Method for Identification of Geometric Feature Family Based on Genetic Algorithm and Neural Approach

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Abstract: - In the mechanical systems the dimensional, shape and position deviations of the components surfaces represent very important attributes in quality assessment. This is why the technical specifications include a large number of requirements regarding these attributes.
In present the verification of these requirements is based on measuring the coordinates of points belongs to the component surface. After the points coordinates are obtained the numerical model of surface is fitted.
Finally the numerical models are used to evaluate the actual dimensions of feature, to compare these dimensions with the model dimensions and to check the tolerances. Due of this cause emerges some uncertainty regarding the dimensions like distance between two planes which are not actual parallel.
This is why is needed the grouping in families of the component surfaces, the obtaining of points cloud coordinates for each surface and the family coherent model instead of individual modeling for each surface.
On the other hand, the quality junction between two assemblies components is given by the compatibility degree between surfaces belong to one piece and the conjugated surfaces belong to the other piece which form the junction.
In this paper are proposed two methods for geometric feature family identification (using genetic algorithm and using neural networks) for better evaluation of surfaces deviations.

Key-Words: - genetic algorithm, neural network, surface identification

1 Introduction

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

In present these requirements are checked by measuring coordinates of points belongs to the component surface, using coordinate measuring machines or similar devices. A cloud of points for each of explored surface 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 surfaces mathematical models are used for the feature actual dimensions evaluation and for compare these dimensions with the model dimensions and checking the prescribed tolerances [12].

This dimension 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. They are many cases more complex.

Secondly, the target of geometry evaluation is the checking of compatibility degree between surfaces group belongs to one piece and the conjugated surfaces group belongs to another piece that form a junction, as for example the case of a bearing covers (see figure 1).

The tolerances assure a good enough superposition between the two surface groups (A-A', B-B' and C-C'). So is more efficiently to inspect the surfaces assembly ABC, fitting simultaneous three point clouds (gathered from A, B and C) in order to obtain the numerical models of A, B and C. The tolerating of minimum zone is making by limiting only certain form deviations of surfaces assembly. For this case is tolerated the distance between A-C, the B surface diameter, the perpendicularity between A and B and the parallelism between A and C. These are the surface form deviations parameters.

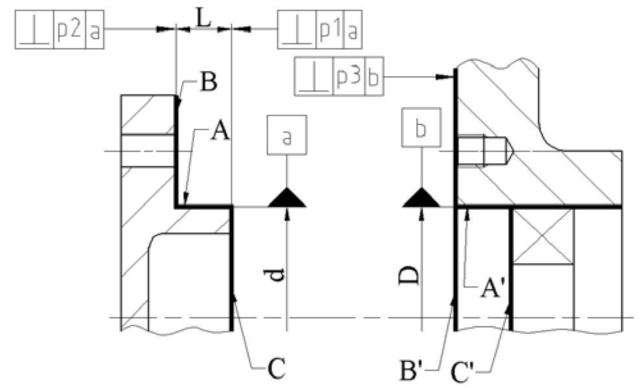

Fig. 1. Conjugated surfaces of junction

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 important the modeling of the surface as so as the reference system modeling.

All of these reveal that the group surfaces should not be apart regarded.

Constituting the family of geometric elements based on the functional relation between the components is needed. Moreover, the CAD models and also the numerical models should unitary describe each geometric features family.

In literature were presented methods which allow the deviations evaluation (statistically techniques [1], ants colony technique [2], [3], Grey theory [4], convex hull technique [5], the technique of finite differences [6], by Monte Carlo simulation, support vector regression [7], Chebyshev approximation [11], kinematic geometry [10], and new approach of Newton methods for non-linear numerical minimization [8], [9]) only for the apart evaluation of various deviations which may appear at complex surfaces machining.

This paper intends to identify the geometric features family by building of coherent numerical model family in order to better evaluate the geometrical compatibility of conjugated surfaces families.

Also are presented two methods for the identification of the geometric features family based on the genetic algorithm approach and on the neural network approach.

2 Algorithm for Geometric Feature Family Identification

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

The proposed algorithm presumes the followings steps:

1. Establishing of a surfaces group belongs to piece, surfaces which will be in contact with another group of surfaces of the mechanical construction where is mounting the piece, forming a couple of surfaces assemblies. This surfaces assembly we will call *topological structure*.
2. Gathering of ordered points cloud from each of surface piece that form the topological structure.
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 two methods: the genetic algorithm method and the neural network method. These methods assure the in-cycle dimensional check with a good precision and a minimum calculus effort.

The topological structure is established based on the criterion of form, dimension and position restrictions for the structure elements.

We have to notice that a topological structure isn't limited only at the surfaces machined in the current operation.

