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Geometry Monitoring Method Based on Surfaces Assembly Identification

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ABSTRACT

In manufacturing, in order to check the geometrical requirements of machined part, for each surface, a points cloud is gathered and a mathematical model is obtained, using an identification technique.

In this paper is presented a new identification technique, based on genetic algorithms and surfaces assembly approach.

By developing this technique the on-line geometric identification of reconfigurable manufacturing systems at whole is targeted.

***Keywords**: reconfigurable manufacturing systems, surfaces assembly, geometrical identification, genetic algorithms.*

1. Introduction

In the mechanical system manufacturing, the dimensional, shape and position deviations of the system components are considered as very important attributes in quality assessment. For this reason the technical specifications include a large number of requirements regarding these attributes.

Now these requirements are checked by measuring coordinates of points belongs to the component surfaces, using coordinate measuring machines or similar devices. A cloud of points for each of explored surfaces is obtained. After this, the cloud of points is used to apart identify each surface, obtaining in this way the mathematical model of surface regarding a certain reference system.

Finally, the surface mathematical model is used for the feature actual dimensions evaluation and for comparing these dimensions with the CAD model dimensions in order to check the prescribed requirements.

This dimensional inspection method has the following shortcomings:

Firstly, identification is making apart for each surface. This is why a certain non-determination emerge. For example if the dimension is the distance between two plane surfaces, the mathematical models of the two planes may be not two parallels planes for which the distance to be clear defined, to give one of the simplest example. There are many more complex cases.

Secondly, the target of geometry tolerancing is the assurance of geometric compatibility between surfaces belongs to one piece and the conjugated surfaces that form a junction, as for example this case of a bearing covers (see figure 1). The tolerancing is designed to obtain a good enough superposition between the bearing cover surfaces A, B, C and the conjugated surfaces A', B', C'. For this case are tolerated the distance between A and C, the B surface diameter, the perpendicularity between A and B, and the parallelism between A and C. But more efficiently would be to inspect the surfaces assembly ABC, simultaneous fitting three point clouds, gathered from A, B and C, in order to obtain the numerical models of these surfaces. This is why the surfaces of which dimensions and relative positions are restricted by tolerances will be called *surfaces assembly*.

The tolerancing of minimum zone is making by limiting only certain form deviations of the surfaces assembly.

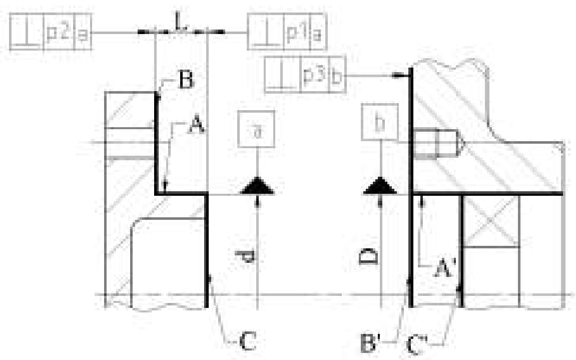

Fig. 1. *Bearing cover: conjugated surfaces of junction*

Thirdly, may appear situations when the dimension of a surface refers to a reference system defined regarding another surfaces of piece. In this case, is necessary to model the surface as well as the reference system at whole as a surfaces assembly.

All of these reveal that, in general, the surfaces should not be apart regarded.

Constituting the surfaces assembly based on the functional relation between two or more system components is needed. Moreover, the CAD models and also the mathematical models obtained from measurements should unitary describe each surfaces assembly of the piece.

In literature were presented many methods which allow the deviations evaluation but only for the apart evaluation of various deviations which may appear at someone surface machining (statistically techniques [1], ants colony technique [2], [3], Grey theory [4], convex hull technique, the technique of finite differences [6], by Monte Carlo simulation, support vector regression [7], Chebyshev approximation, kinematics geometry [10], and new approach of Newton methods for non-linear numerical minimization [8], [9]).

