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MEASURING PROBLEMS ON PROFILE COMPARISONS OF DIGITALIZED FREEFORM AREAS

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Abstract - The measurement of elements of Roll-Works is difficult, because the roughness and the profile-curves are important for the quality of production. Specifications of quality-parameters are not given, but the effects of fault Roll-Works we can see. Through the measurement and the analysis with graphs, which showed the differences in the profile-curves, we recognized the characteristic differences of the faulty Elements of Roll -Works. The transparencies allow the visual control of the elements, which is an easy method to find out the quality parameters for our problem.

Keywords: Best fit-adjustment, freeform measurement, roughness-measurement

1. INTRODUCTION

One of the responsibilities in the industry is to make sure the customer receives his tool with guaranteed quality pro-duction. Often mistakes arise in the phase of manufacturing. or testing. Usually they aren't easy to regulate within the company because its necessity of special measurement, soft-ware and know-how. One typical example for an industrial task is the profile comparison of digitalized freeform areas.

2. THE TEST OBJECT

Characteristic for the quality of those tools are rough-ness, deviation of profile-curve and the material. To mea-sure the roughness accurately, you have to be able to get the tension distance through filtering or arithmetical calculation. A test of profile-curve can be done three or two dimen-sional. The test result is the difference between the „is-con-tour“ and the „should-be contour“. To determine the diffe-rence you have to align the measuring object. You can do that through the best-fit adjustment or the alignment of the object's stricting points. The objects we used were elements of roll work (ERW) which have profile-curves in radial di-rection. With the insert of the ERW the material showed cracks. Therefore we claimed the elements to have syste-matic mistakes in their geometry. It probably were both, the deviation of surface roughness and the deviation of the pro-file-curve in the two- or three- dimensional points. These mistakes had to be shown. To correct them is the base of improving the quality of the production process. We were able to abstain the measurement of the materials parameter, because we could exclude those kinds of mistakes. In other tests we measured the profile's height with conventional technology of measurement. However, differences in height were not the causes for mistakes. Therefore we limited the test to the measurement of the profile-curve and roughness. For our measurement we didn't have more information in order to improve the should-be value“.

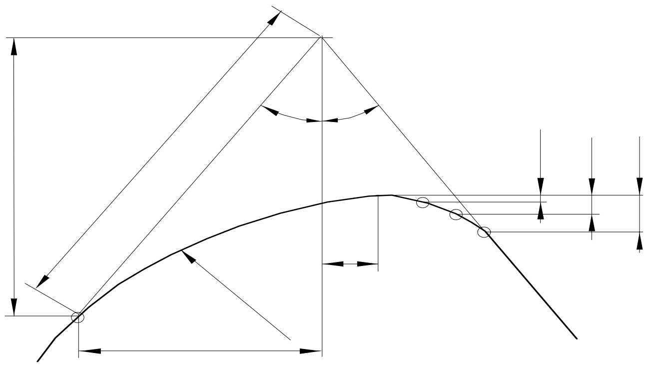

Fig. 1: Profile-curve of ERW

That's why we used the parameter of the perfect ERW as our master. Hence we had to compare the element with faultless „should-be profile“, but not all of the information we got from the specification. Now we concentrated on testing and measuring profiles on similar ERW.

3. HOW TO MEASURE

We used the FORM TALYSURF from the Taylor-Hobson company. This measuring instrument is perfect for tasks of roughness measurements, profile measurements and topographical analyses. For preparation we measured the elements in a revolving apparatus and fixed the angle positions. Therefore the measurement object is being aligned so that:
- the parallel distance of the x-axis is as small as possible
- the y-position of the apparatus is able to be calibrated
- we can get rid off inclination the apparatus has.

Throughout our measurements we didn't change the position of the apparatus at all. The apparatus therefore fixed all pieces reproducible.

4. THE MEASURMENT CONCEPTION

In order to minimize the results of possible fluctuations by measuring, we concluded the data after getting it.

4.1 Procedure of measurement

The following steps are used as procedure:

-get the files for the „should-be“ (SBP) and „is-profile“ (IP),
- get the roughness files,
- vectorize the SBP and IP,
- Best fit adjustment of the IP in the belonging vectorized SBP,
- compare the contours of the SBP and IP,
- graph the differences between the SBP an IP,
- GAUSS-filtering of the profiles,
- evaluate the roughness parameters Ra and tp,
- recognize and correct the software mistakes.

Trough the measurements we received about 200 files, documents and reports of the roughness and profile measurements. We also got vectorized profiles and overlapping presentations after the Bestfit adjustments. To get these information we worked with software from Taylor Hobson used for profile analyses. In addition we used different kinds of graphic programs.

5. MEASUREMENT OF PROFILE-CURVES

The measurement of profile-curves became possible with the help of a sphere caliper (radius 500µm). We put the ERW on the apparatus and defined the profile's position. Later on followed the establishment of data, the measuring of the profile-curve and we saved the data. Afterwards we turned the ERW to the next position and after the establishment of all the profile -curves we investigated the next ERW.

