DE GRUYTER OPEN

ADVANCES IN MANUFACTURING SCIENCE AND TECHNOLOGY
Vol. 39, No. 2, 2015
DOI: 10.2478/amst-2015-0011

ANALYSIS OF THE ACCURACY OF RECONSTRUCTION OF THE GEOMETRY DRIVING WHEEL OF GEAR PUMP WITH APPLICATION OF CATIA SYSTEM

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S u m m a r y

Modern methods of design and manufacture of gears are based on Computer Aided Engineering Systems. This article presents one of the methods to analyze the accuracy of mapping geometry of the model of driving wheel of gear pump designed in CATIA v5 System. Comparison of the accuracy of mapping of the geometry of the hybrid model has been performed with the source model of gear (model .stl format).

Keywords: CAD, cylindrical gears, accuracy analysis

Analiza dokładności odwzorowania geometrii koła zębatego pompy zębatej z zastosowaniem systemu CATIA

S t r e s z c z e n i e

Podstawą nowoczesnych metod projektowania i wytwarzania kół zębatych są komputerowe systemy wspomagania prac inżynierskich. W pracy przedstawiono jedną z metod analizy dokładności odwzorowania geometrii modelu koła zębatego pompy zębatej w systemie CATIA v5. Przeprowadzono porównanie dokładności odwzorowania geometrii modelu hybrydowego ze źródłowym modelem koła zębatego (model .stl).

Słowa kluczowe: system CAD, walcowe koła zębate, analiza dokładności

1. Introduction

Reconstruction the exact numerical model of gear is a complex task. Although, the modelling teeth geometry of the cylindrical gear is described in numerous papers [1-5], however, taking into account all conditions that can meaningful complicate the mapping process of teeth geometry. The article presents analysis of the accuracy of mapping the geometry of the damaged driving wheel of gear pump unit (Fig. 1, 2). Research model was straight external cylindrical gear, which served as a draining gear pump in the engine lubrication system so-colled *dry oil sump*. It is a *positive – displacement pump*.

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Fig. 1. Positive – displacement gear pump

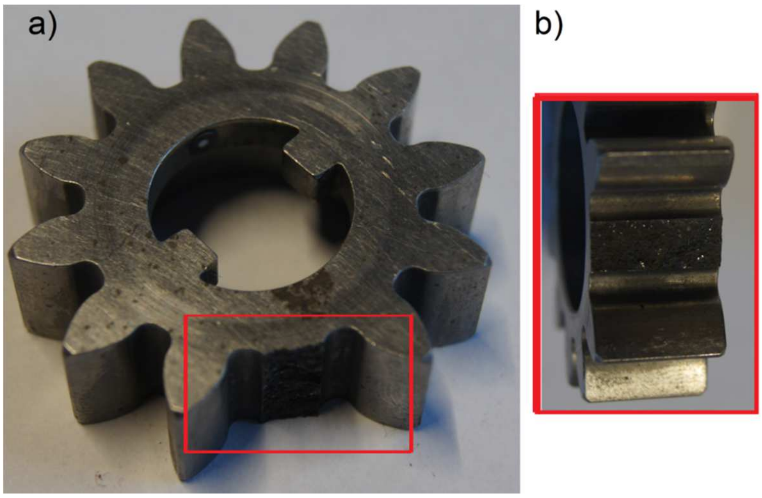

Fig. 2. a) Damaged gear (driving wheel) b) decrement by damaged tooth

2. Methodology of reconstruction of damaged gear geometry

Reconstruction process of geometry was carried out for each of the two gears, because the cooperating wheels of gear transmission are exchanged in pairs, for steady wear, lapping and mating integration. Recovery process of geometry of single gear in industrial practice (e.g.: lack of technical documentation) is not performed. The reason is the inability to determine the actual geometry, high-grade work based on the original calculation.

In a replica of such gear some data is not fully identified, e.g.: *addendum modification coefficient*. That is why a seemingly simple problem becomes much more complex.

The main stages of methodical approach to reconstruction the gears geometry:

- The analysis and assessment of wear state (e.g.: attrition).

Identification of damage, also the type and wear grade of each surface. Determination of particularly important areas for recovery of functional characteristic of cylindrical gear. Indication of fragments of the surface, edges and points on gears, which retained their original geometry (shape, location), that will be possible to reference of reconstruction of damaged fragments.

