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Preventive Maintenance of Taper Bearing Using Arduino in the Application of Industry 4.0

Subekti Subekti [a]
Hadi Pranoto [b]
Beni Rukasah Salmon [c]
Setyo Qomarudin Yusuf [d]
Suyadiyanto [e]
Ari Slamet Ariyadi [f]
Abdul Hamid [g]

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Abstract

The maintenance of industrial tools is very important to support production. Therefore, many companies apply preventive maintenance. A national industrialization agenda discussed that it is crucial especially in the manufacturing industry. The battery-powered IoT sensing device is capable of thorough monitoring of industrial machinery enabling the development of sophisticated predictive maintenance applications under set scenarios. In this paper, we applied the concept of the Internet of Thing (IoT) system using LabVIEW via Arduino. The research method used in this study was similar to Susanto *et al.* (2019) namely Frequency Response Function (FRF) test to investigate the dynamic characteristics of a mechanic structure to identifying damages on X, Y, and Z axes of tapered bearing using harmonic vibration from handphones. Results of FRF and Labview via Ardunio were then compared to identify the results of measurement using LabView via Arduino. It was found much noise in the measurement occupying Labview Via Ardunio because its system does not use a filter like the one in FFT Analyser. However, in general, LabVIEW via Ardunia can predict damages in taper bearing. It is because, under broken condition, there was a two-time movement of natural frequencies from good condition.

Corresponding author:
Subekti,
Jalan Meruya Selatan No. 1, Meruya Selatan, Kembangan, Jakarta Barat,11650
Email address: *subekti@mercubuana.ac.id*

[a] Mechanical Engineering Vibration Laboratory, Universitas Mercu Buana, Indonesia
[b] Mechanical Engineering Vibration Laboratory, Universitas Mercu Buana, Indonesia
[c] SMK Negeri 1 Majalaya, JL. H. Idris NO 99 Majalaya Bandung, Jawa Barat, Indonesia
[d] Mechanical Engineering Vibration Laboratory, Universitas Mercu Buana, Indonesia
[e] Mechanical Engineering Vibration Laboratory, Universitas Mercu Buana, Indonesia
[f] Mechanical Engineering Vibration Laboratory, Universitas Mercu Buana, Indonesia
[g] Mechanical Engineering Vibration Laboratory, Universitas Mercu Buana, Indonesia

1 Introduction

The maintenance of industrial tools is very important to support production. Therefore, many companies apply preventive maintenance. Predictive maintenance provides a detailed check to detect the location and diagnose errors in a machine using various analyses (G. M. Sang *et al.*, 2020; Go Muan Sang *et al.*, 2020). The development of technology nowadays is marked by the industrial revolution 4.0 that was firstly introduced at Hannover Fair, 4-8 April 2011. The system of the industrial revolution 4.0 is the combination of the cyber-physical system, the Internet of Things (IoT), and the Internet of System that allows computers to connect each other and do communication that at the end can make a decision without the involvement of humans (Jena *et al.*, 2020; Putra *et al.*, 2020; Putra and Aslan, 2020;Aslan, 2019; Aslan and Setiawan, 2019)

The main goal of the application of industry 4.0 is to guarantee the maximum working hours in all production processes and to increase productivity while reducing the production cost. One way to reduce the cost of production used techniques of big data Big data and IoT technology play important roles in developingthe data-oriented application like predictive maintenance (Sahal *et al.*, 2020). The success of industrial revolution 4.0 must be supported by 5 layers of industry 4.0 architecture namely data acquisition, data munging, data storing, data analysis, and users' access. These five layers are integrated and adjusted according to the need of the industry (Çimen *et al.*, 2020; Aslan, 2019). By following the trend of industry 4.0, automatization in many manufacturing processes have triggered the use of a smart monitoring system that is very important to improve the productivity and the availability of the production system. To develop such a smart system, semantic technology is required (Martinov *et al.*, 2020).

That the maintenance is very important for manufacturing industries was proven by a recent discussion about the national industrialization agenda. Digitalization, the Internet of Things (IoT), and their connection with sustainable production are identified as the main factors that can increase the production. Generally, periodic supervision is carried out in a particular interval like in every hour or at the end of each working shift using portable indicators like handheld measurement instruments, acoustic emission units, and vibrations.

In this study, the benefit of the predictive maintenance method achieved by the current technology is the automatization system of a machine. The system of predictive maintenance produces a big number of data, and as they are stored in the raw format, it is potential to emerge various problems. After analyzing the data, they will be deleted from the memory, and when there is a problem, they will be shown to the users through a screen. Through this way, the users can be assisted with the complexity by filtering the data to access as they need. At the end of this study, the efficiency of engine speed increased due to the application of industry 4.0 (Cao *et al.*, 2020).