6. ANALYSIS OF THE MEASUREMENT

6.1 Algorithm

To find out a solution for the problem we have used a algorithm to calculate the differences between surface and dimensional specification.

In assessing the departure from geometric forms the method of least squares occupies a dominant place, being the preferred method often in the international metrology and their standards. Although this would appear to be straightforward it is not so because of the many algorithms which could be used to achieve the assessment. Depending on which is used the result could be obtained quickly and accurately. Also, another problem which arises is that very often the parameter is not linear, in which case prior to applying least squares some linearization has to take place from which an approximate solution is obtained and used in the following iteration.

The least squares method has been used in a number of situations. There is one general approach which might prove to be useful. This is based on the technique developed for use in dimensional measuring processes. This technique is valid for surface and metrology problems. The algorithms employ a common approach which has stable parameterization of the measuring work pieces. It is necessary to obtained all the data from the measuring instrument. Surface metrology instruments are different from dimensional measuring machines, like coordinate measuring machines. In measuring an work piece can produce different forms of data, one can usually easily be linearized, the others cannot. Unstable results can be produced if one sort of algorithm is applied to be the wrong data.

The rationale is follows. It concerns parameterization which in turn concerns the way in which the problem of solving for the best fit solution is posed.

For a point x, y, z the distance d is given by:

$$d = a(x - x_0) + b(y - y_0) + c(z - z_0) \quad (1)$$

The ith point d_i has a distance:

$$d_i = a(x_i - x_0) + b(y_i - y_0) + c(z_i - z_o) \quad (2)$$

and one way to estimate the goodness of fit is to look:

$$S = \sum d_i^2 \quad (3)$$

at The sum S depends on the parameters a, b and c. these parameters have to be chosen to minimize S. The steps are the follows:

1. Choose parameters to describe the position, shape and sometimes also the orientation and size of geometrical part
2. Derive a formula for the distance of a point from the geometrical object, the work piece
3. Express the sum of squares S in terms in a set of data points and their distances from the geometrical object
4. Develop a stable algorithm for the determining the parameters such as a, b, c, x_0, y_0, z_0

A precursor to evaluating the best fit to improve the numeri cal accuracy is to find the centroid of the data points $\bar{x}, \bar{y}, \bar{z}$ and to remove these from the general data points so that the new points x_i, y_i, z_i equal the original points $x_i, y_i, z_i - \bar{x}, \bar{y}, \bar{z}$.

The case for the best fit line reduce the simple case of solving a matrix equation, that is finding the eigenvektors of matrices.

In the general the function :

$$S(u) = \sum_{i=1}^{M} d_i^2(u) \quad (4)$$

has to be minimized with m data points and n parametres to be minimized with respect to u where:

$$u = (u_1, u_2, \ldots u_n)^T \quad (5)$$

where T indicates the transpose u, the vector form of u. For a linear systems a good algorithm follows, given a square matrix B, an eigenvector u of B is such :

$$B = \lambda u \quad (6)$$

for some eigenvalue λ . The case in the question is such that :

$$B = A^T A \quad (7)$$

as in (6) for some m x n rectangular matrix A where m>n. In this situation a stable numerical solution is obtained by finding a singular value decomposition of the matrix A. In this A can be written as a product:

$$A = USV^T \quad (8)$$

with U and V orthogonal matrices and S a diagonal containing the singular values of A. If B is as in (7) the squares of the diagonal elements of S are the eigenvalues of B and the columns of V are the corresponding eigenvectors. These are usually produced as standard output from most software implementations.

6.2 Best fit adjustment

To analyze the measurements we used two graphs for each curve. We vectorized the SBP with a form tolerance of 1µm and projected the important IP because of the Best fit adjustment over the SBP. We exported the given differences through a graph and scale recorded it. We also filed the vectorized SBP on transparency, which are usable for the production thereof (shown in figure 2).

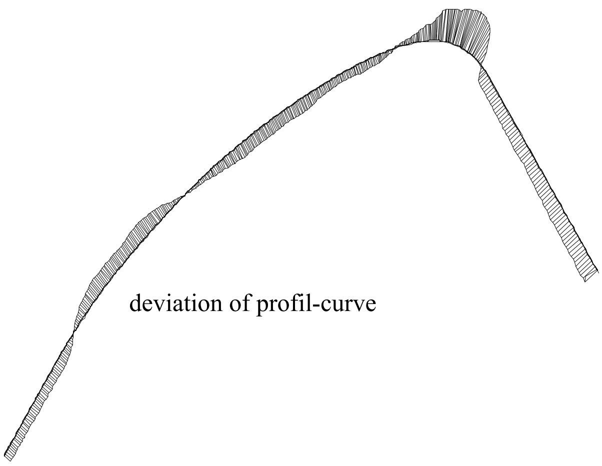

Fig. 2: Best fit adjustment

7. ROUGHNESS MEASUREMENT

For such a measurement we used a sphere caliber with a radius of 2 µm and a measurement area of 6mm. The procedure is the same we used for the measurement of profile-curves, only parts of the roughness measurement-distance, but it doesn't restrict the quality. That's because we had to ensure comparison with another. The

