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AN APPLICATION OF CLOSE RANGE PHOTOGRAMMETRY TO COMBUSTION ENGINE AIR INTAKE MODELLING

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Abstract

Sometimes engine parts geometries in which flow is simulated are hard to define. Engine head ports or other intake parts have complex shape. Here with helps comes modern scanning three-dimensional (3D) technology such as photogrammetry. Thanks to the computer, science development photogrammetry is available for the regular engineer. One of the new, easy, user-friendly software is Autodesk 123D Catch, which takes photography straight from camera card and renders geometry in cloud. It makes engine improvement easiest. Ducts could be tested in virtual reality without destroying to check them on flow benchmark machines or dynamometer. First part of that study describes geometry-scanning process of engine air intake part using Autodesk 123D Catch software. Investigated part is a duct, which connect air filter with intake manifold. That is aftermarket pipe, which is designed to use in motorsport. This intake unit has a controversial shape, which is quite hard to measure. Obtained geometry shows useful accuracy. Second part of article shows investigation of flow in that duct using achieved geometry model. The analysis is done in computational fluid dynamics (CFD) Software Ansys Fluent. In opinion of author intake geometry is not proper. However finally conclusion is that showed process of testing engine ports is easy, useful and possible to done.

Keywords: *motorsport, CFD, simulation, combustion engines, reverse engineering, photogrammetry*

1. Introduction

Popularity of three dimension modelling in mechanical engineering has growing tendency. It is also visible in motorsport and vehicle tuning industry. In this field engineers usually has a finished product but they want to know how to change them, how to improve them. Here with help comes reverse engineering techniques. Sometimes getting the correct model is not easy and requires a time. In this case, modern scanning technologies could help. This article shows how could be analysed combustion engine air intake system with help of simply photogrammetry tool.

2. Photogrammetry

Modern scanning technologies are classified in two types, contact and noncontact scanning. Contact scanners are based on contact sensor, which follow the contours of the model. Modern contact devices are based on coordinate measuring machines (CMM) and have accuracy of estimate 0.02 mm. Measurement is relatively high time consuming.

Noncontact scanners are based on laser technology, optic technology or both of them. In this case, measurement is performed without physical contact and is much faster. However together with high speed comes worst quality of scan [5]. In industry, highly precise and popular method is a laser scanning.

One of noncontact method is photogrammetry. It is a field of technical science, which takes information about physical objects based on image interpretation. Photogrammetry method uses ray lights in passive way. That means that light is not projected by external device. Camera capture ambient light is reflected by the object [1]. Photogrammetry usually refers to topography investigation based on shoots from aeroplane. However author in this article consider *close range photogrammetry* which is also called *engineering photogrammetry*. In Poland, engineering photogrammetry is most popular in architecture and building constructions as a replacement of engineering geodesy. However, in highly developed countries it is quite popular in industry such as spaceship, aeroplane, rocket and automotive industry [3].

3. Photogrammetry software description – Autodesk 123D Catch

This investigation is based on 123D Catch Autodesk software. It is easy and free for non-commercial use photogrammetry software.

Big advantage of 123D Catch software is that it builds 3D models based on nonmetric camera pictures, which can be done with amateur photographic camera. There is no need to describe coordinate of photographic points (perspective centre).

However, user should care about photographic parameters. Picture has to be taken in good exposure time. Room in which photographs are taken should be lighted enough with soft light. On the object should be as low reflections as it is possible. It is important to set properly focus, because information about focus is saved in photo file. Basing on that information software can detect position of camera.

Obtained scan file model could be converted and imported to CAE Software. Producer is not telling what algorithm and information from photo this program use [4].

However, principle of work is taking photography from every side of the object. Required is about 50 shoots taken from two different heights [7]. Fig. 1 shows taking the photo schema, after one revolute height should be changed. Ready images are uploaded to the cloud, where 3D modelling algorithm identifies unique points on the object. Operating in cloud is another big advantage of software because it does not require a high performance computer and makes operation quicker. Although high-speed internet connection is necessary. Program automatically (based on photographic parameters saved in photo files – EXIF) can find position of the camera. Basing on that information software is able to generate 3D mesh. Disadvantage of this software is that user has to scale a model to proper dimensions and commonly change the coordinate system.