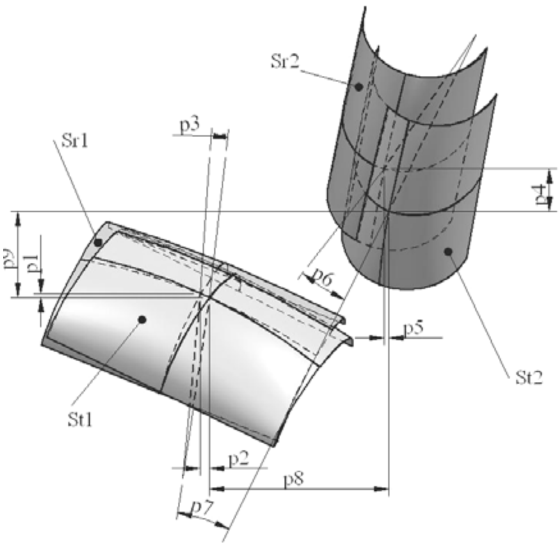

Fig. 2. Topological structure

Each of the topological structure surface is characterized by its model and by the conformity parameters which describe the similitude between actual piece surface and the model (p_1, p_2,…p_n parameters, see figure 2).

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

In figure 2 is show a topological structure 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 topological structure.

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 an equidistance to the theoretical surface to be explored (see figure 3).

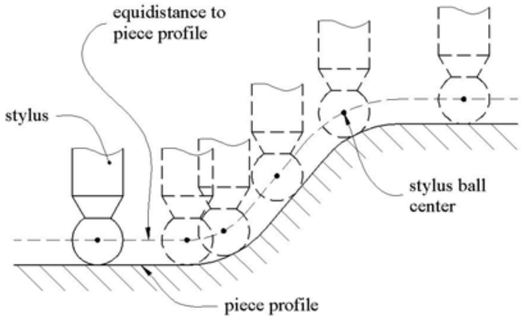

Fig. 3. Surface exploring trajectory

The points cloud will be processed using whether the genetic algorithm or neural network method.

3 Geometric Feature Family Identification Using Genetic Algorithm

We applied this method to identify a feature family composed by two parallel planes with 10 mm distances between them.

In order to simulate the inspection of actual surface was used a software which can generate a mesh with 25 points for each plane.

It was use the plane equation

$$n_1 \cdot x + n_2 \cdot y + n_3 \cdot z + p_1 = 0 . \quad (1)$$

The software gives values on x and y axis in domain (-100…100) with step 50 mm. For each couple (x,y), from (1), is calculating the value for z:

$$z = -\frac{n_1 \cdot x + n_2 \cdot y + p_1}{n_3} . \quad (2)$$

In this way we simulate the gathering of 50 points, 25 from each plane take in discussion.

As objective function was considering the sum of distances from each point to the theoretically planes P_1 and P_2:

$$P_1 : z_1 = p_1 ;\ P_2 : z_2 = p_2 . \quad (3)$$

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

In this way the objective function become

$$d = \sum_{i=1}^{25} \left(n_1 x_i + n_2 y_i + n_3 z_i + p_1 \right)^2 + \\ + \sum_{i=26}^{50} \left(n_4 x_i + n_5 y_i + n_6 z_i + p_2 \right)^2 . \quad (4)$$

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

In table 1 are show the results obtained applying the algorithm for two parallel planes.

Table 1. Numerical results

Parameter	Actual	Calculated	Relative error [%]
n_1	0.01	0.010208	-2.08
n_2	0.015	0.015312	-2.08
n_3	0.9	0.91881	-2.09
p_1	0.001	0.001022	-2.18
n_4	0.012	0.012023	-0.19167
n_5	0.014	0.014025	-0.17857
n_6	1.1	1.102	-0.18182
p_2	10.001	10.019	-0.17998

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.

4 Geometric Feature Family Identification Using Neural Network

In order to model the topological structures by neural network it was generated by simulation a database fill in with coordinates of points belongs to the topological structure surfaces.

Each record of database contain the x,y,z points coordinates from the points cloud corresponding to a certain configuration $p_1, p_2, \ldots p_n$ of parameters set.

This database is pre-processed by calculating the values of function

$$f\left(x, y, z, p_1, \ldots p_n\right) = d , \quad (5)$$

in each of the generated points, where d is distance from point to surface.

After this, each topological structure is neural modeled with d from equation (5) as input data and with $p_1, p_2, \ldots p_n$ parameters values as output data.

Database generation

On each surface belongs to the topological structure are generated points corresponding to the established measuring trajectories. These measuring trajectories will be equidistance to the piece theoretically profile in order to simulate the positions of stylus spherical surface center in time of measuring process.

The coordinates of generated points have a coordinate transformation from the own theoretically surface reference system to a reference system moved with $p_1, p_2, \ldots p_6$ parameters set (see figure 4).

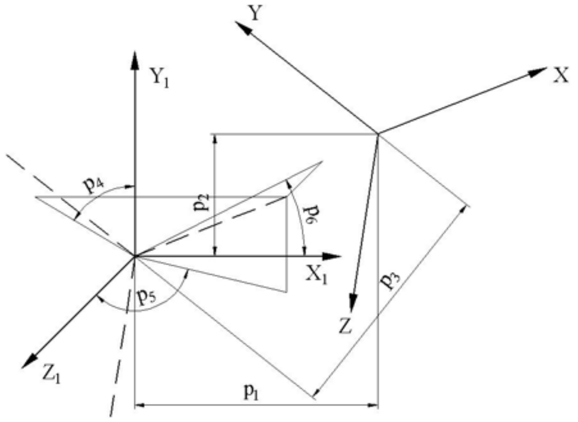

Fig. 4. Reference systems

Figure 4 shows:

$X_1Y_1Z_1$ is the theoretically surface own reference system;

XYZ — moved reference system;

$(p_1, p_2, p_3, p_4, p_5, p_6)$ — conformity parameters set.

