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Analysis and Modeling of Shear Stress Generated Over Wheel and Rim Material during Interaction with Soil

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ABSTRACT

This paper represents the findings of its original paper where the center point between wheel and soil is used as a point of reference to study about the generated stress and other mechanical factors. Generally light weight vehicles are used for this study purpose. The traction force which is generated between wheels is responsible for further generation of shear stress. Sand can be studied in two types like dry sand and wet send. Other electronic components can be used to witness the performance of wheel and sand joining lines. Shear stress can be defined as ratio of parallel force to area.

Keywords: Wheel-Soil, Sensors, Shear stress

INTRODUCTION

Generally, there are different types of force system in solid mechanics. they can be concurrent force system and coplanar force system. It is connected with motion of wheel over sand. Traction control is also established to prevent wheel from slipping action. Transmission system is used with planetary type of gear boxes. The traction force which is generated between wheels is responsible for further generation of shear stress. Sand can be studied in two types like dry sand and wet send. Other electronic components can be used to witness the performance of wheel and sand joining lines. Shear stress can be defined as ratio of parallel force to area [1-3]

WHEEL-SOIL JOINING LINE MEASUREMENT

Model is set with wheel connected with some rough surface to generate stress and inductive stress are responsible for defining the shear stress curve to be more inclined and represents more yielding area along its path. Conventional model can be used to calculate the values which can be obtained be conducting some experiments and obtained these values by using some formula. They may be called as theoretical values. Different research has been used to define these data in different terms and other experimental aspects. Traction control is also established to prevent wheel from slipping action. Transmission system is used with planetary type of gear boxes. [4-6]

EXPERIMENTAL SET-UP [Figure 2]

Sensors are used for this purpose. There may be two types of sensors.

Number one comes as light sensor to sense the different light falling on the surface of joining part of wheel and send trajectory and periphery area to witness soil interaction of wheel and soil. Next another sensor comes and known as tactile sensor. This sensor se4rves the purpose of control and projecting the output force generated during traction motive force. Both sensors are very important from projection point of view as shown in Figure 1. There are another types of sensors can also be used like proximity sensor, vision sensor, flow sensor for general practice. Generally, there are different types of force system in solid mechanics. They can be concurrent force system and coplanar force system. It is connected with motion of wheel over sand. Traction control is also established to prevent wheel from slipping action. Transmission system is used with planetary type of gear boxes. The traction force which is generated between wheels is responsible for further generation of shear stress. Sand can be studied in two types like dry sand and wet send. Other electronic components can be used to witness the performance of wheel and sand joining lines. Shear stress can be defined as ratio of parallel force to area. [7-10]

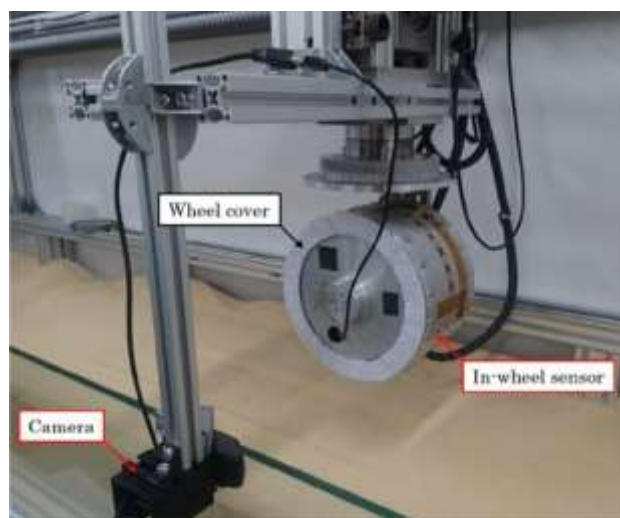**Fig. 1:** *Light and tactile sensor* [3]

Fig. 2: *Experimental set up* [4].

