International Journal For Technological Research In Engineering
Volume 5, Issue 9, May-2018 *ISSN (Online): 2347 - 4718*

DERAILMENT CAUSES OF RAILWAY VEHICLE AND ITS PREVENTION

Srihari Palli[1], Ramji Koona[2]
[1]Mechanical Engineering Department, AITAM, Tekkali, A.P., INDIA.
[2]Mechanical Engineering Department, AUCOE, Visakhapatnam, A.P., INDIA.

ABSTRACT: Train accidents cause not only damage to railway but also it damages the infrastructure and rolling stock together with service disruptions, and canresultlosses of life of human being and harm the environment. Therefore, enhancing train operating safety has long been a primaryconcern of the rail industry and the government. In this paper technical aspects related to railway vehicle derailments are discussed. Railway vehicle derailment modes and safety criteria standards laid by FRA and REA are discussed. Important features related to derailments due to track errors, the effects of derailment and their prevention approach is discussed in this paper.
KEYWORDS: Railway vehicle derailment, Wheel flange climb, track alignment, Switch defects, FRA, REA

I.INTRODUCTION

Train derailment may lead to high human life and infrastructure loss. Derailment is major concern for organisations to avoidas they are relate to safety measures and economic reasons [Palli et al, 2015], [Sharma & Kumar, 2016a], [Sharma & Kumar, 2016b]. Railway vehicle derailments are due to wheels leaving the track which givesare there for stability and negotiation [Sharma, 2012], [Sharma, S. K. et al, 2014]. The logic for wheels leaving rails while run to explain is very complicated [Sharma, 2013a, Sharma, R. C. 2013b, Sharma, R. C. et al 2017a]. The final scenario of derailment predicts the probablereason of derailment why wheels left the rail, rail gauge widening, or rail roll over mayresults wheels to fall among rails. Thus, asituationwhichcandecrease the lateral guidance produced by rail maydevelop the chances of derailment [Sharma, 2011a], [Sharma, 2011b], [Sharma, 2016a], [Sharma, 2016b]. The high speed operation advanced in the recent timesrequires an even more exactvehicle lateral guidance.Generally, at low derailment speeds near 10 mph, different track and human factor cause, i.e. improper train handling, improper braking control, and improper control of switches are the probable reasons of derailments. At higher derailment speeds beyond 25 mph, those causes are not present and reasons arecomponent failures, such as bearing failure, broken wheel, and axle and journal defects. These results represent the first stage in aanalytical process of quantitative risk analysis of railroad freight train safety, with an finalgoal of maximising safety improvement and more cost-effective risk management [Sharma, 2014], [Sharma et al, 2014a], [Sharma et al 2014b]. Derailment is the major issue for railway operations from the beginning when wheels run on rails. The important aspect of wheels moving on rails creates a unique challenge for railways to ensure that wheels remain in contact with rail [Sharma and Palli, 2016], [Sharma and Kumar, 2017a], [Sharma and Kumar, 2017b]. The high speed trains in recent times need a more accurate control of vehicle lateral guidance [Sharma and Kumar, 2014], [Sharma et al, 2015a].Derailment incidents are unfortunately faced all over repeatedly. Searching ―railway derailment‖ oninternet produces so many derailment incidences all over the world, due to different kinds of reasons.Wide gauge, track alignment, bogie hunting, and wheels with worn tread and flanges areprovidedmajor attention as they are relate to improper wheel–rail contact and are likely to be influenced by hollow-worn wheel [Palli and Koona, 2015], [Palli et al, 2015].

II. WHEEL-FLANGE CLIMB DERAILMENT

Railway derailments because of lack of the lateral guidance at the wheel and rail surface may be categorised into four reasons: wheel flange climb, gauge widening, rail rollover, and track panel shift.

Wheel flange climb derailments are resulteddue to wheels jumping onto the top of the railhead then further moving on the rail. Wheel climb derailments usuallyresults in conditions where the wheel is subjected a significant lateral force together with circumstances where the vertical force is decreased on the flanging wheel[Sharma and Kumar, 2018a], [Sharma and Kumar, 2018b], [Sharma and Kumar, 2018c]. The significant lateral force is generallydeveloped by a high wheel set angle-of-attack. The vertical force on the flanging wheel may be decreasedhighly on bogies under poor vertical wheel load equalisation, e.g. when moving on rough track, big track twist, or when under roll resonances.

