OPTICAL ANALYSIS OF FAILURE OF COMBUSTION ENGINES ELEMENTS

Mirosław Karczewski, Krzysztof Koliński
Jerzy Walentynowicz

Military University of Technology, Faculty of Mechanical Engineering
Institute of Motor Vehicles and Transportation
Gen. S. Kaliskiego Street 2, 00-908 Warsaw, Poland
tel.: +48 22 6837754, fax: +48 22 6837754

Abstract

Methodology of analysis of damages of piston combustion engines by using 3D scanner enabling three-dimensional analysis of such damages was introduced in the study. The principle of the device operation and his investigative possibilities were introduced. Presented is a phased process of scanning. The possibilities of the method were analyzed on examples of the damaged pistons for this engine supplied by fuel with low octane number. Precision of the damage measurements were estimated. The piston is one of the busiest part of the engine. The effects of wear on its surface are irregular and difficult to quantify. Geometric shape changes are related to:

- *movement of material in the case of dry friction due to accidents,*
- *loss of material due to burnout,*
- *formation of carbon deposits.*

With the 3D scanner is possible to observe these processes and to quantify the resulting deformation. The measurement results can be edited in many different ways to connect them to present them in an accessible form. Moreover, data obtained in digital form, you can quickly send long-distance transport instead of the actual object which is costly and time consuming.

Keywords: *combustion engines, 3D scanning, piston failure, triangulation principle, poligonization*

1. Introduction

Progressive development of electronics and numerical methods enables more accurate analysis of physical processes and structural changes in a spatially three-dimensional objects in real time. The problem is the experimental verification of this simulation, or preparing data for calculations using the real objects. This requires the processing of dimensions and shapes of real objects in three-dimensional spatial image. Such possibilities have devices for scanning objects and spatial analysis of their shapes in three-dimensional space. Using three-dimensional digital image may be carried out further dimensional analysis and simulations. One area of application of spatial models is analysis of accidents, damages and failures, which effects can be presented as an image instead of a flat three-dimensional images or ambiguous descriptions.

The aim of this study was to present the possibilities and the results of the spatial scan method for failure analysis of vehicle components for example: the piston from compression ignition engine SW-680 damaged during its gasoline supply in the research of checking the multi-fuel properties of this engine.

2. Properties of the method

Among the various systems of non-contact 3D scanning for researches were used scanning system “ATOS” from GOM GmbH. The technology used in the optical system is used to digitizing objects primarily in the automotive industry, the reverse engineering, quality control

(control of the first piece, assembly, production and optimization tools, monitoring, control of supply), for archiving and visualization works of art and other technical objects. The basic advantages of this relatively new technology are:

- scanning and visualization of the whole object in 3D and its compatibility with CAD data, or other similar objects,
- rapid process of measuring,
- high resolution and accuracy.

The coordinates of points on a measured surface area are determined on the principle of triangulation. System consists of the projector which display a range of line stripes, whose image on the rough surface is distorted according to the shape of the surface (Fig. 1). Picture of stripes on the scanned object is recorded by two cameras mounted on a single beam – base of triangle. Vertices of the triangle are: the point on the plane (projected from the projector) and observation cameras, which measure the angle at which you can see the point. From simple geometry dependencies the X, Y, Z coordinates can be determined. In result the cloud of 4 million points for each single measurement performed at time 1 second is obtained.

