlarged towards a completely mobile measurement system that permits the measurement as a reflector, which moves freely, independently by a leading track (as in the case of the coordinate measurement machines). Three-dimensional capture of the coordinates can take place both during the movement of the machines and also on static target points. [2]

The main characteristics of the laser-tracker machine are:

- 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.
- Not stalls.
- It requires approximately 30 minutes warming up before measuring can be started.
- The coordinate system of the machine can be imported in any coordinate system (in our case in the coordinate system of the aircraft).
- The processed piece can overlap with the 3D model (if the model exists and was prepared in a CAD software) and in real time deflections can be determined without the necessity of performing other measurement processing.
- Can measure in a temperature interval of 0 and +40 ^{o}C (does not need acclimatization)

- To compare the measured model with the one projected the PolyWorks 10.0 software was used.

2.1. Reflectors used at the measurement.

As target marking the laser-tracker has many types of appliances for measuring:

- 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 15m (fig 2.3.).

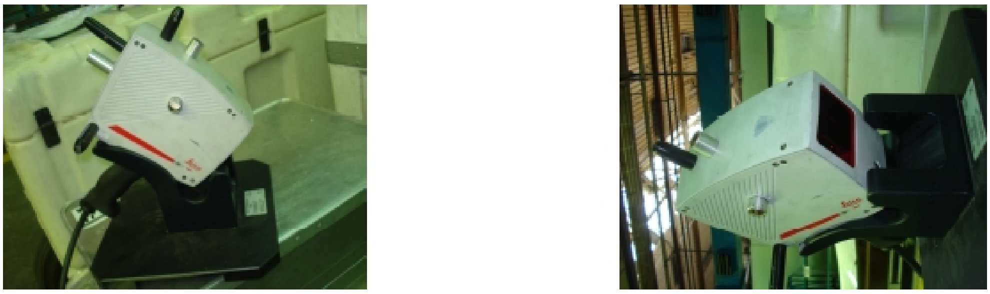

Fig 2.3. T-Scan Scanner

The advantage of the "cat-eye" is its high rotation angle, usable, in de $\pm 60^0$, while the triple mirror permits only one work domain of $\pm 20^0$. The measured values and given correction constants are reported to the center point of the sphere. The radius of the sphere is considered true offset constant. When scanning the surfaces as a result there is an offset surface, with a constant distance to the original surface. [2]

2.2. Experimental determination with the laser-tracker. Profile Pull Block for fuselage shell.

The application consists in determining the work surface for a pull block of the profiles from duralumin used at the fuselage of the Airbus A320 (fig 2.4). This block was built by ROMAERO out of steel having as an initial model a block made out of polycarbonate (that requires frequent reparations for work surfaces).

Fig.2.4. Steel Pull Block

To obtain processed active surface on block the following stages of work are required:

I. Obtain the work surface design of the aircraft that is introduced in the manufacturing process in 3D CAD format (in CATIA software in which the aircraft was designed with all its subassemblies).

The first phase (in CATIA) the outer surface of the profile will be used that will be drawn on the block to which the tolerances will be applied from the manufacturing process of the assembly on the aircraft fuselage profile. This area will be introduced in the data acquisition software (PolyWorks 10.0) where comparison will be made with the surface obtained from processing the steel block.

II. The laser - tracker is brought to optimal operating condition, to the environment temperature in which the work is performed (heating it).

III. Divide the area that is going to be scanned in strips of 10 cm - to reduce overlapping areas of the points scanned (fig.2.4.).

IV. After the device is in operating condition (after heating it), bring the laser-tracker working system in the aircraft’s coordinate system by aligning three known coordinate points (alignment plan - fig.2.5) imprinted on the block that is on its retaining system (which is measured with the T-Probe device)

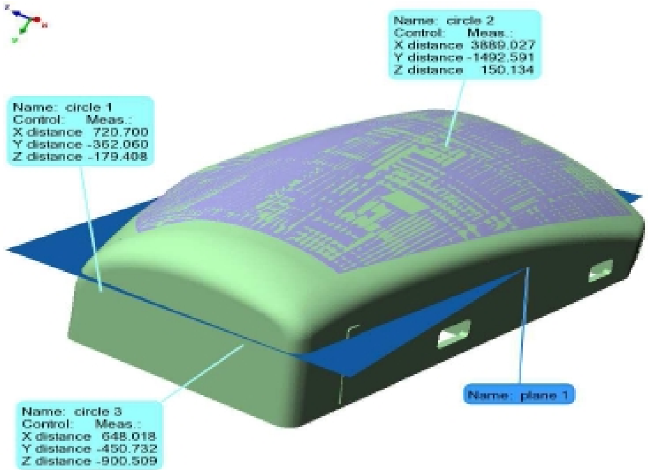

Fig.2.5. Alignment Plan of the Pull Block

V. With the T -Scan device the active surface work is scanned (which previously was divided into strips of about 10 cm to scan uniform and not to have overlapping of the clouds of points) (fig.2.4, fig. 2.7.).

