APPLICATION OF REVERSE ENGINEERING FOR IDENTIFICATION OF DAMAGE AND SUPPORT THE REPARATION OF THE VEHICLES

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Abstract

The methodology of the vehicle damage identification was presented in this article. Presented method used reverse engineering methodology for compare the shape of new vehicle, including CAD models of vehicle, and change of vehicle shape after damage. The method is based on three-dimensional scanning technology and photogrammetry. Identification of the defect is divided into two areas: the accurate reproduction of the vehicle surface damage and measure only changes of the base point's position. In a first method, scanning large areas of vehicle requires connection of the consecutive scanning images of the surface to an object stuck in a random reference points. They form a grid of completing successive scanning images with very high accuracy of the surface point's position. Measuring the angle and length between reference points, scanned surface is measured and digitized by software. However, do not always have to make as accurate measurements. In the second method there is measured only position of the vehicle base points. They may be dispersed very rare so if a damage is very small position of base points does not change. Sometimes it is reasonable to use the first and the second method together. For this purpose, the photogrammetric system is used in the first stage of the scanning surface. The vehicle specific places that are so-called base points are equipped with appropriate measuring adapters. Taking pictures of the object from these points programmatically determine the distance between reference points. This paper presents a method of surface scanning and processing on digital image scans of the vehicle for the calculation of standard deviations between the surface and the reference points. Presented adapters are used for measurement of base point's position. Examples of calculations results of base point's location in multi-wheeled AMV vehicle are described and illustrated in the paper.

Keywords: *motor vehicle, reverse engineering, photogrammetry, 3D scanner*

1. Introduction

Very often, it is need to restore damaged vehicle during operation processes. Random damage of the vehicle often cause deep local destruction. The consequence is change of an object shape significantly different with comparison to the new product. Generally, it is possible to specify the initial state of the object based on the engineering specification or measurement of new object. However, in order to assess of damage depth and choose the appropriate methods and technologies of repairing requires a basic knowledge of the state of the object after damage. Such possibilities offer reverse engineering [5].

Reverse engineering has many applications, including machines operation, quality control, computer simulation of processes around or inside the bodies, measuring surface areas, volumes and dimensions, industrial design, sculpture and many other areas where knowledge of the overall dimensions of object is required. Solid models in a digital form can be useful during reproducing existing objects, allow estimation of the extent of damage or wear. High accuracy of measures allows, for example, to assess the accuracy of the implementation of the newly produced elements, and thus to estimate the degree of machine wear used in production (for example stamping dies). Digital model replacing models formerly made by using clay, wood or other easily workable structural materials. Digital models are durable; offer plenty of simulation and improvement of the objects structure.

The simplest of reverse engineering techniques are measures by using mechanical measuring tools, and then create a digital model based on these measurements. If the shape of the object is very complicated then measures in limited points usually are not able to provide a sufficient amount of data to build the digital model [5]. It is necessary to use another method of expressing the surface. For reconstituted formation shape and surface mapping of the objects currently are used methods of scanning with use of structural light (white or blue), and laser scanning [2, 3]. These methods are very precise, with accuracy lower than 0.001mm, depending on used technology. The result of the measures is the set of simply surface elements, which display a very detailed image of the test object. However, it is not always necessary to restore the complete geometry of the test object. Sometimes mutual position of measured specific points so-called “base points” decides about the object operation and possibility of attaching additional equipment.

The aim of this study was presentation of the reverse engineering method to identify shape changes of the multi-wheeled vehicle such as AMV “Rosomak” in aspect of the repair process. It is large vehicle with various complicated shapes, what makes impossible to manually perform complex geometry measurements. Additionally, using of mechanical or laser methods requires adequate object preparation and application of the special measures equipment. Much easier is to use photogrammetric methods, presented in this paper.

2. Methodology of Vehicle Units Scanning

There are several systems of non-contact, three-dimensional objects scanning methods. During presented work realization scanning system "ATOS" made by GOM GmbH was used. This system is widespread in the automotive industry during the production analysis and quality control (control of the first piece, assembling, optimization of tool selection, monitoring reproducibility, quality control of supplied units, etc.). The main advantages of this technology are:
- possibility to connect smaller images and creation large digital models,
- the ability to compare the designated digital models with CAD data or images received from scanning of other similar units,
- high resolution and accuracy of measurements,
- fairly high speed of scanning.