- Preliminary measurements and calculations of teeth and meshing gear.

Elaboration of the concept of 3D-CAD model construction, based on available data in order to reference-grade models of gears in the generator to the cylindrical gears Autodesk Inventor Professional System [5]. Execution of the numerical model 3D-CAD analyzed gear transmission and continuation of processing 3D-CAD models.

- Measurements of gears using coordinate measuring techniques (in research carried out by optical scanning).

Construction of numerical model 3D-CAD based on obtained data from coordinate measuring (CMM).

- Execution of surface models of the two mating gears in CATIA V5 System.
- Implementation of hybrid models of both gears in CATIA V5 System.
- Analysis of the accuracy of mapping geometries made gears models.
- Elaboration of technical documentation.

The present elaborate descibes a stage, at which executions of the analysis of the accuracy of mapping geometry are made by 3D-CAD gears models. The analysis has been achieved of detected defects and defined on the basis of the results obtained and the reasons for these damages and destruction caused in applied research of driving wheel. Analysis of results was based on comparison of accuracy test model with hybrid model, also model obtained from the generator of cylindrical gear with hybrid model created on the basis of the geometry of the test model.

In the elaborate as the source model (research model) data of cloud points contained in a file of .stl (stereolithography format) is determined. Nominal model (standard model) is a gear model of generator to the cylindrical gears, while the concept of the hybrid model is defined as solid model created based on the source geometry model (research model). The article shows a comparative phase of mapping of research model's accuracy with hybrid model.

3. Pre-processing 3D-CAD model gear (driving wheel) to analysis

In order to perform analyzes of mapping gear geometry research model must be prepared. Gear model in .stl format was obtained from measurements of by optical scanner. The obtained model, firstly isn't parameterized and secondly is affected by fault in relation to the real model. Therefore, it is necessary to build a parametric surface model of the gear. To create a parametric surface model 3D-CAD models in the form of cloud of points were used (Fig. 3).

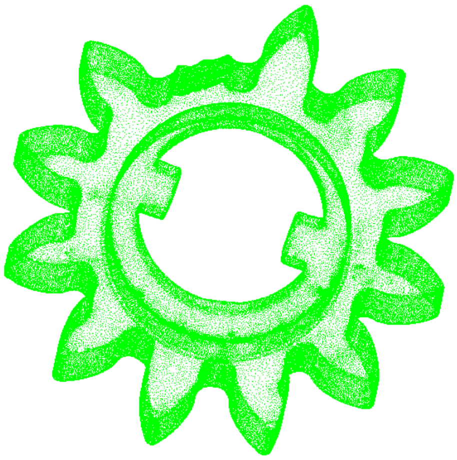

Fig. 3. Model in *.stl* format damaged gear obtained from measurements

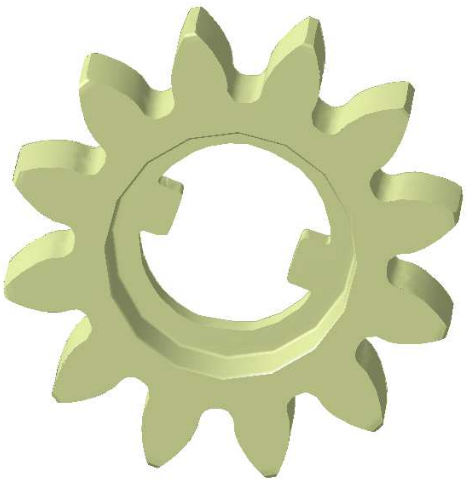

Fig. 4. Surface model of driving wheel of gear pump

In order to obtain a surface model of the closed structure model .stl on gear auxiliary sections were carried, in order to get profiles of the spanned surface which were the basis for the subsequent operations. Based on the constructed surface gear model (Fig. 4) solid model was made.

Pre-processing of gear model for analyzing mapping geometry was carried out in particular modules of CATIA V5 System: *Generative Shape Design* and *Digitized Shape Editor*. The research gear model accounted for reference data, whereas extract geometry of hybrid model has been treated as an object of comparative analyzes. The results of analysis are shown in Fig. 5, 6. Figure 5 shows the stage of mapping geometry of the research gear model relative to nominal (standard) 3D-CAD model. The results are given in *percentages* of the source model geometry (of cloud points) and *length* in mm, where the reference length was automatically set to 1 mm. As a result of comparative analysis of the hybrid model of research gear model, accuracy has been demonstrated in mapping geometry on level 96.68%.