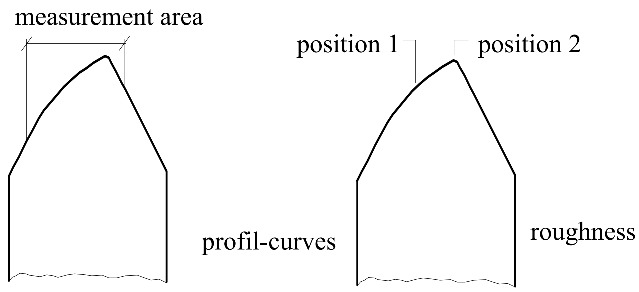

Fig. 3: Measurement areas for profile-curves and roughness

interpretation took place with the same parameters (shown in figure3). For measuring the elements of Roll-Works we need a special arrangement to made sure all measured data and to reach a high repeatability as a base for

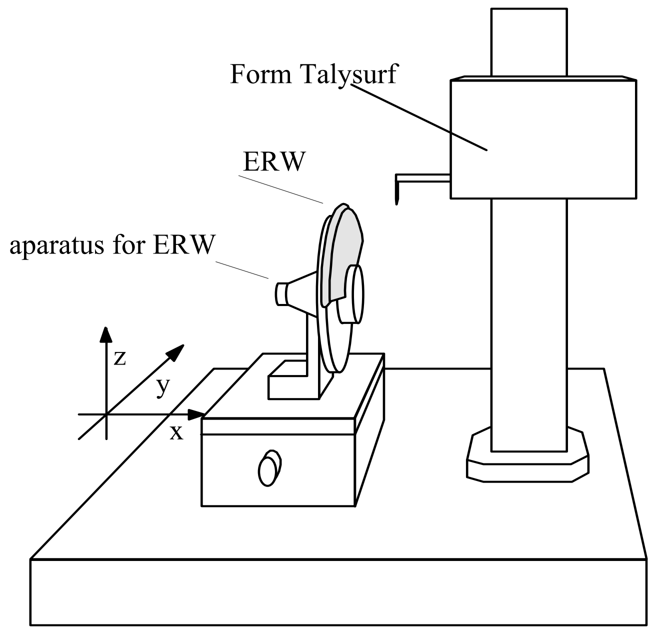

Fig. 4: Arrangement for measurement

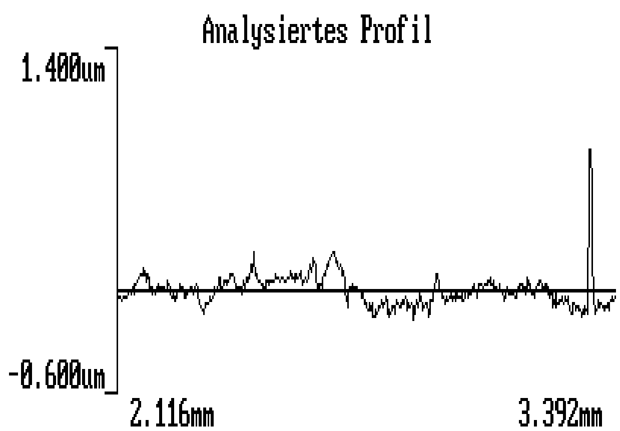

Fig. 5: Profile roughness

8. CONCLUSION

We got to know that the analysis of the roughness data is connected between faulty and faultless working of elements of Roll-Works. Through the graphs, which showed the differences in the profile-curves for all 10 curves, we recognized the characteristic differences of the faulty working elements and on the base of these results we are able to correct all tools for manufacturing. In this case were the best fit method a good way to identify all faults correctly. We are able to identify the difference by enlarging the graph by the ratio 25 / 1. The transparencies allow the visual control of the profiles on the screen of a measurement- projector. The elements of Roll Works are produced like shown on the transparency.

REFERENCES

[1] Forbes, A.B: (1989) Least squares best-fit geometrical elements. *NPL Rep. DITC* 140/89

[2] Mulvancy, D.J., Newland, D.E. and Gill, K.F. (1986). A characterization of the surface texture profiles. *Proc. Int. Mech. Compr*. 200 C(3) 167-78[

[3] Puttok, M.J. and Thwaik, E.G. (1969). *National Standards Lab. Paper No. 25*, (Melbourne CS/RO)

[4] Semenyuk, N.F. (1986). Average height of roughness asymmetry an density of contact spots in contacting isotropic rough surface. *Trenice 1*, Iznos 7, 830-40

[5] Skout, K.J. et al (1993). The Development of Methods for the Characterization of Roughness in *Three Dimensions. Report EUR 15178 EN*, printed at University of Birmingham

[6] Whithouse, D.J, (1978). Surface topography and quality and its relevance an wear. *MIT* Conf p 17

[7] Whithouse, D.J, (1994). Handbook of Surface . *IOP Publishing Ltd.* p.299-301

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