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VIBRATION MEASUREMENT OF THE SPINDLE ASSEMBLY OF AUTOMATED EQUIPMENT

Abstract*: The method and results of vibration measurement of the spindle assembly of the "Haas TL-1" numerically controlled lathe machine are presented in the article. Diagnostics was carried out by the "ECOPHYSICS-110A" special device on various operating modes of automated equipment.*

Key words*: vibration, measurement, the spindle assembly, the CNC lathe machine.*
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Introduction

Vibrations in metalworking equipment are small mechanical oscillations that occur in various parts and mechanisms under the action of variable loads. Oscillations are undesirable during machining, as they affect the accuracy and quality of the workpiece. The output link that sets the machining accuracy during turning is the rotating spindle mounted in the casing.

Vibration measurements are performed in various ways, including special digital devices. The calculation of rigidity of the spindle assembly of the machine in space is performed by comparing the amplitudes of mechanical vibrations without load and under load. The method of vibration measurement of industrial equipment is adopted on the basis of regulatory documents [1-11].

The purpose of this study is to diagnose the numerically controlled (CNC) lathe machine using the electronic device to detect the vibration characteristics of the spindle assembly.

Materials and methods

Vibration measurement of the spindle assembly of the "Haas TL-1" CNC lathe machine (USA) was carried out by the "ECOPHYSICS-110A" multifunctional device (Russia). This device is designed to measure RMS, equivalent and peak sound levels, the corrected levels of vibration acceleration, octave, 1/3-octave, 1/12-octave and narrow-band spectra, for the analysis of signals from various primary transducers, for the record of time waveforms, for the influence assess of sound, infrasound and ultrasound, vibration and other dynamic physical processes on humans in the workplace, in residential and public buildings, determining the vibroacoustic characteristics of mechanisms and machines.

The device consists of the interface unit, the *HF* measuring module, and the primary transducers. The interface unit controls and powers the measurement modules, displays the measurement results and records them in its own non-volatile memory, and transmits the measurement results to external devices. The measuring module receives the analog signals from the primary transducers, amplifies, normalizes and digitally converts the signals, calculates the measured values, and also provides power to the primary transducers.

The "ECOPHYSICS-110A" device has the following technical characteristics (as the vibrometer):

__The input channels:__

1. The *MIC*/*HF* input;
2. The *A* input;
3. The *X*, *Y*, *Z* inputs;
4. The *TTL* input.

__The measured parameters:__

1. The RMS, maximum and minimum vibration acceleration levels with frequency corrections of *Wb*, *Wc*, *Wd*, *We*, *Wj*, *Wk*, *Wm*, *Fk*, *Fm* and with the time characteristics of 1 s, 5 s, 10 s, *Leq*;
2. Peak corrected vibration accelerations of *Wb*, *Wc*, *Wd*, *We*, *Wj*, *Wk*, *Wm*, *Fk*, *Fm*;
3. The vibration dose (*VDV*);
4. The RMS, maximum and minimum vibration acceleration levels with frequency corrections of *Fh*, *Wh* and with the time characteristics of 1 s, 5 s, 10 s, *Leq*;
5. Peak corrected vibration accelerations of *Fh*, *Wh*;
6. The vibration exposure.

__The frequency characteristics of the vibrometer:__

1. The reference frequency in the "General vibration" mode is 16 Hz, in the "Local vibration" mode is 80 Hz;
2. The frequency corrections: the frequency – 0.8…160 Hz, *Wb* attenuation – -8.39…-28.36 dB, *Wc* attenuation – -0.25…-34.57 dB, *Wd* attenuation – -0.08…-46.62 dB, *We* attenuation – -0.52…-52.64 dB, *Wj* attenuation – -6.42…-8.64 dB, *Wk* attenuation – -6.44…-30.69 dB, *Fk* attenuation – -0.27…-8.64 dB;
3. The frequency corrections: the frequency – 6.3…1600 Hz, *Wh* – -2.77…-45.42 dB, *Fh* – -3.01…-5.46 dB.

