Evolutionary Algorithm for Measurement of Screw Parameters

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Abstract: - In this paper we propose to apply the evolutionary algorithm for measurement of screw thread parameters. The proposed method is based on a vision system with the web camera. This method can be applied to real objects quality control and object inspection.

Key-Words: - evolutionary algorithm, parameter measurement, optimization, vision system.

1 Introduction

In recent years the vision systems have penetrated to industry due to fall in prices. They are used for the quality control and object inspection. It is possible also to develop the method of parameter measurements on the base of a vision system. For this purpose we propose to use the evolutionary algorithm.

The evolutionary or genetic algorithms have many applications in area of computer vision. It can be used to solve image reconstruction problems in electrical impedance tomography [1], for the object pose estimation in the 3-D world from a 2-D image [2]. In this case genetic algorithm was used as an optimization procedure in six-parameter space. The genetic algorithm was implemented also for a remote monitoring system to increase the antennas efficacy [3]. In this work the genetic algorithm was used to produce geometries showing improvement over current designs. Detecting specific shape from image is an important problem in computer vision [4]. In [4] the genetic algorithm has been studied in the task of an extraction of certain type of geometric primitives.

We propose to use a vision system and evolutionary algorithm for micromechanics. This area of investigation is sufficiently new one. A special project of microfactory creation based on miniature micromachine tools was initialised in Japan [5]. The Mechanical Engineering Laboratory developed a desktop machining microfactory [6], [7]. Microfactory consists of machine tools such as a lathe, a milling machine, a press machine and assembly machines such as a transfer arm and a two-fingered hand. This portable microfactory has external dimensions 625x490x380 mm^3.

The idea of microfactory creation is also supported in other countries. In Switzerland, the details of precision motion control and microhandling principles for future microfactories have been worked out [8].

A method of sequential generations was proposed to create needed microequipment [9].

According to this method the microequipment of each generation has the sizes smaller than the sizes of the equipment of the previous generations. This approach, called “microequipment technology” (MET), allows one to use low cost components for each microequipment generation and to create the microfactories capable to produce the low cost microdevices [10].

2. Task

The task of this work is the measurement of the parameters of the microscrew thread. It is necessary for the quality inspection of the products, which will be produced by micromachine tools. For the measurement of the conventional thread parameters the thread gauges are used. More precise measurement of these parameters can be made with special optical device. For the measurement of the microscrew thread parameters it is comparatively difficult to use thread gauges;

therefore the most acceptable method is to use the optical measurement devices. The problem in this case is connected with the small specks (for example, the particles of chips, which stick to the surface of microscrew), which substantially distort the object image. Frequently the real screw profile doesn't correspond completely the theoretical thread profile due to the microequipment inaccuracy. That is why it is necessary to use the special procedure for approximation of real image with the aid of the segments of straight lines. Such segments form the theoretical thread profile.

One of the most acceptable methods of this approximation consists in the construction of the mathematical description of the thread profile (for example, with the aid of the segments of straight lines) using such parameters as the pitch of thread, the height of the thread profile, the angles between the segments of lines etc. Thereafter it is necessary to search for the parameter values, which minimize the deviation of the real thread profile from the mathematical model. These parameters are considered as the parameters of real thread. The search is realized by means of minimization of the average squared error using an evolutionary algorithm. Evolutionary algorithm is used because the task is multiparametric and multiextremal one.

2.1. Image preprocessing

The images of screws with the diameter of 2mm and the pitch of 0.4mm were taken with the aid of the web camera, fixed on the optical microscope. Example of image is shown in Fig.1.

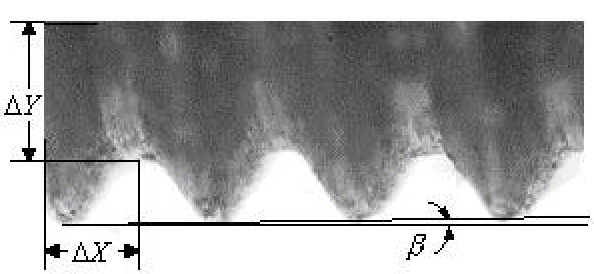

Fig.1. Example of real image

For measurement of thread parameters the image contours were extracted. (Fig.2).

