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INSPECTION OF THE TURBINE BLADES USING SCANNING TECHNIQUES

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Abstract: The paper describes a conception of a scanning system applied to the complex inspection of turbine blades. The implementation of the scanning technique on CMM produced in IOS required to use a new scanning probe, as well as the implementation of an extended control and processing data procedures. In accordance to the technical documentation the analysis program is capable to perform the evaluations of the parameters of blade features. A very accurate comparison with nominal features with graphical presentation can be achieved. The usage of above method has been checked in industrial application.
Keywords: scanning, measurement, quality inspection

1 INTRODUCTION

A development of coordinate techniques concerns more and more the problems of measurements of free surface shapes which have been solved by using gauges and models. Nowadays, the control of parts such as turbine blades, plane parts, cars bodies, machine tools parts (machine tools template), CRT tubes and others is realised by digitising or scanning of checked surface on CMM and then processing the data to formula demanded by technical documentation. Frequently the demanded formula of results is a digital format in standards used for bridging to CAD systems. These demands are due to the integration of production, design and flexible control environments. Coordinate technique is a very good way of realisation of these needs.

In order to improve and to widen control tasks, carried out on IOS's CMM a complex system for turbine blades measurement basing on Renishaw scanning probe SP600M was developed. For using this probe on IOS's CMM it was necessary to improve electronic system, the accuracy of CMM and above all to widen the control software. For the identification of measured surface it was necessary to develop efficient routines for measurement of grid, to formulate the mathematical model of surface, to determine a relation between accuracy of appointed surface and the number of measurement points and their distribution, as well as to adjust technical parameters such as speed for this type of measurement. The result of this work was the rise of the speed of measurement and improvement of measurement's quality and their techniques on IOS's CMM.

2 EQUIPMENT CONFIGURATION

2.1 Scanning head

SP600M Analogue Measurement Probe applied in the system is an autojoined, multiwired scanning probe, mounted on the fixed and motorised Renishaw probe heads. It enables to gather very quickly large amount of data, indispensable for identification of the surfaces.

The probe offers 3 axis movement of 1 mm in each X, Y, Z direction.

2.2 Motorised head

SP600M scanning head is joined with PH10M motorised head, in purpose to achieve necessary in surface measurement angle positions. Reorientation of the scanning head provides 720 of the indexed positions, every 7,5 degree in both (horizontal and vertical) axes.

3 SCANNING

3.1 Principle of the measurement

The probe stylus moves across the surface of the workpiece, along programmed trace, controlled by servo control of the CMM.

This is the ideal way for the inspection of forms and shapes, which are not the standard, geometric elements.

The scales of the CMM controller must be latched at the same time, as the probe axis deflections are read via AC1 interface card. These readings can be summed up to give a data point:

Read data point $\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} u \\ v \\ w \end{bmatrix}$, where $\begin{bmatrix} x \\ y \\ z \end{bmatrix}$-CMM position; $\begin{bmatrix} u \\ v \\ w \end{bmatrix}$-probe position

3.2 Calibration

The SP600M/AC1 system requires the calibration, proceeding the accurate position data performance. The subject of calibration procedure can be as follows:

-the axis scaling for the stylus, i.e. the distance represented by the data count for each axis;
-the alignment of the probe axes relative to the machine coordinate system.

Above purposes can be easily and quickly determined on CMM. The precise sphere was used in calibration procedure. Calibration proceeding consisted in the determining of the differences between the two amounts of probe deflection ($d_1$and d_2) at the same point, and respectively, the differences between the machine positions, for these deflections (m_1). These vectors form the first column of the matrixes $\mathbf{P}$, and $\mathbf{M}$ for the first calibrated axis (X). Then, the measurements were repeated in turn, for the second and third axes Y and Z, up to achievement the full matrixes $\mathbf{P}$ and $\mathbf{M}$.

$$\mathbf{A}\ \mathbf{P} = \mathbf{M}$$

Correction matrix A reaches by the invert the matrix P:

$$\mathbf{A} = \mathbf{M}\ \mathbf{P}^{-1}$$

So, the way of transformation probe coordinates (p) to machine coordinates (m) is found.

4 PROJECT OF SCANNING MEASUREMENT OF TURBINE BLADES ON CMM TYPE MP700E

4.1 Control software

The scanning head is implemented on CMM type MP700E. Electronic system of this CMM is based on two PC class processors connected by serial interface RS232 (Fig. 1).