It forward as the slip ratio increases. Conventional model can be used to calculate the values which can be obtained be conducting some experiments and obtained these values by using some formula. They may be called as theoretical values. Different research has been used to define these data in different terms and other experimental aspects. Trends are completely changed to get different values in alternative research or experiments. There are also maximum and minimum values of shear stress which can be used by some conventional model system. These data will change the obtained values completely and improvement can also be done in this respect of shear stress which has large impact on this interactive area. [11-13]

SOIL DEFORMATION

With the interaction of soil onto the wheel, the soil is generally subjected to some of deformation which can take place in both forward and backward direction. As shown in Figure 3 forward direction deformation has larger impact on soil and wheel surface and generally known as bulldozing effect while backward deformation has smaller impact on surface of wheel. Different research has been used to define these data in different terms and other experimental aspects. Trends are completely changed to get different values in alternative research or experiments. there are another types of sensors can also be used like proximity sensor, vision sensor, flow sensor for general practice. Generally, there are different types of force system in solid mechanics. they can be concurrent force system and coplanar force system. It is connected with motion of wheel over sand. Traction control is also established to prevent wheel from slipping. [14-18]
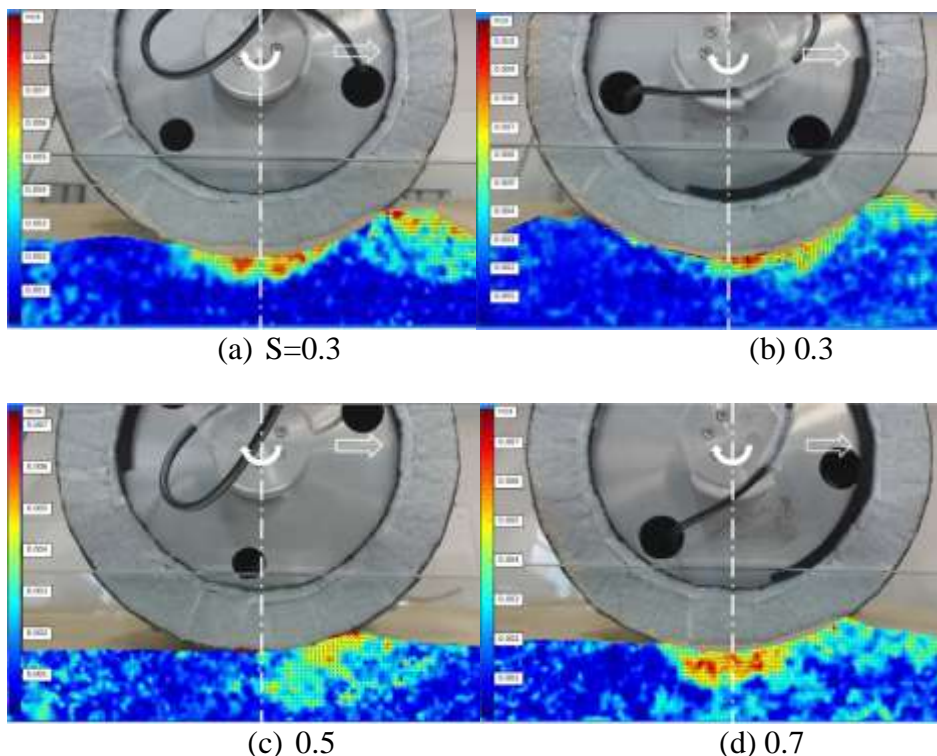

(a) S=0.3   (b) 0.3

(c) 0.5   (d) 0.7

Fig. 3: Soil deformation in joining surface [5]

Different output has been seen to define these data in different terms and other experimental aspects. Trends are completely changed to get different values in alternative research or experiments. There are also maximum and minimum values of shear stress which can be used by some conventional model system. These data will change the obtained values completely and improvement can also be done in this respect of shear stress which has large impact on this interactive area. It forward as the slip ratio increases. Conventional model can be used to calculate the values which can be obtained be conducting some experiments and obtained these values by using some formula. They may be called as theoretical values. [19]

ASPECT OF IMPROVEMENT IN SHEAR STRESS GRAPH

Graph between shear stress and shear strain is generally obtained by conducting a tensile test in universal testing machine which can be seen and represented by different parameter and salient pint and feature of stress model. But there is always the chance of improvement in this model of shear stress which can be employed in this area of research. The traction force which is generated between wheels is responsible for further generation of shear stress. Sand can be studied in two types like dry sand and wet send. Other electronic components can be used to witness the performance of wheel and sand joining lines. Shear stress can be defined as ratio of parallel force to area. There are another types of sensors can also be used like proximity sensor, vision sensor, flow sensor for general practice. Generally, there are different types of force system in solid mechanics. [20,21]