Flange climb derailments usually results on curves. The wheels on the outer rail generally experience abases level of lateral force to vertical force ratio (L/V) that is large depends on:

- Curve radius
- Wheel–rail profiles
- Bogie suspension characteristics
- Vehicle speed

These aspects gather together to develop a base wheel axle angle of attack that progressively develops the base level of lateral curving force. A largely misaligned bogie generally induces high wheel set angle of attack. Any track irregularities and dynamic discontinuities can generate progressive improvement in wheel L/V ratio. When ratio increase after astage that sustainedwheel flange climbcan result. Wheel climb derailments mayeven result on tangent track when track irregularities with vehicle lateral dynamic motion are extreme i.e. during resonance and high speed braking.

The lateral velocity of a wheel is given by

$$V_t = -\omega r \sin\psi$$

Where V_t is the lateral velocity of awheelset, r is rolling radius, and ψ is wheelset angleof attack. If the wheelaxlepossess alateral velocity with a component of lateral velocity because of its rotation, the exactlateral speed of the wheelaxle at the contact point, considering the angleofattack to be negligible ($\sin\psi = \psi$), is

$$V_y = \frac{dy}{dx}(-\omega r \psi)$$

ACCIDENT BY TRACK TYPE

In records four classes of tracks are recorded in the FRA (Federal Railroad Administration and REA (Railway Express Agency) i.e. fundamental, siding, yard, and industry tracks. These classes of track are used for a few operational capacities and worried about a few related mishap composes, causes, and repercussion. Prepare mishaps are separated in to wrecking, impact, highway– rail level intersection mischance, and diverse different less continuous composes i.e, Railway entryway in edge of urban communities mischance. When it is higher than one sort of mischance, the kind of mishap that happened is first indicated for all reports identified with it, e.g. a wrecking because of impact is delegated a "crash". Highway– rail level intersection mishaps in the REA database incorporate just those that happen at the highway–rail interface and include no less than one interstate utilize.

Prepare crash is the standard sort of mishap on each track compose, and prepare impact was the slightest continuous (barring highway– rail level intersection mischances on siding, yard, and industry tracks). High per penny (97%) of highway– rail level intersection mischances happened on fundamental track and sums to be 20% of a wide range of Class I principle line prepare mishaps. The frequencies of these mishaps crosses the FRA detailing edge for harms, yet not generally experience crash. Mischance earnestness is depicted in this work with recurrence of autos wrecked in every mishap differs by track write and mischance compose. Prepare crashes on principle and siding tracks had a more normal mischance harm than did different sorts of mishaps and tracks. Highway– rail level intersection mischances had less autos crashed in every mishap the same number of reportable highway– rail level intersection mischances experience no wrecking. Add up to number of autos crashed represents mishap recurrence and reality. The vast majority of the autos crashed on Class I cargo railways were wrecked due to of prepare crashes. Crashes on fundamental and siding tracks saw for 65% of cargo prepare mishaps and correspondingly 87% of the autos wrecked on all classifications of track. Unmistakably the circulation of mishap composes changed by track write, e.g. 98% of highway– rail level intersection mischances happened on principle tracks, though far less happened on yard tracks. A chi-square test was utilized to assess the connection between track compose (fundamental, siding, yard, and industry) and mischance write (crash, impact, highway– rail level intersection mishap, and other) unintentionally recurrence. The connection between mischance compose and track write propose that few track composes have a few mishap reason dispersions, which will be investigated in this paper. Prepare impacts and highway– rail level intersection mishaps have been talked about in other before work, so this investigation focused on prepare crashes.

TRAIN ACCIDENT CAUSE

FRA train accident cause codes are hierarchically organized and categorized into major cause groups—track, equipment, human factors, signal, and miscellaneous. DERAILMENT ON TRACK

Albeit genuine mischances may bring about the yard and siding tracks, the reason for this investigation is on principle line crashes because of the higher paces and longer comprises especially of primary line activity. The higher mass and speed demonstrate that the power and potential contact concerning property harm, setbacks, and natural impacts are largely correspondingly more prominent. An overview of wrecking reasons did think about the capacity of recurrence and earnestness by crash reason. The degree of the misfortune is essential as crashes in which more autos are included are probably going to be additionally harming and all the more exorbitant, have a greater probability of including a perilous materials auto if any are in the comprise, and if wrecked they will perhaps endure more.