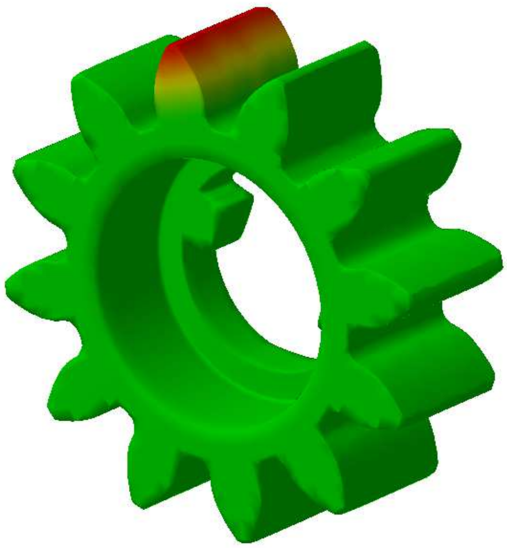

Fig. 5. Results of mapping gear geometry

Special field is the area of the pulled out tooth (yellow and red) (Fig. 6). The difference (in height) between the reconstructed tooth and remains of it, is 5.71677 mm according to the program. Assuming data from the calculation, where the total tooth height was 6 mm, this is approx. 95.28% of the whole tooth. Accuracy of the analyzes was confirmed by the fact that the cylindrical and flat surfaces have not been moved, shifted or distorted relative to the research model.

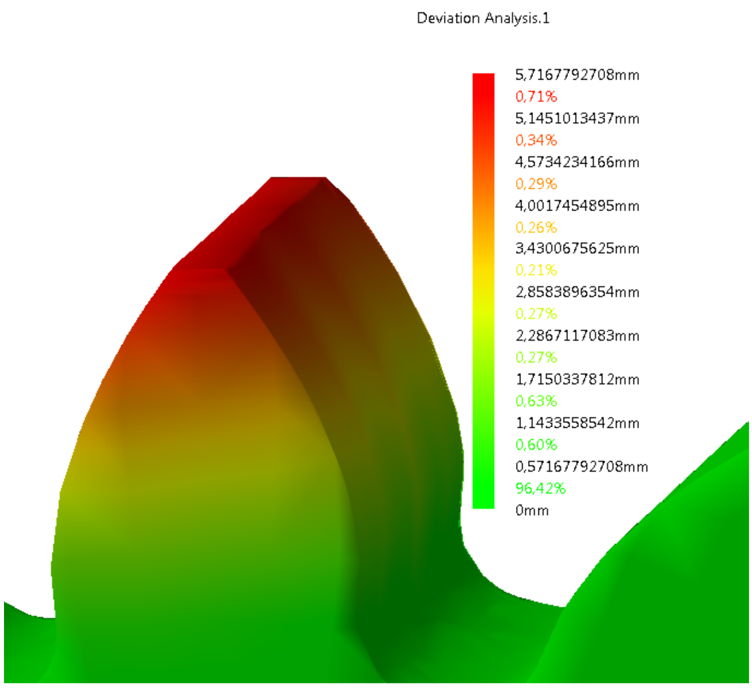

Fig. 6. Detailed analysis areas of the tooth taken out

4. Detailed analysis of gear damage

In order to completely locate the fault, and to determine their causes, two meting gears of gear pump were analyzed. Below are presented the observed damage and fault profile of surface model of both gears: driving wheel and pinion.

Analysis of tooth profile fault. Figure 7 shows damage profile of gear teeth extending into the material to the depth of 1 mm. Profile in sectional 0.25 mm, 0.5 mm and 1 mm was analyzed. Analyses show that this is a typical *indentation*.

Analysis gear hub. Figure 8 shows deviation of profile of internal gear hole which was made from sections in research model (solid line), from theoretical (dotted line). This kind of hole distortion by its nature may be the result of measurement inaccuracies or approximation curves during creating sections.

