Surfaces Identification Based on Parameters Circulation

PhD. Alexandru Epureanu, PhD Virgil Teodor,
PhD. Ciprian Cuzmin

ABSTRACT

The identification technique based on parameters circulation consists in the cyclic search of the model parameters values for which the optimum similitude between the model and the actual surface is reached.

In the appliance of this technique we start from the fact that the deviations from form as so as from position regarding the theoretically surface which appear during surface generation should belong to a small domain namely tolerance field. On the other hand, the mathematical model can be so built that the model parameters are defined as dimensions deviations theyself. In this case the parameters values will belong to a small domain too. The fundament of this technique is the extremes uniqueness in a small enough search space.

By this method is possible to determine the surface position deviations as well as the surface dimensions deviations regarding the theoretically values.

***Keywords**: reconfigurable manufacturing systems, surface identification, parameters circulation.*

1. Introduction

The reconfigurability of the modern manufacturing systems presumes the possibility to change the systems architecture, in order to use different machining scheme and various identification techniques. In this way is increased the machining and control efficiency and is decreased the human effort.

The identification technique based on parameters circulation consist in the cyclic search of the parameters of the mathematical model in a little space, around a known values set for which the optimum similitude between the model and the actual part surface is reached.

This technique is supported by three remarks.

First, the surfaces mathematical model can be so build that the models parameters be the dimensions deviations theyself. In this case, it is foreseen that, for each parameter, the searched value should be find in, or very closed to, its small tolerated domain.

Secondly, in a small enough search space, the function extreme is unique.

Thirdly, from dimensional control point of view, if in a small extension of the tolerated domain the value of the model parameter can not be find, than, usually, an exceptional event have been appeared and the only decision which will be made is to stop the system operation.

In technical literature were presented many search techniques: statistically techniques, ants colony techniques, the technique of finite differences etc.

The technique based on parameters circulation has some advantages regarding the other techniques: simplicity, generality, the speed of convergence, the easy algorithm reconfigurability. All of these recommend this technique to be used for dimensional control of the reconfigurable manufacturing systems.

At this technique application is necessary a points cloud gathering, using the reconfigurable manufacturing system as measuring machine. After this, the deviations of the substitute surface which optimum approximate the actual surface is searched.

By this method is possible to determine the position deviation as so as the dimension deviations regarding the theoretically values.

The paper is structured at four parts. First part is a brief introduction regarding the identification of the reconfigurable manufacturing systems. The second part presents the algorithm used for the surfaces identification based on the parameters circulation. In the third part is showed an example of this technique application for the identification of a cylindrical surface. The last part presents the conclusions regarding this technique.

2. Identification by Parameters circulation

The identification algorithm based on the parameters circulation consists in the following stages:

- The surface model determining starting from the general form:

$$S: f = f\left(x, y, z, p_1, p_2, \ldots p_n\right) \quad (1)$$

where *x,y,z* are the coordinates of a point which belong to this surface and $p_1, p_2, \ldots p_n$ are the model parameters.

- The touch probe trajectory establishing;
- The variable parameters establishing. Usually, all the model parameters are considered as variable.
- The establishing of domain variation limits for each of model parameters;

$$p_i \in \left[p_{i\min}, p_{i\max}\right],\ i = 1 \div n. \quad (2)$$

- The points gathering on the surface to be identified;
- Keeping *n-1* parameters at a fixed value is modified the n^{th} parameter and the surface equation is filled with the gathered points coordinates;
- The objective function is the following:

$$f = \sum_{i=1}^{m}\left[f_i\left(x_i, y_i, z_i, p_1, p_2, \ldots p_n\right)\right]^2, \quad (3)$$

where *m* is the number of gathered points.

- Is calculated the scope function derivative at domain variation limits for this parameter and the domain is decreased until is reached an imposed limit.
- The previous step is repeated until the scope function is smaller than a ε value. The solution will be the parameters set for which the scope function is minimum.

The flowchart for this algorithm is presented in figure 1.

3. Simulations and Discussions

As example for this identification technique was simulated the generation of a cylindrical surface, which has deviations from position, dimensions and forms regarding a theoretically cylindrical surface.

