Identification of joints positions of the landing gear mechanism using laser measurements

INTRODUCTION

Laser 3D scanners are becoming widely used in many industrial branches. They can be used for prototyping, molds design, special tools creation, reverse engineering, quality control. Also in medicine have been used in the generation of digital 3D files body parts or prosthetic. They are also used in diagnostics to analyze the wear of machine parts, deformation analysis of composite structures, creation of digital objects for FEA analysis.

1 DESCRIPTION OF THE MEASUREMENT METHOD USING THE REVSCAN 3D LASER SCANNER

The measuring system consists of a handheld 3D laser scanner REVscan (Fig. 1) supplied from an external source of 220V connected to the efficient laptop with VXelements and Geomagic 3D software.

![REVscan 3D laser scanner](image)

After connecting 3D scanner to the laptop and to the power supply is necessary to perform the calibration. For this purpose attached to the scanner calibration plate was used, which was scanned from several directions according to the instructions displayed by the program VXelements on the

---

1Politechnika Krakowska, Wydział Mechaniczny, Instytut Konstrukcji Maszyn, mail: brewczyn@mech.pk.edu.pl
2Politechnika Krakowska, Wydział Mechaniczny, Instytut Konstrukcji Maszyn, mail: tora@mech.pk.edu.pl
laptop screen. Calibration is used to eliminate the influence of thermal expansion. The system knows the distance between markers on the calibration plate and the program will automatically calculate the distance from the file scan and during measurements makes the appropriate corrections until next calibration in different temperature.

Next step is preparing the examined object. Special circular marker must be placed in such a way that the scanner at any time of scanning (distance from object 150 to 450mm) sees at least 4 markers placed not collinear. Markers can’t be placed at distances of less than 30mm from each other. During scanning it is possible to append additional markers if necessary. The program will automatically bind them together. Subsequently is performing a complete scan (Fig. 2).

![Fig. 2. Scan of the main landing gear with markers and reference system before cleaning the mesh](image)

The program automatically places the reference system at the time when the scanner sees the first 4 markers. All the progress in scanning and the results will be displayed in real time on the laptop screen.

Depending on the size and complexity of the object the scan can be performed with resolution of 0.2mm to 2 mm. The software automatically clears the grid of points received on each other so that it does not overlap (this allows later exports to ANSYS Workbench FEA). Two intersecting laser lines are projected onto the object and are observed by two cameras. The scanner captures up to 18 000 points/s with accuracy declared by the manufacture equal 0.05mm.

2 IDENTIFICATION OF GEOMETRICAL PARAMETERS

To identify the main geometrical parameters Geomagic 3D software was used. It allows to insert in a selected cloud of points geometrical elements such as line, plane, cylinder, cone, cube and sphere.
This program also gives the characteristic dimensions of the inserted elements and their position in space in scanners coordinate system. This enables finding the dimensions of parts, axis positions of rotation (Fig. 3a, 3b) and the ball joint center in the main reference system. These data allows to create precise virtual kinematic model of complex mechanism.

Fig. 3a. Wheel and a fragment of the landing gear with white markers on it

Fig. 3b. Model created by the scanner software with cylindrical element inscribe in axis
3 INFLUENCE OF THE TYPE AND COLOR OF THE OBJECT SURFACE ON THE MEASUREMENT RESULTS

The scanner uses laser light therefore it has problems with scanning shiny objects. During the scanning of objects containing even small shiny elements reflections appear. They are visible as suspended in the air nonexistent points (Fig. 4) which obscures the digital model.

**Fig. 4.** Landing gear fragment with visible on existent points suspended in the air arising as a result of the reflection of the laser light from the shiny surface

The scanner cannot scan the hard to reach areas (Fig. 5a, 5b), which are available using the measuring arm. This is due to the fact that the scanner (Fig. 1) on the bottom has a laser lines emitter. Those crossing laser lines must be visible at all times by the two cameras placed in the upper part. Because of this the scanner is not able e.g. to measure the depth of blind holes, observe small gaps or detect surface imperfections.