This paper intends to identify the surfaces assembly by building of a coherent numerical model family in order to better evaluate the geometrical compatibility of this surfaces assembly with its conjugated surfaces assembly.

By developing this technique the on-line geometric identification of reconfigurable manufacturing systems at whole is targeted.

This paper has four parts. In first part is presented a brief introduction regarding the surfaces assembly. Second part presents the identification technique for surfaces assembly. In third part is showed an example of this technique application for the assembly constituted by two cylindrical surfaces. The last part presents the conclusions regarding the new identification technique.

2. Surfaces Assembly Identification Technique

As we previously show, in order to determine the machined surfaces quality, these surfaces are inspected and the gathered points are processed.

The proposed technique presumes the followings steps:

1. Establishing the piece surfaces which will be in contact with another surfaces belonging to the mechanical structure where it is mounting and forming a couple of two surfaces assemblies.

Starting from piece design the surfaces assembly is established based on the criterion of form, dimension and position restrictions for the piece surfaces.

This is why we have to notice that, during piece manufacturing, a surfaces assembly isn't limited only at the surfaces machined in the current operation.

Each of the assembly surface is characterized by its model and by the conformity parameters which describe the similitude between actual piece surface and the model having $p_1, p_2,...p_n$ parameters.

For each of p_i parameter in the technical specification is indicating a tolerance, representing the variation domain.

In figure 3 is showed a surfaces assembly selected by this criterion, which is composed by two theoretical surfaces S_{t1} and S_{t2}. Due of the machining errors, we can consider that was obtained the actual surfaces S_{r1} and S_{r2}, the position being determinate by p_1, p_2, p_3 and respectively p_4, p_5, p_6 parameters.

Assuming that in technical specifications was restricted the theoretical surfaces positions, by p_7, p_8 and p_9 parameters, it is interesting for us if these restrictions are inside the tolerated field.

Each of the form, position and dimension constraints established at designing will be a conformity parameter of the surfaces assembly.

2. Gathering of ordered points cloud from each of piece surface that form the surfaces assembly.

In the part-program will be implemented a measuring phase. For this phase is established the trajectory of the stylus in order to gathering the points cloud. Because the measuring device stylus has a spherical end is need that the trajectory of the center of this sphere to be programmed as an equidistance to the theoretical surface to be explored (see figure 2).

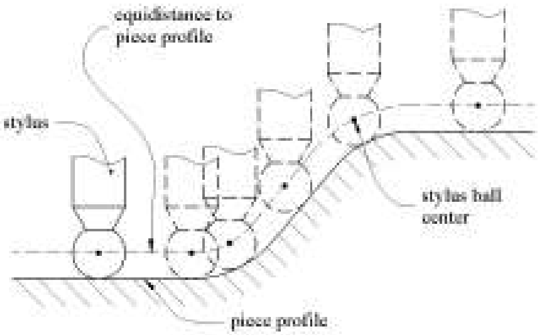

Fig. 2. *Surface exploring trajectory*

3. Processing of these data to calculate the magnitude of deviations which are tolerated in the technical specifications in order to determine the piece conformity with its CAD model.

For data processing are proposed the genetic algorithm method. This method assures the in-cycle dimensional check with a good precision and a minimum calculus effort.

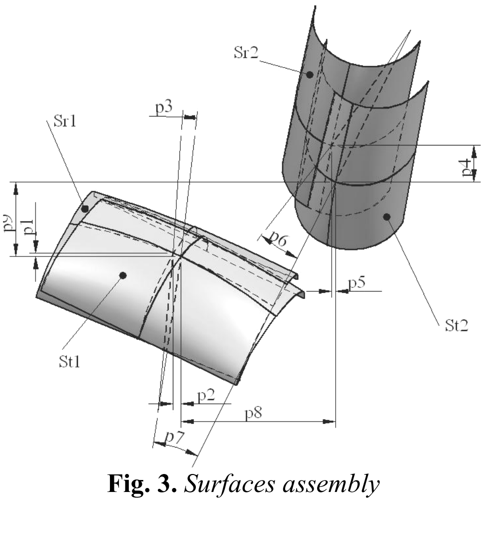

Fig. 3. *Surfaces assembly*

3. Simulations of the Technique Application

As simulation we applied this technique to identify a very simple surfaces assembly composed by two cylindrical surfaces with radius R=100 mm and with distance between axis d=200 mm (see figure 4).