Certain wrecking reasons, outstandingly broken rails or welds, generally happen when utilizing either metric; thus, endeavors to keep this high-recurrence, high-reality mishaps get significant consideration. Crash recurrence and earnestness (normal number of autos wrecked) were plotted against each other, with recurrence on the abscissa and reality on the ordinate is appeared in Figure 1. The chart is gathered into four quadrants based on the normal wrecking recurrence and reality on every hub. The chart empowers simple examination of the relative recurrence and earnestness of various causes. Those reasons in the upper right quadrant force the most serious hazard as they are both more successive and more extreme than the normal. The five cause groups are

- Wide gauge,
- Broken welds orrails,
- Obstructions,
- Buckled track
- Main-line brake operation.

Four other cause groups that are notable because of their high frequency of occurrence are

- Bearing failure ,
- Track geometry ,
- Train handling, and
- Broken wheels.

Three other cause groups are notable because of the high average seriousness of the resultant derailments and because they all have related causes:

- Rail bolted joints defects,
- joint and other rail defects, and

- Defect on Joint bar.

These three causes, alongside the related reason gathering, broken rails or welds, are quite compelling, as when consolidated they result for just about 20% of all crashes and over 30% of all wrecked cars.

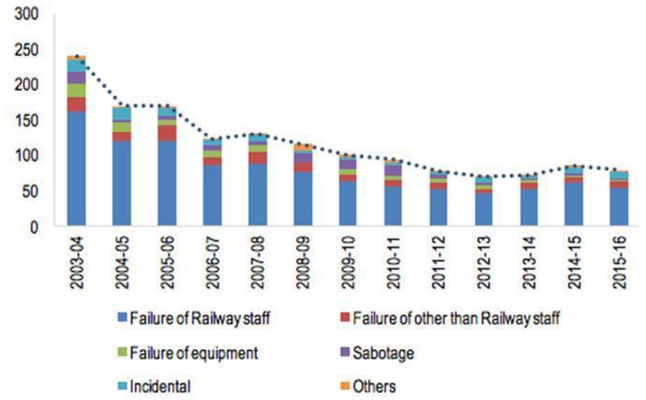

Fig. 1:Causes of consequential train accidents from year 2003 to 2016

III. DERAILMENTS ON SIDING AND YARD TACKS

As said before, fundamental track crashes are most genuine, however investigation of the reasons of crashes on siding and yard tracks is important as few reasons and arrangements are pertinent to both. A chi-square test was done to analyze the appropriations of crash recurrence by the best 20 fundamental line wrecking comes about on principle, yard, and siding tracks. Be that as it may, as opposed to fundamental tracks, bearing disappointments and broken wheels were not among the best mischance causes on the yard and siding tracks, likely because of lower working rates. Rather, human factor–related causes, for example, inappropriate utilization of switches and infringement of exchanging rules were more common. Misaligned switches brought about 14% of yard crashes, and this reason has gotten specific consideration as of late. The higher rate of switch-related crashes in yards and sidings contrasted and principle lines is unquestionably a direct result of the more noteworthy number and more incessant utilization of turnouts on these tracks and in this manner the greater probability of mistake. Another outcome of the more incessant utilization of switches is the higher commonness of switch deserts. Switch deserts brought about almost 10% of crashes on the yard and siding tracks, yet just 3% on fundamental lines. The explanation behind this is likely twofold: the more successive utilization of switches on these sorts of tracks subjects them to more noteworthy presentation and in this manner greater likelihood to bring about a crash, and because of their overwhelming utilize, the changes are liable to more wear and tear and thus quicker weakening. The switch focuses are especially the most helpless parts of switches, consequently their security and oil, alongside enhanced wheel profile and truck guiding execution, can offer intends to avert switch-imperfection crashes. One more distinction between principle tracks contrasted and a yard and siding tracks is that wide measure represented 14% of crashes on siding and yard tracks yet for just 4% on fundamental lines. In addition, this distinction is most likely because of the lower speed normal for the yard and siding tracks yet with an alternate clarification; the lower working velocity permits higher resistances in the track measure principles, hence these tracks might be more delicate to this kind of crash.