**Fig. 5a.** Scanning interior and exterior of the profile

**Fig. 5b.** Object captured by the scanner
When scanning objects with which we want to mapping surface texture or minor faults (Fig. 6a, 6b) scanner fails because of the relatively low resolution (0.2 mm). Multiple scans of the same area does not condense measurement grid because the program automatically removes additional mesh points to make it uniform, in this case, this is disadvantage of the software.

Color of the scanned surface also has influent on the results. During scanning interesting correlation was observed. Because laser light is absorb in different way according to the surface color, the scanner incorrectly evaluates position of this surface. The darker the surface, the greater the distance is observed by the scanner (Fig. 7a).

![Test pattern](image)

Fig. 7a. Test pattern

Black parts of the test pattern are averagely 0.09mm seemingly further from the scanner than the white fragments (Fig. 7b).
RESULTS

During the measurements of the landing gear the 121 markers were used. When scanning in 2mm resolution, 557,021 points of landing gear were registered. After cleaning 451,248 mesh triangles obtained which can then be exported to the ANSYS Workbench. When scanning only major joints at a resolution of 0.2 mm 4,249,140 points was achieved that gave 3,568,256 triangles. All axes positions and orientations were determined.

During examination the influence of the color on the measurement 12 marker was placed. When scanning in 0.2mm resolution, 3,595,388 points were registered. Average imaginary distance between white and black parts of the test pattern was 0.09mm.

CONCLUSIONS

Use of handheld 3D laser scanner REVscan allowed finding characteristic points of the main landing gears, the rotation axis, the coordinate of the ball joints and the dimensions of the links. The obtained results will be used in future work to create a model that will enable the kinematic analysis of the mechanism movement. It will also be possible to analyze the impact of parts accuracy and installation performance on the mechanism operation.

It is important to keep in mind the limitations in use and influence of the tested surface type and color. It is also important to perform calibration every time before proper measurement to compensate the influence of thermal expansion.

Abstract

The article contains a description of the noncontact method of geometry measurement using handheld 3D laser scanner REVscan with a step-by-step guide. The test object is MIG-29 aircraft landing gear. During the analysis performed a complete scan of the landing gear with a resolution of 2.0mm (accuracy of 0.05 mm) and a scan of critical points with a resolution of 0.2mm (0.05 mm accuracy). Subsequently an attempt to determine the position of characteristic points of connections, joints and links dimensions by editing the resulting cloud of points. During measurements has been shown the advantages, disadvantages and limitations in the use of noncontact method using 3D laser scanners. Influence of type and color of the object surface on the measurements was observed. Additional research were performed to examine this phenomenon. Collected data was used to find characteristic point of landing gear in main reference system. VXelements software was used for calibration, configuration of the scanner and collecting data. Geomagic 3D software was used for extensive
Streszczenie

Artykuł zawiera opis bezkontaktowej metody pomiarów geometrycznych przy użyciu ręcznego laserowego skanera 3D REVscan wraz z opisem procedury pomiaru. Obiektem badanym było podwozie samolotu MIG-29. Podczas analizy wykonano kompletny skan podwozia lotniczego z rozdzielczością 2.0mm (dokładność podana przez producenta 0.05mm) oraz skan kluczowych punktów z rozdzielczością 0.2mm (dokładność podana przez producenta 0.05mm). Następnie podjęto próbę ustalenia pozycji charakterystycznych punktów połączeń oraz długości ogniw przez edycję chmury punktów. Podczas pomiarów wykazano zalety, wady oraz ograniczenia w stosowaniu bezkontaktowej metody pomiaru z użyciem laserowego skanera 3D. Został zaobserwowany wpływ rodzaju i koloru badanej powierzchni na pomiary. Dodatkowe badania zostały wykonane w celu zbadania tego zjawiska. Zebrane dane posłużyły do znalezienia charakterystycznych punktów mechanizmu podwozia lotniczego w głównym układzie odniesienia. Oprogramowanie VXelements zostało użyte do kalibracji, konfiguracji skanera oraz zapisu danych. Oprogramowanie Geomagic 3D zostało użyte do szerokiej obróbki danych.

REFERENCES

4. Lemeš S., VALIDATION OF NUMERICAL SIMULATIONS BY DIGITAL SCANNING OF 3D SHEET METAL OBJECTS, ph.d thesis, UNIVERSITY OF LJUBLJANA Faculty of Mechanical Engineering