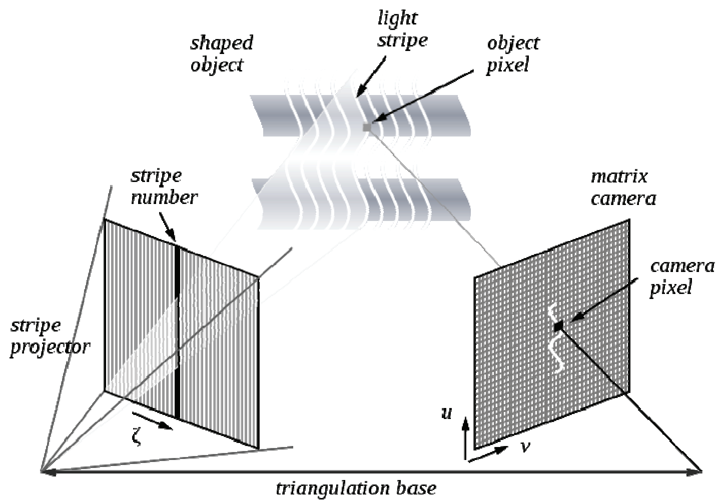

Fig. 1. Application of the triangulation principle in 3D scanning

Surface images are presented in gray scale, allowing to recreate depth. The accuracy with which the scanner can measure changes in the shape of the surface is 0,001 mm. Accuracy was achieved by using two cameras, which allows for high accuracy scanning (Fig. 2). During the measurements the user can position the scanning device on a stand opposite to the object. There is no need for additional devices changing the location of the object. Markers placed on the object or its surrounding serve as reference points, enabling the linking of images. The results can be presented as a triangle mesh, point cloud or as a cross – sections.

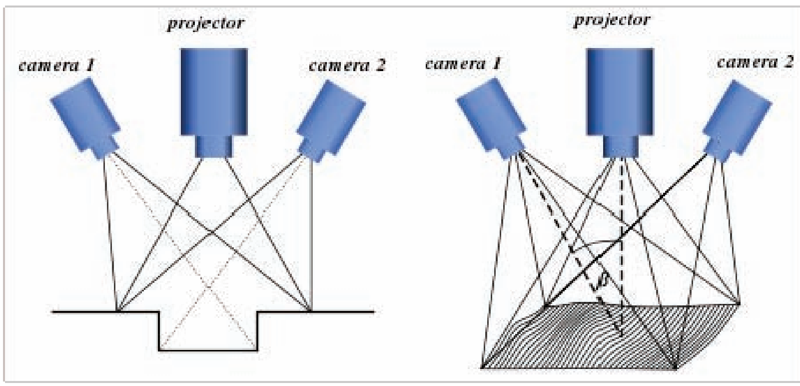

Fig. 2. Scanning using two cameras to increase scanning accuracy

When comparing images of objects with each other or with the data in the form of CAD models, color deviation map gives us graphically a large number of points deviation.

a) b)

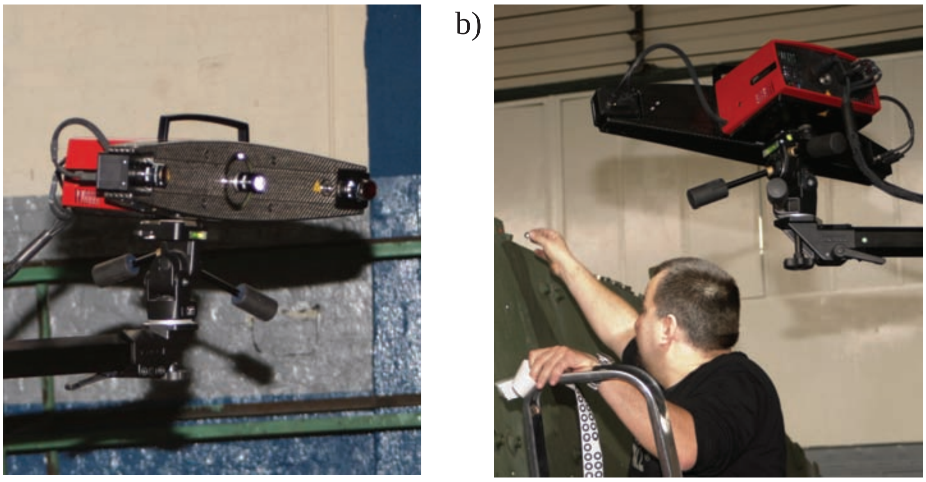

Fig. 3. Optical scanner: a) head of scanner with a projector and two cameras, b) sticking reference points on the scanned surface

The accuracy of the scan depends on the dimensions of space, which is scanned. The smaller the scan area, the greater the accuracy of the image. Dimensions of possible spaces are:

• for measurement with beam, 2000x1600x1600 mm to 250x250x200 mm,

• special configuration for small objects - 55x44x30 mm.

