BALANCING OF RIGID SHAFT

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ABSTRACT

In this work is presented realization of balancing laboratory tester based on measuring card and software frequency analyzer – balancer (balancer), programmed in National Instruments (NI) LabVIEW environment. This tester is assigned for teaching purposes to familiarize students with basics of machine balancing.

1 INTRODUCTION

Unbalance represented by mass disequilibrium of rotating machine around its axis causes rise of vibrations with same frequency as rotational speed of machine (fundamental frequency). If the velocity amplitude of these vibrations overruns limit defined by VDI 2056 standard, it could cause damage or destruction of the machine. This unbalance can be eliminated or set into tolerable limits by placing correction mass. The position and weight of correction mass can be calculated from values of amplitude and phase [1], [2], [3]. They are obtained by measuring of vibrations' velocity amplitude and phase shift between vibrations' and reference signal. The reference signal is obtained from tachometer measuring rotation speed of machine.

2 BALANCING METHOD

On dependence of machine's shaft type, number of bearings, rotating speed and other parameters we will use appropriate balancing method. Method of field balancing is useful for our purpose. It is used for quick diagnostics and balancing of machines directly in place of their installation. The tester consists of motor and its load (balanced machine), which is bedded in two bearings and has a rigid shaft. This type of machine is appropriate to balance in two plains. The balancing plain is plain into which will be the correction mass placed. In general, it is identical with plain of bearing (called measuring plain) [1].

2.1 COMPUTATIONAL PROCEDURE OF CORRECTING MASS

There are two ways how to obtain weight of correcting mass and position of its placing for rigid shaft with two gearings. We can use graphic and numeric method. Graphic method is slow and not always leads to satisfactory solution. On the other hand, unbalance can be fully eliminated by numerical solution [2]. Basic equations for balancing in two plains are as follows [3], [5]:

$$\begin{aligned} \alpha_{11} * tm_1 + v_{10} &= v_{11} \\ \alpha_{21} * tm_1 + v_{20} &= v_{21} \end{aligned} \qquad (2.1) \qquad\qquad \begin{aligned} \alpha_{12} * tm_2 + v_{10} &= v_{12} \\ \alpha_{22} * tm_2 + v_{20} &= v_{22} \end{aligned} \qquad (2.2)$$

$$\begin{pmatrix} m_1 \\ m_2 \end{pmatrix} = inv \begin{pmatrix} \dfrac{v_{11} - v_{10}}{tm_1} & \dfrac{v_{12} - v_{10}}{tm_2} \\ \dfrac{v_{21} - v_{20}}{tm_1} & \dfrac{v_{22} - v_{20}}{tm_2} \end{pmatrix} \qquad (2.3)$$

Where:	$\alpha_{11}, \alpha_{12}, \alpha_{21}, \alpha_{22}$	influence coefficients
	v_{10}, v_{20}	velocity vectors of measured vibrations in both measuring plains (amplitude and phase)
	v_{11}, v_{21}	velocity vectors of measured vibrations with test mass tm_1 placed in measuring plane 1
	v_{12}, v_{22}	velocity vectors of measured vibrations with test mass tm_2 placed in measuring plane 2
	m_1, m_2	computed balancing masses for balancing plain 1 and 2

It can be seen, that it is necessary to perform three measurement runs to obtain needed values of vectors *v*. Then we can compute correction masses and place them into the balancing plains.

There is polar, segment and component method of placing correction mass. The choice of method is dependent on constructional parameters of balanced machine.

3 REALIZATION

Measuring chain used for realization is displayed on figure 1. It consists of balanced machine by SCHENCK (motor and load), two piezoelectric accelerometers KD 91 and their charge amplifiers Aura, optical sensor of rotation speed based on H22A1 circuit, data acquisition card NI PCI 6024 E and PC with installed environment NI LabVIEW.

Acquisition card collects signals from both accelerometers and optical sensor and transfers them into the software balancer, running in PC. Basic scheme of the analyzer is on figure 2. This software enables configure acquisition parameters (selection of measuring channels, frequency, frequency axis resolution and other parameters), signal adjustments (filtering, scaling) and frequency analyzing (computing amplitude and phase frequency spectra of signals). Further to find values of amplitude and phase shift in these spectra and finally it computes weight and position of correction masses. Easy measurement report can be generated at the end of balancing procedure [4], [6].

