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Application of Measurement System Analysis (MSA) for Assesment of Tire Pressure Monitoring in Coal Mining Trucks

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A B S T R A C T

Tire pressure plays an important role in ensuring safe operation and performance of truck vehicles. Improper tire pressure always leads to tire life, vehicle safety, and performance. This paper discusses the application of measurement system analysis on truck tire pressure in a coal mining company. The study evaluates the measurement system of truck tire pressure. The company aims to extend the life span of its tire by maintaining and monitoring the tire pressure regularly. The tire pressure is measure by a pressure gauge. This study used measurement system analysis (MSA) to analyze the Gage R&R, with 2 tire men and 10 parts measured with 3 repetitions. The MSA results in a Total Gage R&R of 18.16% with a repeatability value of 12.34% and a reproducibility value of 13.32%. The result indicated that the measurement system showed good results for tire measurement applications because the Gage R&R was between 10% to 30%.

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1. INTRODUCTION

The mining truck hauling tire is a vital component in the mining industry, responsible for transporting large quantities of materials over rugged terrains. These massive tires must able to withstand the harsh conditions of mining operations, providing traction and durability. In addition to their size and strength, they are also engineered to maximize fuel efficiency and minimize downtime for tire changes. With advancements in tire technology, mining truck hauling tires continue to evolve to meet the unique demands of the industry. Despite of their function, tire are one of the highest cost in coal hauling industry. Generally, mining truck tires are quite expensive due to their size, durability requirements, and specialized construction to withstand the harsh conditions of mining operations. To increase profit, the mining company seek ways to reduce cost, one of the way is to reduce tire cost by increasing the life span. The cost and lifespan of mining truck tires can vary depending on several factors, including the type of tire, the conditions in which they are used, and how well they are maintained (Lindeque, 2016). It's essential for mining operations to carry out proper maintenance practices that can help maximize tire lifespan and minimize operating costs over time.

Underinflated tires can have a significant impact on the lifespan of the tire and its performanc. When tires are underinflated, they can suffer from uneven tire wear, which can lead to premature tire failure. This is because the sidewalls of the tire can become misshapen and bulge out due to the lack of internal air pressure, causing the edges of the tire tread to wear more than usual. This excessive wear can eventually lead to tire bursts in areas where the rubber is too thin to hold the pressure. Additionally, underinflated tires can result in poor fuel economy due to increased rolling resistance, which means your engine must work harder to maintain the same speed, leading to increased fuel consumption. This can result in higher fuel costs over time. Underinflated tires can lead to premature tire wear, increased fuel consumption, and reduced handling and safety, all of which can significantly impact the lifespan of the tires (Sivaraos et al., 2019).

Many mining operations have specific tire pressure requirements to ensure the safety and efficiency of their equipment. Monitoring tire pressure is important for truck mining operations for several reasons. Underinflated tires can lead to blowouts, reduced traction, and instability, which can pose a safety risk to the driver and other road users. Underinflated tires can increase fuel consumption, as they have higher rolling resistance . This can lead to increased operating costs and reduced vehicle performance. Proper tire pressure maintenance can extend the life of the tires and reduce the need for premature replacements. Monitoring tire pressure can help identify issues early, reducing downtime and maintenance costs associated with tire-related issues

Regularly checking and maintaining the correct tire pressure is essential to ensure the longevity and safety of the tires. Furthermore, underinflated tires can result in destitute fuel economy due to expanded rolling resistance, which implies your motor must work harder to preserve the same speed, driving to expanded fuel utilization. This may result in higher fuel costs over time. Proper maintenance practices, such as regular inspections, correct inflation, rotation, and alignment, can significantly impact tire lifespan (Abdulaev et al., 2019). Investing in proactive maintenance can help maximize the lifespan of tires, thereby reducing the total cost of ownership over time.

In this study the company take initiatives to conduct regular inspection of the truck tire pressure and correct inflation regularly. This initiatives aim to extend the tire life span. Recently the company aim to extend life tire to 70.000 kilometer from 50.000 kilometer. To make sure this program run well, therefore MSA need to be performed to validate the tire pressure monitoring system. Since tire pressure monitoring plays significant role, to maintain tire pressure. The company use pressure gauge to check the pressure. This study aim to evaluate and analyze the tire pressure measurement system using ANOVA study. Measurement System Analysis (MSA) is a critical component of quality management and statistical process control. It involves evaluating the capability and reliability of a measurement system to ensure that the data obtained is accurate and consistent. An effective MSA helps organizations identify and minimize sources of variation in their measurement processes, leading to improved decision-making and product quality (Galli, 2020). Therefore, this article explore the implementation of the key concepts of MSA in hauling truck tire. Aim to validate that tire pressure measurement systems are reliable.