Vibration is measured in the domain of time then converted to the domain of frequency using a frequency analyzer like a mathematic algorithm known as Fast Fourier Transform (FFT). In the context of industry 4.0, it is performed using the peak frequency from the FFT spectral analysis as the bases to identify the tolerated degradation level and alarm limit settings.

Earlier studies about vibration used various methods like Identification of nonlinearity using the Frequency Response Function (FRF) method and analysis using wavelet packet decomposition (Subekti *et al.*, 2018). While the application of bump test to identify damage on sigra disc brake (Subekti *et al.*, 2018) shows that the vibration on End Mill Feeds will occur due to friction between the workpiece and end mill (Biantoro *et al.*, 2020), investigate the effect of heaving and pitching of ship motion due to springing bending moment (Hamid, 2011). Therefore, this paper aims to explain the preventive maintenance to deal with industry 4.0.

Literature Review

The Internet of Things (IoT) has changed our paradigm. Friendly IoT will bring a significant effect on the economy and business because it boosts innovation and productivity. On the other hand, the rapid adoption of IoT emerges new challenges related to connectivity, security, data process, and scalability (Firouzi *et al.*, 2020). The sensor of vibration is an important part ofthe Internet of Things (IoT) and supported by rapidly developed technology, it increases the accuracy of measurement and reduces the hardware cost. Physically, vibration sensory is attached to the core tools in control and manufacture systems (Jung *et al.*, 2017). The industrial machinery is comprehensively monitored using battery-powered IoT sensing devices, thus enabling the development of sophisticated predictive maintenance applications under-considered scenarios (Civerchia *et al.*, 2017). Recently, there has been advancement in technologies of IoT and application in the target maintained areas. However, IoT maintenance application has not been widely spread in Japan because sensing and analysis solutions are one-time for each case, the cost of sensing data collection is high and the maintenance automation is insufficient. This paper suggested a maintenance platform that only analyses anomalous data in the cloud and can automatically order maintenance (Yamato *et al.*, 2017). IoT platform well supports predictive maintenance because it can integrate information from many machines and manufacturing systems. The main weakness in integrating the production system and IoT platform is the communication frame as the communication protocol of the main industry is not compatible with the modern communication protocol applied in the platform of IoT (Parpala & Iacob, 2017).

2 Research Method

The concept of IoT has been explained in the literature review section above. In this paper, we used the concept of IoT based on an earlier study using the FRF test method to investigate the dynamic character of a mechanic structure in identifying damage on x, y, and z axes of tapered bearing with harmonic vibration from handphones[18]. Considering that most of the communication protocols are not implemented in industrial wares, one of the quick solutions is the use of Arduino as the translator between the industrial machine and IoT platform (Figure 1).

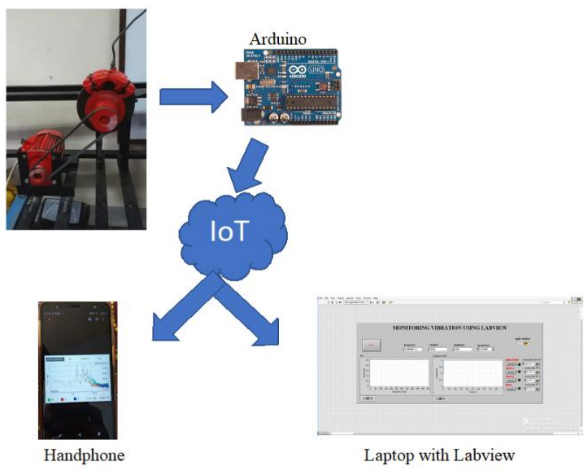

Figure 1. IoT design for preventive maintenance

In this study, we would identify damage at taper bearingby identifying theFrequency Response Function (FRF) obtained from the comparison of analysis result using FFT Analyzer by connecting the Arduino to the Labview. Excitation force was given to taper bearing in the form of a harmonic signal from a handphone that was then used as a vibration analyzer. The harmonic signal was given to bearing surface in vertical and perpendicular directions to the surface of the tapered pad. Vibration response on three axes (x, y, and z) using Modul Accelerometer GY-521 MPU-6050 is illustrated in Figure 2.

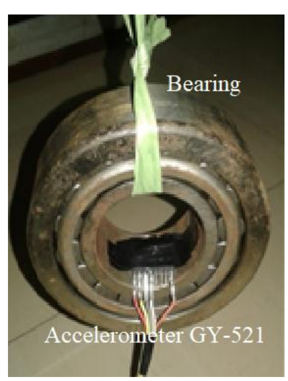

Figure 2. Photo of measurement frequency response function

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The set of test photos to measure the FRF in this study can be seen in Figure 3. Response used in Accelerometer GY-521 MPU-6050 were reducing exploration analysis with Labview and Arduino.

