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# Virtual Analysis of Manufacturability of Vane Pumps

Georgi Dinev[1,a], Peter Angelov[2,b], Emilia Chalakova[3,c]

[1,3]Technical University , Faculty of Mechanical Engineering – Bulgaria,
1000 Sofia, Bvd. “Kliment Ochridski” - 8, Blok 4

[2] University of Ruse “Angel Kanchev”, Faculty of Manufacturing Engineering– Bulgaria,
7000 Ruse, Str. “Studentska” - 8

[a] gdinev@tu-sofia.bg, [b]pangelov@uni-ruse.bg, [c]e_chalakova@tu-sofia.bg

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**Abstract.** It is necessary to ensure performance characteristics of vane pump using virtual analysis of scale and geometrical tolerances. As performance characteristics are chosen axial and radial clearance between the rotor and the other details ensuring normal operation of the pump.
The virtual analysis may be made by creating of nominal 3D-CAD model in Solid Works medium using the modules for dimensional analysis by DimXpert and analysis of tolerances TolAnalyst.
The dimensional chains related to determined characteristics are developed. The results obtained will be used for amelioration of manufacturability of these pumps. This approach allows to find the most suitable constructional decision on this stage and to shorten the time for design.

## Introduction

The integrated media for digital design are more widely used for ensuring better operational characteristics of mechanical products in the process of computer design and assembling. They allow possibility for significant development of products and their use for quality improvement [1,2].

The expert systems work with data knowledge named “examination” worked out by experts and their results represent data knowledge. Through formulated dependences and output rules may be look for collisions at assembling components in the process of computer design [3,4].

The virtual analysis is more widely used in computer design and assembling of mechanical products and their production. The virtual initiative and development of products includes expert design for their development, production and marketing. It involves participation of technical and nontechnical specialists starting with the earliest stages of conceptions [5,6].

In contemporary CAD/CAM/CAE systems are used two approaches. The first one is related to developments of individual CAT (Computer Aided Tolerancing) packages (3DCS), CETOL (Sigmetrix), VSA and eM-TolMAte (Siemens PLM), and the other one with the development of specialized modules to existing CAD systems, for example CATIA, Solid Works etc.[7,8].

From the point of view of dimensional analysis at creation of 3D geometrical models of assembled units containing axial and radial deviations can be used virtual analysis in Solid Works medium. Except resolving of dimensional chains the geometrical tolerances of corresponding components are of significant importance.

The contemporary CAD/CAM program systems ensure precise modeling of details, their assembling obtaining of final product and two ways for virtual analysis [9,10]. This allows us to consider that the discussed problem for virtual analysis of manufacturability of vane pumps is actual.

The aim of the present work is to made a virtual analysis of vane rotor pump by nominal 3D CAD model in medium of Solid Works through modules for dimension and analysis of tolerances.

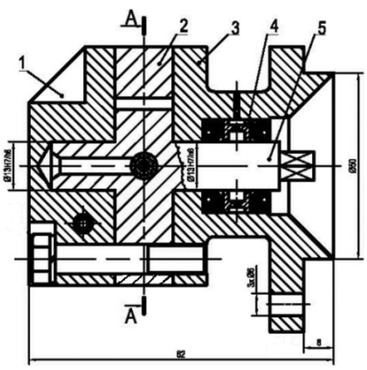
The main purposes are following:

- Development of 2D and3D geometrical models of rotor vane pump;
- Selection of exploitation characteristics – axial and radial tolerances of pump;
- Resolving the system of dimensional chains, related to operational characteristics of pump.

**Geometrical modeling of assembled unit of vane pump**

For presentation of assembled units through their components in CAD medium may be used the so call constructional elements. These elements are determined by the computer draft using description of properties. Then the constructor can develop a graph model by the structure of assembled unit and the contacts between them in component details. The constructor can take decisions when working with solids models on the base of his knowledge and especially worked out selection plan. He can observe simultaneously the dynamically changed strategy and obtained result, as well as the influence of applied parameters [11].

On Fig.1 is presented a fragment of drawing of total look of assembled unit executed by graphical system AutoCAD, and on Fig.2 is given the three dimensional geometrical model of vane pump. On Fig.3 is given the pictorial shaded exploded assembly drawing of vane pump. The developed 3D geometrical models of important components from vane pump are: Cap -1, Body -2, Flange -3 and Rotor -5.