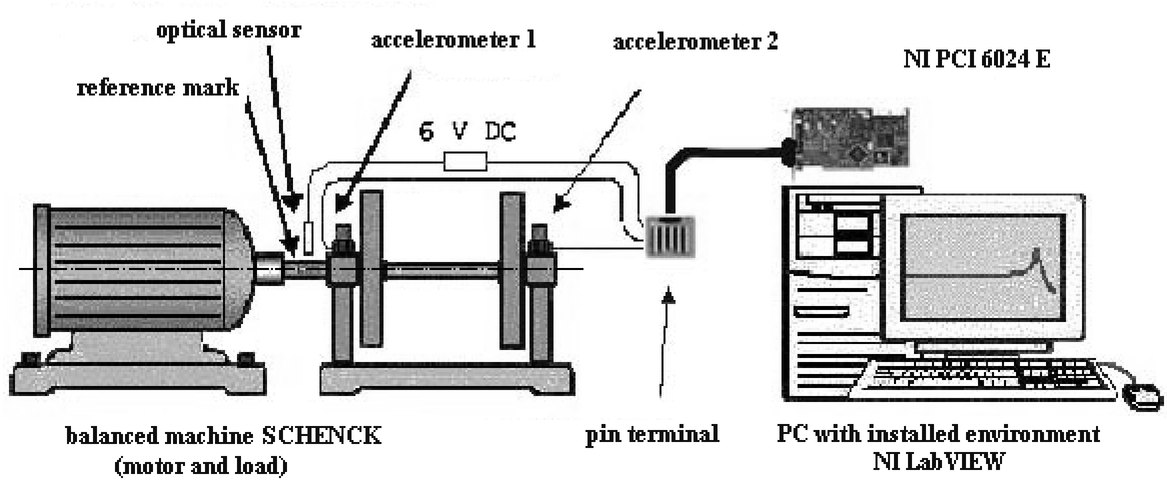

Fig. 1: *Measuring chain*

3.1 BALANCER DESCRIPTION

Program consists of several blocks (fig. 2). Short description of their function follows.

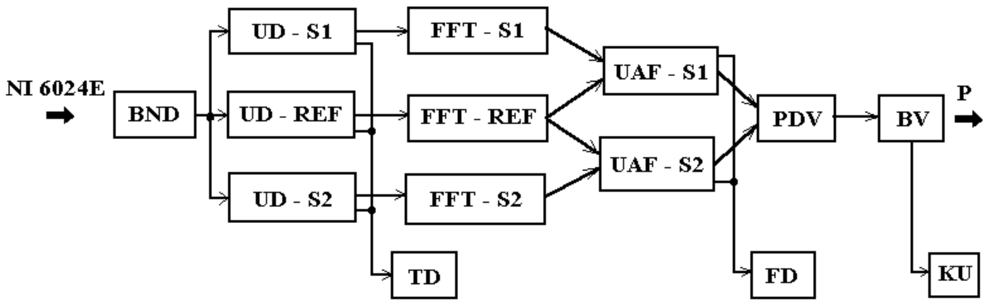

Fig. 2: *Basic block scheme of balancer*

BND – this block sets acquisition parameters of card – measuring channels, input signals range, sample frequency, bandwidth and number of lines, buffer size and type of acquisition.

UD-S1, S2, REF – measured values scaling, integration of acceleration signal to velocity signal (S1, S2), filtering (vibration signals S1 and S2 high-pass filter, reference signal REF low-pass filter)

TD – displays vibration signals and reference signal in time domain

FFT-S1, S2, REF – fast Fourier transform of signals and their averaging

UAF-S1, S2 – search amplitude and phase components of spectra on fundamental frequency

PDV – transfer of found components into computing block BV

FD – displays amplitude and phase assigned spectra of vibration signals

BV – computes correction masses through equation 2.3

KU – evaluates and displays balancing state of machine before and after placing correction masses according to VDI 2056 standard

P – optional, generates measurement report

4 BALANCING SCHENCK MACHINE

Functionality of tester was verified by several balancing procedures of SCHENCK machine. There are measured waveforms, velocity vectors and computed frequency spectra and correction masses displayed on figure 3, 4, 5. These are results of one of balancing procedures.

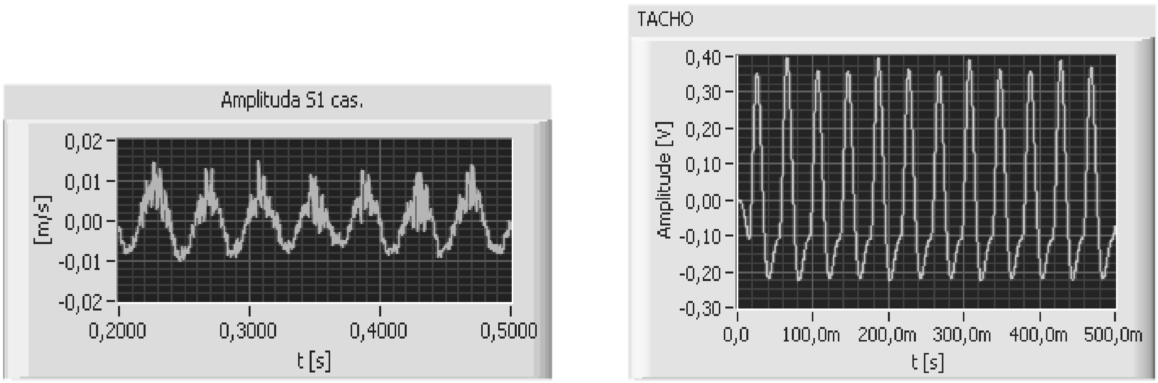

Fig. 3: *Time behavior of vibration signal S1 (left) and reference signal REF(right)*