__The measurement ranges of vibration acceleration:__

1. The reference level of vibration acceleration is 140 dB relative to 10^{-6} m/s^2;
2. The self-noise level in the "General vibration" mode (with the short-circuited equivalent of the IEPE sensor, at the calibration values corresponding to the vibration transducer with the nominal sensitivity of 10 mV/ms^{-2}), dB relative to 10^{-6} m/s^2:

A/D1 (The input/The range) *Wk* – 49, *Wd* – 43, *Wm* – 45, *Fk* – 56, *Fm* – 56, *Wb* – 49, *Wc* – 48, *We* – 41, *Wj* – 55;

A/D2 (The input/The range) *Wk* – 39, *Wd* – 33, *Wm* – 35, *Fk* – 46, *Fm* – 46, *Wb* – 40, *Wc* – 38, *We* – 31, *Wj* – 46;

A/D3 (The input/The range) *Wk* – 28, *Wd* – 28, *Wm* – 26, *Fk* – 34, *Fm* – 33, *Wb* – 28, *Wc* – 29, *We* – 27, *Wj* – 33;

X, *Y*, *Z* *Wk* – 31, *Wd* – 30, *Wm* – 29, *Fk* – 37, *Fm* – 36, *Wb* – 31, *Wc* – 32, *We* – 29, *Wj* – 36.

3. The self-noise level of the device with the DN-4-E vibration transducer in the octave frequencies bands, dB relative to 10^{-6} m/s^2:

A. In the "General vibration" mode: the band – 1…125, the *A* (*D3*) input – 54…52;

B. In the "Local vibration" mode: the band – 8…1000, the value – 49…56.

When changing the calibration correction or the value of the nominal sensitivity of the vibration transducer, the measuring ranges are shifted by the value of $\Delta = 20\lg\left(\frac{10}{S_0}\right) + K$, where S_0 is the value of the nominal sensitivity of the vibration transducer, mV/m/s^2; *K* is the value of the set calibration correction, dB. For the non-sinusoidal signals with the peak factor of k, the upper limits of the linear ranges change by the value of $\Delta_k = 20\,lg\left(\frac{\sqrt{2}}{k}\right)$.

