The Models for The Comparison of Roundness Profiles

Submitted 10th October 2011; accepted 12th November 2011

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Abstract:

Roundness is one of the mostly frequently observed geometrical deviations. A profile of a machine part consisting of simple harmonic courses or their sums depends on a number of factors. Modeling of geometrical deviations requires applying the Fourier to extend each periodical function into an infinite series of harmonic components. Using of harmonic analysis we are able to determine the values of amplitudes of single components and their phase shifts. These parameters can be used for example for comparison of roundness profiles by means of correlation coefficients. The obtained correlation coefficients are concrete parameters, on the basis of which it is possible to determine the degree of conformity and unity between the compared profiles. The comparison of evaluated roundness profiles can be represented as mathematical statistical models. In these models is detected sequence of single steps, which are necessary for determination of required correlation coefficients [1, 2] .

Keywords: *roundness, correlation coefficients, mathematical models, comparison*

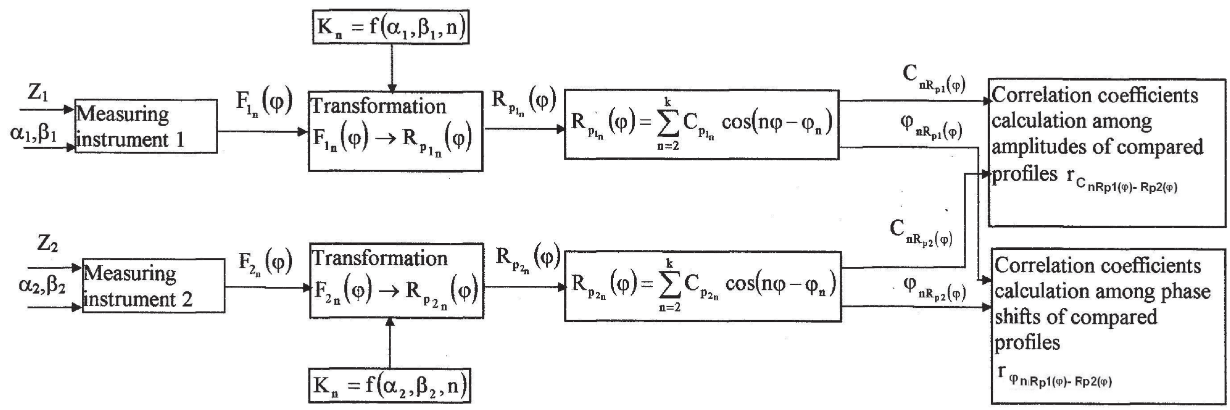
1. Introduction

The functional surfaces of rotary machine component need to be as accurate as possible from the point of view of geometrical quality. To assure good co-operation of rotary parts (e.g. couple journal-bearing), following are necessary:

- high dimensional accuracy,
- high form and position accuracy,
- low surface waviness,
- low roughness parameters.

One of the most relevant factors of rotary surfaces macro geometry is **roundness**. The value of roundness deviation ΔR (EFK) and profile for have an effect on the functioning of a machine part and indirectly on the cooperation of rotary surfaces. In case of a rotation, the profile form directly influences vibrations.

A profile of machine part at dependence on various influences can consist of the simple harmonic components (oval, tri-lobbing, square…), or their sums. This depends on the surface machining conditions of during the manufacturing process. During modeling of geometric deviations Fourier's series are used. Thus, each periodical function can be extended into an infinite series of harmonic components. Irregularities of roundness profile correspond to the irregularities periodically occurring on basic wavelength, which is equal to perimeter of profile. After a harmonic analysis it is possible to assign amplitude and phase shift to all irregularities which define the size and the character of irregularities on the surface of machine part. These parameters can be used for additional processing, e.g. for comparison of roundness profiles courses [2].



$\alpha_1, \beta_1, \alpha_2, \beta_2$ … parameters of method

Z_1, Z_2 ... quantities, which influence accuracy of measuring,

$F_{1n}(\varphi)$, $F_{2n}(\varphi)$ … measured profiles (before transformation)