Coordinates of points on the surface being measured, are determined on the basis of triangtion. Projector projects series of white and black lines on the scanning surface series. The image of projected lines on the uneven object surface is distorted (Fig. 1a). Two cameras mounted on a common observation beam with the projector (the measurement head), record the spatial lines image (Fig. 1b). Each point on the surface is the top of the triangle (projected from the projector). Observation cameras measure the angles at which is seeing the point. From the geometrical dependences are determinate three coordinates of each point (x, y, z). The result of this procedure is a cloud of up to 4,000,000 points for each measured area, performed in approximately one second.

Images of scanned surface are presented in shades of gravy. It allows visual reconstruction of picture depth. Changes of shape can be presented also by using colour scale. The accuracy of the surface shape measurement is estimated up to 0.001 mm, and it depends on the dimensions of the measuring field (length of the beam). If the scan area is smaller, then greater is accuracy of the image. There are possible three-dimensional measurement areas:
- measuring beams for scanning spaces from 175x140x135 mm to 2000x1600x1600 mm,
- measuring plates SO type ("small object") – designed for spaces from of 55x44x30 mm to 250x250x200 mm.

According to the dimensions of the scanned object and scanned field the proper measuring arm must be chosen, where are mounted observation cameras. During the measurements, the user can freely set the head on a tripod in front of the scanned object so that the system can recognize minimum three reference points.

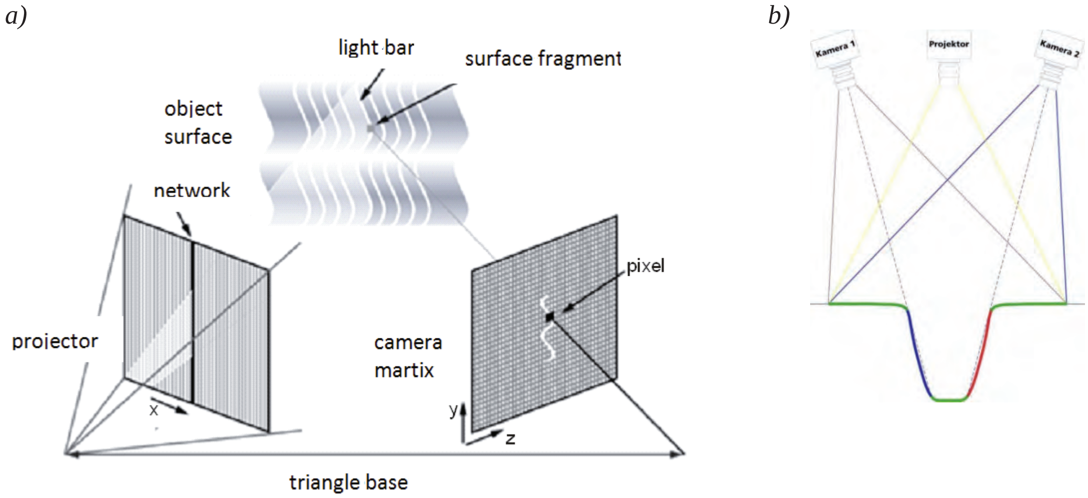

Fig. 1. The principle of three-dimensional scanning: a) the triangulation in three-dimensional scanning, b) mutual positioning of the projector and camera

Scanning the object runs in two stages. The first stage is a random distribution of markers on the scanned surface. Markers have the form of small white dots on a black background. They create reference points for connection multiple images obtained during scanning the object from different angles, and connect images after partial scanning of the large object that requires combining many images. Markers can also be placed on adjacent surfaces to an object, but surfaces and object position must not be change during measurement. Scanning of external and internal surfaces are possible with additional sensor, which has references points defining position of the special sensor tip.

Using the camera (Tritop system) can be done any number of object images prepared for scanning through large number of reference points. In the centre of Fig. 2a are visible reference points and length beams (yellow). Spatial locations of the camera outside the object are also visible. Reference points formed the points mesh on the scanned surface. This mesh is then successive "filled by" images of the scanned surfaces, which are joined into one solid object (Fig. 2b).

a)

b)