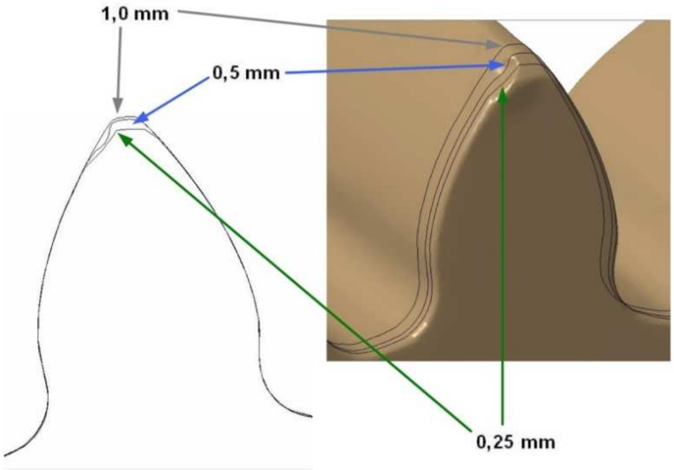

Fig. 7. Analysis of tooth profile in cross-sections of 0.25 mm, 0.5 mm and 1 mm

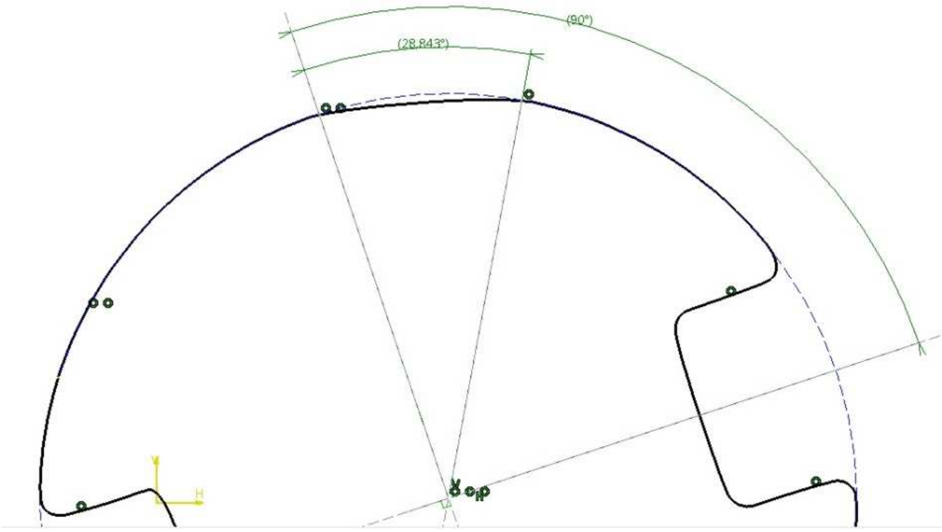

Fig. 8. Distortion in profile of internal gear hole

Analysis of tooth surface. Figure 9 shows tooth surface distortion as wipe in thickness of 0.066 mm on the side of one tooth from the vertices. This type of distortion (such as wiping) on the tooth surface for individual character may be (similarly as the above internal hole damage), the result of measurement inaccuracies or approximation curves during creating sections.

Fig. 9. Distortion of tooth surface as wiping (0,066 mm)

Analysis of teeth pinion profile. Figures 10÷12 show the distortion of involute tooth profile. Figure 10 shows profile of distortion relative to reconstructed tooth profile, and additionally mapped profile compared to notch surface (tooth space), and location of distortion. The profile distortion was located in tooth sections thickness of 0.5 mm on both sides of toothed pinion rim (Fig. 11, 12). A similar type of deformation (indentation) exists on adjacent tooth and following tooth side (Fig. 11). In acknowledgement of this, there were sections made in locations of high density mesh of triangles.