K_n ... enlargement coefficients,

$R_{p_1}(\varphi), R_{p_2}(\varphi)$ ... profiles after transformation,

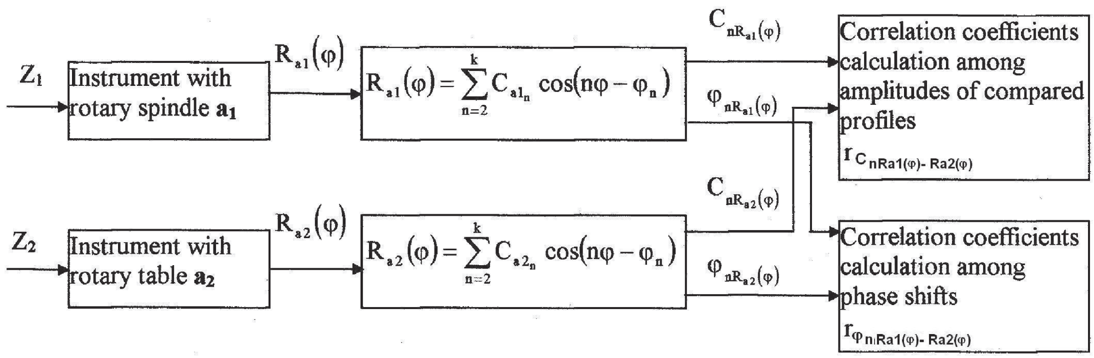
$C_{nRp(\varphi)}$ ... amplitude of n^{th} harmonic component of profile after transformation,

$\varphi_{nRp(\varphi)}$ ... phase shift of n^{th} harmonic component of profile after transformation

$r_{C_{nRp1(\varphi)-Rp2(\varphi)}}$ · correlation coefficient among values of amplitudes for n^{th} harmonic component of profiles,

$r_{\varphi_{nRp1(\varphi)-Rp2(\varphi)}}$ correlation coefficient among values of phase shifts for n^{th} harmonic component of profiles.

Fig. 1. *The model of comparison roundness profiles measured by the relative method for various parameters* α *and* β



Z_1, Z_2 ... quantities, which influence accuracy of measuring,
$R_{a1}(\varphi)$, $R_{a2}(\varphi)$ ... output functions determining profile of measured machine part,
$C_{nR_{a1}(\varphi)}$, $C_{nR_{a2}(\varphi)}$ ... values of amplitude for n^{th} harmonic component of measured profiles,
$\varphi_{nR_{a1}(\varphi)}$, $\varphi_{nR_{a2}(\varphi)}$ ... values of phase shifts for n^{th} harmonic component of measured profiles,

$r_{C_{nRa1(\varphi)-Ra2(\varphi)}}$. correlation coefficient among values of amplitudes for n^{th} harmonic component of profiles,
$r_{\varphi_{nRa1(\varphi)-Ra2(\varphi)}}$. correlation coefficient among values of phase shifts for n^{th} harmonic component of profiles.

Fig. 2. *The model of comparison roundness profiles measured by the non-reference methods*

2. The comparison of roundness profiles

Mostly methods for the comparison of roundness profile involve evaluation on the basic of roundness deviation ΔR (EFK). However, this evaluation is not objective, nor does it concern the geometrical form of machine part as the whole. Two components of roundness profile can be evaluated by the same value of ΔR, but in fact the courses will be different [2].

Objective evaluation of geometrical form of rotary machine parts requires applying appropriate measuring methods. The instruments used for that register roundness profiles courses in the form of measuring signal. The signal it then processed and the resulting parameters can be applied for instance to:

– comparison of roundness profiles obtained with different methods of measurement,
– comparison of roundness profiles obtained with one method of measurement,
– the evaluation of form changes of parts caused by aging,
– assessment of machine-tools from viewpoint of their reliability etc.

Roundness profiles can be compared objectively using a statistical method, of calculation of correlation. The correlation coefficients can be calculated either by means of the Pearson method (linear correlation) or by the less known and less frequently used Spearman method (range correlation). The obtained correlation coefficients are then used for the determination of the degree of conformity and unity between the compared profiles.