Characteristics of Joining Area Material

There are two types of characteristics are taken into account for study purpose in this research paper. They may statics characteristics and other may be dynamics characteristics. Model is set with wheel connected with some rough surface to generate stress and inductive stress are responsible for defining the shear stress curve to be more inclined and represents more yielding area along its path. There are also maximum and minimum values of shear stress which can be used by some conventional model system. These data will change the obtained values completely and improvement can also be done in this respect of shear stress which has large impact on this interactive area. Different research has been used to define these data in different terms and other experimental aspects. Trends are completely changed to get different values in alternative research or experiments. There are another types of sensors can also be used like proximity sensor, vision sensor, flow sensor for general practice. Generally, there are different types of force system in solid mechanics which can be seen and represented by different parameter and salient point and feature of stress model. But there is always the chance of improvement in this model of shear stress. The traction force which is generated between wheels is responsible for further generation of shear stress. Sand can be studied in two types like dry sand and wet send.

The traction force plays very important role in proper study of stress generated over wheel and rim material, which is generated between wheels, is responsible for further generation of shear stress. Sand can be studied in two types like dry sand and wet send. Other electronic components can be used to

witness the performance of wheel and sand joining lines. Shear stress can be defined as ratio of parallel force to area. Stress generation also define parameters distribution to calculate soil and wheel interaction effectiveness for shear stress measurement. Shear stress can be seen and represented by different parameter and salient point and feature of stress model. Stress model is important for measuring the strength of rim material on spoke side and hole side during interaction with soil. Different research has been used to define these data in different terms and other experimental aspects. Trends are completely changed to get different values in alternative research or experiments. [22-25]. The Boundary friction coefficient representation is shown in Figure 4.
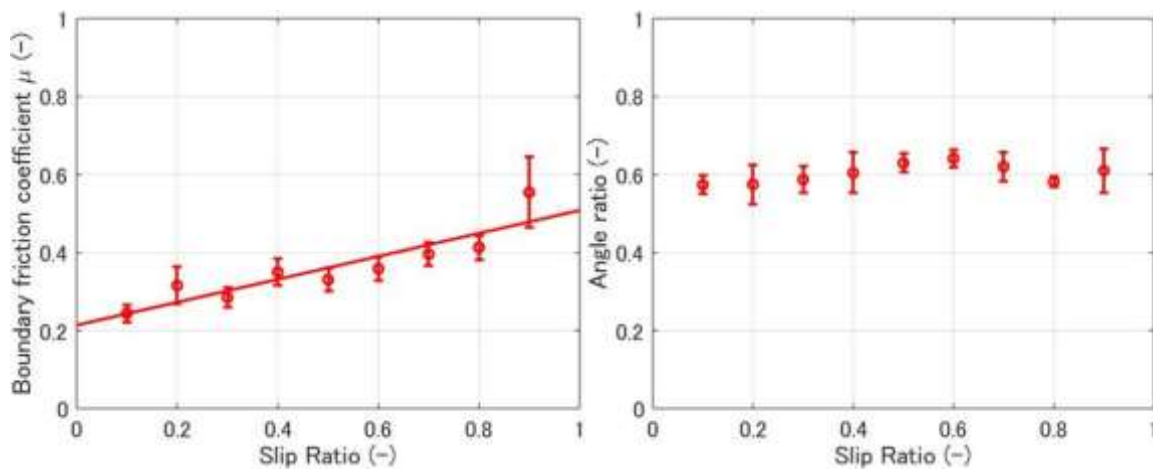

Fig. 4: Boundary friction coefficient representation [6].

Wheel Type and Specifications of Rim Body

Wheels are generally made of different composites, steel or alloy. Alloys used in making of wheel are generally aluminum alloy. Strength of these alloys is very high as compare to other steel and material. Weight of alloy is less than other material. Most common wheel type is wearing spoke and steel disc wheel. While interaction of wheel with soil is taken under consideration with the help of wheel and primarily elements like pitch circle diameter and center diameter to join the spike with rim various welding process are used as shown in Figure 5.
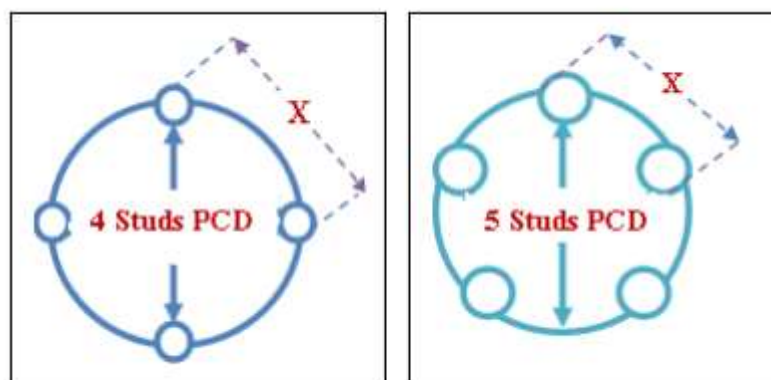

Fig. 5: Pitch circle diameter [7]

A wheel has different components like wheel hub, wheel rim etc. various tastings are done to check the stress distribution along periphery of wheel as shown in figure no. 6. Software is used to check the developed stress during the movement of wheel and on other components.