2. LITERATURE REVIEW

In Six Sigma and the automotive standard (ISO/TS 16949), MSA is crucial for evaluating the dependability of the data used in the manufacturing process, assessing variations brought about by appraisers, equipment, techniques, materials, and the environment, and analysing data to improve processes (Saikaew, 2018). Measurement errors from different sources of variance in a process are quantified by MSA. According to international standards, measurement systems analysis is defined as “a series of studies that explain how a measurement system works (Schmitt & Marcin Bauza, 2012). Decisions based on measurements depend solely on the quality of those measurements. A higher number of measurement errors means more errors in decisions. Measurement System Analysis aims to provide more accurate, precise and stable data (Galli, 2020). Tire measurement result is directly affected by the quality of the measurement; Therefore, adoption of a measurement system is an important issue. A gauge repeatability and reproducibility (GR&R) study can determine whether the total variability observed in a process comes from the measurement system (Soares et al.,2022). Gage Repeatability and Reproducibility (GR&R) is a method used to assess the variation in a measurement system. It is often expressed as a percentage and can be used to determine the percentage of total variation that is due to the measurement system, as opposed to the process or the parts being measured.

Measurement systems analysis (MSA) is a systematic process used to evaluate the performance of a measurement system, including its accuracy, precision, and stability (Saikaew, 2018). It is the main tool to ensure measurement quality in various industries, such as manufacturing, engineering and scientific research. The primary objectives of MSA are to identify and quantify sources of variation in the measurement system, evaluate the system's capabilities, and determine appropriate control limits for the measurement process. Several study has discussed the implementation of MSA to solve manufacturing problem (Sumasto et al., 2023; Dhawale & Raut, 2013; Ted Hessing, 2016). By understanding the characteristics of measurement systems and identifying sources of variation, organizations can improve their measurement processes and make better decisions based on accurate data. Common tools and techniques used in MSA include: Gauge Repeatability and Reproducibility (G R&R) and ANOVA study (Cepova et al., 2018; Yadav, 2016; Shao & Qian, 2015). Gauge Repeatability and Reproducibility (GR&R) is a method used to determine the amount of variability present in data measurement data due to the measurement system (Gerger et al., 2021). Gage R&R then compares the obtained measurement variation with the total observed variation, then determines the capacity of the measurement system (Deshpande et al., 2020).

ANOVA developed by Ronald Fisher in 1918 is an extremely important tool used in statistics to test mathematical hypotheses by analyzing the variation between different data sets. Analysis of variance (ANOVA) is a general statistical technique for analyzing variance and identifying other sources of variation in a measurement system (Zhou et al., 2008). In the MSA context, ANOVA is the most widely used because it takes into account the interaction between the operator and part, which other methods do not take into account. It is also best for flexibility and accuracy if a suitable computer program is available (Yadav, 2016). During the use of ANOVA method, the occurrence of interaction is leading to higher %GRR values.

The ANOVA method provides an additional test of possible interactions between operators and part. Therefore, the results obtained by the ANOVA method are more accurate. The ANOVA gage R&R measures the amount of variation caused in measurements by the measurement system itself and relates it to the total variation examined to verify the viability of the measurement system. Repeatability and Reproducibility Error (R&R), Appraiser variation (EV) or Repeatability Error, Equipment Variation (EV) or Reproducibility Error, Total Variation (TV) and PartTo-Part Variation are the sources of variation to be taken into account. ANOVA can separate interpretations with repeatability and reproducibility. This method could segregate repeatability and reproducibility. These segregations are between variations related to operators and instruments (Moatari-Kazerouni, 2009).

3. RESEARCH METHOD

The object used in this research is tire measurement system in one of the coal mining hauling contractor in Indonesia. The company transported coal from pit to port utilize truck. Each truck has 10 tires. Rear tire use 8 tire with size 11 inch and front tire uses size 10 inch. The data used in this study are primary data from the measurement results of tire pressure 11 inch. To measure the tire pressure the company use pressure gauge as described in Figure 1. MSA study approach was based on the standard automobile industry action group (AIAG) GR&R study to evaluate the pressure gauge measuring performance. In this article analysis of variance (ANOVA) was used to investigate the effect of tire inflation and inspector and their interaction on the pressure variation. In the

ANOVA method, we can easily distinguish between repeatability and reproducibility interpretations. In GR&R, two to three operators are typically involved to measure the results of the process. The cause of higher variability due to the influence of interaction operator-sample is possible by using ANOVA (Klaput & Plura, 2012).