3. The models for the comparison of roundness

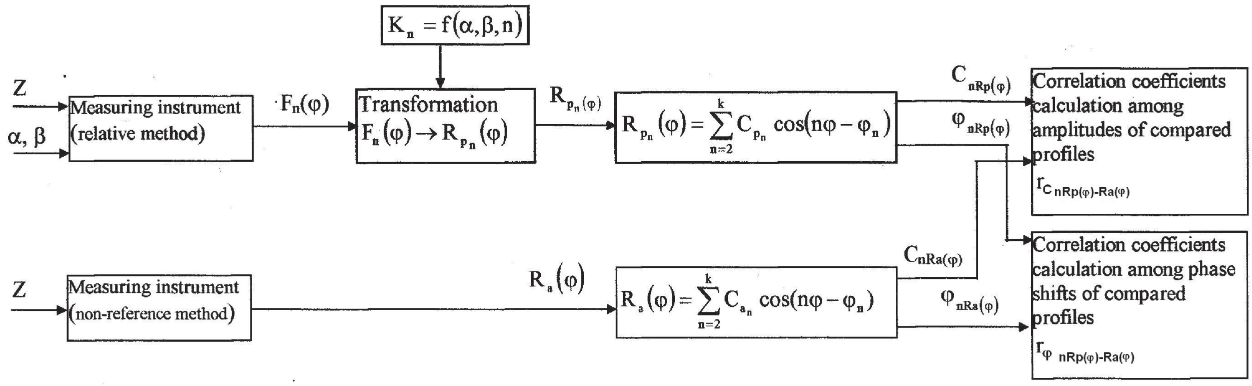
It is possible to represent the concept of comparison of the evaluated roundness profiles as mathematical models. These models are composed of a sequence of steps necessary to determine the correlation coefficients for roundness profiles. The correctness of developed models was verified experimentally, see ref. [2].

Figure 1 shows mathematical model for the comparison of roundness profiles obtained by measurement with a relative method at different values of method parameters α and β. It is necessary to transform measured profiles $F_n(\varphi)$ into real ones $R_n(\varphi)$. This transformation requires application of complicated mathematical formulas. The result of the harmonic analysis of the transformed profiles are values of amplitudes and phase shifts of each harmonic components, which are the used for calculation of correlation coefficients. On the basis it is possible to determine the type of correlation and degree of unity.

Figure 2 presents a mathematical model used for comparing two roundness profiles measured with non-reference instruments (i.e. with a change in radius). The principle of non-reference measurement is simple and so is the mathematical model, which does not require any complicated transformation. The measured profile is the same as the real one. From harmonic analysis of measured profiles we obtain values of quantities demanded for the calculation correlation coefficients.

The third mathematical model is applied to the comparison of roundness profiles measured with relative and non-reference methods (Fig. 3). This model is more complicated than model two became of the complex transformation theory of relative profile measuring. The steps following the transformation are identical with those in other models.

In all the three models it is necessary to take account of the influence of several disruptive factors on the accuracy and objectivity of comparison. There are mainly method errors, errors of the measuring system and well as errors made during the mathematical processing of information.



Z ... quantities, which influence accuracy of measuring,
K_n ... enlargement coefficients,
$F_n(\varphi)$ ... profile measured by relative method (before transformation),
$R_p(\varphi)$ ... profile measured by relative method (after transformation),
$R_a(\varphi)$ ... profile measured by non-reference method,
$C_{nRp(\varphi)}$ ... amplitude value of n^{th} harmonic component of profile after transformation,
$\varphi_{nRp(\varphi)}$ ... phase shift value of n^{th} harmonic component of profile after transformation,
$C_{nRa(\varphi)}$ ... amplitude value of n^{th} harmonic component of profile measured by non-reference method,
$\varphi_{nRa(\varphi)}$ ... phase shift value of n^{th} harmonic component of profile measured by non-reference method,
$r_{C\,nRp(\varphi)-Ra(\varphi)}$ ... correlation coefficients among amplitude values of profiles $R_p(\varphi)$-$R_a(\varphi)$ for n^{th} harmonic component,
$r_{\varphi\ nRp(\varphi)-Ra(\varphi)}$ .. correlation coefficient among phase shift values of profiles $R_p(\varphi)$-$R_a(\varphi)$ for n^{th} harmonic component.

Fig. 3. *The model of comparison roundness profiles measured by the relative and non-reference method*

4. Conclusion

At present much emphasis is put on evaluation of form accuracy of rotary machine parts. In practice the methods and procedures have to be adjusted for each case individually. The suitability and objectivity are assessed by comparing the obtained harmonic components of roundness profiles. Also, it is essential to calculate the coefficients of correlation between the values of amplitudes and of phase shifts of each harmonic component. It is possible to represent the algorithm of this comparison by the means of mathematical models and procedures enabling calculation of correlation coefficients. These models can be used, after small modifications, for the representation of the conception concerning the evaluation of form changes of rotary machine parts resulting from ageing or the assessment of technological heredity etc.

ACKNOWLEDGEMENTS

This paper was created under the Grant of the Ministry of Education, Youth and Sports Czech Republic No. 2548/2011/F1

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