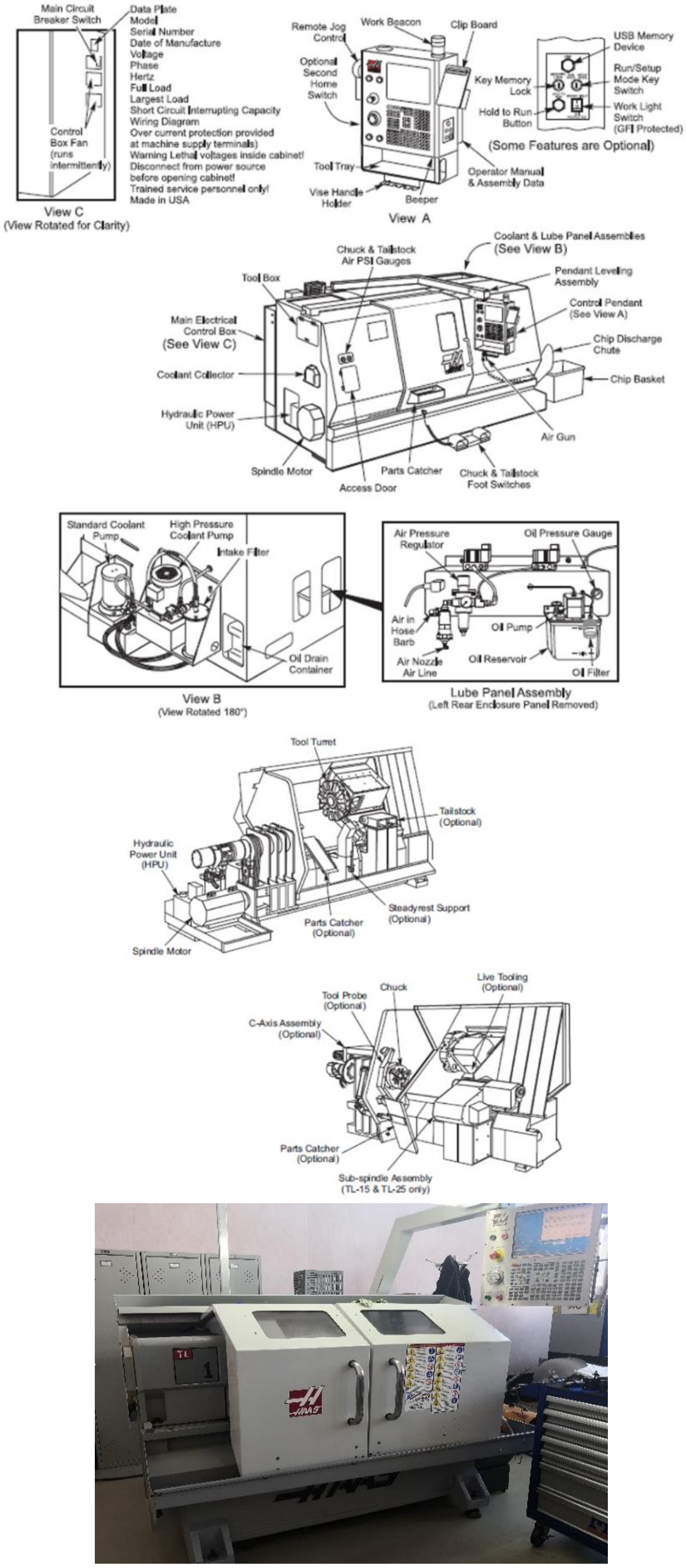


Figure 1 – The structure of the "Haas TL-1" CNC lathe machine.

Figure 2 – Locations of the sensor on the casing of the spindle assembly for vibration measurement.

The linearity error limits in the linear operating range are ±0.5 dB. The error limits for switching the ranges are ±0.2 dB.

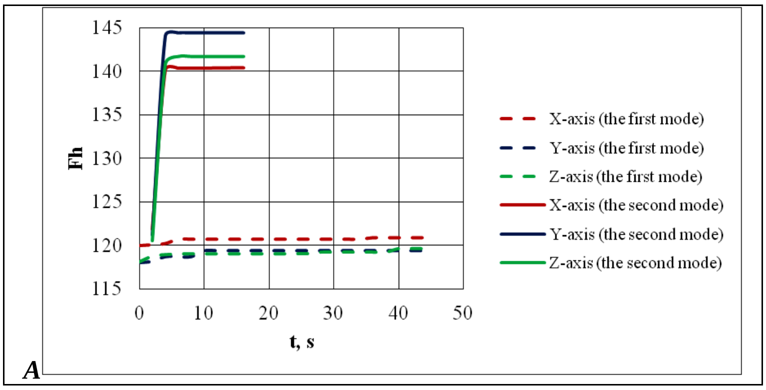
The structure of the "Haas TL-1" CNC lathe machine and locations of the sensor on the casing of the spindle assembly for vibration measurement are presented in the Figs. 1 and 2. The machine was put into the operation in 2009.The three-component IEPE sensor was attached to the magnet. The magnet was attached to the casing of the spindle assembly of the CNC lathe machine according to the photos. Measurements were performed in three directions: horizontal (the first location of the sensor), vertical (the second location of the sensor) and axial (the third location of the sensor). Vibrations of the spindle assembly were measured in two modes of the operation of the CNC lathe machine: the first mode is without load (the spindle speed – 500 rpm), the second mode is under load (the spindle speed – 800 rpm; the cutting tool feed – 0.15 mm/rev; the cutting depth when turning steel – 1 mm). The measurement time in the first mode was 45 seconds; in the second mode was 15 seconds.

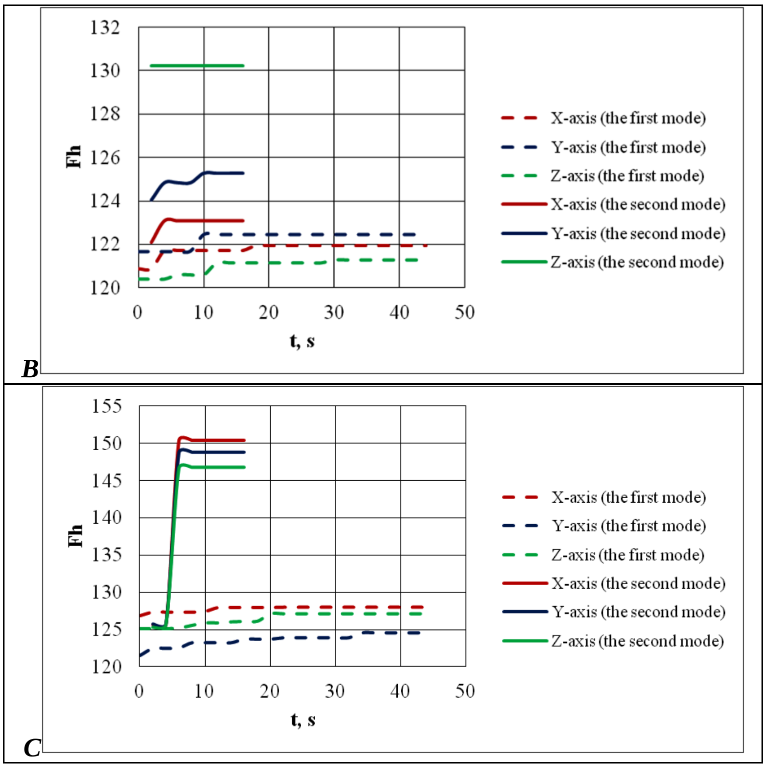
Vibration measurements of the spindle assembly of the machine were carried out in the "Local vibration" mode (the frequencies range from 6.3 Hz to 1250 Hz), selected on the device. The maximum amplification factor (*D2*) was selected for measurement. The following parameters were measured in this mode: the current, maximum, and minimum RMS values for 1, 5, and 10 seconds; equivalent accelerations (*Leq*); the vibration exposure per shift (*A*); peak accelerations.