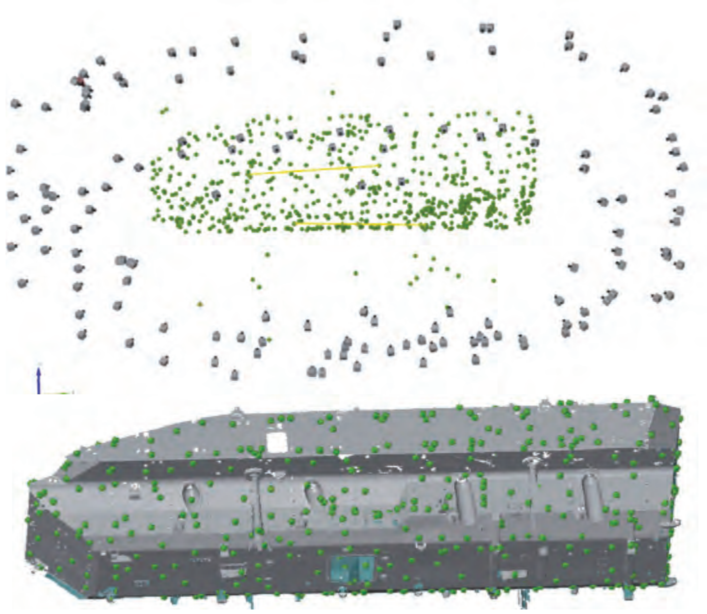

Fig. 2. Scanning stages: a) the image of markers placed on the surface and the positions of the camera around the vehicle, b) view of the vehicle body after scanning with markers

Due to the limited scope of a single surface "seen" by the scanner camera (1000 x 800 x 800 mm), measurements are necessary to be done on many camera positions with images overlapping. Measurements should be taken from different angles in order to reach the larger shape hollows. Images invisible to the camera looks in the pictures as blank "transparent" areas.

The result of scanning is a series of points "clouds" - one "cloud" for each image. These clouds are transformed to a polygon mesh by processing points to triangle mesh. Overlapping repeated elements are averaged. Depending on the curvature of the object surface obtains different mesh density. So prepared points cloud can be converted into a grid triangles imported to FEA programs. Images of objects can be compared each other or with a CAD model. Colour deviation map shows deviations for a large number of measuring points (Fig. 3).

Surface deformation caused by external factors (i.e. after a crash), can be evaluated by "applying" to the virtual plane and calculate the deviations between the scanned object and plane (Fig. 3a). The figure shows a vehicle body and frame deformation as a colours on the units surface. It is also possible to compare all scanned deviation of the vehicle with the CAD model of vehicle or a scanned surface image of another vehicle, which was adapted as a model object. Collared map of deviations made easier changes interpretation in vehicle shape. Additionally, it is possible to generate a cross-body cuts, show local variations and dimensions (angles, distances).

a) b)

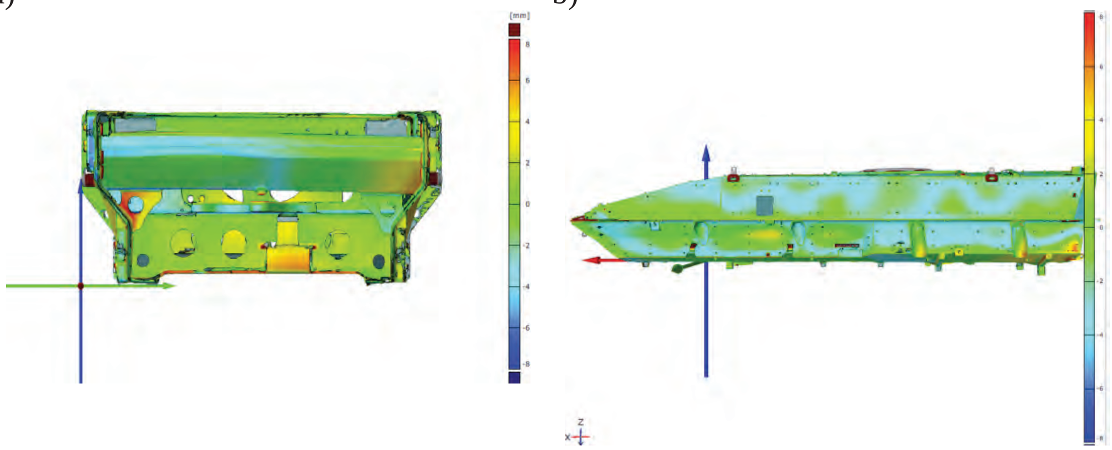

Fig. 3. Results of the transporter frame and body scan: a) the differences between the shapes of the damaged vehicle frame and the CAD model, b) the shape difference between the vehicle body of the new vehicle and the damaged vehicle

3. Methodology of base points scanning

The geometry of the vehicle body and frame plays an important role in the operation of the vehicle and during vehicle assembling. To the frame of the vehicle are mounted suspension components, and the same frame is connected to the hull in very specific points. Even a small change in the relative position of each attachment points, as a result of force impact or vehicle collision may adversely affect the controllability and stability of the vehicle and hinders montage of units. The deformation depth of the structure of individual vehicle parts determines the profitability of vehicle repairing, and above all, the possibility of its implementation.