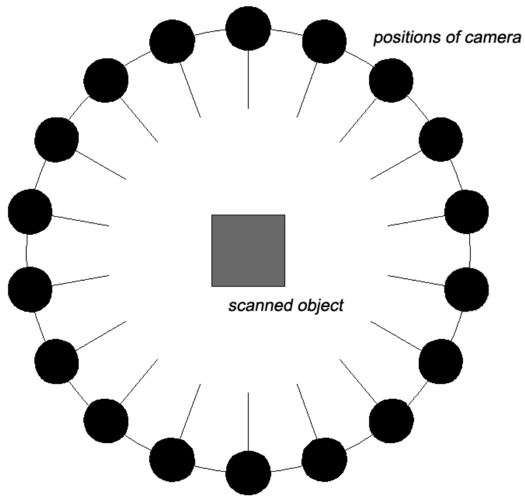

Fig. 1. Photographic process schema

4. Tests

Photogrammetry was done on the special table with adjustable revolving arm. Table had a special mat with a pattern, which makes easier identification of camera position in each shoot. From the same reason, recorded object has been stuck with coloured stickers. Photographic record was done with Nikon D80 nonmetric, amateur, CCD image sensor, photographic camera (resolution of 3872x2592 – 10 million pixels) with Sigma 18-50 mm f/3.5-5.6 DC Autofocus Zoom Aspherical Lens. To avoid reflections was used circular polarizer Fujiyama DHG Circular P.L.D 58 mm.

Photo was taken with ISO 400; exposure time 1/40 s; focal length 18 mm, aperture f/6.3 without flash light.

System 123D Catch did not offer calibration of cameras, but results show that automatic calibrations in 123D Catch software are good enough.

Fig. 2. Test Stand (without camera)

5. Intake geometry

Investigated part is a duct, which connect air filter with intake manifold. It is designated to the Honda B-series engine. Although it is not original manufacturer design. That is aftermarket part dedicated to motorsport. Producer claim that this intake increase performance.

The duct has a controversy, characteristic design (Fig. 3). Interesting is fact that it is fast going wider after air filter and then going even more narrow. Part is also bended to fit in engine bay. All of that makes it quite hard to measure and model but interesting in a CFD analysis point of view.

To improve geometry to both end was added, a cylindrical shape volume. Intake geometry directly from photogrammetry software has not ideal rounded ends.

Fig. 3. Real intake unit geometry (lower) [8] versus obtained geometry (upper)

6. Computational Fluid Dynamics analysis

Geometry was meshed and analysed with Ansys software. On the inlet of the intake, port was set atmospheric pressure (101325 Pa). On the outlet, side was set under pressure. Viscosity model, which was use, is a k-epsilon. Temperature is 300 K. Volume from which the air is inducted is a sphere.

At the XZ coordination cross section can be seen that volume is not efficient used. The edges are going wider but close to them is formed area where the airflow is equal zero. Vena contracta effect is typical to flat-ended pipe [2]. Probably shape of the intake has more sense if vena contracta effect would be eliminated by not flat ending but e.g. elliptical.

At the YZ view is also visible vena contracta and that the volume is not used in efficient way. In the middle part of intake duct in upper part flow is really low, because of that widening in the middle has no sense. Author draws attention at the efficient use of geometry because volume of that intake duct is relatively high. High cross section area (or diameter) of intake ports decrease dynamic effects which take part in air intake system and help to increase volumetric efficiency [6]. Probably this part could be optimized to reduce volume but maintain similar discharge coefficient and in this way obtained better volumetric efficiency of combustion engine. Some Internet sources and dynamometer tests shows improve of performance. However probably that increase of power results from decreasing flow resistance and shortening of the duct but it could be much higher after optimization.