According to the chosen field the beam, in which each camera is placed, is selected (Fig. 3a). Since the scanning object is measured several times from different sides and different angles, the reference points are situated on the object, that allows orient surface in space and linking images together (Fig. 3b). The result is a series of scanning images which are combined together (Fig. 4a). Multiple surface scanning combined with moving cameras and scanning at different angles allows to eliminate the empty areas, which may not be visible due to large deflection area (Fig. 4.b).

a) b)

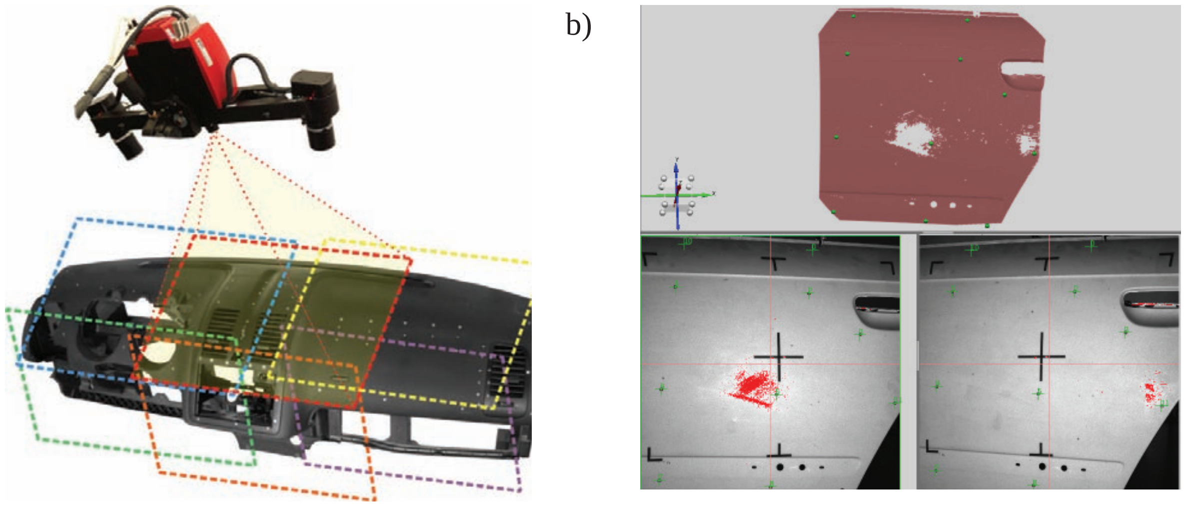

Fig. 4. Scan results: a) combining the surface images, b) discontinuity surface view of two cameras

The result of scanning is a number of "clouds" of points - one "cloud" for each image, which are transformed to a polygon editable mesh. This is done by poligonization, or processing the non-overlapping triangles in the mesh. Depending on the curvature of the mesh it has a different density (Fig. 5). This "poligonization raster" is matched to each other and re-calculated at the highest resolution. Overlapping areas are removed, and then "stitched" in a polygon mesh.

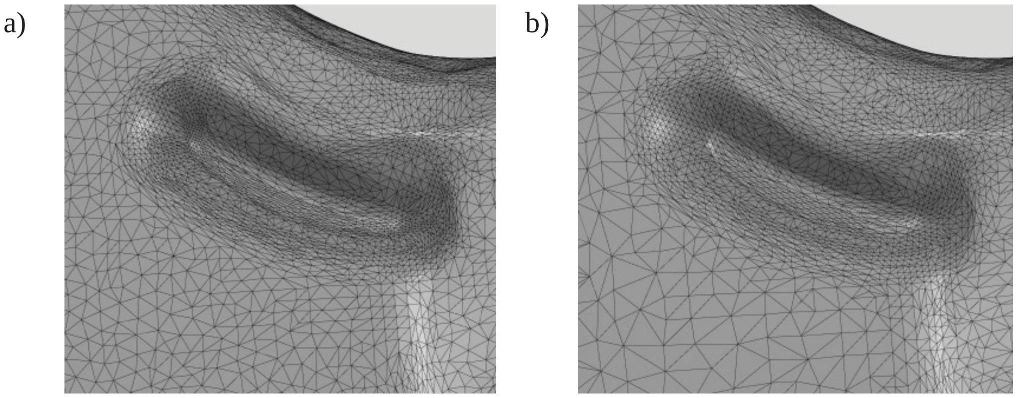

Fig. 5. Different grid density after poligonization, a) a dense grid, b) a rare grid

That cloud of points can be converted into a triangle mesh, which can then be imported into FEM softwares.

3. Scanning of the damaged piston

The effect of supply compression ignition engine with low octan number gasoline was significant damage of piston head and their lateral surfaces between head and the first ring. Effects could not be accurately presented on flat images, and measurements of the depth of damage were very difficult and inaccurate. These information were obtained by processing the piston image using a 3D scanner.

