GROSTLOG 2025
Global Research on Sustainable Transport & Logistics

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

An Evaluation of the Locking System of Bracket Adjuster for AC Compressor on Shunting Locomotives at PT INKA (Persero)

Adrian Kristianto Tamara[a], Gendoet Indarto Wibisono[a], Dimas Handriyanto[a]
[a]Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia
Corresponding author: adrian.tamara@gmail.com

Abstract: Air conditioning compressors on locomotives play an important role in maintaining driver comfort and cooling efficiency. However, problems often arise related to nut loosening and system failure due to vibration resonance that occurs in the bracket. This study aims to identify and analyze the resonance phenomena affecting the locking system on the shunting locomotive AC compressor using a Finite Element Analysis (FEA) approach. Through simulations conducted using Ansys software, researchers examined the natural frequencies of components that could potentially cause excessive vibration in the system, especially the M12 nut which has a significant impact on locking strength. The analysis showed the presence of resonance at a frequency of 200 Hz, which could lead to susceptibility to loosening and operational failure. This in-depth understanding of the interaction between vibration and locking design provides important insights for future system improvements. The discussion also includes an evaluation of various locking techniques that can be applied to overcome resonance issues, including recommendations for the implementation of new, more effective designs. The findings of this research are expected to contribute to the transportation industry, especially PT INKA, in the development of a more reliable and durable bracket of AC compressor. Thus, this research not only targets technical aspects, but also considers the implications for the safety and comfort of public transportation users. Awareness of the importance of engineering design capable of reducing the effects of vibration on the locking system is key to improving the performance and reliability of AC compressors on locomotives in the future.
Keywords: *Vibration Resonance, Locking System, Bracket Adjuster, Finite Element Analysis (FEA).*

1. Introduction

The railway industry in Indonesia is showing rapid growth, especially in providing safe and efficient means of transportation. PT Industri Kereta Api (Persero) plays an important role as a major manufacturer of railway equipment, including locomotive warehousing used by PT Kereta Commuter Indonesia (KCI) at DIPO KRL Depok. The locomotive has a strategic function in managing and pulling the train, which is crucial for the smooth operation of the railway transportation system. One important aspect of the locomotive is the cooling system that maintains the cabin temperature. In this cooling system, the AC compressor plays a vital role. However, various problems often arise related to the transmission system that connects the radiator fan pulley with the air conditioning compressor pulley, especially the slip on the V-belt which can result in non-optimal compressor performance.

The quality and montage stability of the AC compressor adjuster bracket is greatly affected by vibrations generated during locomotive operation. This condition can not only reduce cooling effectiveness, but also potentially cause greater damage to the system. Excessive vibration conditions as well as weaknesses in the locking design can lead to decreased operational efficiency while shortening component life. Therefore, this study aims to analyze the locking system of the AC compressor adjuster bracket using the finite element analysis method.

2. Literature review

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

This literature review explores relevant research on the phenomenon of vibration resonance, its impact on locking systems, and the analysis methodologies used in mechanical engineering studies. A number of studies have investigated the effect of resonance on mechanical components and found that resonance can cause structural failure of important elements in the system. One of the studies by:

Zhang et al. (2019) showed that resonance in mechanical systems can cause significant wear, as well as reduce the life of the components involved. In this context, designs that do not take into account the natural frequencies of components can be at risk of premature failure. This highlights the importance of frequency analysis prior to design implementation, especially in systems operating under dynamic conditions such as locomotive air conditioning compressors. The Finite Element Analysis (FEA) method has become a commonly used tool in structural evaluation to understand the behavior of materials under dynamic loads.

Lee and Kim (2021) discuss the use of FEA to analyze resonance in various automotive components. They show how FEA can be used to predict weak points in designs, as well as identify natural frequencies that could potentially cause resonance.

Larsson (2017) emphasized the importance of control aspects in complex hydromechanical transmission systems, particularly in displacement control. This research shows that proper control in transmission systems can improve operational efficiency and reduce damage to components.