The cylindrical surface in its own reference system is:

$$S: x^2 + y^2 - R^2 = 0 \quad (4)$$

If we admit that the surface is rotated around *Ox* axis with value φ, around *Oy* axis with value ψ, the directix center is displaced with values Δx, Δy and the cylinder radius has the deviation ΔR, the surface equations in the machine reference system is:

$$\begin{Vmatrix} X \\ Y \\ Z \end{Vmatrix} = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & \cos\varphi & \sin\varphi \\ 0 & -\sin\varphi & \cos\varphi \end{Vmatrix} \cdot \begin{Vmatrix} \cos\psi & 0 & -\sin\psi \\ 0 & 1 & 0 \\ \sin\psi & 0 & \cos\psi \end{Vmatrix} \cdot \begin{Vmatrix} x \\ y \\ z \end{Vmatrix} - \begin{Vmatrix} \Delta x \\ \Delta y \\ \Delta z \end{Vmatrix} \quad (5)$$

In this way, the scope function becomes:

$$f = \sum_{i=1}^{m}\left(X_i^2 + Y_i^2 - \left(R + \Delta R\right)^2\right)^2 \quad (6)$$

where *m* is the number of gathered points and X_i, Y_i, Z_i are give by (5) equation.

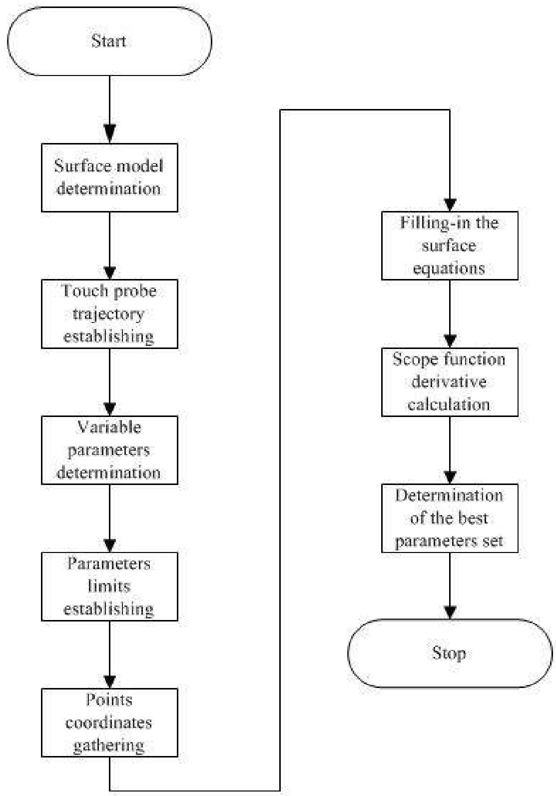

Fig. 1. *Algorithm flowchart*

The model parameters are the directrix circle, the centre coordinates; the rotation angles around *Ox* and *Oy* axis, and the deviations from theoretically radius.

If these parameters are determined, we can say that we have identified the cylindrical surface from point of view of position, form and dimensions.

The identification was made using a program written in Matlab software, and the obtained results confirmed the viability of this method.

The software flowchart is presented in figure 2.

In table 1, are presented the actual parameters values, the calculated parameters values and the error level for various case of parameters commutation (see equations (5) and (6)):

- for case 1, the commutation was $\Delta x, \Delta y, \varphi, \psi, \Delta R$;
- for case 2, the commutation was $\varphi, \psi, \Delta x, \Delta y, \Delta R$;
- for case 3, the commutation was $\Delta R, \Delta x, \Delta y, \varphi, \psi$;

- for case 4, the commutation was $\Delta R, \Delta x, \Delta y, \varphi, \psi$.

Is obviously that the parameter commutation have a light influence regarding the error level.