Before scanning the surface of the piston was covered with a layer of powdered chalk using an airbrush, protecting it from the image distortion due to reflections (Fig. 6b). Then the reference points were applied to the surface. Their role to enable the linking of individual scan images (Fig. 6c). while rotating the object on a rotary table with electric drive.

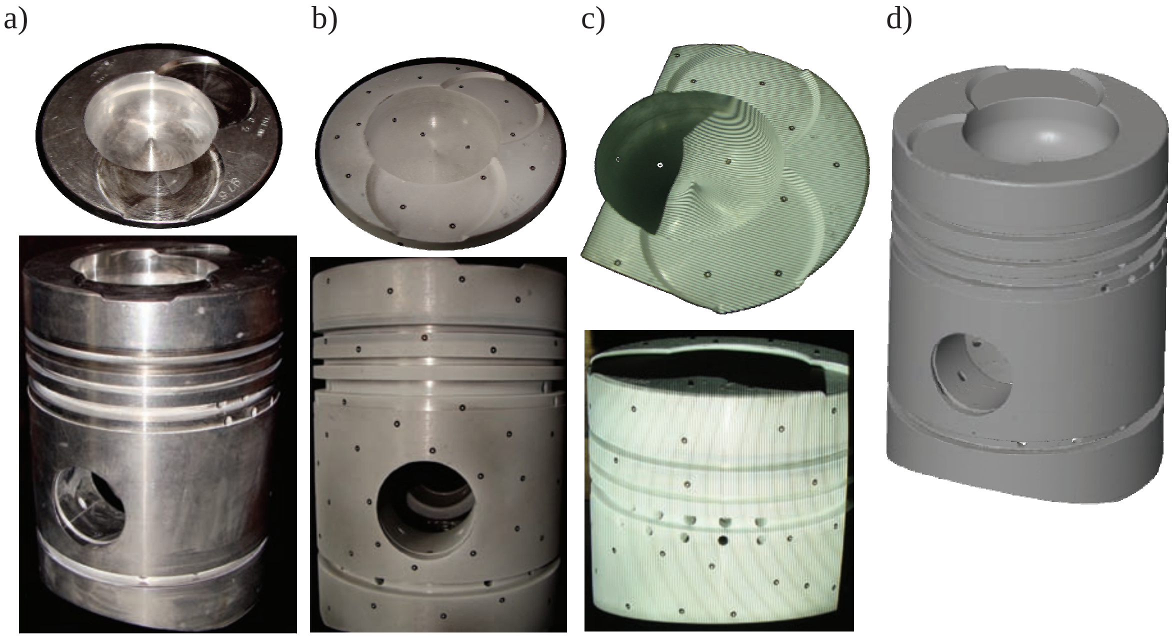

Fig. 6. Stages of piston scanning: a) prior to scanning, b) after tarnishing the surface and stick on reference points, c) illuminated by a projector during the scan, d) after the poligonization

Images of damaged pistons are shown in the figure (Fig. 7).

Color map visualizes measured deviations. Each object has origin in its lower left corner. Each point in the measurement is described by three dimensions. The fourth value is a deviation.