3. Research Method

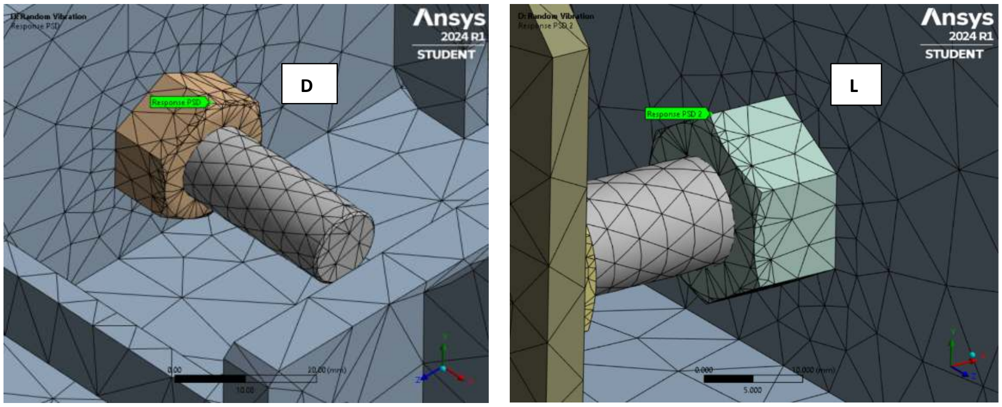
This research uses the Finite Element Analysis (FEA) method to analyze the locking system on the locomotive AC compressor. Ansys software was used to create geometric models of the bracket adjuster and M12 nut. Simulations were performed by applying dynamic loads that reflect real operational conditions. Natural frequency analysis was evaluated to identify resonance points, while the simulation results were compared with existing design standards. With this approach, it is expected that a more effective design solution can be found to reduce the impact of resonance on the locking system and improve the reliability of the air conditioning compressor.

4. Result and discussion

Simulation Results

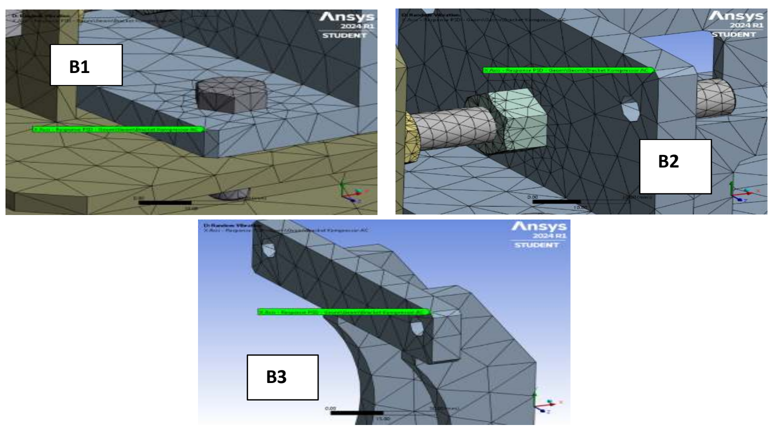
The analysis results using the Finite Element Analysis (FEA) method show that the locking system on the AC compressor adjuster bracket experiences resonance at a frequency of 200 Hz. The natural frequency value of the bracket adjuster obtained from the simulation is 202.02 Hz. This figure shows that the excitation frequency is close to the natural frequency, giving rise to the resonance phenomenon. The vibration amplitude at the measurement point shows an average value of up to 9 mm in the Y axis and about 0.3 to 0.5 mm in the X axis. The strong vibration in the bracket can be caused by the low structural rigidity and unstable connection, resulting in sagging of the M12 nut. This phenomenon can significantly affect the performance of the air conditioning compressor as the V-belts connecting the fan pulleys to the compressor become slack, impacting the cooling of the locomotive cab and potential failures in the cooling system.

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr



Source: Researcher, 2024

Figure 1. Vibration sampling points on the inner (D) and outer (L) bracket M12 nuts



Source: Researcher, 2024

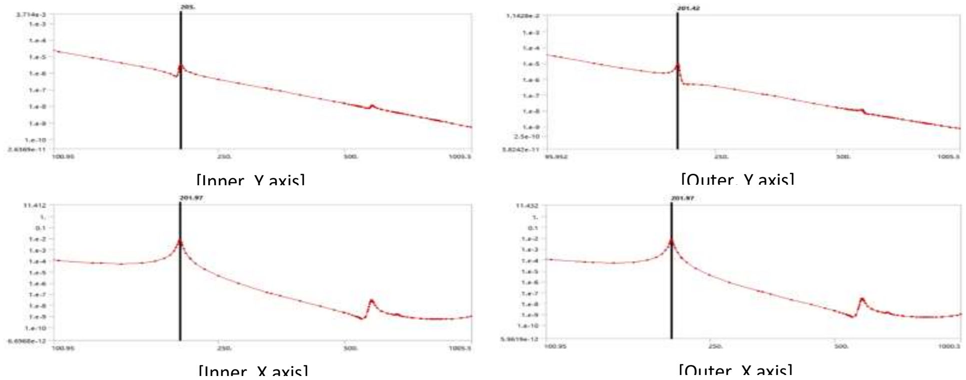
Figure 2. Vibration sampling points on the compressor *bracket*