IV. EFFECTS OF DERAILMENT

The earlier sections has mentioned accident and track kind as factors adversely influencing the chance that a train or rail automotive can derail, but a new crucial variable adversely influencing mischances is train speed at the time of derailment. Infect, speed is that the crucial issue to a number of the variations cited earlier. Rationale needs that speed is a trouble powerful accident earnestness, and prior examinations have set up numerous subjective and quantitative connections amongst crashes and speed. The most astounding ten mishap reasons for primary line prepare crashes were arranged into very surprising groups, reminiscent of the FRA track class speed extends, and analyzed, again by setback recurrence and assortment of autos wrecked. By and large speed ranges, broken rails or welds were the fundamental reason of crashes; in any case, the proportion of future most common mischance sorts varied well for bring down versus higher speed crashes. At diminished paces of about 10 mph, beyond any doubt track associated and human factor– related causes happened a great deal of oft than gear related causes. in any case, at incident speeds in excess of 25 mph, human elements mischances looking like dishonourable prepare dealing with, braking activities, and despicable utilization of switches were almost one hundred truant, supplanted by part causes, taking after bearing disappointment, broken wheel, and shaft and diary absconds.

V. ACCIDENT PREVENTION APPROACH

To pick up bits of knowledge into the potential wellbeing advantages of methodologies to diminish different kinds of crashes, an affectability examination was directed. Estimation was done to decide by what rate principle track prepare and auto wrecking rates would be decreased if certain mischance causes were lessened or killed. Four of the main fundamental line mischance causes were viewed as: broken rails or welds (08T), track geometry abandons (04T), bearing disappointment (10E), and broken wheels (12E). There are various methodologies by and by or being produced that may address these. Broken rail preventive measures incorporate rail investigation, rail crushing, rail repair and restoration. The adequacy of a mishap avoidance procedure is characterized here as the level of the greatest security advantage it may possibly figure it out. The affectability examination shows the significant potential security advantage that may be acknowledged if advancements or systems were executed with shifting degrees of viability. The impacts of various mischance aversion methodologies may not really be free of each other. For instance, enhanced wheel condition can diminish dynamic stacking of track, along these lines decreasing track deformity rates, and the other way around.

This paper focuses on shaping a systematic structure to examine the relative significance of various mischance causes amid different working conditions. The examinations talked about here are only the initial phase in a hazard based way to deal with wrecking counteractive action. The usage expenses of various hazard decrease measures can be severely impacted by the adequacy of innovation, degree of execution, establishment and support rehearses, and numerous different perspectives.

Track upkeep can come about prepare delay in the limited ability to focus enhance proficiency in the long traverse by lessening the potential administration disturbances because of mishaps. Besides inquire about is expected to break down the connection between mishap rates and event with reference mischance recurrence and comparing activity introduction. This examination will give a superior relationship of the mischance hazard under different working conditions, for example, principle lines versus yard tracks. The last advance is to evaluate the benefits and expenses of particular hazard lessening measures, in this manner permitting reconciliation of the numerous exchange offs including security, proficiency, and cost. In that way, intelligent impacts among methodologies can be ascertained for, and the ideal blend of speculation systems chose for any given level of budgetary assets.

VI. CONCLUSIONS

Mischance reason conveyance changes unintentionally type, track compose, and speed. Crashes are the most well-known sort of prepare mischance on each track write, and the greater part of autos wrecked are because of prepare crashes. Track and segment disappointments are the primary reasons of prepare crashes on principle tracks, and the utilization of switches and exchanging rules affects wrecking recurrence on siding and yard tracks. Hardly any mischances reasons liable to happen all the more much of the time at higher rates, though others are more probable at bring down velocities. The intuitive impacts of crash speed and mishap cause gravely impact prepare mischance recurrence and earnestness. The wellbeing benefits of mishap avoidance systems were inspected according to the rate diminish in prepare and auto wrecking rates. Anticipation of broken rails or welds is probably going to give a bigger rate lessening in prepare and auto crash rates than other mischance counteractive action systems. Be that as it may, the cost-viability of this and other mischance counteractive action techniques must be adequately contrasted with select the best method for improving train working security. Finaly these systems must be expected as a component of a coordinated structure to upgrade venture that improves wellbeing merits and diminishes hazard.

REFERENCES

[1] M. Dhingra, R.C. Sharma, M.H. Salmani, “An introduction & overview to magnetically levitated train,” Journal of science, vol.5, no.11, pp. 1117-1124, 2015.

[2] R. Kumar, M.P. Garg, R.C. Sharma, “Vibration analysis of radial drilling machine structure using finite element method,” Advanced Materials Research, , vol. 472-475, pp. 2717-2721, 2012.