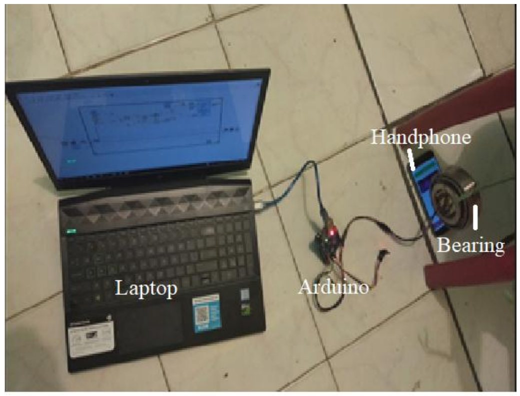


Figure 3. Photos of Setting-up the frequency response functions testing

The Accelerometer GY-521 MPU-6050 serves to measure response vibrations. Following are the specifications of Accelerometer GY-521 MPU-6050:
- Chip MPU-6050-based
- Voltage Supply about 3-5V
- Gyroscope range + 250 500 1000 2000°/s
- Acceleration range: ± 2 ± 4 ± 8 ± 16 g
- Communication standard I2C
- Chip built-in 16 bit AD converter, 16 bits data output
- Distance between pin header= 2.54 mm
- The model dimension (20.3mm x 15.6mm)

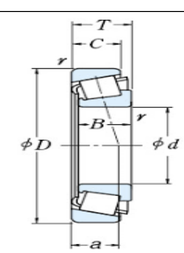
The specifications of the bearing tapper can be seen in Table 1.

3 Finding and Discussion

In this study, the excitation force was in the form of a harmonic signal that originated from a cellphone, which can be seen in Figure 4. This harmonic signal gave an excitation force to the taper bearing, and then the response was measured in three axes (x, y, and z). The measurement was carried out at taper bearing with or without bearing housing by comparing the result of measurements using the FFT analyzer and Arduino. Figures 5 and 6 show one of the results of FRF measurements without bearing on X-axis. Figure 5 shows the results of FRF measurement on FFT analysis and Labview via Arduino.

Table 1
The data of tapered roller bearing dimension: pinion shaft side

Symbol	Unit of Measurement [mm, kg]
A	25
D	50
D	110
T	36
d^1	73,5
B	35
C	30
r^1	2,5
r^2	2,5
m bearing	1,31 kg



In monitoring breakage in taper bearing under undamaged condition, the peak frequency by using Labview via Arduino was higher than the one showed by the FFT analyzer as illustrated in Figure 5.

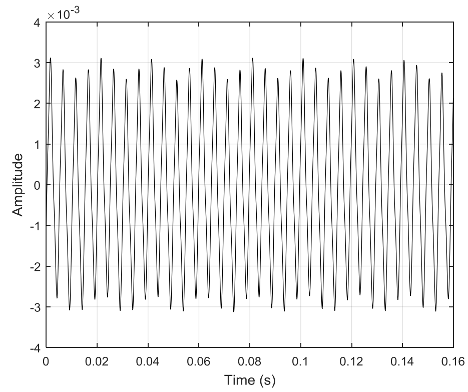


Figure 4. The excitation force in the form of a harmonic signal

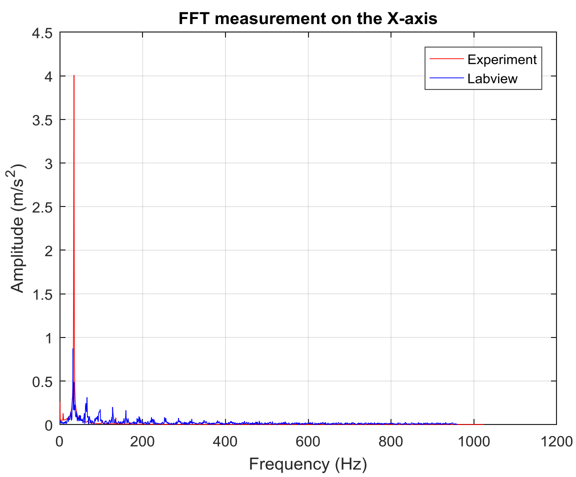


Figure 5. FRF measurement on the X-axis

In Figure 5, it is shown that measurement using FFT analyzers caused frequencies peaking at 67 Hz, 97 Hz, 135 Hz, 169 Hz, 202 Hz, 236 Hz, and 840 Hz.While the measurement using Labview via Arduino showed that the natural frequencies happened at 31 Hz, 65 Hz,97 Hz, 127 Hz, 159 Hz,191 Hz, 221 Hz, 253 Hz, 284 Hz, 287 Hz, 319 Hz, 349 Hz, and 384 Hz.