VI. Since the T -Scan scanner and laser tracker must have permanent vision (fig. 2.6) it was decided to scan in two stages on both sides of the block. If the laser tracker loses visual contact with the T-Scan device the measurement is resumed from the alignment of the coordinate system (fig.2.5).

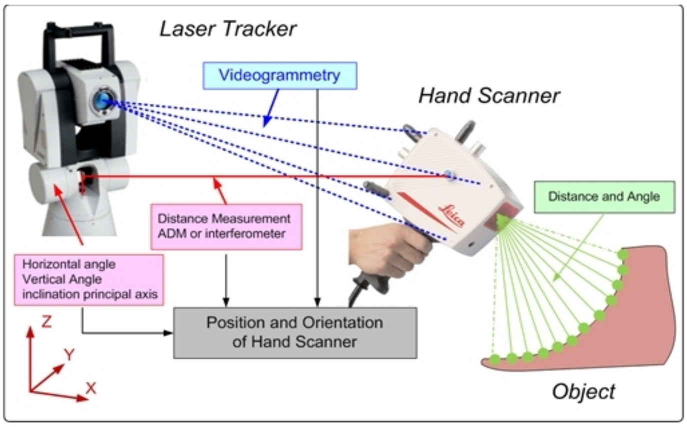

Fig. 2.6. Laser-tracker with hand scanner T-Scan. [1]

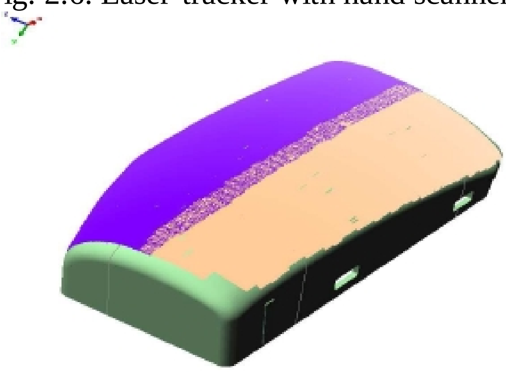

Fig.2.7. Scanned surfaces

VII. Point clouds partially overlap as a result of the measurements. After scanning a mesh type surface is generated by merging scan point clouds (fig.2.7.). To the resulting surface a precision alignment is performed (which is allowed by the software) with the designed surface obtained from the 3D model (taken from CATIA) of the profile to be achieved (fig.2.8.). If the measured section falls within the tolerance ranges then the active surface of the block can be used in the shaping of the aircraft's wing profile. If the measured section does not fall within tolerances range then areas where deviations from tolerance ranges appear are processed after they have been previously identified.

