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MEASUREMENT EQUIPMENT FOR LOW LEVEL VIBRATION STUDIES IN MASS LABORATORY

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Abstract: High-accuracy mass measurements may be influenced by a number of factors, incl level of vibration. We have developed vibration monitoring system capable of measuring low vibration levels in the Estonian National Mass Standard Laboratory. The measurement system consists of three accelerometers attached to the massive base block in three perpendicular axes. The capabilities of our vibration monitoring system are limited to the range of frequency from 1 Hz to 100 Hz and acceleration from 1 mm/s^2 to 5 m/s^2. The first results show that vibration in this frequency range may influence the performance of our high-accuracy mass comparator.

Keywords: Vibration measurement, mass measurement, uncertainty, frequency response.

1. INTRODUCTION

Often users of sensitive equipment face compromise between location and favorable exploitation conditions. Amongst the other things, determination of suitable location for sensitive equipment requires vibration measurements. For example, NIST (National Institute of Standards and Technology) have elaborated vibration criteria in which location characterizations are described based on the vibration condition for different processes and devices [1]. These criteria have been further compared with other vibration conditions including those proposed and applied for metrology laboratories at Justervesenet, Norwegian metrology institute [2]. Similar criteria were aimed at during planning of the location for the Estonian National Mass Standard Laboratory and were studied before construction [3].

After the construction, the neighbourhood of the foundation have changed causing unexpected disturbances. For that reason, demand for vibration monitoring has become acute.

In the present paper, we describe the developed vibration monitoring system and first measurement results in our mass laboratory.

2. INSTRUMENTATION FOR VIBRATION MEASUREMENTS

Low-level vibration measurement systems are usually not commercially available. Therefore, the measurement system was elaborated onsite. Moreover, metrological properties of measurement system need to be assessed thoroughly and it is usually somehow complicated with commercial system.

The goal of the developed system is to investigate vibration conditions during the mass measurements. The mass measurements are conducted according to scheme ABBA and one cycle lasts for about 70 minutes. The vibration monitoring system should be incorporated with mass measurement program and should delay further mass measurement cycles if level of vibration is observed to be above acceptable limit.

The vibration measurements in the Estonian National Mass Standard Laboratory are carried out with triaxial measurement system, which was developed onsite. The developed measurement system consists of three accelerometers, located in three perpendicular axes (Fig. 1). The accelerometers are mounted to a massive aluminium base block and are connected to data acquisition device and computer with measurement program.

Figure 1. Triaxial vibration measurement system

The selection of the accelerometers was based on the targeted measurable low vibration level starting from 1 mm/s^2. For that reason, the sensitivity of the selected accelerometers is rather high, ie about 1000 mV/m/s^2. The sensors in use are two accelerometers of type 3191A1 from Dytran Instruments, Inc and one accelerometer type KB 12VD from Metra Mess- und Frequenztechnik in Radebeul e.K. The accelerometers have factory calibration upon purchase. The calibration data as a deviation from nominal value are shown in figure 2.

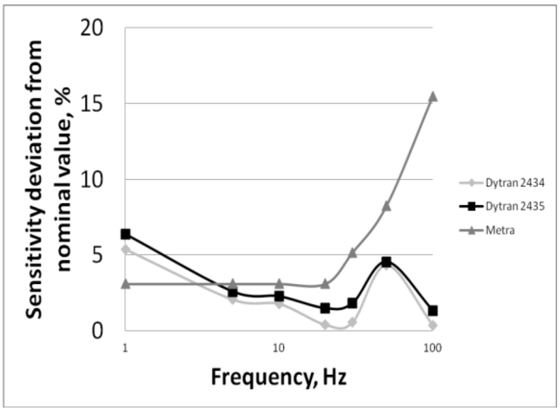

Figure 2. Accelerometers calibration results as sensor sensitivity deviation from nominal value as a function of frequency in percents

The significant deviation rise of sensor type KB12VD above frequency 50 Hz can be explained by the resonance frequency, which is close to 350 Hz according to manufacturer. The other parameters relevant to measurement result and associated uncertainty estimation by using selected sensors are listed in table 1.

Table 1. The selected parameters of used sensors

*Parameter***Sensor**	**KB 12VD**	**3191A1**
Transverse sensitivity	5%	5%
Sensitivity	2%	5%
Temperature coefficient	0,02%/K	0,14%/K

The used data acquisition device is commercially available four channel analogue digital converter with internal current source for accelerometers. The developed measurement program utilizes MatLab environment and its different libraries.

The measurement capabilities of our system are up to 100 Hz and 5 m/s^2 in frequency and acceleration scales, respectively. The expected measurement uncertainty should be lower than 10 % of measurement result. However, very low vibration levels are extremely hard to measure and the measurement uncertainty minimal limit is about 100 µm/s^2.

3. LABORATORY CONDITIONS

One of the main tasks of the Estonian National Mass Standard Laboratory is to realize mass scale from 1 mg to 50 kg by subdivision and multiplication based on 1-kg reference weights [4]. For that purpose, the laboratory is equipped with three high-accuracy mass comparators manufactured by Mettler-Toledo.