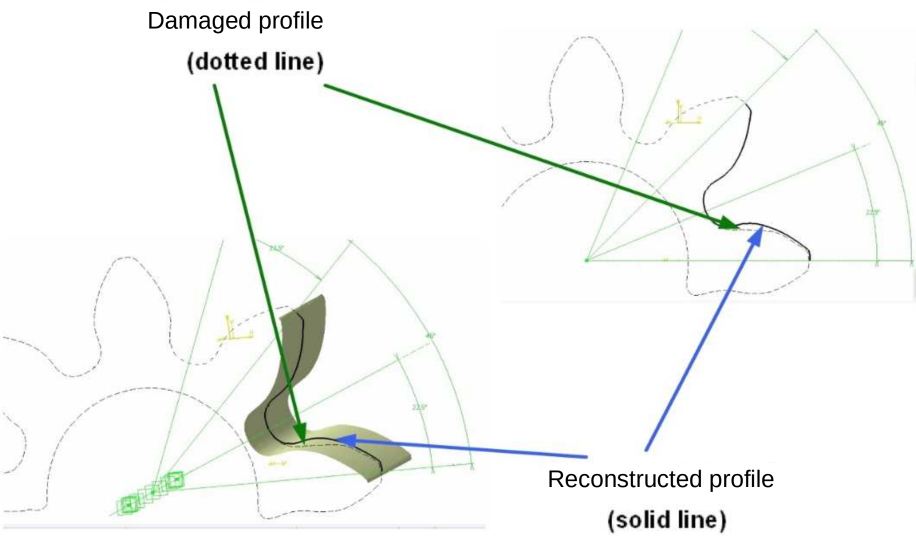

Fig. 10. Distortion involute tooth profile

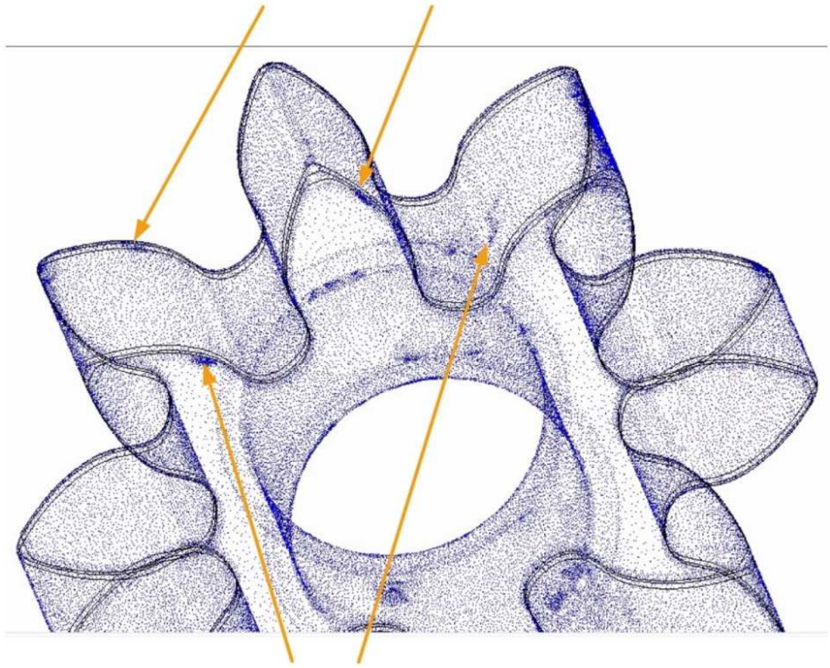

Fig. 11. Areas of distortion of tooth profile
(concentration of cloud points)

Figure 12 represents profile distortion as line sections placed on the mesh model. Typical mesh density in the indicated tooth areas is shown.

Analysis of pinion tooth space (notch). Figure 13 shows the damage distortion profile of tooth space (notch) in the cross section in front plane. The observed damage – discontinuity (like "ragged" profile) is the result of processing. This is due to the fact that this area is not included in functional profile. In support of this proposal the kinematics cooperation (meshing) in gear notch should be restored.

Analysis of pinion hub. Figures 14 and 15 show distortion of profile under-rolling in internal gear hole. Damage reflect destruction caused by wear during gear pump operation.