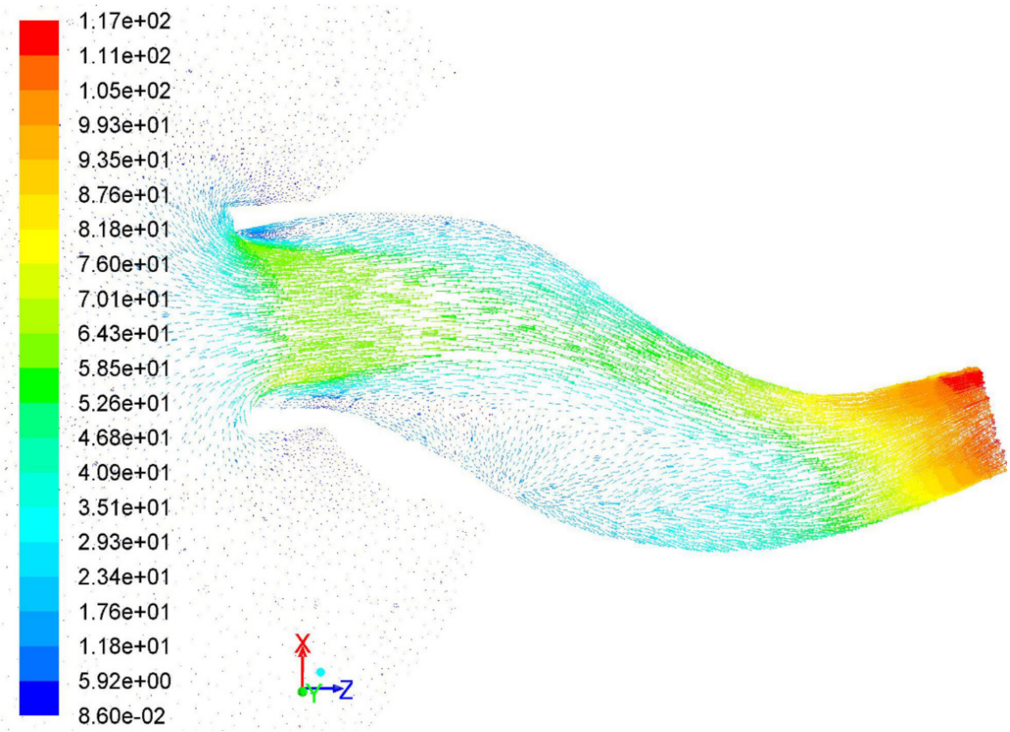

Fig. 4. Velocity vectors at X-Z coordination system; outlet pressure 92114 Pa

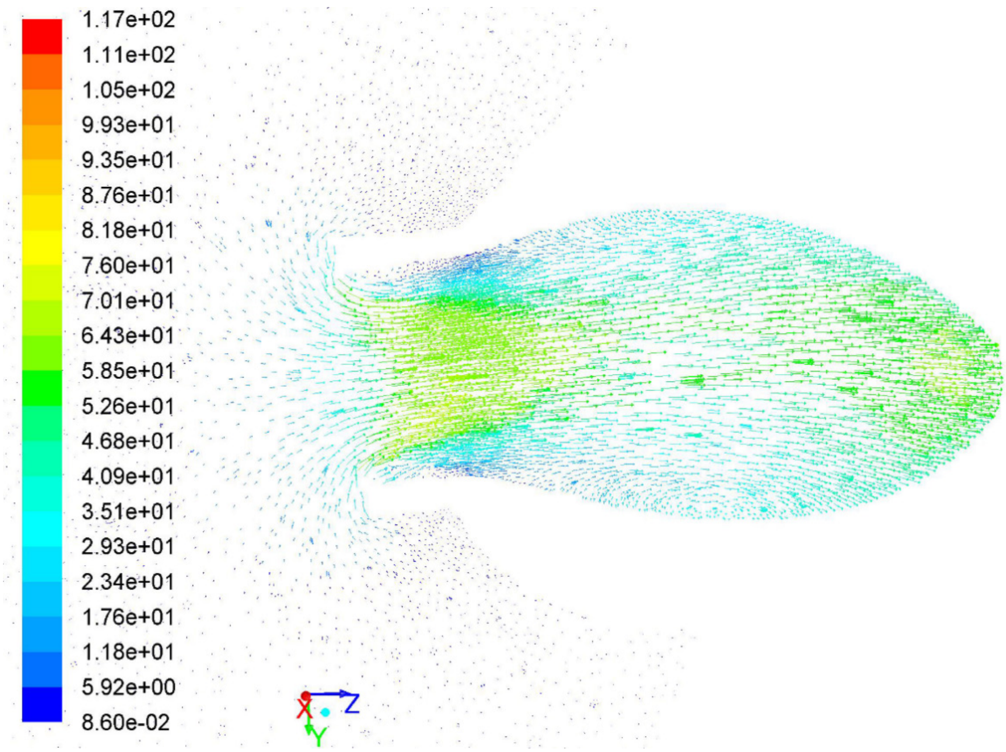

Fig. 5. Velocity vectors at Z-Y coordination system; outlet pressure 92114 Pa

7. Conclusion

Author proves that showed process of intake system testing is useful. Even simple and fast measurements could show weakness of engine parts. Sometimes there are tasks where high accuracy is not obligated. In this cases CCD nonmetric photo camera photogrammetry appears to be precise enough.

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