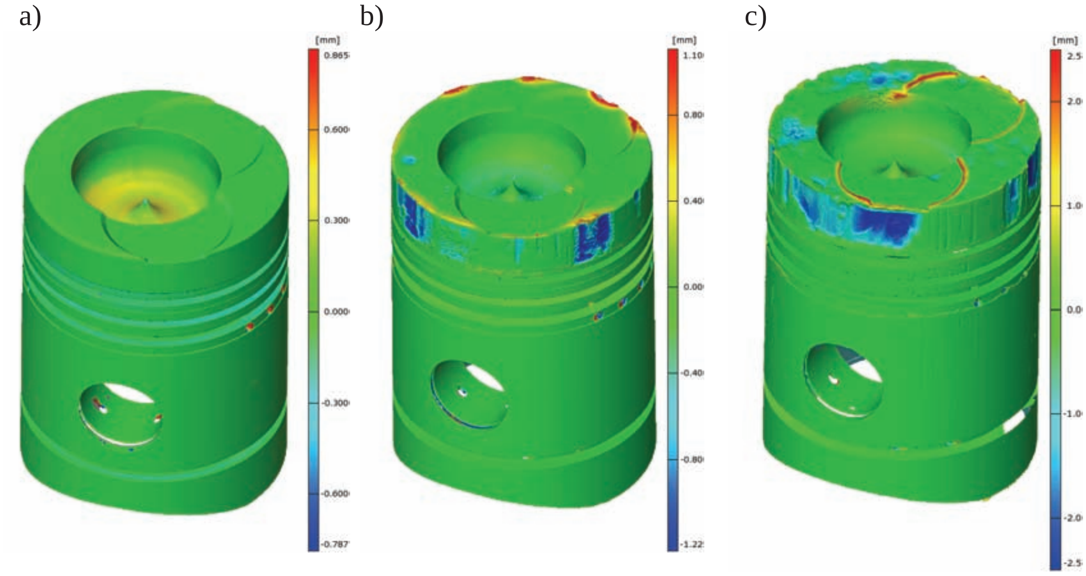

Fig. 7. The SW-680 engine piston: a) the new piston, b) the pistons damaged sides, c) damaged surface of the piston and piston head with burnouts

Low viscosity and density of low octane gasoline, combined with the injection of fuel into the combustion chamber, extend the period of self-ignition of the fuel and cause injection of fuel delivery to the piston head. The result was a knock on the piston head, piston overheating and the plastic deformation connected with the transmission of material from the piston to cylinder piston engine, particularly visible in figure 7c. As the result large deformation of the side surface of the piston were created, as well as hollows in the piston head.
Implementation of cross-sectional drawing in the plane perpendicular to the axis of the piston allowed to examine the depth of the damages and their position on the lateral surface of the piston (Fig. 8). Sections made at a distance of 5 mm from the piston head surface shows that the greatest hollows in the lateral surface of the piston head was found for the piston on figure 7c. Comparison of the cross - section to the new piston allowed to quantify the dimensions of hollows. In addition, you can see that the largest hollows occur near the axis of the pin, in places where the piston is not in contact with the sleeve. No contact with the sleeve, and thus the deterioration of heat transfer from the hot piston undoubtedly caused these changes.

4. Conclusions

1. Presented results demonstrate the usefulness of 3D scanning to analyze the deformation and determining the dimensions of many objects with very complex shapes and different sizes (from very small to large objects), whose analysis by the methods of contact would be very difficult and inaccurate.
2. The method allows the comparison of nominal and real values between measurement and numerical data, such as CAD model, point clouds or STL data.
3. Using the presented method may be carried out quality control, e.g.: measuring deformation, construction errors, verify the accuracy of cooperation between the elements by a virtual assembly in the software, as well as changes in surface shape due to damage.
4. This method allows you to create data to control machine tools to produce or copy on the CNC machining centers (e.g. milling machines) and Rapid-Prototyping Systems.

a) b)

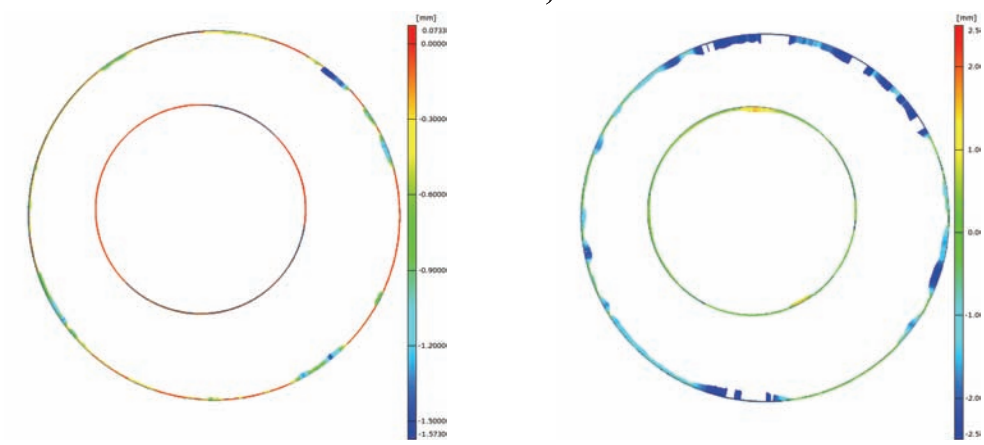

Fig. 8. Changes in profiles of the sidewall above the first ring, corresponding to the pistons in Fig. 7: a) the piston 7b, b) the piston 7c

References

[1] ATOS V6, Basic Training ATOS.
[2] Company materials GOM, www.gom.com.

Acknowledgements

This scientific works has been financed by Ministry of Science and High Education from found for science in the years 2009-2011 as the development project.