[3] S. Palli, D. Azad, & D. Sreeramulu, Optimization of rail inserts using finite element analysis, International Journal of Engineering, Science and Technology, Multicraft Publications, vol. 6, no. 2, pp. 65-75, 2014.

[4] S. Palli and R. Koona, Analyses of Dynamic Response of a Railway bogie, Int. J. Vehicle noise and Vibration, vol. 11, no. 2, 103-113, 2015.

[5] S. Palli, R. Koona, R.C. Sharma and V. Muddada, “Dynamic Analysis of Indian Railway Integral Coach Factory bogie,” Int. J. Vehicle Structures & Systems, vol. 7, no. 1, pp. 16-20, 2015. http://dx.doi.org/10.4273/ijvss.7.1.03

[6] S.S. Prabhu, P. Srihari, & D.Ramajogi Naidu, “Transient thermal analysis of modified emergency container,” International Journal for Research in Applied Science & Engineering Technology, vol. 4, no. 8, pp. 336- 340, 2016.

[7] K. Ramji, V.K. Goel, SASO Rao, and M.K. Naidu, “Dynamic behaviour of Indian Railway Coach and Bogie Frame using Finite Element Analysis,” Journal of the Institution of Engineers (India), Part MC, Mechanical Division, , vol. 87, pp. 7-17. 2007.

[8] Dr. C.J. Rao, , Dr. D. Nageswara Rao, & P. Srihari, “Influence of cutting parameters on cutting force and surface finish in turning operation,” Journal of Procedia Engg., Elsevier Science Direct, pp. 1405-1415, 2013.

[9] Ch. Ravikumar, P. Srihari, Y. Sagar, “Thermal analysis of artificial hip joint by using biodegradable materials,” International Journal for Research & Development in Technology, vol. 8, no. 3, pp. 211- 216, 2017.

[10] M.H. Salmani, R.C. Sharma, H. Kumar, M. Dhingra, “Efficiency Analysis of Used Transformer Oil for Compression Ignition Engine,” International Conference on Newest Drift in Mechanical Engineering (ICNDME- 14), December 20-21, M. M. University, Mullana, INDIA. Mullana - Ambala: M. M. University, pp. 237-242, 2014.

[11] M.H. Salmani, R.C. Sharma, H. Kumar, M. Dhingra, “Effect of used transformer oil on efficiency of compression ignition engine,” International Journal for Technological Research in Engineering, vol. 2, no. 7, pp. 786-791, 2015.

[12] R.C. Sharma, “Ride analysis of an Indian railway coach using Lagrangian dynamics,” Int. J. Vehicle Structures & Systems, vol. 3, no. 4, pp. 219-224, 2011. http://dx.doi.org/ 10.4273/ijvss.3.4.02

[13] R.C. Sharma, “Parametric analysis of rail vehicle parameters influencing ride behavior,” International Journal of Engineering Science and Technology, vol. 3, no. 8, pp. 54-65, 2011.

[14] R.C. Sharma, “Recent advances in railway vehicle dynamics,” Int. J. Vehicle Structures & Systems, vol. 4, no. 2, pp. 52-63, 2012.

[15] R.C. Sharma, “Sensitivity Analysis of ride behaviour of Indian railway Rajdhani coach using Lagrangian dynamics,” Int. J. Vehicle Structures & Systems, vol. 5, no. 3-4, pp. 84-89, 2013.

[16] R.C. Sharma, “Stability and eigenvalue analysis of an Indian railway general sleeper coach using Lagrangian dynamics,” Int. J. Vehicle Structures & Systems, vol. 5, no. 1, pp. 9-14, 2013.

[17] R.C. Sharma, M. Dhingra, R. K. Pathak, M. Kumar, “Air cushion vehicles: Configuration, resistance and control,” Journal of Science, vol. 4, no. 11, pp. 667-673, 2014.

[18] R.C. Sharma, M. Dhingra, R. K. Pathak, M. Kumar, “Magnetically levitated vehicles: suspension, propulsion and guidance,” International Journal of Engineering Research & Technology, vol. 3, no. 11, pp. 5-8, 2014.

[19] R.C. Sharma, “Modeling and simulations of railway vehicle system,” International Journal of Mechanical Engineering and Robotics Research, vol. 1, no. 1, pp. 55-66, 2014.

