Form error evaluation criteria and its mechanical interpretation

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Evaluation of form errors in manufactured parts is essential in determining conformance to tolerance specifications. Types of geometric forms typically encountered are straightness, flatness, roundness, and cylindricity. In this paper, the straightness and roundness error evaluation problem were considered from the mechanical point of view. The data points acquired by CMM were treated as fixed mass points and the ideal geometric forms that enclosing the data points were considered as rigid bodies that can move randomly but keep their forms or just change their size and position. When the rigid bodies reached their equilibrium state, the form error was got. It was either the radius of a circle or cylinder or the distance between two ideal geometric forms that enclosing all the data points between them. Here they were turned into rigid bodies. Whether the mechanical system had reached the equilibrium state or not could be judged using the theory of mechanics. Experiments verified the effect of the proposed method.

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1. Introduction

Form deviation measurement includes the acquisition of geometric information and the evaluation method of form error from the measuring data. In general, in order to evaluate form error based on the minimum enclosing zone method, the mathematic model for the problem needs to be built and then it is solved using math methods. In this paper, the mechanical principles are to be introduced into the solving of the form error evaluation problem and a unified evaluation method satisfying the minimum enclosing zone is to be built. The idea of the method is as follow: The geometric forms are divided into open curves(surfaces) and close curves(surfaces). The sampled discrete data which represent the geometric form are treated as particles. For the open curve(surface), a model of particles-rigid ideal element-spring model is to be built. And for the close one, a model of particles-semi-rigid ideal element-spring is to be built. Firstly, the initial state of the model is set. Then the steady state of the model is got using mechanical principle and method. The result of form error is the length of the spring in steady state. In this method, the mechanical principles are flexibly used to solve the problem of form error evaluation based on the minimum enclosing zone, which is a unified method and can be used to solve various form error evaluation problems. The research work of the paper finds a new approach for form error evaluation based on the minimum enclosing zone, which has significant academic sense and actual application potential

2. Straightness and roundness evaluation

2.1 Straightness evaluation

2.1.1 Model building

According to the definition of minimum zone straightness, if the acquired data points are treated as fixed mass points, and the geometrical form are considered as movable rigid body, then when the equilibrium condition is reached, the system has the least energy, that is the two parallel lines has the smallest distance. The model is shown in Fig. 1.

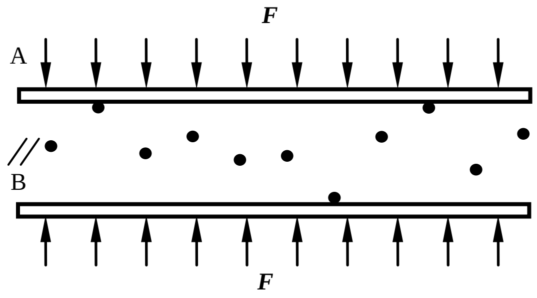

Fig.1 Mechanical model for straightness evaluation

2.1.2 Solving of the model

From the theory of equilibrium for static forces in mechanics, when the system showed in Fig. 1 reached its equilibrium state, there must be three supporting points. For rod A, there were two contacting points; for rod B, there was one contacting points. There were different states of the two rods. Only if the distance between the two rods was the smallest, it was the straightness error that conformed to the minimum request.

2.2 Minimum circumscribed roundness evaluation

2.2.1 Model building

As showed in Fig. 4, the data points normally sampled by a CMM are considered as fixed nails on a plane. A cirque is place on the plane with all the nails in it. Then as if a force is exerted on the cirque, it will change its position and radius but keep its form. When at last it can not change, it is the minimum circumscribed circle. As the cirque's radius and position can be changed, which is different from rigid bodies, it is denoted as "semi-rigid body".

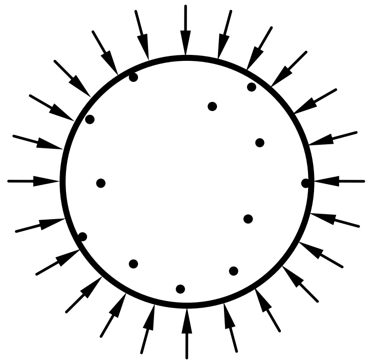

Fig. 4 Mechanical model for roundness assessment

2.2.2 Solving of the model

Three steps are taken in this paper to solve minimum circumscribed roundness evaluation problem as showed in Fig.5.

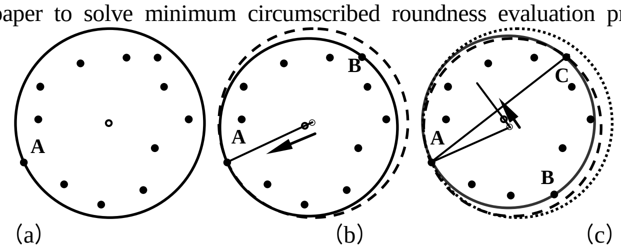

Fig. 5 Solving procedure of MMC

4. Conclusions

In this paper, the evaluation of straightness and roundness was considered from the mechanical point of view. Firstly, Graham scanning method was used to construct a convex hull from the acquired data points. Secondly, the minimum zone straightness error and minimum circumscribed roundness error were derived from the convex hull constructed. The evaluation results were conformed to the minimum request. As a convex hull is firstly constructed, the total calculating time was greatly shortened. For minimum circumscribed roundness evaluation, the equilibrium condition of planar concurrent forces and the vector algebra method were used to judge whether the final result was got. The proposed method can also be used in other form error evaluation process.

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