

# 11TH INTERNATIONAL WORKSHOP “ADVANCED METHODS AND TRENDS IN PRODUCTION ENGINEERING”

## THE METHOD OF WORKPIECE EXACTITUDE EVALUATION ON THE BASIS CAD MODEL BY MEANS OF COORDINATE MEASURING MACHINE

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**Abstract:** *The following paper deals with new current trends in coordinate measuring techniques. The inspection procedure of machines elements by means of comparison with standard 3D CAD models was described. 3D CMM cooperating modeling systems were enumerated. Functions used for evaluation of geometrical elements, free surfaces, curves and sections were also specified.*

**Key words:** *coordinate measuring machine, 3D model, cad systems, reverse engineering.*

### 1. INTRODUCTION

The development of measuring systems based on machines' elements' evaluation on the basis of CAD models has recently taken in significance. Such systems are often called inspective ones. More and more of the constructed products cannot be described by use of basic geometrical features such, as planes, lines, cylinders, cones, spheres, etc. At present, many of the produced elements of machines like bodies of cars, turbine blades, and optical units contain curves and free surfaces the mathematical description of which is complicated. Such cases often occur in production of moulds and matrices for metal elements as well as plastic products.

At the beginning, the idea of coordinate measurements depended on measurement of geometrical figures, however with the expansion of machine elements construction aiding software, the coupling of CAD software with CMMs was needed.

That is why additional software modules of coordinate machines comprehensible for CAD systems were developed. The possibility of comparison of real element's surface with its digital record in form of ideal CAD model is owe to the modern software of coordinate measuring machines. The possibility of comparison of ideal CAD model with real element has its significance in design stage, where the comparison of the first production batch provides substantial data for CNC machine tool. This is then the connection of CAD / CMM / CAM systems as construction coupling with the element manufacturing process by means of coordinate measuring machine.

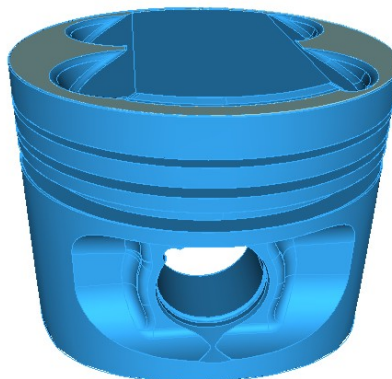


*Fig.1 Piston measurement on WENZEL CMM*

## **2. CONVERSION OF CAD MODEL TO CMM SYSTEM (Orientation of the model in coordinate system, bestfit)**

The first step of CAD / CMM system operation is various format data records import to the system of coordinate measuring machine. The most popular format used for describing curves and three-dimensional free surfaces is the developed by German Automobile Association format VDA-FS. The VDA -FS format is CAD data generated and then transferred to the measuring system. CAD measuring system data import is possible by means of various file formats. Valid CMM cooperative formats are as follows:

- ACIS (the end of file name. SAT /. SAB /. SAX)
- VDA (the end of file name. VDA)
- IGES (the end of file name. IGS)
- STEP (the end of file name. STP)
- CATIA (the end of file name. EXP or. MODEL)
- ProEngineer (the end of file name. PRT)
- Unigraphics (the end of file name. PRT)
- Parasolid (the end of file name .X\_T or .X\_B)

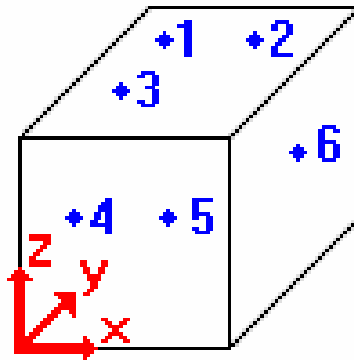


*Fig.2 Example of CAD model - a piston*

The majority of coordinate measuring machines software houses distinguishes the conversions of specific file formats to CMM systems as separate modules. Reading of the models in measuring program requires the selection of the appropriate conversion level, securing the read-off of useless free curves (constructional), surfaces or points.

The emerging CAD/CMM technique problem is orientation of the model on the machine, in other words the adjustment of the CAD coordinate system to the real element fixed in workspace of measuring machine. The assignment of the coordinate system to the real model should take place on the base surfaces, the exactitude of which is ensured. The adjustment of the coordinate system to the model is executed by means of measurement of characteristic model surface points, by placing them in a way that fixes the degrees of freedom, and next taking them over to newly created coordinate system.