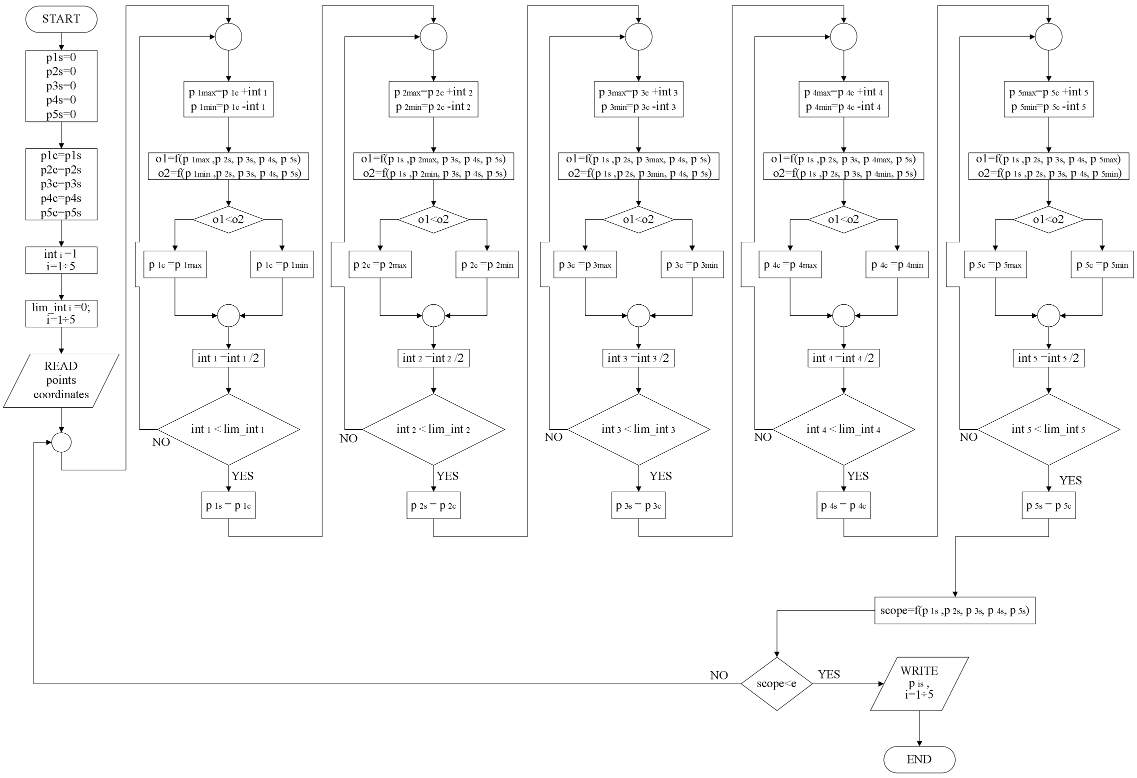

Fig. 2. *Software flowchart*

Table 1.

	Real	Case 1	Case 2	Case 3	Case 4	Error 1	Error 2	Error 3	Error 4
Δ x [mm]	0.8	0.80011	0.79991	0.79989	0.79992	-0.00011	9E-05	0.00011	8E-05
Δ y [mm]	-0.5	-0.5012	-0.49884	-0.49881	-0.49887	0.0012	-0.00116	-0.00119	-0.00113
φ [°]	-1.5	-1.498	-1.502	-1.502	-1.502	-0.002	0.002	0.002	0.002
ψ [°]	0.5	0.50009	0.49993	0.49991	0.49994	-9E-05	7E-05	9E-05	6E-05
Δ R [mm]	0.25	0.24972	0.25026	0.25031	0.25031	0.00028	-0.00026	-0.00031	-0.00031
scope function	1.76E-09	0.000996	0.000971	0.000999	0.000972	-0.001	-0.00097	-0.001	-0.00097

In table 2, are presented the actual parameters values, the calculated parameters values and the error level for various case of parameters commutation, for 1000 loops.

In figure 3 is presented the error of each parameter regarding the parameter circulation order.

In table 3, are presented the influence of admissible error of scope function regarding the software loops number.

In figure 4, is presented the total loops number of the software and in figure 5 is presented the loops number for each parameter.