Results and discussion

The measurements results were processed in the "Excel" program. The values of peak corrected vibration acceleration (*Fh*) were selected every two seconds of the measurement process. The dependencies of changes in the values of peak corrected vibration accelerations on the rotation time (*t*) of the lathe machine spindle in the first and second operating modes are presented in the table 1. The dependencies are built on three coordinate axes.

Table 1. The dependencies of changes in the values of peak corrected vibration accelerations on the rotation time of the lathe machine spindle in the first and second operating modes: *A* – the first location of the sensor; *B* – the second location of the sensor; *C* – the third location of the sensor.





In accordance with the obtained values of peak corrected vibration accelerations after measurement in the first mode of the operation of the CNC lathe machine, it can be concluded that the minimum deviations of the spindle in all directions are observed in the first 20 s. In the remaining time, the stable values of vibrations of the rotating spindle of the machine are observed. The vibrations range increases by an average of 20% at the moment of overcoming the material resistance of the workpiece during semi-finishing turning. The *X*-axis was aligned with the axis of the machine spindle when the sensor was positioned vertically. Vibrations in the radial direction were determined along the *Y*-axis. The machining errors of the workpiece diameters will be higher than the machining errors of the linear dimensions in the time range of longitudinal turning of 10 s.

Conclusion

Vibrations of the spindle assembly do not exceed the maximum permissible values for 12 years of the operation of this CNC lathe machine. The workpiece dimensions can vary in the radial and axial directions by up to 20% in the short period of the cutting process. Thus, continuous turning with the small cutting depths is recommended to reduce the profile deviations of the workpieces.

References:

1. (1980). *GOST 24346-80. Vibration. Terms and definitions.*
2. (2006). *GOST ISO 8041-2006. Vibration. Human response to vibration. Measuring instrumentation.*
3. (2004). *GOST 12.1.012-2004. Occupational safety standards system. Vibration safety. General requirements.*
4. (2004). *GOST 31192.1-2004 (ISO 5349-1:2001). Vibration. Measurement and evaluation of human exposure to hand-transmitted vibration. Part 1. General requirements.*
5. (2005). *GOST 31192.2-2005 (ISO 5349-2:2001). Vibration. Measurement and evaluation of human exposure to hand-*

transmitted vibration. Part 2. Requirements for measurement at the workplace.

6. (2004). *GOST 31191.2-2004 (ISO 2631-2:2003). Vibration and shock. Measurement and evaluation of human exposure to whole-body vibration. Part 2. Vibration in buildings.*
7. (2002). *GOST ISO 5348-2002. Vibration and shock. Mechanical mounting of accelerometers.*
8. (1997). *GOST ISO 10816-1-97. Mechanical vibration. Evaluation of machine vibration by measurements on non-rotating parts. Part 1. General guidelines.*
9. (2014). *GOST ISO 2954-2014. Mechanical vibration. Condition monitoring of machinery using measurements made on non-rotating parts. Requirements for instruments.*
10. (2002). *GOST ISO 10816-3-2002. Vibration. Evaluation of machine vibration by measurements on non-rotating parts. Part 3. Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15000 r/min.*
11. (2014). *GOST IEC 60034-14-2014. Rotating electrical machines. Part 14. Mechanical vibration of certain machines with shaft heights 56 mm and higher. Measurement, evaluation and limits of vibration severity.*