Stress plays an important role in defining the strength of wheel material and rim. If forces act parallel to the plane of rim then they can develop a shear stress in wheel as shown in Figure 6. While if these forces take place ibn direction perpendicular to the direction of shear plane then normal stress will be developed. Commonly wheel type is wearing spoke and steel disc wheel. While interaction of wheel with soil is taken under consideration with the help of wheel and primarily elements like pitch circle diameter and center diameter.

To join the spike with rim various welding process are used. Experimental results explain about shear stress model as shown and improvised can be done in this concept.

Friction coefficient is also a factor which is used to define the traction loss in rolling action of wheel. We tried to conduct to different experiments to obtained good data. However, results are certainly good and we can rely on them for defin9ng and explain the function wheel when it interacts with soil in different direction. [26]
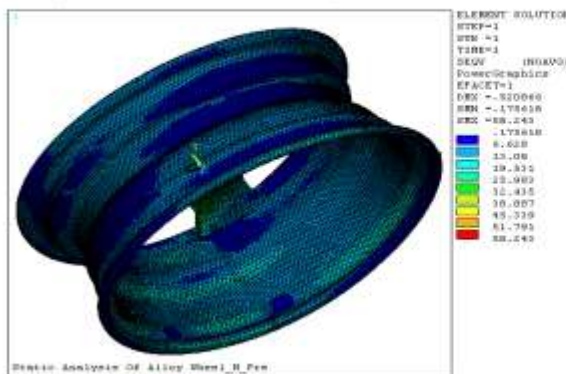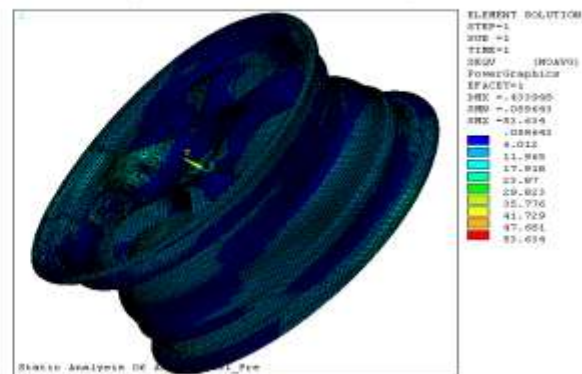

Fig. 6: *Stress distribution* [8].

Shear Stress Displacement Analysis
Stress is taken as von miss's stress. As per experimental setup and at different parameters like wheel speed and temperature developed at the joining of surface, force of friction distribution, we obtained different values of shear stress. Stresses were also recorded on two sides of wheel like spoke side and whole side of wheel. We recorded stress at spoke side was 52.93 Mpa at speed 42kmph and at hole side it is 51.96 Mpa at speed of 40kmph.[27].
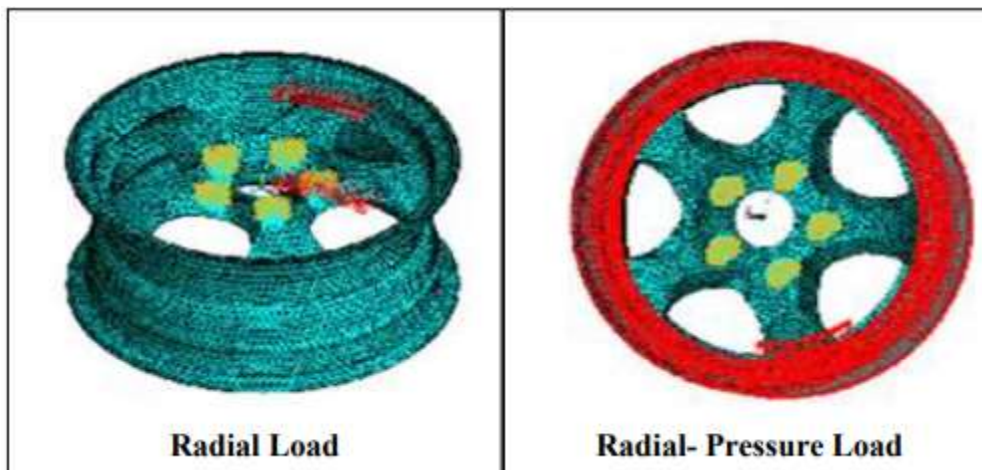Its pressure distribution is shown in Figure 7.