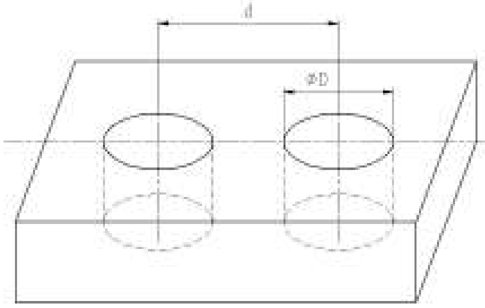

Fig. 4. *The surfaces assembly*

In order to simulate the inspection of actual surface was used a software which can generate two points clouds (one on each surface) with 7 points each.

For the cylindrical surfaces was used the equations:

$$X_1 = \begin{Vmatrix} R\cdot\cos(\alpha) \\ R\cdot\sin(\alpha) \\ p\cdot\alpha \end{Vmatrix};\ X_2 = \begin{Vmatrix} R\cdot\cos(\alpha)+d \\ R\cdot\sin(\alpha) \\ p\cdot\alpha \end{Vmatrix}. \qquad (1)$$

Let us consider that the surfaces axis have deviation with φ_1 and φ_2 angle regarding the theoretically position. In this way the points coordinates are:

$$x_i = \omega_2^T(\varphi_i)\cdot X_i,\ i=\{1,2\}, \qquad (2)$$

where

$$\omega_2(\varphi_1) = \begin{Vmatrix} \cos(\varphi_i) & 0 & -\sin(\varphi_i) \\ 0 & 1 & 0 \\ \sin(\varphi_i) & 0 & \cos(\varphi_i) \end{Vmatrix},\ i=\{1,2\}. \qquad (3)$$

In order to define the objective function was applied the less squares method.

In this way the objective function become

$$d = \sum_{i=1}^{7}\left(X_i^2+Y_i^2-R^2\right)^2 + \\ +\sum_{i=8}^{14}\left[\left(X_i-d\right)^2+Y_i^2-R^2\right]^2. \qquad (4)$$

As solving software were used the Genetic Algorithms Toolbox from Matlab version 7.

In table 1 are show the results obtained applying this toolbox for various values of φ_1 and φ_2 angles.

The Genetic Algorithm Toolbox options were set to: Population Size=20; Elite Count=2; Crossover Fraction=0.8; Migration Interval=20; Migration Fraction=0.2.

Table 1. Numerical results

φ_1 actual [º]	φ_1 calc [º]	φ_2 actual [º]	φ_2 calc [º]	$\Delta\varphi_1$ [º]	$\Delta\varphi_2$ [º]
-2	-2.0048	1	1.0009	0.0048	-0.0009
0	0.0008	0	0.0061	-0.0008	-0.0061
-5	-5.007	4	4.0008	0.0070	-0.0008
1	0.9867	-1	-1.0239	0.0133	0.0239
5	5.0001	-5	-5.0004	-0.0001	0.0004

More complex simulations, which are not presented here, was conducted at conclusion that the results obtained are coherent with the above presented case.

4. Conclusion

The simulations show that the proposed technique may be successfully applied for geometric identification.

The obtained results prove that the surfaces assembly identification have same precision as the individually identification of each surface.

The proposed technique is one of the fastest due to the algorithm characteristics as so as to the fact that the identification is simultaneous for all the surfaces from assembly.