For more detailed information about the difference of natural frequencies happening in both measurement methods, the logarithm is illustrated in Figure 6. It can be seen that there is a difference between the frequencies in both measurement methods. The most noticeable difference is that in measurement using Labview via Arduino, there is noise.

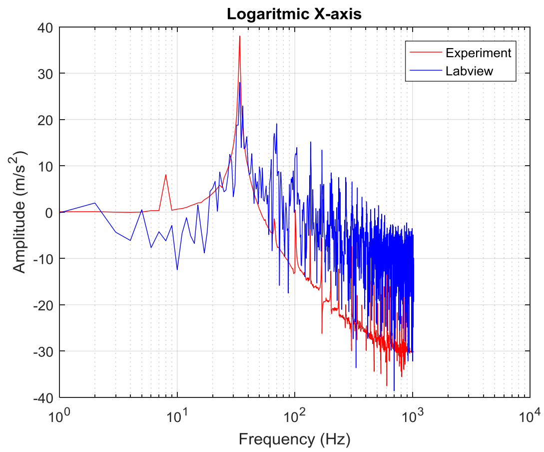


Figure 6. Logarithmic FFT on the X-axis

At y-axis, it is shown that in the measurement using FFT analyzer, the natural frequencies happened at 8 Hz, 34 Hz, 65 Hz, 103 Hz, 135 Hz, 172 Hz, 206 Hz, 241 Hz, 272 Hz, 298 Hz, 310 Hz, 344 Hz, 378 Hz, and 447 Hz, as illustrated in Figure 7.

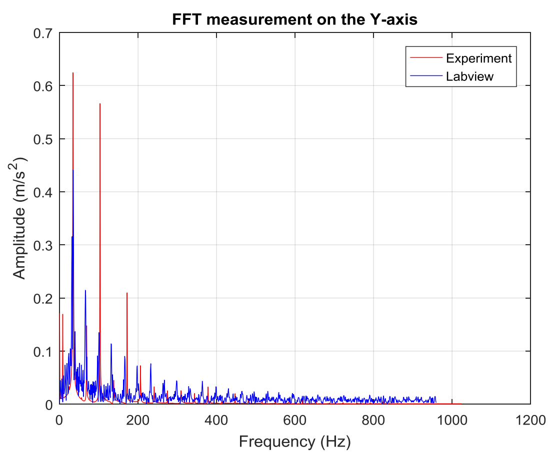


Figure 7. FRF measurement on the Y-axis

Measurement using Labview via Arduino showed the natural frequencies at 34 Hz, 65 Hz, 103 Hz, 131 Hz, 165 Hz, 197 Hz, 232 Hz, 267 Hz, 310 Hz, 333 Hz, 364 Hz, 399 Hz, and 430 Hz. On Y-axis, measurement using FFT Analysis andLabview via Arduino showed similar frequencies at 34 Hz, 65 Hz, 103 Hz, and 310 Hz. Measurement using LabVIEW via Arduino shows noise, as shown in the logarithmic graph (Figure 8).

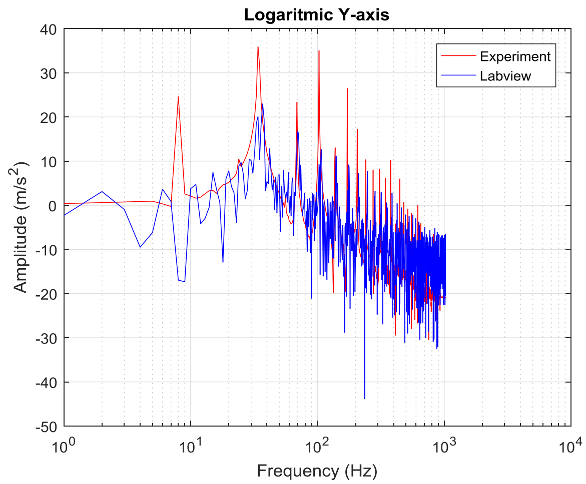


Figure 8. logarithmic FFT on the Y-axis

Measurement using Labview via Arduino shows fewer natural frequencies at Z-axis compared to measurement using FFT Analysis as shown in Figure 9. Measurement using Labview via Ardunio indicated the natural frequencies at 34 Hz, 68 Hz, 102 Hz, 131 Hz, 165 Hz, and 232 Hz.