Fig. 7: Pressure distribution [9].

CONCLUSION

The relationship with the slip ratio and entry angle was seen clearly with the above experimental setup as per original paper. They can be summarized as different aspect and slip ratio of transmission boxes. Experimental witness also defines the data's in very clear formatter. Experimental results explain about shear stress model as shown and improvised can be done in this concept. Friction coefficient is also a factor which is used to define the traction loss in rolling action of wheel. We tried to conduct to different experiments to obtained good data. However, results are certainly good and we can rely on them for defin9ng and explain the function wheel when it interacts with soil in different direction. Stress is taken as von misses stress. As per experimental setup and at different parameters like wheel speed and temperature developed at the joining of surface, force of friction distribution, we obtained different values of shear stress. Stress were also recorded on two sides of wheel like spoke side and hole side of wheel. We recorded stress at spoke side was 52.93 Mpa at speed 42kmph and at hole side it is 51.96 Mpa at speed of 40kmph.

REFERENCES

1. Tsubaki, H., & Ishigami, G. (2021). Experimental study on wheel-soil interaction mechanics using in-wheel sensor and particle image velocimetry Part I: Analysis and modeling of normal stress of lightweight wheeled vehicles. *Journal of Terramechanics*, *93*, 23-39.

2. Hiroki, T., Shirai, T., & Ishigami, G. (2015). Accurate measurement of multidirectional interaction mechanisms between wheel stress and soil deformation using in-wheel sensor and PIV techniques. In *Proc. of the 13th European Conf. on the International Society for Terrain Vehicle Systems, Rome, Italy* (pp. 97-109).

3. Terramechanics-based Analysis and Control for Lunar/Planetary Exploration Robots Ph. D thesis. Tohoku University, Japan. Janosi, Z., Hanamoto, B., 1961. The analytical determination of drawbar pull as a function of slip for tracked vehicles in deformable soils. In: Proc. of the 1st International Conference on Terrain-Vehicle Systems, pp. 707–736.

4. Meirion-Griffith, G., & Spenko, M. (2013). A pressure-sinkage model for small-diameter wheels on compactive,

deformable terrain. *Journal of Terramechanics*, *50*(1), 37-44.

5. Sela, A. D. (1964). *The Shear to Normal Stress Relationship Between a Ridgid Wheel and Dry Sand* (p. 0081). US Army Tank-Automotive Center.

6. Senatore, C., & Iagnemma, K. (2014). Analysis of stress distributions under lightweight wheeled vehicles. *Journal of Terramechanics*, *51*, 1-17.

7. Shirai, T., & Ishigami, G. (2015). Development of in-wheel sensor system for accurate measurement of wheel terrain interaction characteristics. *Journal of Terramechanics*, *62*, 51-61.

8. Karthik, L., Kumar, G., Keswani, T., Bhattacharyya, A., Chandar, S. S., & Bhaskara Rao, K. V. (2014). Protease inhibitors from marine actinobacteria as a potential source for antimalarial compound. *PloS one*, *9*(3), e90972.

9. Stamhuis, E., & Thielicke, W. (2014). PIVlab–towards user-friendly, affordable and accurate digital particle image velocimetry in MATLAB. *Journal of open research software*, *2*(1), 30.

10. Tsubaki, H., & Ishigami, G. (2016). Modeling of Wheel-Soil Interaction Mechanisms Based on Accurate Measurement of Pressure Distribution for Lightweight Vehicle. In *Proc. of the 8th Americas Conf. of ISTVS*.

11. Wong, J. Y., & Reece, A. R. (1967). Prediction of rigid wheel performance based on the analysis of soil-wheel stresses part I. Performance of driven rigid wheels. *Journal of Terramechanics*, *4*(1), 81-98.

12. Wong, J. Y., & Reece, A. R. (1967). Prediction of rigid wheel performance based on the analysis of soil-wheel stresses: Part II. Performance of towed rigid wheels. *Journal of Terramechanics*, *4*(2), 7-25.