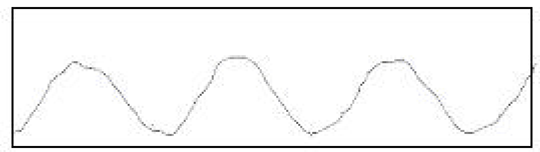

Fig.2. The contour image

The contour images were used for thread profile approximation.

A standard metric thread profile shown in Fig. 3 was used as a mathematical model.

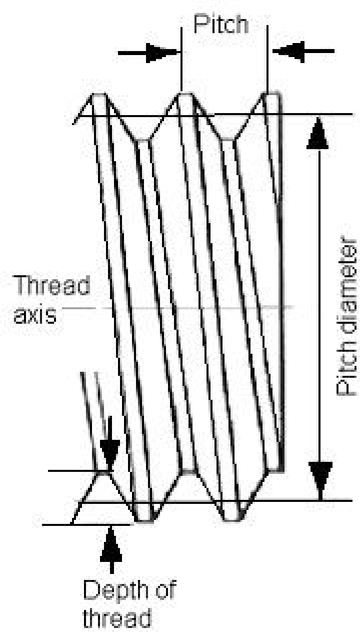

Fig.3. Standard screw thread

In Fig. 4 the standard metric screw thread is presented with the base features of a screw. The features are: P- screw thread pitch; H – height; F_1 - width of flat crest; F_2 - width of flat root; D – single depth of thread

The list of features that were used in evolutionary algorithm as parameters of optimization is presented in Table 1.

The screw on the image can have different position and inclination. So to take into account this fact we added three additional parameters which define the position of screw in the real image (Fig. 1). So we added ΔX , ΔY , and the angle between the screw axis and the horizontal line b .

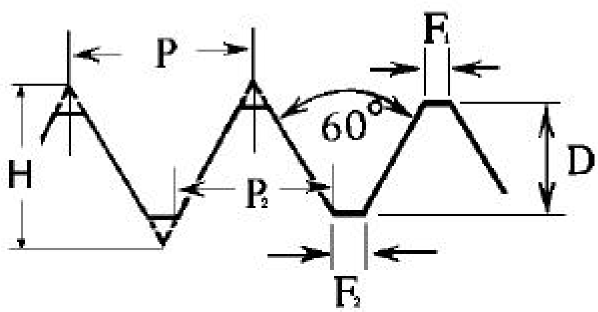

Fig. 4. Metric thread: P- screw thread pitch; H – height; F_1 - width of flat crest; F_2 - width of flat root; D – single depth of thread

Table 1.
The list of metric screw thread features

Name	Symbol and relative value
Thread parameters (Fig. 4)	
1. Width of flat crest	$F_1 = 0.125P$
2. Width of flat root	$F_2 = 0.25P$
3. Single depth of thread	$D = 0.625H$
4. Pitch between adjacent fillets	$P_2 = P – 0.25P = 0.75P$
Thread position parameters (Fig.1)	
5. Horizontal shift	ΔX
6. Vertical shift	ΔY
7. Angle between the screw axis and the horizontal line	*b*

So evolutionary algorithm works with four parameters to determine thread profile unambiguously and 3 parameters to determine its position in a rectangular coordinate system, i.e. the optimization procedure is realized in a seven-parameter space.

The most of these parameters are expressed through one general parameter *P* (screw thread pitch), as it is represented in Table 1. But these relationships are accurate only for the ideal thread. For the real thread, which is made in the factory, all these relationships are disrupted and the purpose of measurement (with the aid of the evolutionary algorithm) is to define all these real parameters, which in this case it is correct to consider as independent variables, since the deviations can be arbitrary for each of them.

2.2. Evolutionary algorithm

In our case the mono-sexual model of evolutionary algorithm was used. Each new offspring was born from one parent with the influence of the mutations. The optimization criterion was selected from the point of view that is necessary to build the curve which is closed as much as possible to real curve of thread contour. We select points on the mathematical model curve. For every point we find the nearest point of the real contour curve and calculate the distance till this point. The sum of all squared distances is the criterion of the optimization.

The parameters were presented in the form of floating-point numbers. The mutations (positive and negative), which have been selected according to the specific rule, were added to the values of the parameters.

In one generation 1000 offsprings were generated. The best 100 offsprings were selected for the new generation.

3. Results

The obtained results of evolutionary algorithm realization are shown in Fig. 5.