The coordinate transformation is give by equation

$$X_1 = \omega \cdot X + T, \quad (6)$$

where

$$T = \left\| p_1 \quad p_2 \quad p_3 \right\|^T, \qquad \omega = \omega_1^T(p_4) \cdot \omega_2^T(p_5) \cdot \omega_3^T(p_6), \quad (7)$$

or, after development:

$$\begin{Vmatrix} X_1 \\ Y_1 \\ Z_1 \end{Vmatrix} = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & \cos p_4 & -\sin p_4 \\ 0 & \sin p_4 & \cos p_4 \end{Vmatrix} \cdot \begin{Vmatrix} \cos p_5 & 0 & \sin p_5 \\ 0 & 1 & 0 \\ -\sin p_5 & 0 & \cos p_5 \end{Vmatrix} \cdot \begin{Vmatrix} \cos p_6 & \sin p_6 & 0 \\ \sin p_6 & \cos p_6 & 0 \\ 0 & 0 & 1 \end{Vmatrix} \cdot \begin{Vmatrix} X \\ Y \\ Z \end{Vmatrix} + \begin{Vmatrix} p_1 \\ p_2 \\ p_3 \end{Vmatrix}. \quad (8)$$

If between the surface in discussion and the reference surface exists some constrains, these will generate an additional number of conformity parameters, and it is need a new coordinate transformation on type (6) between the surface own reference system and the reference system associated with the reference surface.

For each of generated point is calculated the value of $f(X_1, Y_1, Z_1, p_1, \ldots p_n)$ function, obtained filling the general equation of theoretically surface with points coordinates.

In this way is obtained a database with M records and N fields for each record, M and N are given by:

$$M = \prod_{i=1}^{m} v_i, \qquad N = \sum_{i=1}^{n} k_i, \quad (9)$$

where:

m is the number of conformity parameters corresponding to the topological structure;

v_i — number of values for p_i parameter;

n — number of surfaces which compose the topological structure;

k_i — number of generated points on each theoretically surface.

The database obtained in this way is used as input matrix for neural network training. The output matrix will be composed with conformity parameters set.

Application

As application was used the neural network modeling to identify a feature family composed from two parallels planes with distance of 10 mm between them.

In order to simulate the inspection of actual surface was used a software which will generate a mesh with 25 points for each plane.

The theoretically planes are moved by coordinate transformation

$$X_1 = \omega(\alpha_1) \cdot X, \quad (10)$$

for first plane, and

$$X_2 = \omega(\alpha_1 + \alpha_2) \cdot X + T, \quad (11)$$

for second plane.

In equations (10) and (11) ω and T is:

$$\omega(\alpha_1) = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{Vmatrix}; \quad \omega(\alpha_1+\alpha_2) = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & \cos(\alpha_1+\alpha_2) & -\sin(\alpha_1+\alpha_2) \\ 0 & \sin(\alpha_1+\alpha_2) & \cos(\alpha_1+\alpha_2) \end{Vmatrix}; \quad T = \left\| 0 \quad 0 \quad Z_0 \right\|^T. \quad (12)$$

The software gives values on X and Y axis in domain (-100…100) with step 50 mm. In this way we simulate the gathering of 50 points, 25 from each plane take in discussion.

For neural modeling were used the NNMODEL Version 1.400 software.

In table 2 are show the results obtained by interrogating the network when the parameters belongs to the training values set.

Table 2. Numerical results

Parameter	Actual	Calculated	Relative error [%]
α_1	-0.01047	-0.01036	1.069519
α_2	-0.01047	-0.0104	0.687548
Z_0	9.4	9.402	-0.02128

In table 3 is show the results obtained interrogating the network with parameters different by the training values set.

Table 3. Numerical results

Parameter	Actual	Calculated	Relative error [%]
α_1	-0.01396	-0.01388	0.594428
α_2	-0.01396	-0.0139	0.451192
Z_0	9.8	9.80307	-0.03133

The Neural Network options were set to: Hidden Neurons=50; Maximum Training Count=10000; Fixed number of Hidden Neurons=True; Training Method=Standard BEP.

5 Conclusion

For sake of simplicity was presented the simplest case, but the method was applied for more complex topological structures composed by plane and cylindrical surfaces and for various deviations (perpendicularity, parallelism, distances etc.).

The results were reveal that the differences between the deviations exactly values and the values obtained by applying the two methods aren't larger then 5%.

The calculus time is longer for genetic algorithm than for neural network in case of complicated topological structures (structures with more than 2 or 3 surfaces).

The numerical models built for a surface family as whole is coherent and better describe the geometrical compatibility of conjugated surfaces families comparing to individual modeling of each surface.

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