For verification positions of the base points of a large object like a multi-axis vehicle, had to be applied system enabling easily measures a large number of base points of the structure. The system must be simple and easy to use in garages. For measurement of distribution of base points was used photogrammetric system TRITOP produced by GOM GmbH. It was designed to determination of the reference points for the system names ATOS. TRITOP system consists of the following main units:

– digital camera with a special lens,

- coded points used for the integration of individual images,
- measuring adapters mounted in base points,
- set of the certified pattern length,
- computer and software.

An important advantage of this method is ease measurement of base points' positions of large vehicles units (e.g. hull, frames, etc.). For measurements with using a measuring arm is needed to mount a long arm around the object and its movement along the rails. But too long arm would be deformed under the influence of gravity. Measurements using a laser device requires object placement on the turntable at sufficient distance from the laser. Application of photogrammetric method requires only vehicle lift to fit a camera under the vehicle.

Method of base points' measurement requires the use of special adapters with reference points. Set of these adapters have been developed at the Department of Engines, and Engineering of Motor Vehicles Operation MUT (Fig. 4). Photogrammetric system TRITOP with adapters and end gauge was used for the measurement of base points of the frame and the hull.

Fig. 4. Test adapters printed in 3D technology

To properly assess the geometry of the object, benchmark drawings are needed. It is usually the technical documentation of the units made by producer. With the aid of the documentation, it is possible to determine the starting base points and places of their measurements. In those points were placed special adapters, which were detected by the measurement system. This allows determining the distances between the base points.

a) b)

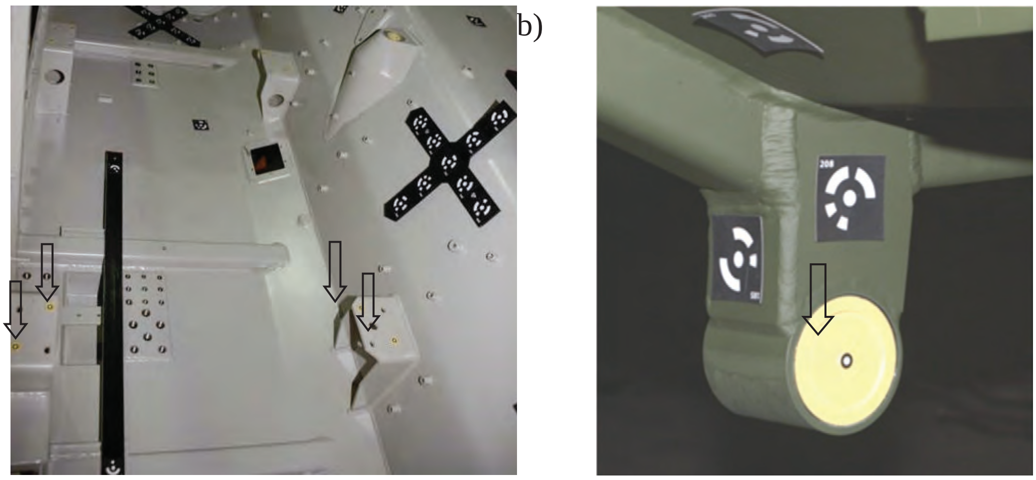

Fig. 5. The measuring adapters (under the arrows) and the length and angle patterns: a) adapters in the interior of body, b) adapter on the outside body

The characteristics of the AMV requires a large number of images. In the case of the presented object, 102 camera pictures were taken. Pictures were analysed by use of photogrammetric method. While scanning, attention was focused on reference points at each picture, what facilitates the combination of data from different photo shots. After proper definition of reference length, the current position of the base points was identified and compared with the nominal producer points. Next step was to determine the differences between these points.