Table 1. PSD response displacement

	M12 inner		M12 outer		Bracket compressor		
Vertex	D		L		B1	B2	B3
Axis	X	Y	X	Y	X	X	X
PSDR [mm^2/Hz]	7,24E-03	3,13E-06	7,24E-03	9,11E-08	6,56E-03	7,77E-03	1,56E-02
Frequency [Hz]	201,97	203	201,97	201,44	201,97	201,97	201,97
RMS [mm]	6,7465	0,25493	6,7523	0,3364	6,5661	7,0036	10,902
Amplitude [mm]	1,2089	0,0252	1,2095	0,0043	1,1513	1,2531	1,7733

Source: Researcher, 2024

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

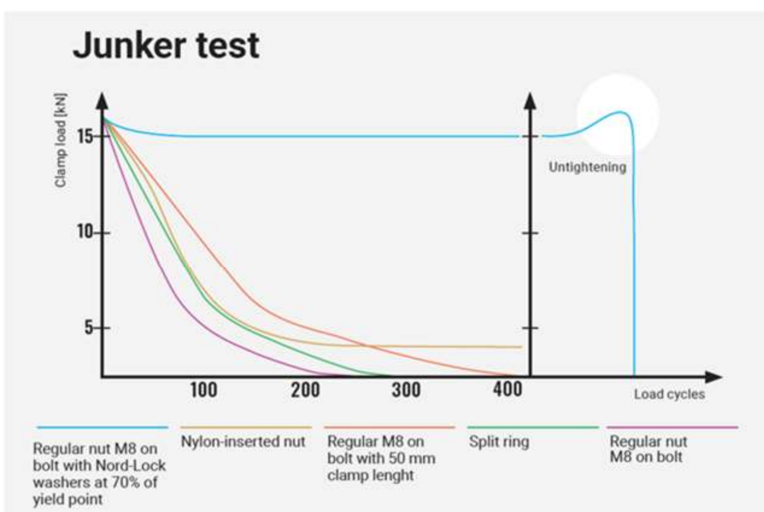


Source: Researcher, 2024

Figure 3. Vibration resonance graph of M12 nut

Analysis of Results and Alternative Recommendations

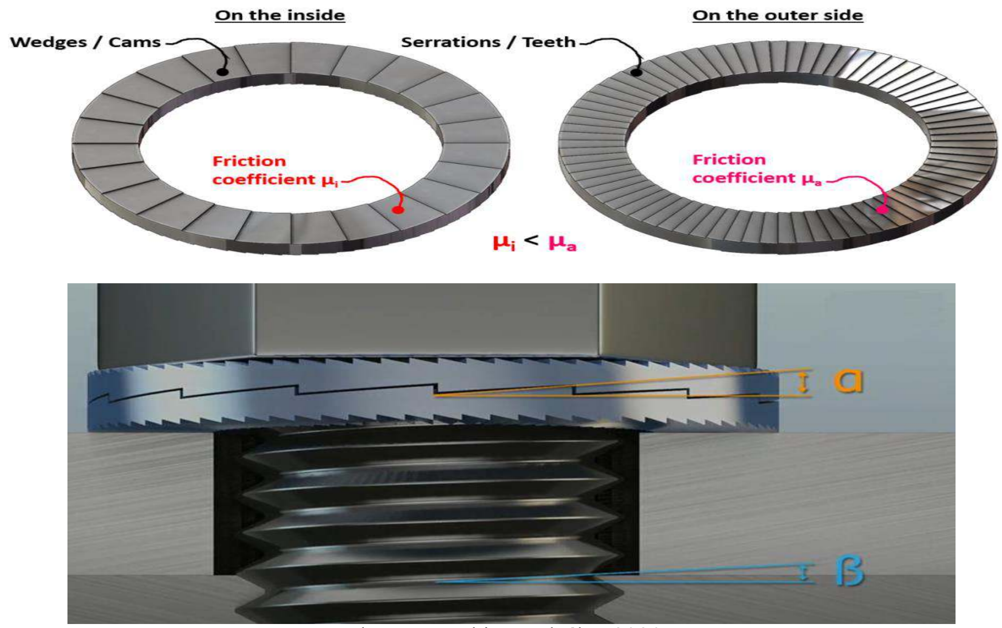
From the analysis results, it is concluded that resonance causes sagging in the locking system, where there are several factors at play. To minimize vibration-induced sagging, the use of some more effective locking system alternatives is recommended. In this study, the use of wedge-lock washers is recommended as it can increase the resistance to vibration up to 10.33 times compared to using conventional locking, which has been proven by the junker vibration test. In addition, the use of thread-lock adhesive as a permanent lock can provide an additional solution to prevent nut loosening, although it does not affect the resonance level. Welding of joints between components should be considered as it can increase the stiffness of the structure and reduce the amplitude of the resulting vibrations, as evident from the simulations that show an increase in the fundamental frequency to 532.27 Hz with an amplitude below 1 mm. These results are expected to contribute to designing a more efficient locking system for the AC compressor adjuster bracket, in order to improve the operational performance and reliability of the locomotive. Implementation of these recommendations is expected to reduce downtime and improve operational efficiency in the future.