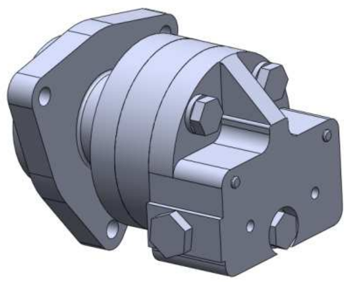
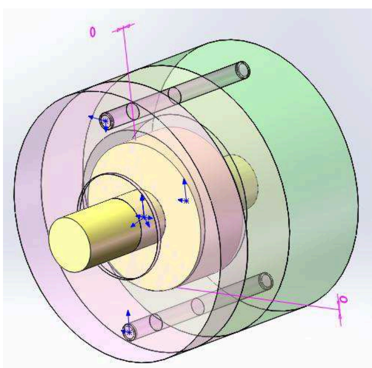



Fig.1Assembly unit Fig.2 3D geometrical model Fig.3 Pictorial shaded exploded drawing

Their assembling on the point of manufacturability of designed mechanical product and increasing the precision of produced product for competitiveness of market is important in training of students from specialty “Mechanical Engineering”, “Industrial Engineering” and PhD students in Mechanical Engineering. For this purpose here is used the developed simplified model of investigated pump given on Fig. 4 and Fig. 5.



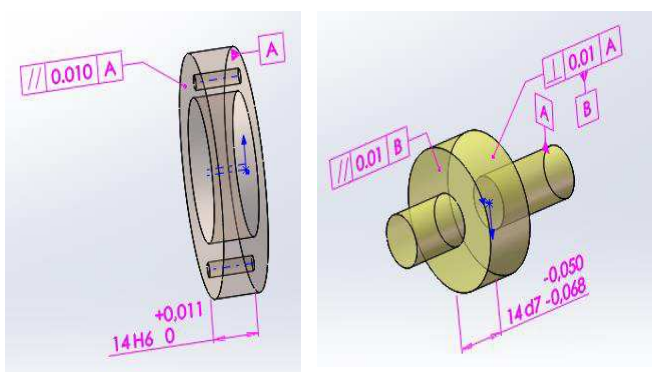



Fig.4 3D simplified geometrical model of vane pump

Fig. 5 3D models of body and rotor

## Operational characteristics of vane pumps

The most important parameters of operational point of view characterizing normal work of this pumps are: axial and radial clearances between the body and rotor. The recommended values for axial clearances are 0 – 0,02 mm and for radial one 0,02 - 0,03 mm.

The axial clearances can be obtained by prescribing of:

- suitable tolerance fields of the main dimensions of body and rotor;
- geometrical tolerance for deviation of parallelism of contact surfaces of body with cap and flange;
- geometrical tolerance for deviation of parallelism of front surfaces of rotor.

The radial clearances may be obtained by description of:

- suitable tolerance fields of diameter of operational hole in body and external diameter of rotor;
- geometrical tolerance for deviation from perpendicularity of holes for adjusting pins in body and flange;
- radial run out of external cylindrical surface of rotor regarding bearing journals;
- geometrical tolerance for deviation from perpendicularity of bearing hole in flange.

## Virtual analysis of manufacturability of vane pump

The virtual analysis of the manufacturability of vane pump is made using a nominal 3D-CAD model, worked out in SolidWorks 2012 SP 5.0. The components forming dimensional chains for determination of axial and radial tolerance between body and rotor are measured of by the aid of module DimXpert, according standards for measures and geometrical tolerances [12,13,14].

The analysis is made by module TolAnalyst and is realized like four degree procedure, including:

- choice of critical parameter (dimension between two elements, measured of by DimXpert);
- creation of arranged consequence of details, forming dimensional chain for determination of critical parameter;
- putting restrains determining mutual situation of participating details in dimensional chain;
- determination of minimal and maximal values of critical parameter for the most unfavorable case.

The determination of critical parameters values is made by the method of whole interchangeability and by probability method, according normal standard distribution of dimensions in the frame of tolerance field and rise percentage of 0,27%.

Except this the critical parameter is determined in two cases: taking into consideration only the dimensional tolerances and with combined reading dimensions and geometrical tolerances.

## Virtual analysis of axial clearance

For evaluation of axial clearance as critical parameter the distance between front surfaces of body and rotor is accepted, which in the nominal 3D-CAD model has zero value which is shown in Figure 4.