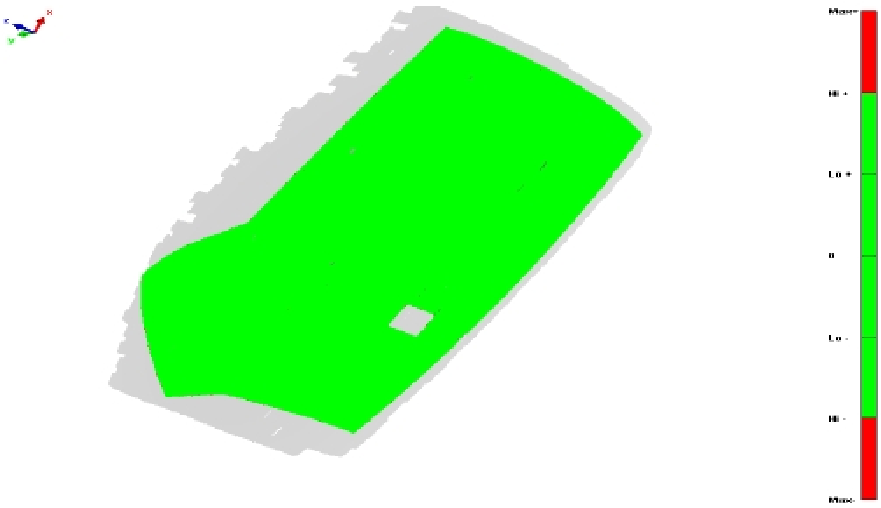

Fig 2.8.Scanned surface – representing results

Table 2.1 Scan results of the active block surface

Table Type	Data to Reference (Data Point)
Cmp Object(s)	200_1, 200_2
Ref	RA201
Cmp Angle	
HiTol +	0.350000
HiTol -	-0.350000
Err Dir	Shortest Distance
#Points	1574562
Mean	-0.000283
StdDev	0.071098
RMS Error	0.071099
Max Error	0.499712
Min Error	-0.499367
Pts within +/-(1 * StdDev)	1091995 (69.352302%)
Pts within +/-(2 * StdDev)	1501573 (95.364489%)
Pts within +/-(3 * StdDev)	1568026 (99.584900%)
Pts within +/-(4 * StdDev)	1573592 (99.938396%)
Pts within +/-(5 * StdDev)	1574089 (99.969960%)
Pts within +/-(6 * StdDev)	1574329 (99.985202%)
#Pts Out of HiTol	498 (0.031628%)
Surface Out of HiTol	0.024356%

VII. More detailed verification in some areas of the results of the performed determinations, in case in which is necessary, in can be done in sections, it is possible to be obtained from any areas of the controlled piece, on a suitable representation level, with the help of the data processing software. Some sections in the verified areas are presented below.

Deviations from the theoretic profile for the fuselage section to be within the tolerance range must be between ±1mm.

After the measurement it was obtained that:

- 49.786% of the surfaces fall within in [-0.35,0] mm interval
- 50.182% of the surfaces fall within the [0,0.35] mm interval
- 0.007% of the surfaces fall within the [-1,-0.35] mm interval
- 0.024% of the surfaces fall within the [0.35,1] mm interval

The measured block falls within the tolerance range.