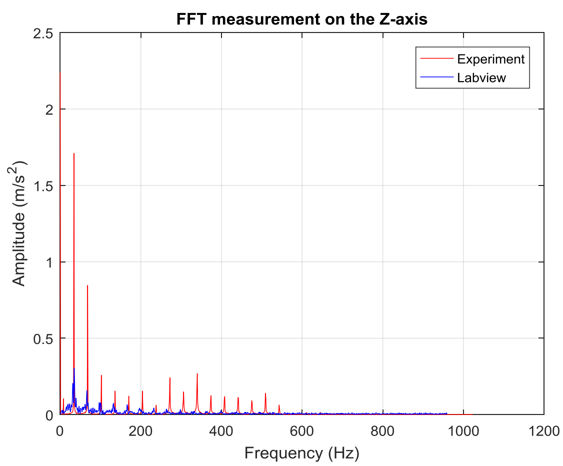


Figure 9. The FRF measurement on the Z-axis

While measurement using FFT analysis showed the natural frequencies at 8 Hz, 34 Hz, 68 Hz, 102 Hz, 131 Hz, 165 Hz, 204 Hz, 238 Hz, 272 Hz, 306 Hz, 374 Hz, 408 Hz, 442 Hz, 475 Hz, 509 Hz,and 543 Hz.On Z-axis, measurement using FFT Analysis andLabview via Arduino pointed similar natural frequencies at 34 Hz, 68 Hz, 102 Hz, 131 Hz,and 165 Hz. Measurement using Labview via Arduino showed noise as in the logarithmic graph in Figure 10.

After that, we carried out this study using a taper house under damaged condition by comparing the results of measurements using FFT analysis and Labview via Arduino. Figure 11 shows the results of FRF measurement at the x-axis using both measurement methods.

In Figure 11, it can be seen that measurement using FFT analysis shows that the natural frequencies happened at 8 Hz, 34 Hz, 65 Hz, 99 Hz, 132 Hz, 172 Hz, 199 Hz, 232 Hz, 265 Hz, 296 Hz, 331 Hz, and 365 Hz. While measurement using Labview via Arduino showed that natural frequencies at 66 Hz, 117 Hz, 177 Hz, 237 Hz, and 293 Hz.

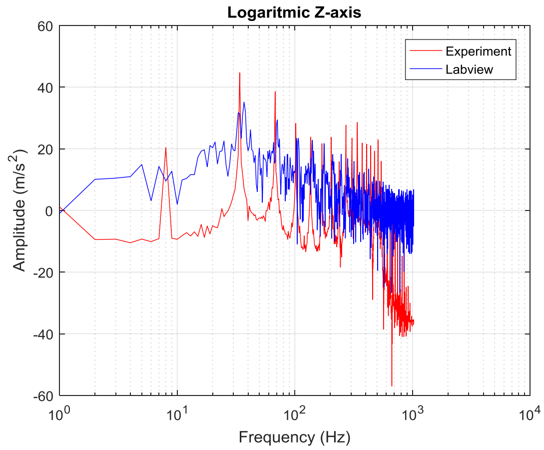


Figure 10. Logarithmic FFT on the Z-axis

For a more detailed about the difference of natural frequencies between both measurement methods is shown in the logarithmic graph (Figure 12). It can be seen that frequencies shown by both measurement methods had a significant difference. In this case, measurement using Labview via arduinoshows noise.

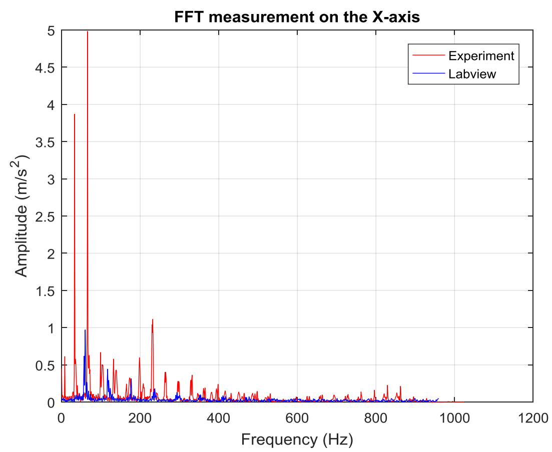


Figure 11. The FRF measurement on the X-axis

On Y-axis, FFT analyses showed the natural frequencies at 8 Hz, 24 Hz, 40 Hz, 56 Hz, 72 Hz, 88 Hz, 104 Hz, 120 Hz, 136 Hz, 168 Hz, and 184 Hz, as in Figure 13. While the measurement using Labview via Arduino identified fewer natural frequencies which were 59 Hz, 120 Hz, and 177 Hz.

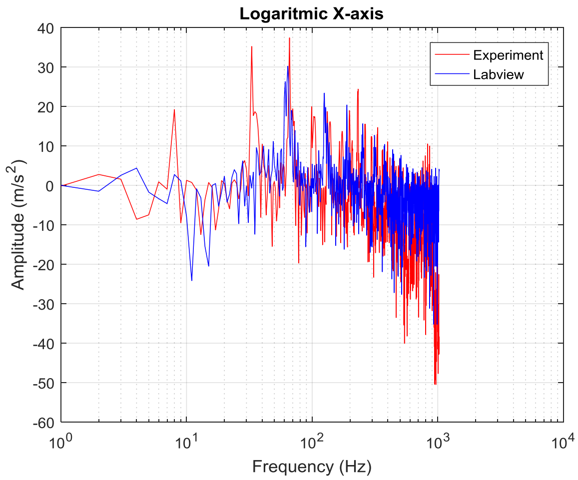


Figure 12. Thelogarithmic FFT on the X-axis

Figure 14 shows the logarithmic on the Y-axis. Both measurements did not show a difference in frequencies.