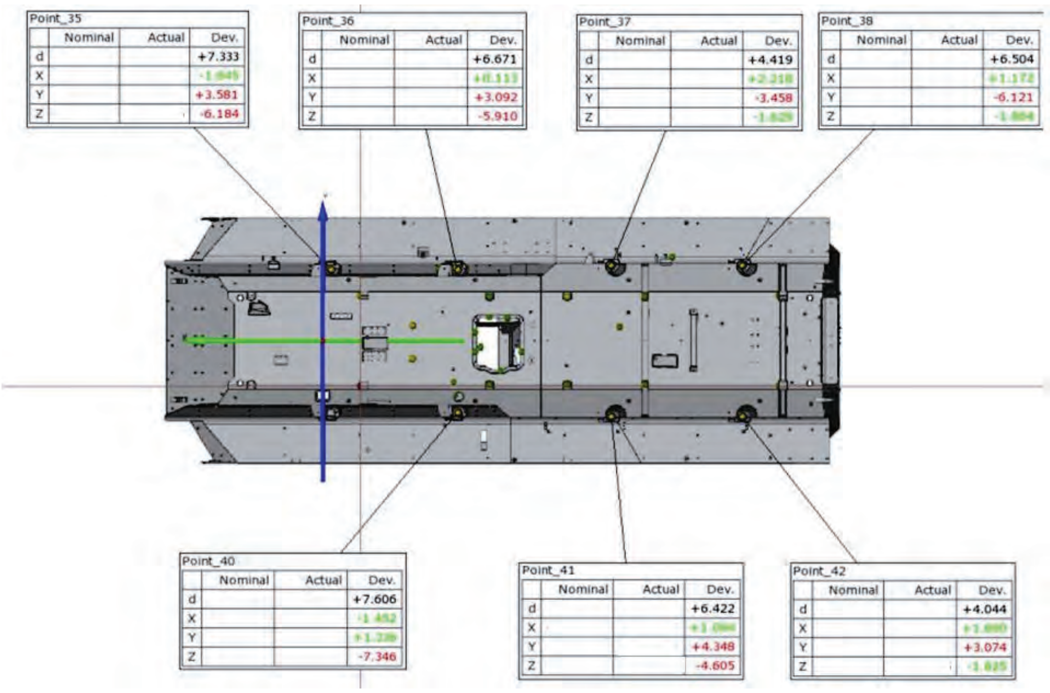

Fig. 6. Example of base points description for vehicle body

The system was used to assess the degree of deformation of the vehicle hull and a frame structures after damages as well as to assess the accuracy of repair of these units. Examples of documentation prepared after measurement the base points' position of the frame and hull are shown in Fig. 6 and 7. The table shows the values of the measured dimensions and reference dimensions, as well as the results of calculations relevant deviations.

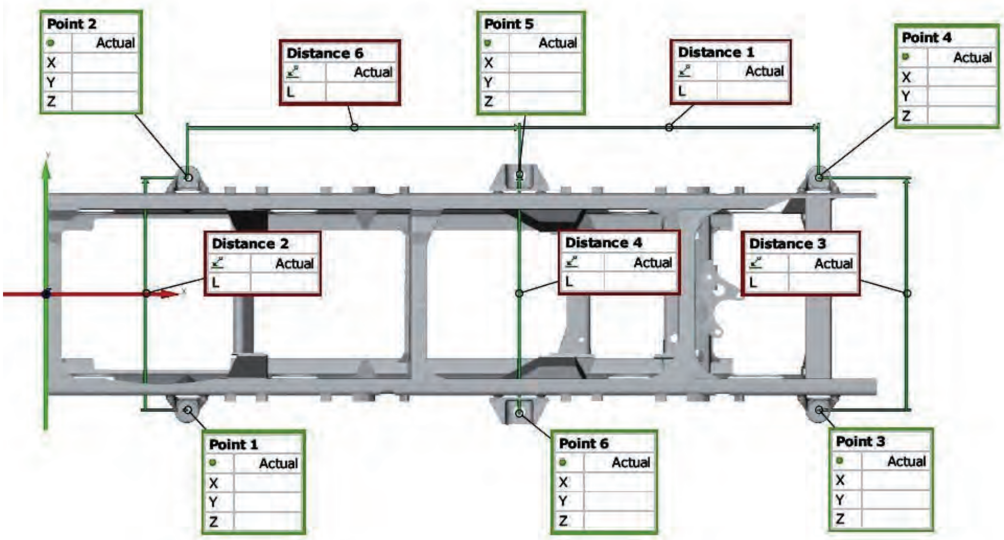

Fig. 7. Example of base points description for vehicle frame

4. Conclusions

1. Presented results show the high usefulness to scan three-dimensional analysis of deformation and determination of the dimensions, even very large objects with complex shapes, which analyse by the contact methods, would be very difficult or impossible. The method allows comparison nominal and real differences between measurement and reference data such as CAD models and "digital" planes.
2. Due to drawn up and applied set of adapters with the reference points, photogrammetric method can be used to identify of the base points position in large objects. These measurements can be made in any workshop without necessity of rotate scanned elements or use large size mechanical systems.
3. With use of presented method, quality control of measurements deformation can be implemented, repair technology of large vehicles, verify the accuracy of the mutual matching elements by using digital models of objects like vehicles, as well as changes in the surface shape due to damage. These measurements can be carried out during manufacture and operation of large dimensions vehicles. Measures can be performed in standard workshop premises, allowing only the elevation of the test object.

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