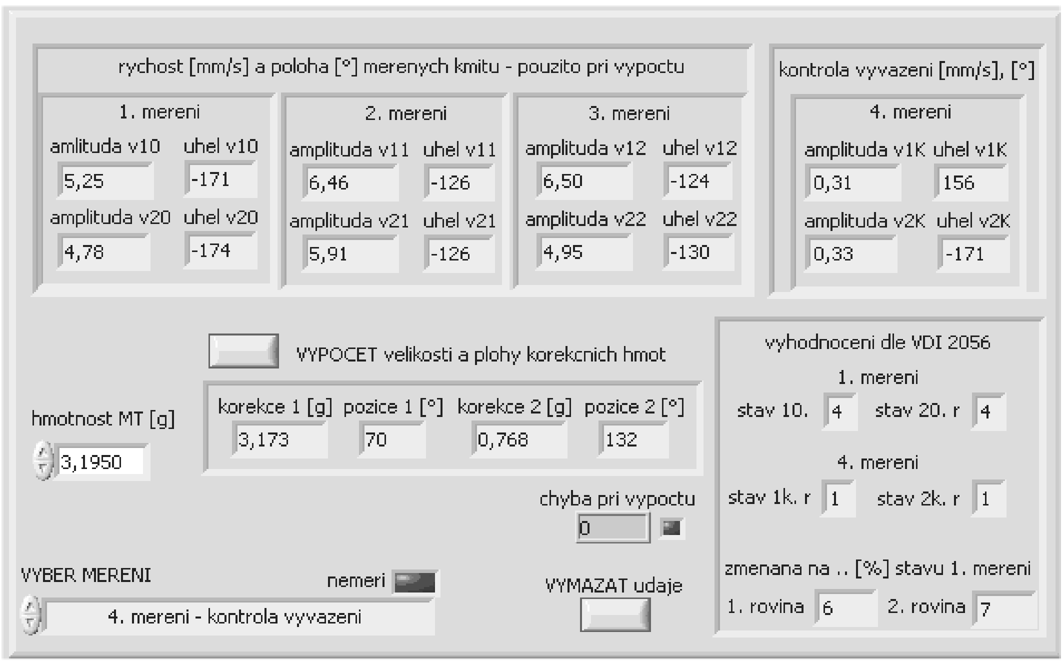

Fig. 4: *Display of measured values of velocity vectors in single runs, computed correction masses and balancing state of machine before and after placing corr. masses*

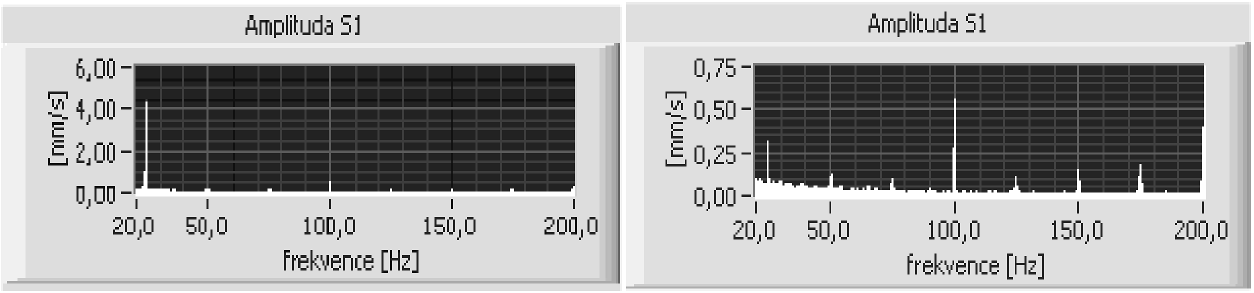

Fig. 5: *Frequency amplitude spectra of vibrations' velocity in measuring plain 1 before (left) and after (right) placing corr. masses; fundamental frequency 24,8 Hz*

Figures 3, 4, 5 are display components of balancer front panel.

As it can be seen on figure 4 and 5, the machine is balanced after placing computed correction masses. Residual non-zero amplitude component on fundamental frequency is caused by shaft coupling influence [1].

There was further measurements undertook on SCHENCK machine with using the balancer – finding direction of greatest oscillations, identification of vibrations source, effects of machine mounting stiffness. With adding frequency converter, it will be possible to measure starting and retardation characteristics of machine.

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