The adjustment of the element can be also executed through characteristic geometrical elements occurring in the measured element. For the selected elements provided with CAD coordinate system alignment informing constructional data, a new coordinate system can be assigned orienting the element according to "the minimum" or „zero" in the appropriate axis of coordinate system. This is so called "bestfit" method depending on marking of characteristic points and geometrical features on CAD model (in order to block all degrees of freedom of the measured element) and next conducting manual or CNC measurement. Machine's software executes the bestfit, which is the element's assignment to the coordinate system given by the design engineer. In other words, the iteration process of distance of real points from nominal on CAD model is minimized. Optionally 6 measuring points' distance can be fit to zero. For each iteration CAD model nominal points are again computed. The process guarantees the highest mathematical exactitude. All of 6 degrees of freedom can be fixed by means of marked points, edge points or circles, otherwise bestfit is not executable or the result is questionable.



*Fig. 3 Distribution of measuring points:*

Example of distribution of measuring points:

- first point sets Z-axis translation
- second point sets Y-axis rotation
- third point sets X-axis rotation
- fourth point sets Y-axis translation
- fifth point sets Z- axis rotation
- sixth point sets X-axis translation

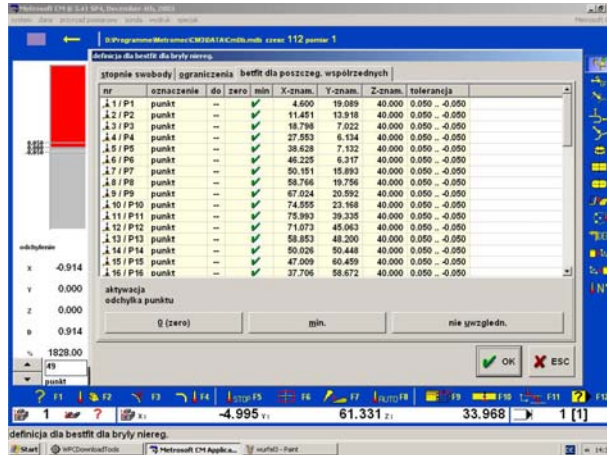


Fig.4 Definitions of bestfit function for free solid

Unless there are given by the constructor base surfaces on which the bestfit is to be executed, or there is no certainty of used elements exactitudes, it is necessary to perform bestfit procedure measuring report, that is coordinate system generating. It is important to know that the results of measurements depend on the exactitude of generated coordinate system. To make the results of measurements comparable amidst various operators the assumption of common bases as well as assumptions regarding fit procedure exactitude is necessary.

### 3. MEASURING POSSIBILITIES OF SURF 3D – METROSOFT PROGRAM

SURF 3D Metrosoft software is a component of the whole applications package for coordinate measuring machines. Owe to SURF 3D module the analysis of curvilinear surfaces on the basis of CAD models is possible. This option compares CAD surfaces converted to measuring system (CAD data are converted to software internal format of measuring machine) with real surface on measuring path by coordinate measuring machine. The division of the element into individual geometrical features such, as planes, curves, circles etc. is executed by the software of measuring machine

#### 3.1. Measurement of free surfaces

The measured solid element can be represented in any view in program's window. We can choose between standard views such, as front view, side view or any given orientation in space. When surface analyses is needed it has to be activated and the measuring path has to be determined by means of determination of normal measuring vectors on individual measuring points. Evaluation of real values deviations from the nominal on each measuring points is done automatically in software window with the values marked.

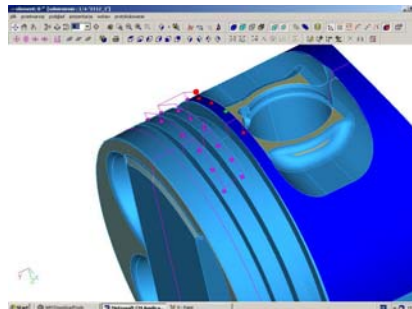
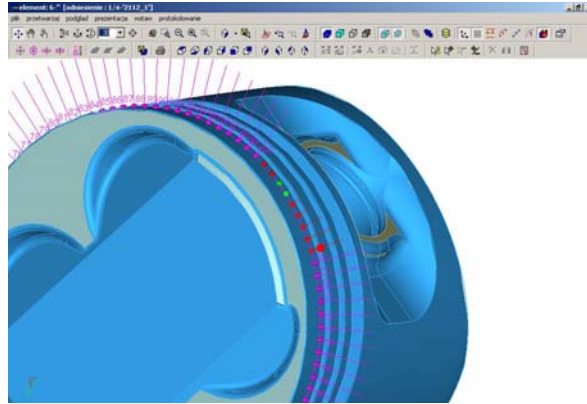