Sumber: Konecki & Talaśka, 2020

Figure 4. Graph from the Junker vibration test

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr



Sumber: Konecki & Talaśka, 2020

Figure 5. The essence of the wedge block effect

Conclusion

Based on the results of research that has been carried out on the AC compressor adjuster bracket on the PT INKA (Persero) locomotive wagon, it can be concluded that the resonance problem and the loosening of the M12 nut have a significant impact on the performance and reliability of the locking system. This research uses a finite element analysis approach with Ansys Workbench software, which produces critical data related to component behavior under vibration conditions.

Simulation results show that the AC compressor adjuster bracket resonates at a frequency of 200 Hz, which is closely related to the natural frequency of the component, 202.02 Hz. This relationship indicates that as the excitation frequency approaches the natural frequency, an exponentially increasing vibration occurs, resulting from the complex interaction between dynamic forces and structural characteristics of the adjuster bracket. The high vibration amplitude, which was measured to exceed 1 mm, was the main factor causing the loosening of the M12 nut. Nut loosening in this context is particularly concerning, given the impact that it can have on the failure of the refrigeration system, which in turn can affect the overall performance of the locomotive. Given that the service condition of the air conditioning compressor is critical for passenger comfort and operational efficiency, an in-depth understanding of the cause of this resonance is essential for the development of appropriate and effective solutions.

The alternative solutions proposed to prevent vibration-induced slippage are significant and include several methods. First, the use of wedge-lock washers, identified in this study as a highly effective method, can increase the locking resistance to vibration up to 10.33 times higher than the conventional locking mechanism through friction. The working mechanism of the wedge-lock washer relies on interlocking wedges and angular shapes, thereby significantly preventing sagging.

Secondly, the use of Loctite as a permanent lock also showed encouraging results in preventing the loosening of M12 nuts. Loctite forms a strong bond to threaded components that can withstand the acting force without relying on traditional locking mechanisms. That said, it

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

should be noted that this product does not affect the vibration resonance level of the adjuster bracket itself. In other words, while Loctite can prevent sagging, it acts more as a reinforcement to the existing locking without addressing the underlying cause of resonance. There is also an alternative solution in the form of welded fasteners, which have proven to be effective in improving structural stiffness and vibration resistance. In the tests conducted, the application of welded fasteners to the adjuster bracket resulted in an increase in the fundamental frequency from the previously measured natural frequency to 532.27 Hz, and the vibration amplitude was measured below 1 mm. These results indicate that welding not only increases the stiffness of the component, but also significantly reduces the vibration response at critical frequencies, thereby preventing loosening of the M12 nut.

It is important to take steps to implement this proposed solution in operational practice at PT INKA (Persero). Applying improved locking techniques, such as wedge-lock washers and welded fasteners, as well as the use of locking materials such as Loctite, can contribute to improving the reliability and performance of the AC compressor system. It is hoped that by implementing these solutions, not only can they prevent nut loosening, but also extend the life of existing components and reduce future maintenance costs. Overall, this research resulted in a better understanding of the interaction between locking design and vibration resonance. The findings not only make an important contribution to the railway industry, but also to further research in mechanical engineering. For further development, it is recommended that this research be extended to include analyzing the interaction between various components in more complex systems as well as conducting field testing for further verification of the proposed solutions.