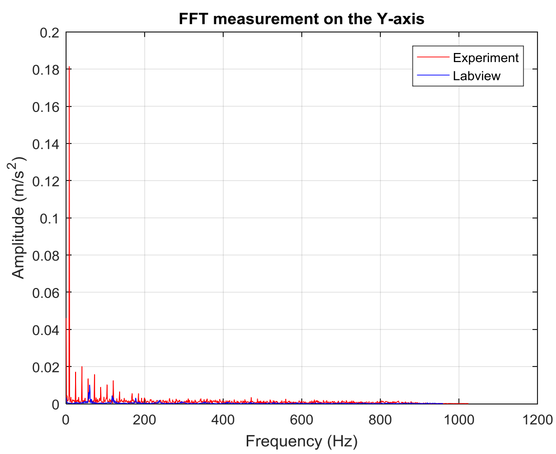


Figure 13. The FRF measurement on the Y-axis

Measurement using Labview via Arduino shows that on Z-axis, the natural frequencies were fewer than measurement using FFT analysis as illustrated in Figure 15. Measurement using Labview via Ardunioshowed the natural frequencies at 60 Hz, 117 Hz, 177 Hz, 237 Hz, and 300 Hz. While measurement using FFT analysis showed the natural frequencies at 8 Hz, 33 Hz, 100 Hz, 166 Hz, 233 Hz,and 300 Hz. In both measurements, it showed a similar frequency at 300 Hz.

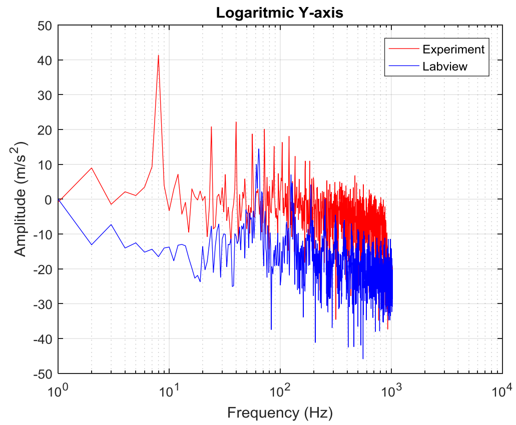


Figure 14. logarithmic FFT on the Y-axis

Measurements with the two methods showed a very striking difference in frequency where the measurements using Labview via Arunio showed noise, as shown in Figure 16.

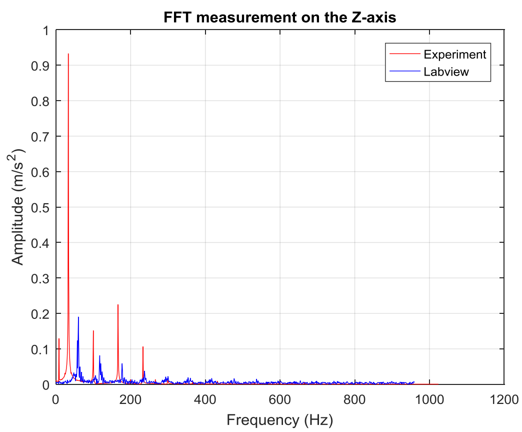


Figure 15. The FRF measurement on the Z-axis

To achieve the goal of the study about preventive maintenance in industry 4.0, this study compared broken and unbroken tape bearings.

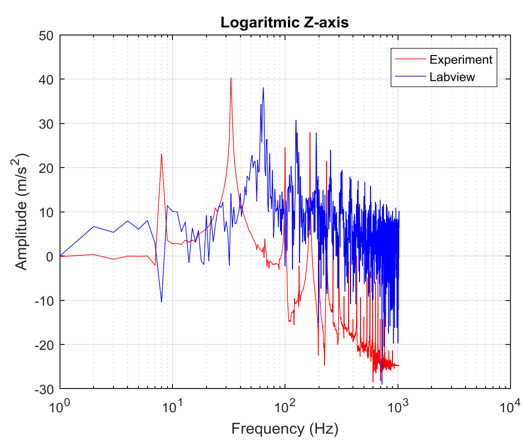


Figure 16. FFT logarithmic in the Z-axis

The measurement using the FRF method showed that in a good tape bearing, there was a movement of natural frequencies from the broken condition. The natural frequencies were 31 Hz, 65 Hz, 97 Hz, 159 Hz, 197 Hz, 221 Hz, 253 Hz, 287 Hz, and 319 Hz, as shown in Figure 17.