Fig.5 Surface with marked measuring path and measuring probe moving direction vectors

### 3.2. The measurement of intersection curves

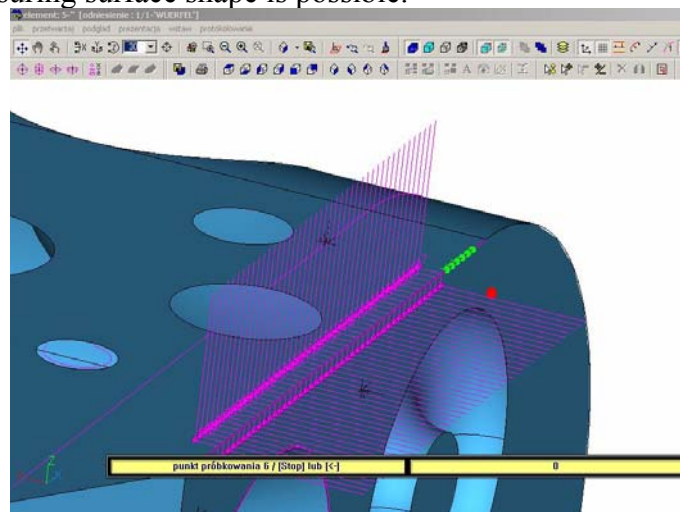
Measurement of free curves in measuring program requires their generation by means of elements intersection with a plane in the specified plane of coordinate system. The intersection planes in coordinate system as well as intersection distance have to be determined for generating the curve.



*Fig.6 Measurement of intersection curve generated by intersection of the model with a plane parallel to the plane of coordinate system*

### 3.3. Measurement of edges

Metrosoft SURF 3D program also enables execution of measurement of the edge between two free surfaces. Determination of the edge requires generation of the curve with measuring vectors near to the specified planes. For measurements simple touch-trigger (Renishaw TP 20, TP 200) or scanning probes for fast digitalization (Renishaw SP 600, SP 25, SP 80) are used. Owe to scanning probes the largest number of measuring points is achievable so a very accurate determination of measuring surface shape is possible.



*Fig.7 Measurement of edge curve with specified probe path measuring vectors*

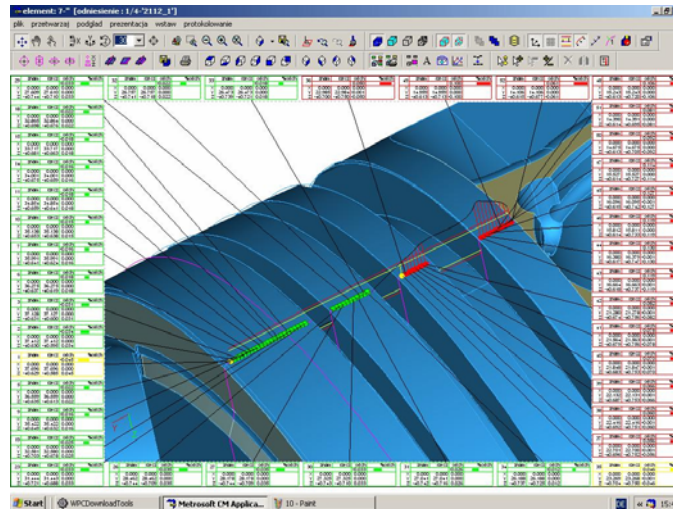


Fig. 8. View of measurement protocol with point deviations and tolerances

### 3. CONCLUSION

The construction of elements is more often based on free surfaces the mathematical equivalent of which is not defined by typical geometrical features. However, modern production systems enable free forming of workpieces. Therefore there is necessity for usage of measuring methods integrated with automated production systems. The emergent needs can be matched only by coordinate measuring machines equipped with appropriate measuring software. Measuring evaluation of machined object by comparison of real surface with CAD model becomes standard in coordinate technique.

Measuring possibilities resulting from utilization of SURF 3D option are very wide; both the estimation of straight lines, geometrical structures, as well as complicated from free surface elements can be done.

The possibility of the measured points export in the VDA format to CAD systems also has its significance. Owe to this the so-called reverse engineering can be used. Having a given element, i.e. a mould or a die block the export of the measured points to CAD by means of their digitalization can be executed. Next free surfaces can be created resulting in complete workpiece documentation in form of 3D model. On the basis of the received model the CNC program for machine tool is generated and next the ready workpiece is compared using CMM with nominal 3D model.

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