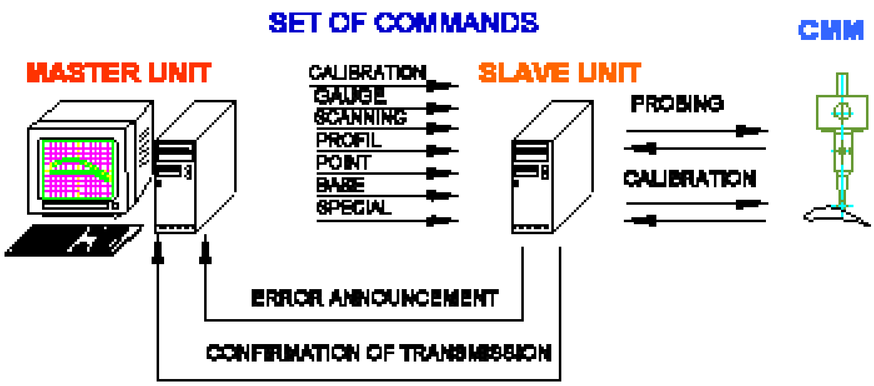

Figure 1. Schematic diagram of the scanning system concept.

Slave unit is working in real time mode and controlling linear measuring systems, probe electronic and drives. Master unit is controlling users interface, data processing, creation of measurement reports and automatic cycles generation by sending all necessary commands to Slave unit. For such task distribution it was necessary to develop a protocol of information interchange between Master and Slave units.

The scanning measurement for the Slave unit required a new software for calibration of SP600M probe and a new control software for collecting (gathering) measured points. Calibration task is performed using two functions: "SYSTEM", which is used for requalification of the system after changing its angular position, and function „CALIBRATION" used to establish a value of the probe stylus radius. Control functions of the probe are activated by „INIT" command and disactivated by

„END" command. Measurement procedures for collecting measured points were developed in such a way, that their realisation could guarantee the measurement of all types of profiles and edges. For the complex measurement of turbine blades the system has got special procedures: „POINT" command- for measuring point in dedicated axis and direction, „SCAN" command- measurement of established numbers of points on the interval between two points with set coordinates, „PROFIL" command- measurement established number of points on the interval with set length, „SPECIAL" command- measurement of established number of points on the interval set by points, which declare limits of measured edge (this command is used for measurement of sharp turbine blades with small edge radius). Besides these procedures, for measurement of points it was also necessary to develop new command for transport movements connected with axe system (origin) inscribed in real part profile. Standard set of transport commands was enlarging in command „BASE", which allowed measurement of reference points and „PARK" command- doing such movement according to measured references.

User on Master unit activates the SLAVE unit commands performed using Slave unit, and it's why the new information exchange protocol was necessary on serial interface. Because the automatic way of measurement was necessary, all these commands work in LEARN mode of CMM and system has the created formal instruction set, as for standard transport and measurement actions with classical probe. Each command has their symbolic name under which is store in automatic program file.

4.2 Blade measurement methodology

Quality inspection of profile of blades is pretty complicated due to its complex form.

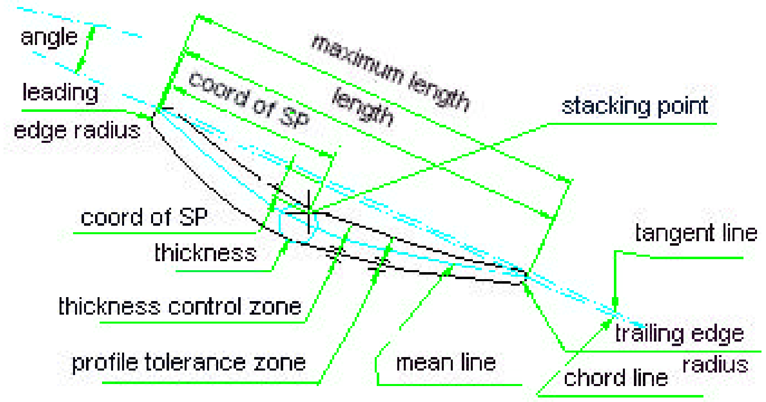

Figure 2. Dimensioning of the turbine blade

Aerodynamically shaped parts can be distinguished in blade's section:
- leading contour: blade's contour from the side of air entry – blade's back;
- trailing contour: blade's contour from the side of air outflow – blade's body;
- leading edge;
- trailing edge.

Detailed rules of blade's dimensioning and tolerancing are stated in manufacturer's technical documentation. Full set of inspected blade's parameters include dimensions and conditions stated in drawing, tables with nominal profile's coordinate sets and special conditions referring to specified type of blade [2].

Rules of dimensioning and geometrical tolerancing of curvilinear outlines, which include fragments of blade's profile, are governed by international standard ISO [1]. According to this standard curvilinear outlines can be dimensioned stating rectangular coordinates of points determining theoretical curvilinear profile and tolerance range should be symmetrically positioned to theoretical outline.