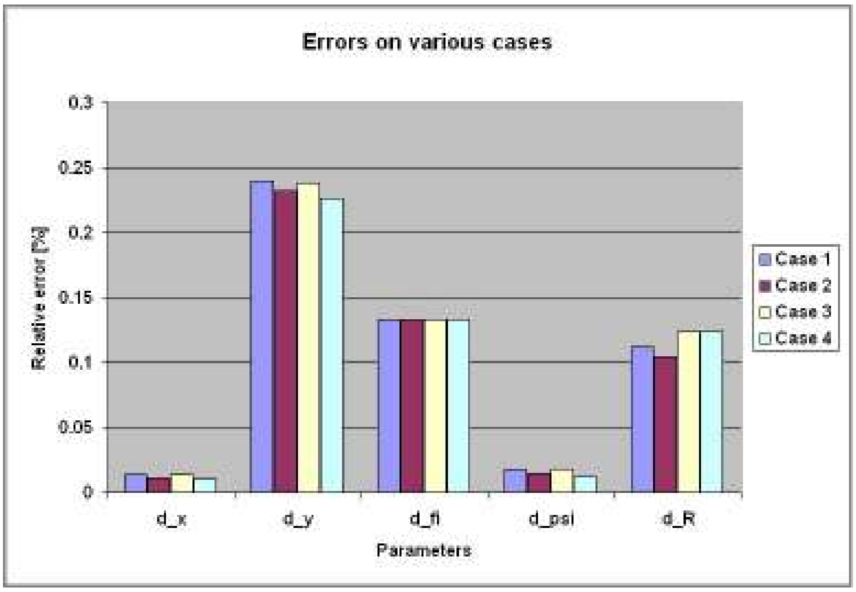

Fig. 3. *Relative error regarding the parameters circulation order*

Table 2.

	Real	Case 1	Case 2	Case 3	Case 4	Error 1	Error 2	Error 3	Error 4
Δ x [mm]	0.8	0.80082	0.79973	0.80082	0.79971	-0.00082	0.00027	-0.00082	0.00029
Δ y [mm]	-0.5	-0.5087	-0.49651	-0.50853	-0.49624	0.00864	-0.00349	0.00853	-0.00376
φ [°]	-1.5	-1.4858	-1.5063	-1.486	-1.5068	-0.0142	0.0063	-0.014	0.0068
ψ [°]	0.5	0.50068	0.49978	0.50068	0.49976	-0.00068	0.00022	-0.00068	0.00024
Δ R [mm]	0.25	0.24795	0.25092	0.24778	0.25109	0.00205	-0.00092	0.00222	-0.00109
scope function	1.76E-09	0.05133	0.009288	0.050653	0.010931	-0.05133	-0.00929	-0.05065	-0.01093

Table 3.

Admissible error ε	Scope function value	Total loops number	Loops for x	Loops for y	Loops for φ	Loops for ψ	Loops for R
100	82.131	1052	210	212	210	210	210
10	9.4413	2207	441	443	441	441	441
1	0.92085	3467	693	695	693	693	693
0.1	0.091066	4727	945	947	945	945	945
0.01	0.009148	5987	1197	1199	1197	1197	1197
0.001	0.000917	7247	1449	1451	1449	1449	1449