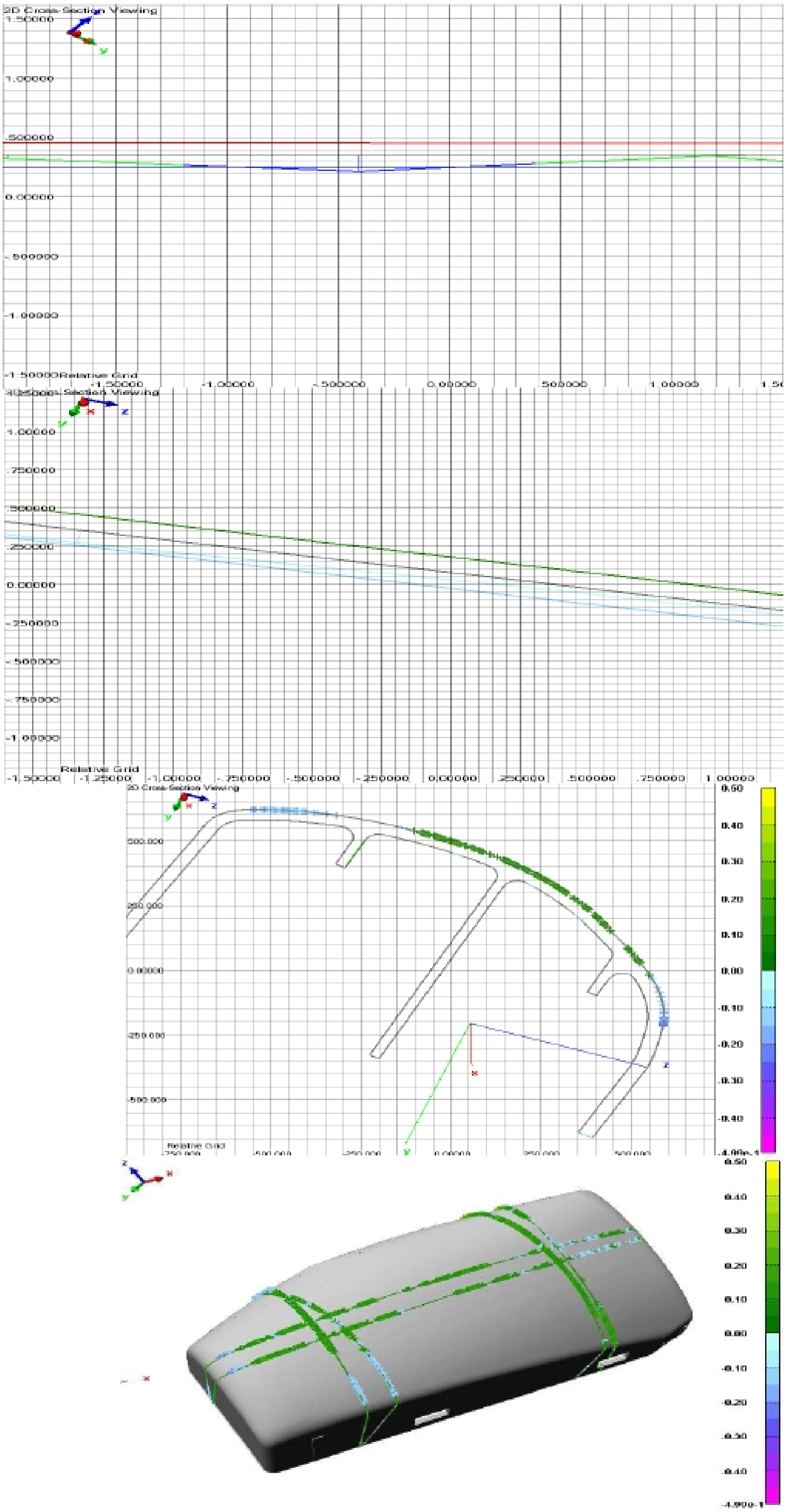

Fig.2.9. Deviations representation in various section

Table 2.2 Representing the deviation in sections

Cmp Dist	0.25							
Cmp Angle								
Err Dir	Short. Dist.							
Name	Index	Pints	StdDev	RMS Error	Max Error	Min Error	%Out HiTol	%Out LoTol
cross-section 1	1	905	0.090383	0.092534	0.248991	-0.248585	0.0000	0.0000
cross-section 2	2	1025	0.073174	0.083036	0.245634	-0.155299	0.0000	0.0000
cross-section 3	3	1794	0.076245	0.085906	0.246481	-0.248370	0.0000	0.0000
cross-section 4 (x=1402.592)	4	960	0.081028	0.081016	0.216597	-0.224467	0.0000	0.0000
cross-section 5 (x=2864.025)	5	1099	0.067077	0.112844	0.247465	-0.198008	0.0000	0.0000
cross-section 6 (z=-412.118)	6	3514	0.073666	0.080287	0.248166	-0.241469	0.0000	0.0000

3. Conclusions

Measurement technique, respectively the determination of the three-dimensional coordinates (3D), starting from simple deformation measurement cases, is used efficiently in many and diverse domains.

Measurement with laser-tracker is a process in which measured dimension is quantitatively compared with a reference dimension of a same type. From the result of a measurement conclusions can be drawn regarding the followings:

- quality of the measured object, example if the piece is suitable or it is not suitable, and if deviation can be corrected;
- the processing parameters, for example if the process is adequate, the status of the machine-tools, regulating the production process parameters, choosing the tool for processing;
- capacity of the supplier to produce products with the required characteristics

Advantages of using the laser-tracker:

- Can be used to measure the area of known coordinate points, to scan surfaces and the combination of these two, which makes this a complete quality control system of the pieces obtained as a result or during the processing.
- Allows importing its coordinate system in any coordinate system (in our case the coordinate system of an aircraft).
- Can be transported in an area where the products are processed, measurement of the pieces done even during the manufacturing process and it is not necessary demount/mount the pieces of the processing machines in order to perform intermediate verifications.
- Can operate in a large temperature interval (0, +40^{o}C) – does not need acclimatization.

Being a complex measurement machine the laser-tracker offers today lots of usage possibilities in diverse branches of the industry. This can replace old fashion machines as it would be measurement machines in coordinates, measurement systems with theodolite and laser scanners.

4. References

1- Rudolf Staiger - Push the Button – or Does the “Art of Measurement” Still Exist? International Federation of Surveyors Article of the Month – June 2009, p. 6/17 ;

2- Mototolea Corneliu - Comparative study regarding static and dynamic measurement methods of determining the shape of the products/piece in order to establish standards for quality control Scientific research report no.3, p. 21-36, 2013