Coordinate system, in which dimensional blade's parameters are stated and points of nominal profile section are situated, has origin which real position is determined by comparative analysis of profile's real outline to its nominal outline. Determining of coordinate system has important meaning on following analysis of parameters. Blade's reference point is positioned in intersection of mean line and leading edge, assuming that mean line is a geometrical set of points equally distant from concave and convex side of profile's section from leading edge to trailing edge. Fitting of real profile to nominal is

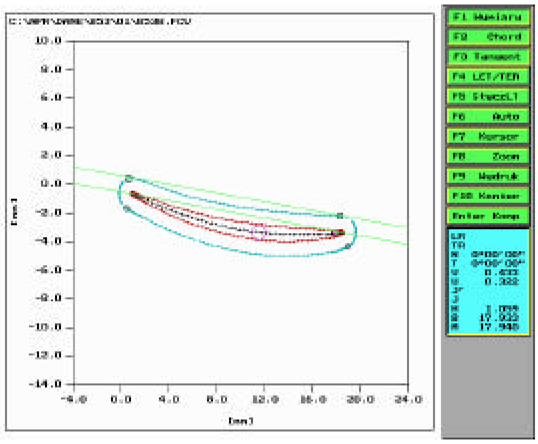

Figure 5. Mean line and thickness.

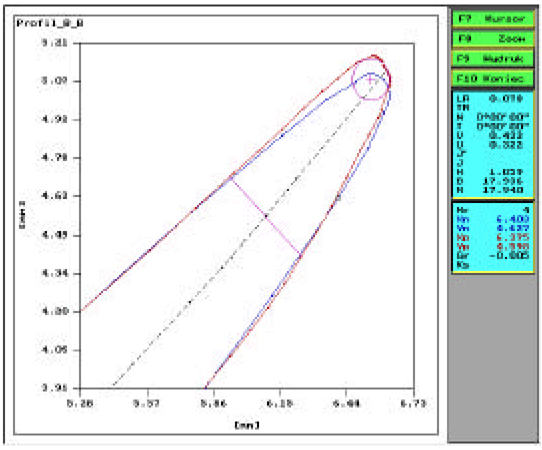

Figure 6. Determining of deviations.

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connecting points formed by intersection of mean line of section with the radii of leading edge and trailing edge of profile is called the chord line;

- blade twist angle as the angle of rotation between chord line of profile section and reference datum specified on drawing;
- thickness as a greatest distance between concave and convex sides of a given profile section;
- thickness of trailing edge and leading edge as limiting sizes normal to the mean line at a basic distance from the trailing edge (leading) of a given profile section;
- blade length;
- check of stacking point: the real point of origin of coordinate system of intermediate sections should lie in tolerance area to blade medium axis;
- check of blade thickness using checking field applied to concave and convex side of profile in each section;
- inspection of shape of profile section: concave and convex side of profile section is checked.

5 BLADE ANALYSIS PROGRAM

The program was developed to perform numerical analysis of blade's form and sizes. The program performs calculations on the basis of data set that comprises coordinates of points measured in determined in documentation sections of profile received during measurements performed by scanning head. Nominal data and configuration settings are transferred to the program by the use of text files.

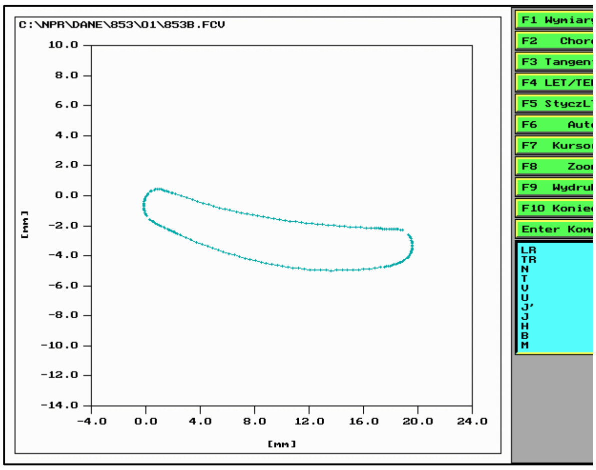

Figure 3. Graphic presentation of points.

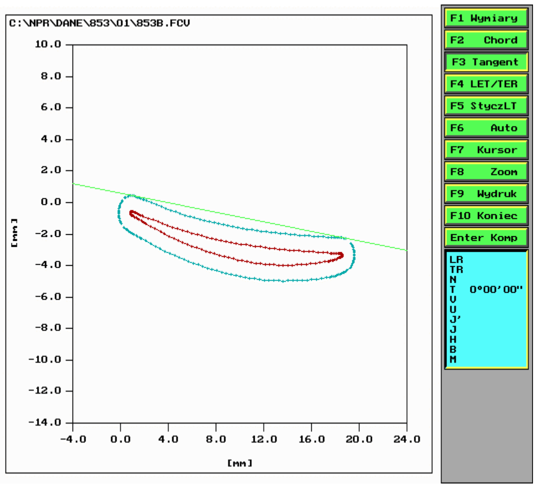

Figure 4. Correction of the tip radius.