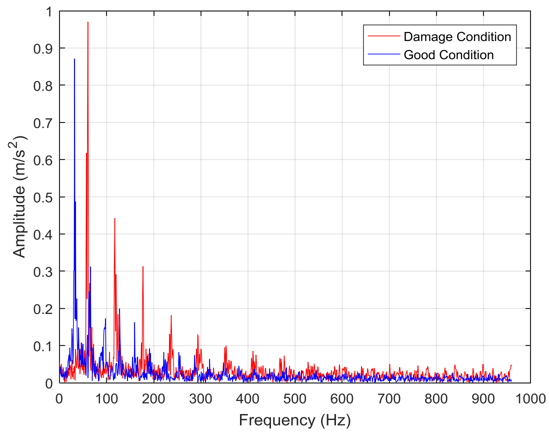


Figure 17. The FRF measurement

While in broken condition, there were two times movements from the natural frequencies in good condition. In broken condition, the natural frequencies were 60 Hz, 117 Hz, 177 Hz, 237 Hz, 294 Hz, 353 Hz, 410 Hz, and 477 Hz. Figure 14 shows the logarithmic of good and broken tape bearings. Under the broken condition, it can be seen the frequency movement. The noise happened in both conditions indicating that a filter is needed in the Labview program. However, in general, Labview via Ardunioa can predict damages in taper bearing.

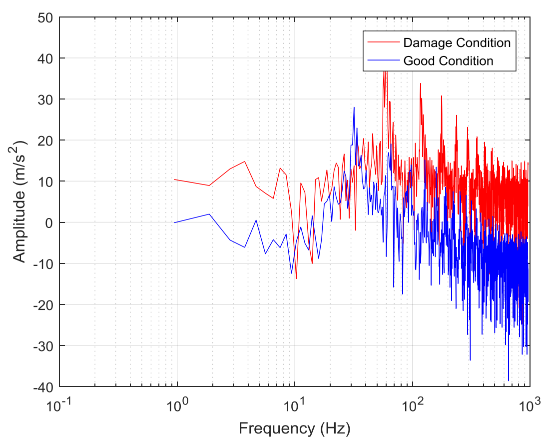


Figure 18. FFT logarithmic in the Z-axis

4 Conclusion

In this study, it can be concluded that the measurement using Labview via Arunio shows a lot of noise generated because this tool does not use a filter like the FFT Analysis. However, Labview via Arduino can show differences in vibration signals on the taper pads in good and damaged bearing conditions. Furthermore, this research will be carried out using warless connected with IoT, so that preventive maintenance to face the industry 4.0 can be achieved.

Conflict of interest statement
The authors declared that they have no competing interest.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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References

Aslan, A. (2019). Peran Pola Asuh Orangtua di Era Digital. *Jurnal Studia Insania*, *7*(1), 20-34.

Aslan, A. (2019). Pergeseran Nilai Di Masyarakat Perbatasan (Studi tentang Pendidikan dan Perubahan Sosial di Desa Temajuk Kalimantan Barat).

Aslan, A. (2020). Pengembangan bahan ajar berbasis imtaq dan iptek di era revolusi industri 4.0 pada mata pelajaran sains madrasah ibtidaiyah. *TaLimuna: Jurnal Pendidikan Islam*, *9*(1), 1-15. https://doi.org/10.32478/talimuna.v9i1.345

Aslan, A., & Setiawan, A. (2019). Internalization of value education in temajuk-melano malaysia border school. *Edukasia: Jurnal Penelitian Pendidikan Islam*, *14*(2), 419-436.

Biantoro, A. W., Maryanto, H., Hidayanto, A. K., & Hamid, A. The investigation of end mill feeds on cnc router machine using vibration method.

Cao, B., Wang, Y., Wen, D., Liu, W., Wang, Jingli, Fan, G., Ruan, L., Song, B., Cai, Y., Wei, M., Li, X., Xia, J., Chen, N., Xiang, J., Yu, T., Bai, T., Xie, X., Zhang, L., Li, C., Yuan, Y., Chen, H., Li, Huadong, Huang, H., Tu, S., Gong, F., Liu, Y., Wei, Y., Dong, C., Zhou, F., Gu, X., Xu, J., Liu, Z., Zhang, Y., Li, Hui, Shang, L., Wang, K., Li, K., Zhou, X., Dong, X., Qu, Z., Lu, S., Hu, X., Ruan, S., Luo, S., Wu, J., Peng, L., Cheng, F., Pan, L., Zou, J., Jia, C., Wang, Juan, Liu, X., Wang, S., Wu, X., Ge, Q., He, J., Zhan, H., Qiu, F., Guo, L., Huang, C., Jaki, T., Hayden, F.G., Horby, P.W., Zhang, D., Wang, C. (2020). A Trial of Lopinavir–Ritonavir in Adults Hospitalized with Severe Covid-19. New England Journal of Medicine 0, 1–13. https://doi.org/10.1056/NEJMoa2001282

Çimen, O., Topbaşoğlu, T., & Saklakoğlu, I. E. (2020). Industry 4.0 applications in wet wipes machines. *Industry 4.0*, *5*(1), 7-9.