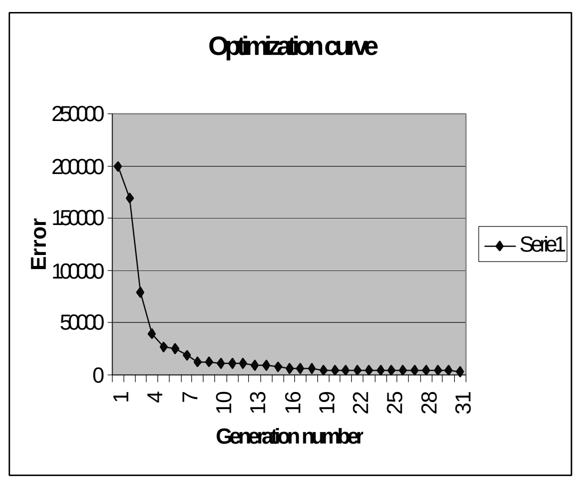

Fig. 5. Evolutionary algorithm results

Two thread contour curves are shown in Fig. 6: initial contour curve and approximating curve. The curves coincidence is sufficiently good. So we can use the parameters of approximating curve as the thread profile characteristics.

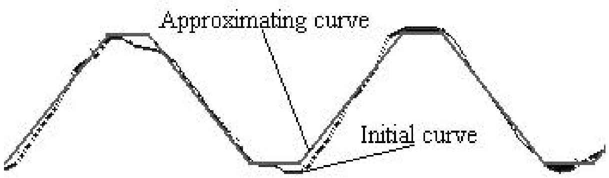

Fig.6. The curves coincidence

4. Discussions

We propose to use a vision system and evolutionary algorithm for micromechanics. The task of this work is the measurement of the parameters of the microscrew thread.

The images of screws with the diameter of 2mm and the pitch of 0.4mm were taken with the aid of the web camera, fixed on the optical microscope.

For the measurement of the thread parameters of conventional sizes the thread gauges are used. For the measurement of the microscrew thread parameters it is comparatively difficult to use thread gauges; therefore the most acceptable method is to use the optical measurement devices. The problem in this case is connected with the small specks (for example, the particles of chips, which stick to the surface of microscrew), which substantially distort the object image. Frequently the real screw profile doesn't correspond completely the theoretical thread profile due to the microequipment inaccuracy. That is why it is necessary to use the special procedure, which realize an approximation of real image with the aid of the segments of straight lines. We use for this purpose the evolutionary algorithm.

The problem consists in the fact that the most of parameters of ideal thread are assigned in the form of the relationships of the values (for example, as function of parameter P), which it is not possible to measure directly in the real curve. The task of comparison with the ideal curve does not relate to the evolutionary algorithm. It must be carried out according to the results, which the evolutionary algorithm will give out. Actually, in the real curve there is no flat crest neither flat root, there are no marked points, along which it would be possible to measure the value of step P, there are no straight lines, between which it is possible to measure the angle (60 degrees for the metric thread). Therefore, there is no possibility to verify directly on the image the relationships between the parameters, if they really are close to those, which are assumed in the ideal thread. For this checking it is necessary to find the method to measure the values of these parameters not in the ideal, but in the real thread. This method consists in the fact that we, considering these parameters as independent variables, construct the thread profile from the line segments, which in the best way approximate real curve. After this, it is already easy to compare real thread with the ideal. For example, after dividing F_1 by P and obtaining, for example, 1.132, it is possible to compare this value with the permissible deviations of this relationship, which usually are given in the technical reference books and to conclude about the real thread does or does not satisfy these technical requirements. But if we make the optimization procedure only with one independent parameter P, we will be able to conclude only about pitch of thread and nothing be able to say about its other important parameters and characteristics.

The obtained results show that it is possible to use the evolutionary algorithm for such problem solving.

In future we plan to apply the evolutionary algorithm to obtain the parameters of microgears. This task is more complicated and demands more parameters to include into the model.

5. Conclusions

The measurement of microscrew thread profile is a difficult problem because it is almost impossible to use the tread gauges. The direct application of the optical methods of tread profile measurement is also difficult because images as a rule are distorted by small particles on the screw surface or the real screw profile doesn't correspond completely the theoretical thread profile due to the microequipment inaccuracy. To eliminate the influence of such effects we use the evolutionary algorithm that gives good approximation of real tread profile and permits us to obtain the parameters of theoretical profile that corresponds to real one. These parameters must meet with the tolerances for this type of the screw. So, the evolutionary algorithm could be used for microthread profile measurement.

5. Acknowledgment

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