With reference to the results of the research and analysis carried out, it can be concluded that serious attention needs to be paid to the design of locking and resonance management in compressor systems, in order to ensure optimal performance and the safety and comfort of public transportation users who depend on reliable refrigeration systems.

Implication

The findings from this study have significant implications for the transportation industry, particularly in the development of locomotive air conditioning compressors. First, a better understanding of vibration resonance and its impact on locking systems can help engineers design more reliable and efficient components. The use of updated locking techniques and stronger materials can reduce the risk of failure, ensuring the refrigeration system works optimally. Secondly, this research can serve as a reference for manufacturers in implementing design innovations that not only pay attention to technical aspects, but also improve passenger safety. The application of the results of this research is expected to contribute to the development of better industry standards in terms of air conditioning compressor design and maintenance. In addition, this research paves the way for further studies that can explore the deeper interactions between vibration, component design and overall system performance. The long-term implication of this research is improved operational efficiency and reduced maintenance costs, which in turn can improve public services in the public transportation sector.

Research limitation

This study has some limitations that need to be noted. Firstly, the main focus is only on the locking system and resonance at the M12 nut of the adjuster bracket, without considering other components that can also affect the overall performance of the AC compressor. This may lead to limited generalization of the results. Secondly, the analysis was conducted only under certain conditions that may not fully reflect real operational conditions, such as dynamic variations in

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

temperature, humidity, and load. FEA simulations, although robust, still have limitations in replicating real-time material behavior in the field. In addition, this research did not explore all possible locking designs on the market, so other innovations may remain unaddressed. Finally, a better approach could be developed involving more variables and empirical methods, such as field testing, to gain a more comprehensive understanding of resonance and its impact. The implication of these limitations is the importance of further research that not only broadens the scope of the analysis, but also integrates various approaches to optimize the design of the locking system on locomotive air conditioning compressors.

References

Kim, Y. G., Hwang, S. J., & Cho, K. H. (2017). Characteristics of propulsion shafting system in ships with engine acceleration problems in the barred speed range. *Ocean Engineering*, 145, 479–471

Konecki, K., & Talaśka, K. (2020). Analysis of wedge lock washer using the finite element method. *MATEC Web of Conferences, 357*, 02025. https://doi.org/10.1051/matecconf/202235702025

Larsson, L. Viktor. (2017). Control Aspects of Complex Hydromechanical Transmissions : With a Focus on Displacement Control. Linkopings Universitet.

Liu, Z., Wang, B., Li, Y., Zhang, C., Wang, Y., & Chu, H. (2021). *Analysis of self-loosening behavior of high strength bolts based on accurate thread modeling*. Engineering Failure Analysis.

Mendes, A. S., Meirelles, P. S., & Zampieri, D. E. (2008). Analysis of torsional vibration in internal combustion engines: Modelling and experimental validation. *Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics*, 222(2), 155–178

MIL-STD-810H, ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS (2019). http://www.everyspec.com

Moosavian, A., Ahmadi, H., Tabatabaeefar, A., & Sakhaei, B. (2012). An appropriate procedure for detection of journal-bearing fault using power spectral density, K-nearest neighbor and support vector machine. *International Journal on Smart Sensing and Intelligent Systems, 5*(3), 557-576.

Nagayama, T., Reksowardojo, A. P., Su, D., Mizutani, T., & Zhang, C. (2015). *Bridge natural frequency estimation by extracting the common vibration component from the responses of two vehicles*. University of Illinois, Urbana-Champaign.

Nassar, S. A., & Yang, X. (2009). *A mathematical model for vibration-induced loosening of preloaded threaded fasteners*. Journal of Vibration and Acoustics, 131, 557-557.

Nishida, S. (1992). *Failure analysis in engineering applications*. Butterworth-Heinemann.

NTN Corporation. (2023). *Ball and Roller Bearings*.

Peacock, D. C. P., & Marrett, R. (2000). *Strain and Stress: Reply*. Geological Society of America.

Reddy, J. N. (2019). Introduction to the finite element method: Theory and applications. McGraw-Hill Education.

Roark, R. J., & Young, W. C. (1976). *Formulas for Stress and Strain*. McGraw-Hill.

Roylance, D. (2001). *Finite element analysis*. Massachusetts Institute of Technology.

Rusianto, T., & Susastriawan, A. A. P. (2021). *Buku ajar getaran mekanis*. Udayana University Press.