Figure 1. Pressure gauge

In this study, we asked 2 tireman to participate and they had to randomly measure 10 parts and 3 tests were performed by each measurement. Collected data processed and analyzed using Minitab software. MINITAB is one of the most reliable and easy-to-use statistical software and has been used by many successful companies to implement quality control functions. On MINITAB software, using the ANOVA method, we can evaluate the repeatability and reproducibility of the measurement system (Kumar et al., 2020).

The value of the G&RR is used to evaluate the system. Acceptance of decision findings from a measurement system is based on the resulting Gage R&R %. Acceptance criteria for GR&R studies vary, but generally, a GR&R of less than 10% is considered acceptable, while a GR&R between 10% and 30% may be acceptable depending on the application and cost factors. A GR&R of over 30% is generally considered unacceptable and should be improved (AIAG, 2010). To ascertain whether the measuring system in use can satisfy the established quality criteria, the analysis's findings will be analyzed. Additional analysis will be done to identify the error's source and the required corrective action if the measurement system fails to fulfill the set. In this research, MSA study used the NDC (Number of Distinct Categories) criterion to assess the sensitivity of the measuring equipment. It shows how many different categories the employed measurement method can differentiate with clarity. The NDC is used to evaluate the sensitivity of the measuring apparatus. A more sensitive measurement system that can identify more groups in the process or product data is indicated by a higher NDC number. Acceptance for values between two and five can be subject to additional restrictions and the intended usage Acceptance criteria for NDC desdribed below (AIAG, 2010).

NDC:

Good: ≥ 5

Acceptable: Between 2 and 5

Not acceptable: < 2

4. RESULT AND DISCUSSION

4.1 Two Way ANOVA

Normality test was conducted before to be able to perform a measurement system analysis on the collected data. According to the Anderson-Darling normality test; The p value was determined above p value 0.05. These values show that the data are normally distributed. The analysis of the MSA can be performed due to normal distribution of the data. MSA data then analize using minitab software used ANOVA Method.

Table 1. Two-Way ANOVA

Source	DF	SS	MS	F	P
Part	9	2893,75	321,528	85,7407	0,000
Part*Tyreman	1	3,75	3,750	1,0000	0,343
Repeatability	9	33,75	3,750	4,5000	0,000
Total	**40**	**33,33**	**08833**		
	59	**2964,58**			

Table 2. GR&R Evaluation

Source	StdDev (SD)	Study Var (6 x SD)	%Study Var
Total Gage R&R	1,34371	8,0623	18,16
Repeatability	0,91287	5,4772	12,34
Reproducibility	0,98601	5,9161	13,32
Tyreman	0,0000	0,0000	0,00
Tyreman*Part	0,98601	5,9161	13,32
Part-to-Part	7,27757	43,6654	98,34
Total Variation	**7,40058**	**44,4035**	**100,00**

The results of the Two-Way ANOVA to find out the effect of the two factors, namely the inspector factor and the Part (tire) described in Table 1. Since the study has two inspector and 10 types of tires with three replications. The ANOVA result showed in Table 1. that the part and interaction of part and inspector effected tire pressure statistically significant, since p-value below 0.05. However, it was found that there was no significant difference between inspector, means that inpector did not effect the tire pressure, it can bee seen from p-value 0.343.

4.2 Gage R&R Results

The minitab analysis result for GR&R evaluation showed in Table 2, repeatability as the variation within inspector 12.34%, this variation are contribution of measuring devices. Reproducibility as the variation between inspector 13.32%. This explains that the error variance of the measurement results caused by the measuring instrument contributed 12.34% and the error variance caused by the operator and interaction between operator was 13.32%.