On Table1 are shown the found rational decisions for axial clearances between the body and rotor of vane rotor pump. The geometrical limits for deviations of parallelism between these two main details of designed mechanical product are given.

As a basic element for determination of dimensional chain is taken the body. The flange and the cup come into contact with it by their front surfaces, as they are centered to the body by the aid of two pins. For the rotor are given two limits with cup for coincidence of front surfaces and concentricity of bearing journal of hole. The formed combination of bearing details allows to include in the analysis all dimensional and geometrical tolerances, related to axial tolerance which is shown in Figure 5.

At initial dimension of 14H6/d7, without concerning geometrical tolerances, by the method of whole interchangeability is obtained the minimal clearance X min = 0,05 mm and maximal clearance X max =0,079 mm, but by the probability method - XRSS min = 0,054 mm and XRSS max = 0,075 mm.

Table 1 Axial clearance

| № | Dimensions, *mm* | | Geometric Tolerances (fig.5) | | Min. & Max. worst-case conditions | | Root Sum Squared Min & Max worst-case conditions | |
|---|---|---|---|---|---|---|---|---|
| | Body | Rotor | Body | Rotor | Xmin, *mm* | Xmax, *mm* | XRss min, *mm* | XRss max, *mm* |
| 1 | 14H6 | 14d7 | none | | 0,050 | 0,072 | 0,054 | 0,075 |
| 2 | 14H6 | 14d7 | Parallelism 0,01 *mm* | Parallelism 0,01 *mm* | -0,076 | 0,141 | 0,055 | 0,133 |
| 3 | 14H6 | 14h7 | none | | 0 | 0,022 | 0,003 | 0,019 |
| 4 | 14H6 | 14h7 | Parallelism 0,01 *mm* | Parallelism 0,01 *mm* | -0,019 | 0,030 | 0,005 | 0,025 |
| 5 | $14^{+0,008}_{-0,005}$ | 14h7 | Parallelism 0,01 *mm* | Parallelism 0,01 *mm* | -0,016 | 0,025 | 0 | 0,020 |

If considered the joint influence of dimensions and geometrical tolerances for minimal and maximal clearances is obtained Xmin =- 0,076 mm (i.e. interference is obtained), Xmax =0,141 mm, XRSS min =0,055 mm and XRSS max =0,133 mm.

From the information given by the module TolAnalyst about influence degree of individual participants in dimensional chain is noted that the greatest influence has the main dimension of the rotor. For this reason is made a correction of this dimension as tolerance field d7 is replaced by h6. This is obtained: Xmin =- 0,019 mm, Xmax =0,030 mm, XRSS min =0,005 mm and XRSS max =0,025 mm.

With this way by the probability method is obtained clearance range 0.020 mm.

Aiming translation of range of clearances change for axial dimension of the body is accepted $14^{+0,008}_{-0,005}$ accept 14H6. By this manner by probability method is reached the operational requirement for axial clearance XRSS min =0 mm and XRSS max =0,020 mm.

## Virtual analysis of radial clearance

For evaluation of radial clearance is accepted as critical parameter the distance between external cylindrical surface of the rotor with diameter size 35h6 and operational hole of the body diameter size 38±0,25mm. This distance in the nominal 3D-CAD model has zero value which is shown in Figure 4.

On Fig.6 are given the dimensions and geometrical tolerances of orientation, location and run-out at determination of radial clearance.

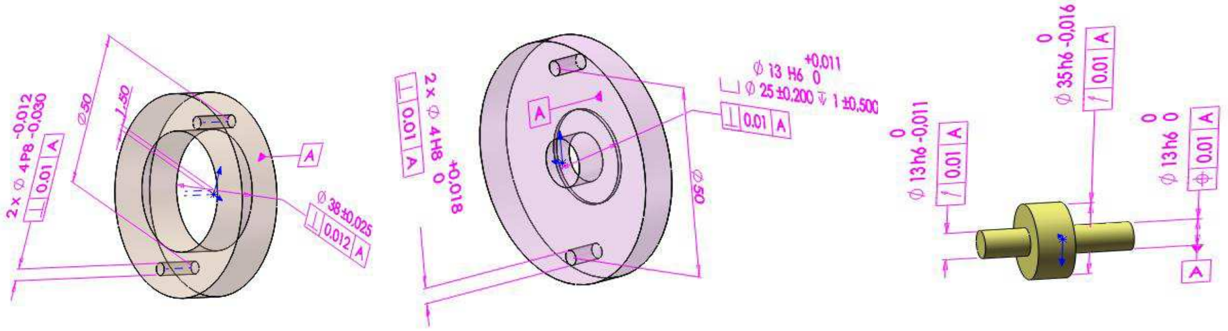


Fig.6 Dimensions and geometrical tolerances

The results of the computer simulation are shown in Table 2.