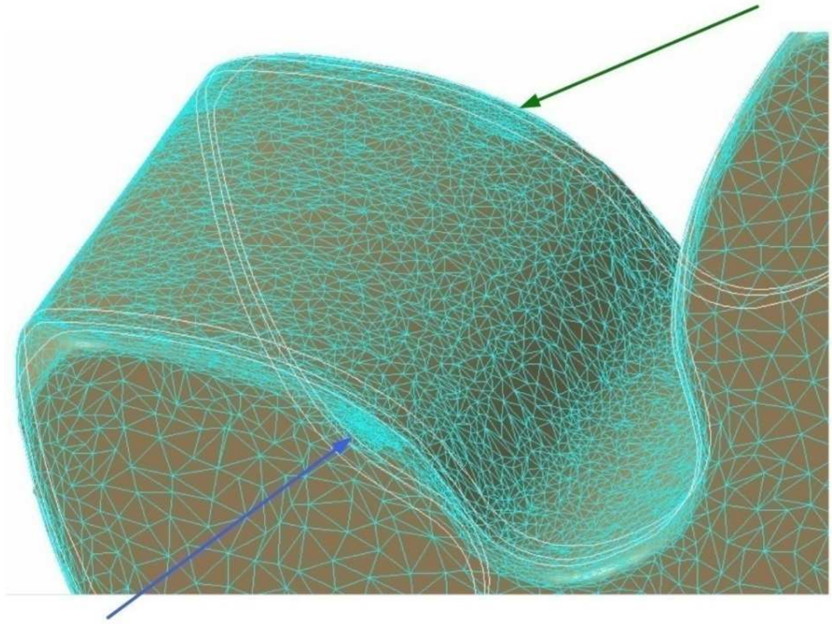

Fig. 12. Distortion of tooth profile (density triangle mesh)

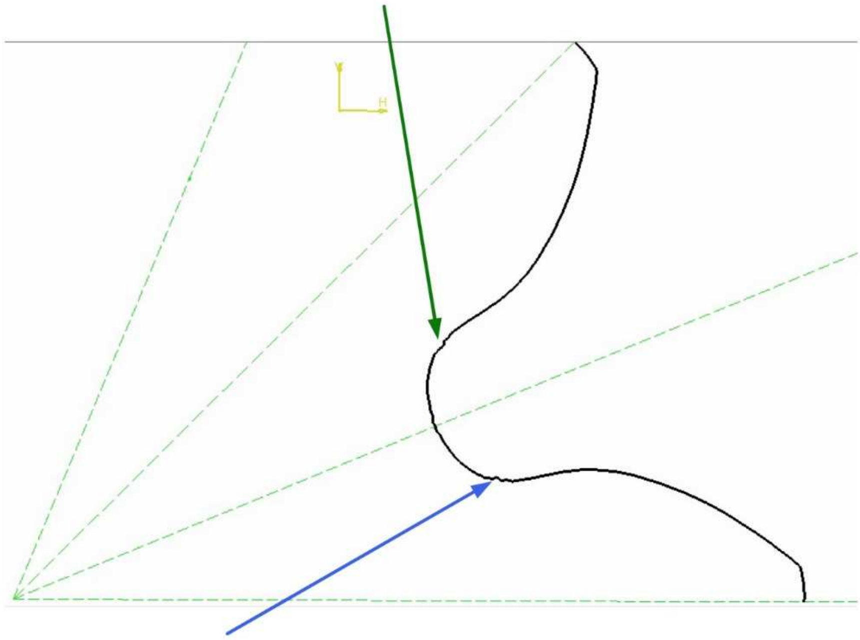

Fig. 13. Damage of profile notch

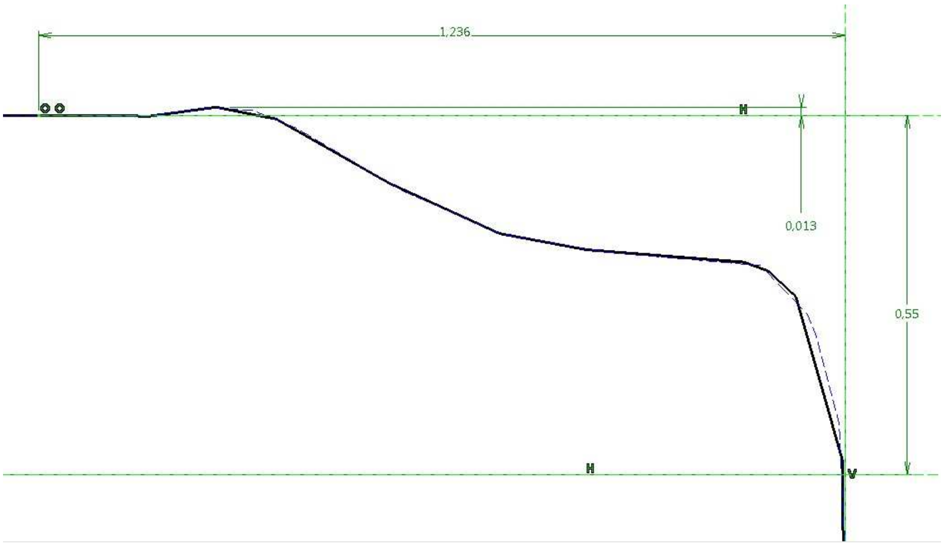

Fig. 14. Distortion profile of under-rolling internal hole
(from the front side toothed wheel rim)