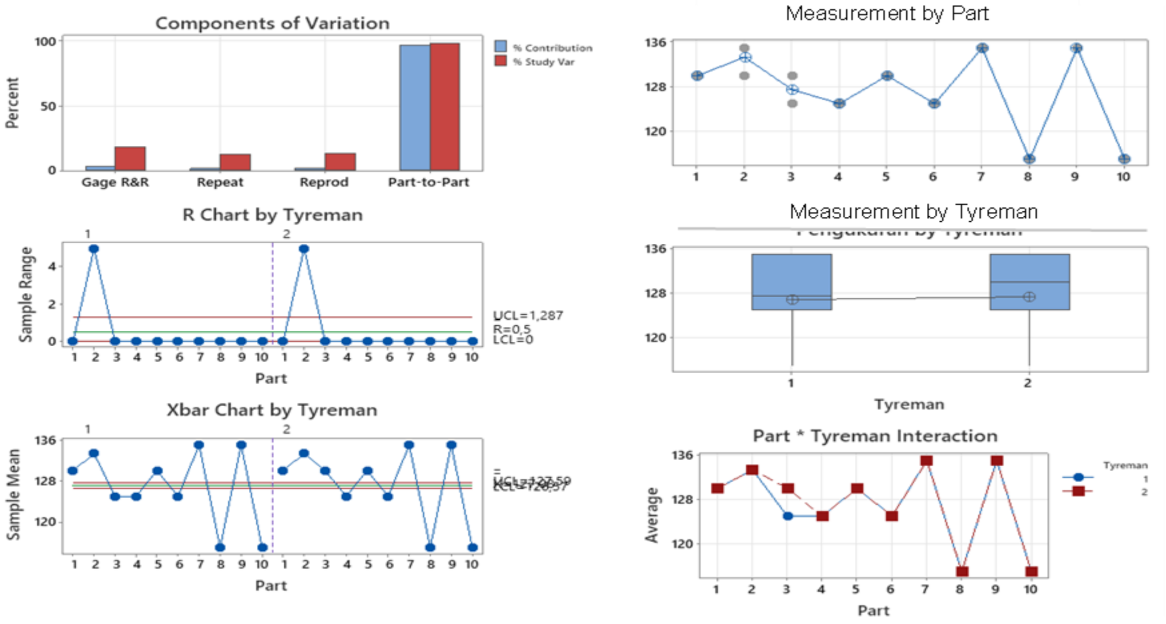

Figure 2. Gage R & R analysis result

The % GR&R of the study showed 18.16%, means that 18,16% of the variation is a result of the measurement system variation. Part to part variation showed 98.34%, this indicate that Most of the variation came from part to part variation. If the reproducibility and repeatability are high, it means the measurement system is unstable. The study variance has been determined that total variation of GR&R% = 18.6%. Compare to standard GR&R between 10% and 30%, so it can be concluded that the measurement system is acceptable for some application according to standard established by Automotive Industry Action Group (AIAG).

Based on graphical analysis in Figure 2, component of variataion bar showed that variation contribution come from part to part variation. Range chart swhoe that tire number 2 has two different reading for each inspector which cause range 5 psi which lead to repeatability variation. Graph of interaction of tire and inspector tire number 3 has different redaings between both inspector, this will lead to reproducibility variation.

4.3 Number of Distinct Categories

In GR&R studies, one metric used to determine a measuring system's capability to detect a change in the measured characteristic is the number of distinct categories. It is a measurement of the variation in the sample parts. It represent the number of non-overlapping confidence intervals that cover the range of product variation is represented by the number of unique categories. The measurement system is said to be acceptable if the value number of distinct categories is greater than 5 (AIAG, 2010). The NDC of this study was 8, means that there is enough part variation to use the ANOVA method to calculate Gage R&R.

5. CONCLUSION

Gage repeatability and reproducibility studies are important for the validity of data, which is essential for deision making. The use of Measurement System Analysis (MSA) to highlight the accuracy of operations would be very beneficial. The applied method efficiently simplifies measurement difficulties; consequently, measurement analyses might be referred to as a tracing method for the significant sources of process variations. This study result showed that significant source of variation came from tires itself. The MSA resul ts in a Total Gage R&R of 18.16% with a repeatability value of 12.34% and a reproducibility value of 13.32%. The result indicated that the measurement system showed good results because the Gage R&R fell between 10% and 30% which is good for tire measurement application. Since tire pressure does not need high precision measurement during operation. The NDC value was 8 indicated that the measuremen system with ANOVA method to calculate Gage R&R used properly.

REFERENCES

(AIAG), A. I. A. G. (2010). *Measurement System Analysis (MSA) Fourth Edition* (Vol. 4, Issue 1).