Table 2 Radial clearance

| № | Dimensions, *mm* | | Geometric Tolerances | | | Min. & Max. worst-case conditions | | Root Sum Squared Min & Max worst-case conditions | |
|---|---|---|---|---|---|---|---|---|---|
| | Body | Rotor | Body | Rotor | Flange | Xmin, *mm* | Xmax, *mm* | XRss min, *mm* | XRss max, *mm* |
| 1 | Ø38±0,025 | Ø35h6 | none | | | 0,013 | 0,020 | -0,009 | 0,017 |
| 2 | Ø38H7 | Ø35h6 | none | | | 0 | 0,020 | -0,010 | 0,005 |
| 3 | Ø38H7 | Ø35h6 | Parallelism 0,012 *mm* Parallelism 0,01 *mm* | Circular Runout 0,01 *mm* | Parallelism 0,01 *mm* Parallelism 0,01 *mm* | 0,019 | 0,049 | -0,004 | 0,032 |
| 4 | Ø38H6 | Ø35h6 | Parallelism 0,012 *mm* Parallelism 0,01 *mm* | Circular Runout 0,01 *mm* | Parallelism 0,01 *mm* Parallelism 0,01 *mm* | 0,019 | 0,045 | -0,005 | 0,028 |
| 5 | Ø38H6 | Ø35h6 | Parallelism 0,012 *mm* Parallelism 0,01 *mm* | Circular Runout 0,01 *mm* | Parallelism 0,01 *mm* Parallelism 0,01 *mm* | 0,008 | 0,034 | 0 | 0,021 |

Dimensional and geometrical tolerances in mechanical engineering design can to select trough the National and International geometric Tolerances Standards [9]. Also for the greater convenience at work in CAD environment designers use most often data base from modules of the graphics system with which the operate in the design process.

On the table are shown the possible radial clearance between the rotor and the body of pump, as well as geometrical tolerances for deviation of radial run-out, and parallelisms deviation between contact surfaces of the three main details. The following final values are accepted after the made analysis:

- As geometrical clearances in the analysis are included deviations from perpendicular of holes in body, cap and flange 0,01 mm toward basic front satandart run-out 0,01 mm of rotors cylindrical surface towards bearing journal on hole;
- As a result of analysis, corrections were made and finally were accepted: diameter of operational hole in body diameter size 38H6; rotor diameter size 35h6 and deviation from perpendicular of all holes 0,005mm.

By probability method as a result were obtained limiting clearances (considering geometrical tolerances) XrRSS min =0 mm and XrRSS max =0,020 mm.

The results obtained will be used for amelioration of manufacturability of rotor vane pumps, and other technical products.

This approach allows to find the most suitable constructional decision on this stage and to shorten the time for design.

Also, these results obtained are useful for amelioration of computers qualification of students, PhD students, and specialists working with software products of higher class, ensuring modules for virtual analysis in the design of technical objects.

The modern industry needs qualified specialists able to work in team for design, production and marketing for creation and investigation of high technological products. This needs to look for creative decisions trough methods like Failure Mode and Effects Analysis, Finite Element Method, and etc.

Also the use of simulation modeling and digital prototyping in the design of high technology and operating indicators.

**Conclusion:**

The developed 3D geometrical model of vane rotor pump allows to make virtual analysis of its manufacturability. The rational values of dimensions and geometrical tolerances, ensuring operational characteristics of the pump were obtained.

As a result the operational reliability of designed mechanical product and its competitive power on the market is increased. Possibilities for the search of creative decisions of constructors technologists and specialists, ensuring marketing activity working together to be applied high industrial manufacturability are found.

The digital prototyping serves to ameliorate the quality of the project. The functional relevance of this approach is illustrated by the given example for virtual analysis of the manufacturability of the vane rotor pump.

The results obtained will be used for amelioration of manufacturability of this pumps. This approach allows to find the most suitable constructional decision on this stage and to shorten the time for design.

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