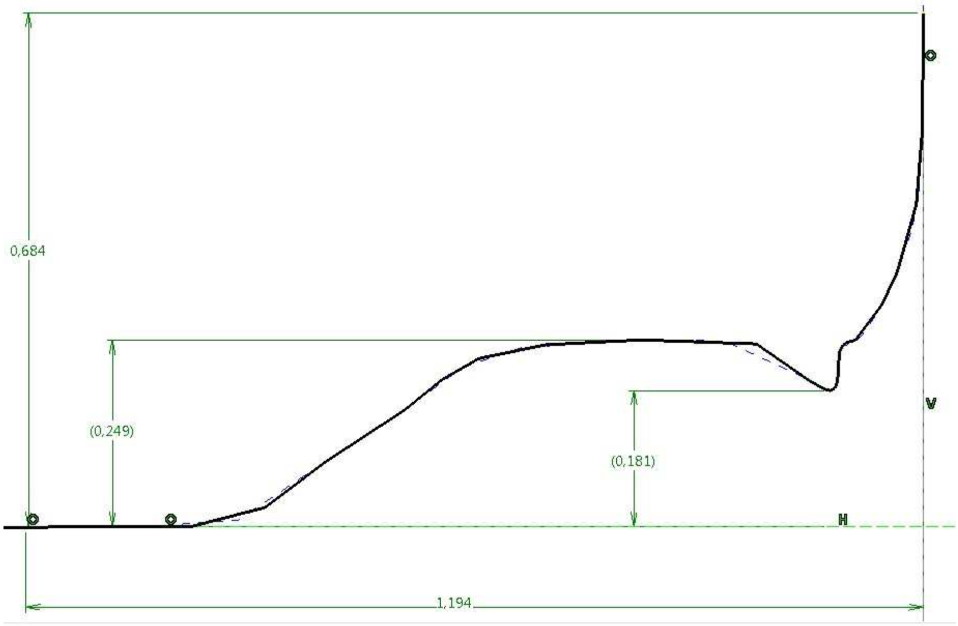

Fig. 15. Distortion profile of under-rolling internal hole
(from the back side toothed wheel rim)

5. Conclusions

The example of analysis accuracy of mapping geometry gear model of gear pump carrying out in CATIA System, as well as achieved analysis detected damage based on made wheels models is only one possibility of realizing this type of analysis. The elaborate does not exhaust the subject of associated problems with analysis of accuracy and damage, but allows to develop in different direction areas damaged machine parts, in order to improve their geometry and/or reconstruct detail, for example one of the methods of *Rapid Prototyping* [6, 7].

References

[1] J. WIKTOR: Analityczno-numeryczne metody analizy parametrów geometrycznych, zakłóceń ruchu i wytrzymałości przekładni walcowych. Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2004.
[2] Z. JAŚKIEWICZ, A. WĄSIEWSKI: Przekładnie walcowe. Geometria, wytrzymałość, dokładność wykonania. WKŁ, Warszawa 1992.
[3] K. OCHĘDUSZKO: Koła zębate. Konstrukcja. Tom I. WNT, Warszawa 1985.
[4] G. BUDZIK: Dokładność geometryczna łopatek turbin silników lotniczych. Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2013.
[5] P. PŁUCIENNIK: Projektowanie elementów maszyn z wykorzystaniem programu „Autodesk Inventor – Obliczenia przekładni”. PWN, Warszawa 2015.
[6] M. ZABORNIAK, I. TOFIL-KOZDRA: Zastosowanie inżynierii odwrotnej w procesie odtwarzania kół zębatych. *Mechanik*, (2015)12, 193-196.
[7] G. BUDZIK, T. DZIUBEK, B. KOZIK, M. ZABORNIAK: Rekonstrukcja kół zębatych z zastosowaniem systemów CMM/CAD/RP. *Mechanik*, **80**(2015)12,18-21.

Received in February 2015