13. Yamamoto, H., Utumi, R., & Kushida, A. (1986). The Friction Coefficient of Fused Alumina Due to Wall Material. *Journal of the Society of Powder Technology, Japan*, *23*(9), 641-646.

14. Maurya, A. K., Rai, A. K., & Ahuja, H. (2022). Performance Analysis of a 40kWp Grid Connected Solar PV System in Northern India. *Journal of Research and Advancement in Electrical Engineering*, *4*(3).

15. Maurya, A. K., Rai, A. K., & Ahuja, H. (2022, December). Comparative Analysis of Different MPPT Algorithms for Roof-Top Solar PV System. In *2022 International Conference on Automation, Computing and Renewable Systems (ICACRS)* (pp. 1412-1417). IEEE.

16. Maurya, A. K., Tyagi, Y., Khan, H., Narang, D., & Ahuja, H. (2022, December). Components & Control Scheme used for Line of Sight Stabilization in Defence Applications. In *2022 International Conference on Automation, Computing and Renewable Systems (ICACRS)* (pp. 1425-1431). IEEE.

17. Maurya, A. K., Khan, H., Rai, A. K., & Ahuja, H. (2022, December). Load Frequency Control by using Different Controllers in Multi-Area Power System Networks. In *2022 International Conference on Automation, Computing and Renewable Systems (ICACRS)* (pp. 1418-1424). IEEE.

18. Maurya, A. K., & Khan, H. (2022). Converters' Topologies & Experimental Characteristics of Roof-top Solar PV System: A Comparative Analysis. *Advancement and Research in Instrumentation Engineering*, *5*(3).

19. Maurya, A. K., Khan, H., & Tyagi, Y. (2022). Experimental Investigation of Roof-top Solar PV System. *Advancement and Research in Instrumentation Engineering*, *5*(3).

20. Maurya, A. K., Rai, A. K., & Ahuja, H. (2022, November). Performance Analysis of Roof-top Solar PV System

in Composite Environment. In *2022 IEEE 10th Power India International Conference (PIICON)* (pp. 1-6). IEEE.

21. Maurya, A. K. (2021). Design and Fabrication of a Prototype Electric Vehicle. *AKGEC International Journal of Technology*, *12*(1).

22. Maurya, A. K., & Khan, H. (2021). Performance Study of Grid Connected Solar-PV System. *AKGEC International Journal of Technology*, *13*(1).

23. Singh, A., Maurya, A., & Patel, R. (2019). Study of Thermal Decomposition of Polystyrene Using Viscometric Analysis and Assessment of Its Reaction Rate Models. *AKGEC International Journal of Technology*, *10*(2).

24. Maurya, A. K., Khan, H., & Ahuja, H. (2023, March). Performance of Load Frequency Control of Two-Area Power System by Using Proportional Integral Derivative Controller. In *2023 10th International Conference on Signal Processing and Integrated Networks (SPIN)* (pp. 168-173). IEEE.

25. Khan, H., Maurya, A., Kalra, S., & Ahuja, H. (2023, January). Load Frequency Control using PID Algorithm in Multiarea of Power System for Uncertain Load Conditions. In *2023 Third International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)* (pp. 1-6). IEEE.

26. Maurya, A. K., Khan, H., & Ahuja, H. (2023, January). Stability Control of Two-Area of Power System Using Integrator, Proportional Integral and Proportional Integral Derivative Controllers. In *2023 International Conference on Artificial Intelligence and Smart Communication (AISC)* (pp. 273-278). IEEE.

27. Maurya, A. K., Khan, H., & Ahuja, H. (2023, January). Stability Control of Two-Area of Power System Using Integrator, Proportional Integral and Proportional Integral Derivative Controllers. In *2023 International Conference on Artificial Intelligence and Smart Communication (AISC)* (pp. 273-278). IEEE.

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research and innovative approach to teaching and learning.

He involved in many projects like Smart India Hackathon, KPIT Sparkle, University Innovation and R&D projects, etc. In addition, he actively participated in various technical and non-technical events at Zonal, University, National, and international levels. He was recently honored with **Young Researcher Award 2021** by INSC Bangalore for the no. of achievements, rewards, and publications at various national and international bodies. He has a good no of publications in his credits. His key interest areas include Renewable Energy, Power Systems, and Control & Instrumentation Systems, etc.