The surfaces assembly identification describes in a more realistic manner the piece geometry, being closely to the mounting behavior of the mechanical structure components.

Bibliography

[1] **Barcenas, C.C., Griffin, P.M.**, *Geometric tolerance verification using superquadrics*, IIE Transactions, 2001, 33, pag. 1109-1120;

[2] **Baskar, N., Saravanan, R., Asokan, P., Prabhaharan, G.**, *Ants colony algorithm approach for multi-objective optimization of surface grinding aperations*, Internation Journal of Advanced Manufacturing Technology, 2004, DOI 10.1007 / s 00170-002-1533-6;

[3] **Li, Y.Y., Li, L.X., Wen, Q.Y., Yang, Y.X.**, *Data Fitting Via Chaotic Ant Swarm*, Springer-Verlag Berlin Heidelberg, 2006, ICNC 2006, Part II, LNCS 4222, pag. 180-183;

[4] **Lin Z.C., Lin, W.S.**, *The Application of Grey Theory to the Prediction of Measurement Points for Circularity Geometric Tolerance*, Int. J. of Adv. Manuf. Technology, 2001, DOI 17:348-360;

[5] **Orady, E., Li, S., Chen, Y.**, *Evaluation of Minimum Zone Straightness by a Nonlinear Optimization Method*, Journal of Manufacturing Science and Engineering, 2000, vol. 122, pag. 795-797;

[6] **Gosavi, A., Phatakwala, S.**, *A Finite-Differences Derivative-Descent Approach for Estimating Form Error in Precision-Manufactured Parts*, Journal of Manufacturing Science and Engineering, 2006, vol. 128, pag. 355-359;

[7] **Prakasvudhisarn, C., Trafalis, T.B., Raman, S.**, *Support Vector Regression for Determination of Minimum Zone*, Transactions of the ASME, 2003, vol. 125, pag. 736-739;

[8] **Tucker, T., Kurfess, T.**, *Newton methods for parametric surface registration. Part I. Theory*, 2002, Elsevier Science, Computer-Aided Design, 35, pag. 107-114;

[9] **Tucker, T., Kurfess, T.**, *Newton methods for parametric surface registration. Part II. Experimental validation*, 2002, Elsevier Science, Computer-Aided Design, 35, pag. 115-120;

[10] **Zhu, L.M., Ding, H.**, *Application of kinematic geometry to computational metrology: distance function based hierarchical algorithms for cylindricity evaluation*, 2002, International Journal of Machine Tools & Manufacture, 43, pag. 203-215.

Metodă de monitorizare a geometriei bazată pe identificarea ansamblurilor de suprafețe

Rezumat

În procesul de fabricație, în scopul controlului respectării prescripțiilor geometrice ale piesei prelucrate, pentru fiecare suprafață se determină modelul ei matematic utilizând o anumită tehnică de identificare.

De obicei această tehnică se bazează pe recoltarea unui nor de puncte şi modelarea matematică a acestui nor.

În prezenta lucrare este prezentată o nouă tehnică de identificare, bazată pe abordarea ansamblurilor de suprafețe utilizând algoritmi genetici.

Prin dezvoltarea acestei tehnici este posibilă identificarea geometrică on-line a sistemelor de fabricație reconfigurabile privite ca un întreg.

Surfaces assemblées identification basées sur des algorithmes génétiques

Résumé

Pour mettre en place le dispositif et les écarts géométriques modèle mathématique sont nécessaires de mettre au point de nouvelles techniques d'identification.

Ces techniques sont fondées sur le rassemblement des nuages de points et la modélisation mathématique de ces nuages. De cette façon, on obtient le modèle mathématique du morceau de surfaces.

Ensuite, ce modèle peut être étendu à des systèmes de fabrication reconfigurables géométriques assemblées. Dans le présent document, est présenté une nouvelle technique de l'identification, basée sur les algorithmes génétiques.