Abdulaev, E. K., Makharatkin, P. N., & Pumpur, E. V. (2019). A Priori Ranking and an Analysis of Factors Affecting Tire Wear. *IOP Conference Series: Earth and Environmental Science*, *378*(1), 3–7. https://doi.org/10.1088/1755-1315/378/1/012001

Abhimanyu Yadav. (2016). Measurement Systems Analysis and a Study of Anova Method. *International Journal of Research in Engineering and Technology*, *05*(02), 123–127. https://doi.org/10.15623/ijret.2016.0502022

Cepova, L., Kovacikova, A., Cep, R., Klaput, P., & Mizera, O. (2018). Measurement System Analyses - Gauge Repeatability and Reproducibility Methods. *Measurement Science Review*, *18*(1), 20–27. https://doi.org/10.1515/msr-2018-0004

Deshpande, A., Dhakrao, R., Bhawsar, V., Bhavsar, S., Rayjade, G., & Ranade, P. (2020). Measurement System Scrutiny using Gage R&R: Case Study. *International Research Journal of Engineering and Technology*, *June*, 4224–4229. www.irjet.net

Dhawale, R., & Raut, D. N. (2013). Evaluating Measurement Capabilities by Gauge R&R Using ANOVA for Reliability. *International Journal of Engineering Research and Applications*, *3*(3), 726–730. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.419.6350

Galli, B. J. (2020). Measurement System Analysis and System Thinking in Six Sigma. *International Journal of System Dynamics Applications*, *9*(1), 44–62. https://doi.org/10.4018/ijsda.2020010103

Gerger, A., Gör Atakan GERGER Ege Üniversitesi, Ö., & Meslek Yüksekokulu, E. (2021). Conducting a Gage R & R Study: An Application Example in Automotive Industry. *Journal of Economics and Social Research Ekonomi ve Sosyal Araştırmalar Dergisi Conducting a Gage R & R Study: An Application Example in Automotive Industry*. https://www.researchgate.net/publication/349625419

Klaput, P., & Plura, J. (2012). Influence of Used Method on The Results of Gage Repeatability and Reproducibility Study. *METAL 2012 - Conference Proceedings, 21st International Conference on Metallurgy and Materials*, 1756–1761.

Kumar, T. V., G.Ramya, P.Kowsalya, Priya, B. S., & P.Tharani. (2020). SMEs Perception towards Adoption of Measurement System Analysis Strategy : A Case Study in Pump Manufacturing Industry. *Materials Science and Engineering, IOP*

Conference Series, *954*. https://doi.org/10.1088/1757-899X/954/1/012006

Lindeque, G. C. (2016). A Critical Investigation into Tire Life on an Iron ore Haulage System. *Journal of the Southern African Institute of Mining and Metallurgy*, *116*(4), 317–322. https://doi.org/10.17159/2411-9717/2016/v116n4a3

Moatari-Kazerouni, A. (2009). Design and Analysis of Gauge R & R Studies : Making Decisions Based on ANOVA Method. *World Academy of Science, Engineering and Technology*, *52*(4), 31–35.

Saikaew, C. (2018). An Implementation of Measurement System Analysis For Assessment of Machine and Part Variations in Turning Operation. *Measurement: Journal of the International Measurement Confederation*, *118*(March 2018), 246–252. https://doi.org/10.1016/j.measurement.2018.01.008

Schmitt, R., & Marcin Bauza. (2012). Measurement system analysis. *CIRP Encyclopedia of Production Engineering*, *70*(9). https://doi.org/10.1002/9781118307502.ch6

Shao, J., & Qian, T. (2015). Measurement system Performance Analysis Using MINITAB. *Proceedings of the First International Conference on Information Sciences, Machinery, Materials and Energy*, *126*(Icismme), 1679–1683. https://doi.org/10.2991/icismme-15.2015.347

Sivaraos, Raguvaran, M. J., Ali, A., Abdullah, M. F., Sivakumar, D., Ali, M., Hambali, A., Salleh, & Umesh, K. (2019). Vestigation of Tire Pressure Drop Phenomenon Using Specially Designed Real-Time Data Mining And Storage System. *International Journal of Recent Technology and Engineering*, *7*(5), 533–537.

Sumasto, F., Nugroho, Y. A., Purwojatmiko, B. H., Wirandi, M., Imansuri, F., & Aisyah, S. (2023). Implementation of Measurement System Analysis to Reduce Measurement Process Failures on Part Reinf BK6. *IJIEM - Indonesian Journal of Industrial Engineering and Management*, *4*(2), 212. https://doi.org/10.22441/ijiem.v4i2.20212

Ted Hessing. (2016). Gage Repeatability and Reproducibility (R&R). *Six Sigma Study Guide*, *1*. https://sixsigmastudyguide.com/repeatability-and-reproducibility-rr/

Zhou, J., Hall, R. A., Fowler, G., & Huntingford, K. (2008). Evaluation of The Effect of Off-The-Road Tire Air Pressure Setting on Tire Performance. *International Journal of Mining, Reclamation and Environment*, *22*(3), 237–244. https://doi.org/10.1080/17480930701679459