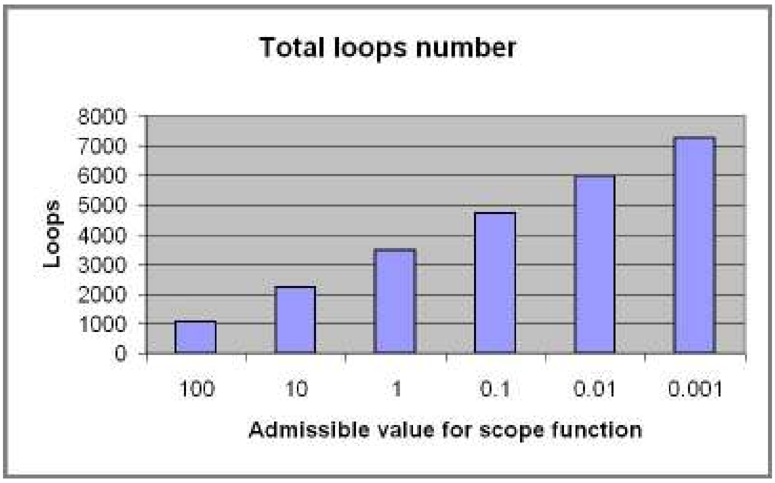

Fig. 4. *The total loops number*

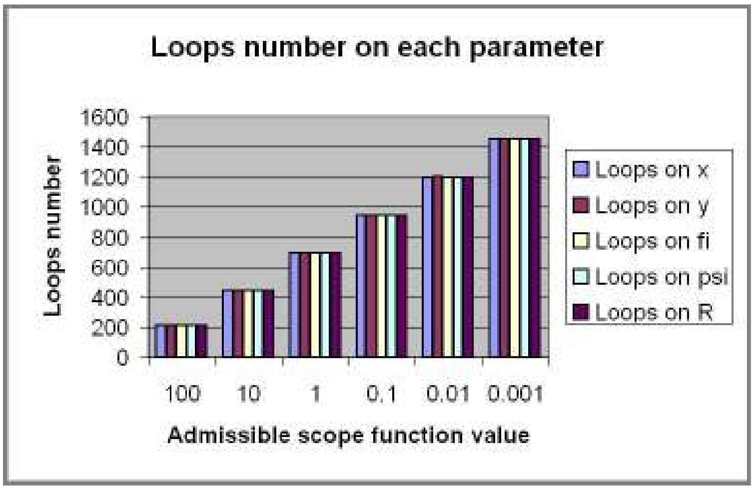

Fig. 5. *The loops number on each parameter*

4. Conclusion

The presented identification technique allows obtaining the needed information regarding the mathematical model of the surfaces of the reconfigurable manufacturing system components (work piece, devices, tools etc.). This technique is precisely and fast enough to be used at on-line geometry monitoring and control during the manufacturing process.

The identification technique based on parameters circulation is general and flexible due of fact that is enough to change the reference system of gathered point (in measuring phase) in order to use the same model for another surfaces on same type.

Using the proposed technique it is possible to determine the deviation from nominal position and from theoretically geometric form as well.

The parameter commutation isn't very important as regard the technique performance level (see table 1 and table 2).

The loop number, as so as the time for software running, will increase with the admissible scope function error decreasing.

Bibliography

[1] **Damodarasamy, S., Anand, A.,** *Evaluation of minimum zone for flatness by normal plane method and simplex search*, IIE Transactions, 1999, pag. 617-626;

[2] **Segonds, S., Landon, Y., Mousseigne, M., Lagarrigue, P.,** *The characterisation of the dimensional change of the Z-axis in NC turning*, International Journal of Advanced Manufacturing Technology, 2004, 23, pag. 800-805;

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

[4] **Yadong, L., Peihua, G.,** *Free-form surface inspection techniques state of the art review*, 2004, Elsevier Science, Computer-Aided Design, 36, pag. 1395-1417;

[5] **Zhu, L.M., Xiong, Z.H., Ding, H., Xiong, Y.L.,** *A Distance Function Based Approach for Localization and Profile Error Evaluation of Complex Surface*, 2004, Journal of Manufacturing Science and Engineering, vol. 126, pag. 542-554;

[6] **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.

Identificarea suprafeţelor utilizând algoritmi genetici

Rezumat

Tehnica de identificare bazată pe circulaţia parametrilor constă în căutarea exhaustivă a valorilor parametrilor modelului matematic al suprafeţei, valori care determină similitudinea optimă între model şi piesa reală. Fundamentul acestei tehnici este reprezentat de unicitatea extremelor în spaţiul de căutare.

În aplicarea acestei tehnici se porneşte de la faptul că, la generarea suprafeţelor vor apare abateri de la formă şi poziţie teoretică faţă de suprafaţa teoretică. Aceste abateri sunt dificil de determinat prin metode obişnuite.

Prin această metodă este posibilă atât determinarea abaterilor de poziţie cât şi a celor de formă faţă de valorile teoretice.

Surfaces identification basées sur des algorithmes génétiques

Résumé

La technique basée sur l'identification des paramètres de circulation consistent recherche sur l'épuisement de valeurs des paramètres du modèle mathématique qui déterminent les valeurs optimales de similitude entre le modèle et la réalité. Le fondement de cette technique est la singularité extrêmes dans la recherche spatiale.

Dans le système de cette technique, on part du fait que lors de la génération de surface apparaîtra déviations de forme ainsi que de la position en ce qui concerne la théorie de surface. Ces écarts sont difficiles à établir avec les méthodes habituelles.

Cette méthode permet de déterminer la position d'écart ainsi que de la dimension des écarts en ce qui concerne la théorie des valeurs.