Civerchia, F., Bocchino, S., Salvadori, C., Rossi, E., Maggiani, L., & Petracca, M. (2017). Industrial Internet of Things monitoring solution for advanced predictive maintenance applications. *Journal of Industrial Information Integration*, *7*, 4-12. https://doi.org/10.1016/j.jii.2017.02.003

Firouzi, F., Farahani, B., Weinberger, M., DePace, G., & Aliee, F. S. (2020). IoT Fundamentals: Definitions, Architectures, Challenges, and Promises. In *Intelligent Internet of Things* (pp. 3-50). Springer, Cham. https://doi.org/10.1007/978-3-030-30367-9_1

Hamid, A. (2011). The Investigation of the Effect of Heaving and Pitching on Wave-Induced Vertical Hull Vibration of a Container Ship in Regular Waves. *Journal of Mechanics Engineering and Automation*, *1*(6), 491-496.

Hammid, A., & Biantoro, A. W. (2018, November). Identifying the Nonlinearity of Structures Dynamics by Wavelet Packet Decomposition. In *IOP Conference Series: Materials Science and Engineering* (Vol. 453, No. 1, p. 012003). IOP Publishing. https://doi.org/10.1088/1757-899X/453/1/012003

Jena, M. C., Mishra, S. K., & Moharana, H. S. (2020). Application of Industry 4.0 to enhance sustainable manufacturing. *Environmental Progress & Sustainable Energy*, *39*(1), 13360. https://doi.org/10.1002/ep.13360

Jung, D., Zhang, Z., & Winslett, M. (2017, April). Vibration analysis for iot enabled predictive maintenance. In *2017 IEEE 33rd International Conference on Data Engineering (ICDE)* (pp. 1271-1282). IEEE. https://doi.org/10.1109/ICDE.2017.170

Martinov, G. M., Kovalev, I. A., & Chervonnova, N. Y. (2020, January). Development of a platform for collecting information on the operation of technological equipment with the use of Industrial Internet of Things. In *IOP Conference Series: Materials Science and Engineering* (Vol. 709, No. 4, p. 044063). IOP Publishing. https://doi.org/10.1088/1757-899X/709/4/044063

Parpala, R. C., & Iacob, R. (2017). Application of IoT concept on predictive maintenance of industrial equipment. In *MATEC Web of Conferences* (Vol. 121, p. 02008). EDP Sciences. https://doi.org/10.1051/matecconf/201712102008

Putra, P., Mizani, H., Basir, A., Muflihin, A., Aslan (2020). The Relevancy on Education Release Revolution 4.0 in Islamic Basic Education Perspective in Indonesia: *TEST Engineering & Management 83*, 10256–10263.

Sahal, R., Breslin, J. G., & Ali, M. I. (2020). Big data and stream processing platforms for Industry 4.0 requirements mapping for a predictive maintenance use case. *Journal of Manufacturing Systems*, *54*, 138-151. https://doi.org/10.1016/j.jmsy.2019.11.004

Sang, G. M., Xu, L., de Vrieze, P. T., Bai, Y., & Pan, F. (2020). Predictive maintenance in Industry 4.0.

Sang, G. M., Xu, L., de Vrieze, P., & Bai, Y. (2020, June). Towards Predictive Maintenance for Flexible Manufacturing Using FIWARE. In *International Conference on Advanced Information Systems Engineering* (pp. 17-28). Springer, Cham. https://doi.org/10.1007/978-3-030-49165-9_2

Sang, G. M., Xu, L., de Vrieze, P., & Bai, Y. (2020, June). Towards Predictive Maintenance for Flexible Manufacturing Using FIWARE. In *International Conference on Advanced Information Systems Engineering* (pp. 17-28). Springer, Cham.

Susanto, Y. K., Pirzada, K., & Adrianne, S. (2019). Is tax aggressiveness an indicator of earnings management?. *Polish Journal of Management Studies*, *20*.

Yamato, Y., Fukumoto, Y., & Kumazaki, H. (2017). Predictive maintenance platform with sound stream analysis in edges. *Journal of Information processing*, *25*, 317-320. https://doi.org/10.2197/ipsjjip.25.317