In the Estonian National Mass Standard Laboratory the most sensitive mass comparator is type AX107H which is used for weight measurements in the range from 1 mg to 100 g with the resolution of 0,1 µg (Fig 3).

Figure 3. Mass comparator AX107H

The acceptable standard deviation of the abovementioned mass comparator is 0,8 µg [5]. However, many repeated measurements showed accidental observation of standard deviations larger than 0,8 µg. To determine the cause for that a number of aspects in the mass laboratory were checked and improved, e.g. temperature and humidity control, accurate determination of air pressure, CO_2 concentration etc.

The vibration level in the Estonian National Mass Standard Laboratory is monitored continuously. The vibration measurement system is placed close to the mass comparator AX107H and the results are recorded during the measurement cycles of comparator AX107H. Typically, to determine the standard weight mass by comparison, several ABBA measurement cycles are needed. The whole weight calibration in total takes about 24 h or more

In normal conditions, the vibration values of all three sensors are slightly above noise level over frequency range studied. In unfavourable conditions, vibration values can increase several times and can cause increase in mass measurement standard deviation. As an example, two cases of vibration measurement results are presented in Figs 4a and 4b.

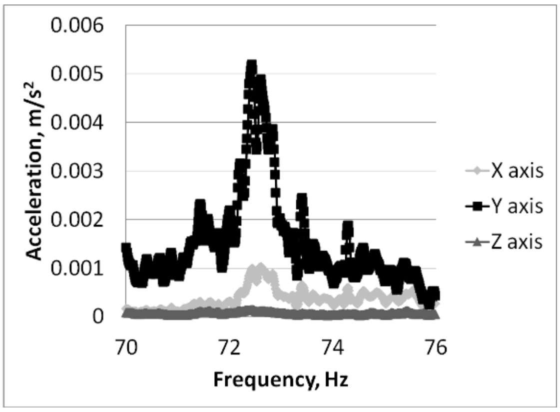

Figure 4a. Fraction of vibration frequency response while the mass measurement standard deviation was near acceptable limit

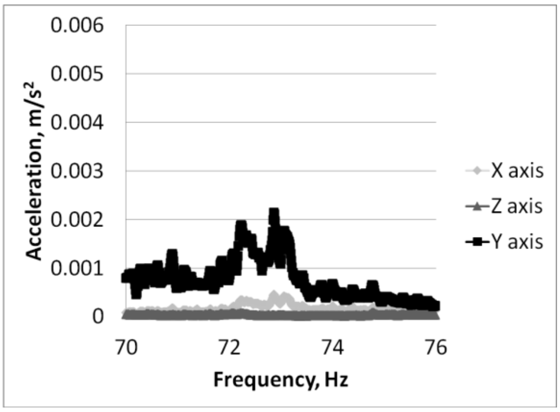

Figure 4b. Fraction of vibration frequency response while increase in the mass measurement standard deviation was not noticed

The figure 4a shows the fraction of frequency response of vibration measurement system when the standard deviation of the mass measurement approached to its limit. The figure 4b shows the same range of frequency response when the standard deviation of mass measurements was well below 0,8 µg. As can be seen in Fig. 4a, the clear peak was recorded around 73 Hz. The reasons for this are not fully understood yet, but it can be due to milling complex nearby at the same floor of the building.

Determination of vibration characterization of the Estonian National Mass Laboratory was done as comparison of vibration measurement systems frequency response in different circumstances. The difference in circumstance was determined by the standard deviation of mass measurements carried out by mass comparator AX107H.

The vibration measurements described above are relative measurements. To achieve better understanding of vibration characterization of laboratory the absolute vibration measurements need to be improved.

4. CONCLUSION

We have developed a vibration measurement system for monitoring purposes in the Estonian National Mass Standard Laboratory. The conducted measurements indicate that the difference in frequency responses can cause increase in the determined mass measurement standard deviation, which are larger than specified by the manufacturer. However, the accuracy and traceability of measurement results obtained with our developed vibration system need improvement. Moreover, the sections of frequency response whose effect on the mass measurement standard deviation is the largest should be further examined.

5. REFERENCES

[1] H. Amick, M. Gendreau, T. Busch and C. Gordon, “Evolving criteria for research facilities: I-Vibration,” in Proceedings of SPIE Conference 5933: Buildings for Nanoscale Research and Beyond, San Diego, 2005.

[2] B. Bessason, C. Madshus, H. A. Froystein and H. Kolbjornsen, “Vibration criteria for metrology laboratories,” Meas. Sci. Technol., vol. 10, no. 11, pp. 1009-1014, 1999.

[3] “Vibration Measurements at construction site of the new Metrosert building,” Measurement Report, MIKES Metrology, Espoo, Finland, 2012.

[4] V. Vabson, “Measurement uncertainty in Estonian Standard Laboratory for Mass”, Dissertationes Physicae Universitatis Tartuensis, 2013.

[5] Operating instruction, “Comparator Balances AX1006, AX106H, AX107H”, Mettler-Toledo AG 08/2013.