Blade profile analysis is performed according to the following algorithm:

1. Picking up of sets of points representing measurements in particular sections (Fig.3).
2. On the basis of data included in information file the measurement file is divided on back area, bed, edge radii and "transient" area.

3. The borders of thickness checking area are determined for nominal file.
4. Introductory determining of edge radii on the basis of square minimum criterion.
5. Measurement file is sorted. “Transient” areas are divided on points belonging to blade contour and to edge rounding.
6. Determination of rounding radii on the basis of sets complemented with “transient” points and correction of measuring tip radius for all points are performed (Fig.4).
7. Mean line and blade maximum thickness are determined (Fig.5).
8. Transformation of coordinates to nominal system is done.
9. Control thicknesses are determined in established distances from edge.
10. Measurement profile is introductory fitted to nominal. Adjustment is done on the basis of Gauss’ criterion.
11. Iterative determination of best fit profile according to maximum thickness deviation in thickness checking area.
12. Blade length and profile twist angle are determined.
13. Checking of form for concave and convex side of profile section (Fig. 6).

Following analysis of form is performed using program’s graphic interface.

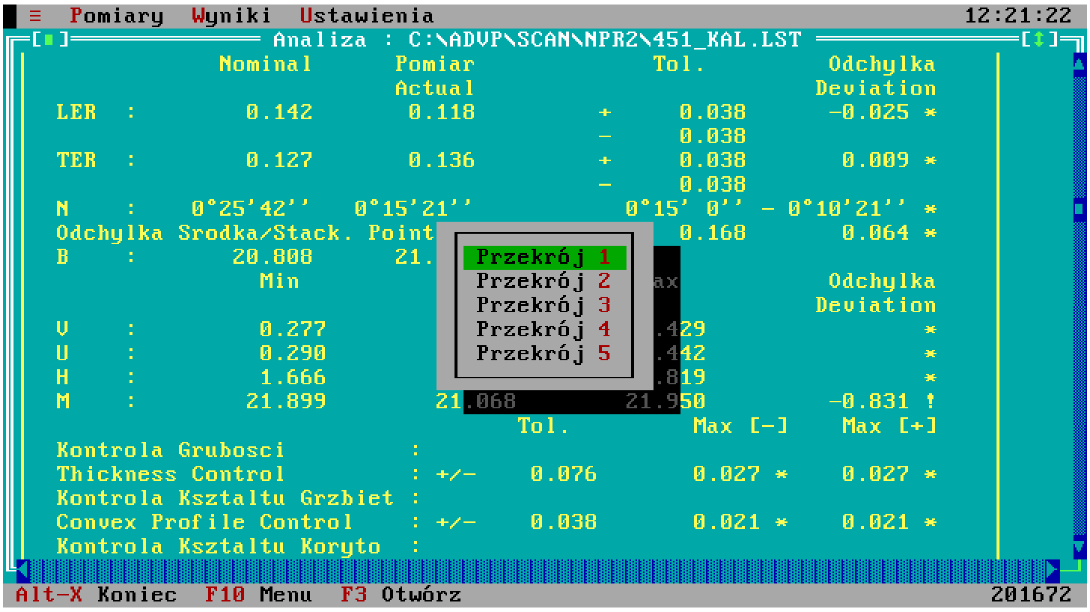

Figure 7. Result screen.

By the use of friendly interface the user has possibility of performing calculations on chosen set of data, construction of data sets by preparing list of files, making individual program configurations for specific data sets by edition of information files. The results of analysis are included in text reports: dimensional parameters and maximum deviation values, listing of local deviations (Fig.7), and in graphic form showing dimensioning of sections and relation to nominal profiles. There is the possibility of saving of full report to file.

6 SUMMARY

Developed scanning system was implemented for plane blades checking. The application was based on performing a set of tests and measurements for types of blades determined by the user. The method used in blades quality inspection includes procedures allowing transformation of data to defined blade coordinate system, fitting of real profile to nominal data sets, data filtration and programs for calculating of blade dimensional parameters according to standard. Elaborating of particular sections (including sorting and selection of points, correction of measuring tip radius and section fitting) can be exported to text files in format accepted by CAD applications.

Measurements of blades using current software cover 2.5D measurement problems, which means that measurements are performed in three axis system and their analysis in plane. Described methods are still developed to give the possibility to check and analyse machine parts in 3D space using coordinate machines made in IOS.

REFERENCES

[1] EN ISO 1660:1995, ISO/FDIS 10360-4
[2] *Technical documentation of the turbine blades*

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