[20] S.K. Sharma, A. Kumar and R.C. Sharma, “Challenges in railway vehicle modeling and simulations,” International Conference on Newest Drift in Mech. Engg. (ICNDME-14), December 20-21, M. M. University, Mullana, INDIA. Mullana - Ambala: M. M. University, pp. 453–459, 2014.

[21] S.K. Sharma and A. Kumar, A comparative study of Indian and Worldwide railways, International Journal of Mechanical Engineering and Robotics Research, vol. 1 , no. 1, pp. 114–120, 2014.

[22] R.C. Sharma, Dhingra, M., Pandey, R. K., Rathore, Y., Ramchandani, D. Dynamic analysis of railway vehicles, Journal of Science, vol. 5, no. 3, pp. 193-198, 2015.

[23] R.C. Sharma, M. Dhingra, R.K. Pathak, “Braking systems in railway vehicles,” International Journal of Engineering Research & Technology, vol. 4, no. 1, pp. 206-211, 2015.

[24] S.K. Sharma, R.C. Sharma, A. Kumar, S. Palli, “Challenges in Rail Vehicle-Track Modeling and Simulation,” Int. J. Vehicle Structures & Systems, vol. 7, no. 1, pp. 1-9, 2015.

[25] R.C. Sharma, “Evaluation of Passenger Ride Comfort of Indian Rail and Road Vehicles with ISO 2631-1 Standards: Part 1 - Mathematical Modeling,” Int. J. Vehicle Structures & Systems, vol. 8, no. 1, pp. 1-6, 2016.

[26] R.C. Sharma, “Evaluation of Passenger Ride Comfort of Indian Rail and Road Vehicles with ISO 2631-1 Standards: Part 2 – Simulation,” Int. J. Vehicle Structures & Systems, vol. 8, no. 1, pp. 7-10, 2016.

[27] R. C. Sharma, and S. Palli, “Analysis of creep force and its sensitivity on stability and vertical-lateral ride for railway vehicle,” Int. Journal of Vehicle Noise and Vibration, vol. 12, no. 1, pp. 60-76, 2016.

[28] S.K. Sharma and S. Chaturvedi, “Jerk analysis in rail vehicle dynamics,” Perspectives in Science, vol. 8, pp. 648–650, 2016. doi: 10.1016/j.pisc.2016.06.047

[29] S.K. Sharma and A. Kumar, “Dynamics Analysis of Wheel Rail Contact Using FEA,” Procedia Engineering, vol. 144, pp. 1119-1128, 2016. doi:10.1016/j.proeng.2016.05.076

[30] S.K. Sharma and A. Kumar, “The Impact of a Rigid-Flexible System on the Ride Quality of Passenger Bogies using a Flexible Carbody,” in Pombo, J. (ed.) Proceedings of the Third International Conference on Railway Technology: Research, Development and Maintenance, Stirlingshire, UK, 5-8 April 2016, Cagliari, Sardinia, Italy. Stirlingshire, UK: Civil-Comp Press, 2016, 87. doi: 10.4203/ccp.110.87. 27

[31] R.C. Sharma, S. Palli and R. Koona, “Stress and vibrational analysis of an Indian railway RCF bogie,” Int. J. Vehicle Structures and Systems, vol. 9, no. 5, pp. 296-302, 2017.

[32] R.C. Sharma, S. Palli, S.K. Sharma and M. Roy, “Modernization of railway track with composite sleepers,” Int. J. Vehicle Structures and Systems, vo. 9, no. 5, pp. 321-329, 2017.

[33] S.K. Sharma and A. Kumar, “Impact of electric locomotive traction of the passenger vehicle Ride quality in longitudinal train dynamics in the context of Indian railways,” Mechanics & Industry, vol. 18, no. 2, pp. 222, 2017. doi: 10.1051/meca/2016047

[34] S.K. Sharma and A. Kumar, “Ride performance of a high speed rail vehicle using controlled semi active suspension system,” Smart Materials and Structures, vol. 26, no. 5, pp. 55026, 2017. doi: 10.1088/1361-665X/aa68f7

[35] S.K. Sharma and A. Kumar, “Ride comfort of a higher speed rail vehicle using a magnetorheological suspension system,” Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, vol. 232, no. 1, pp. 32–48, 2018. doi: 10.1177/1464419317706873

[36] S.K. Sharma and A. Kumar, “Disturbance rejection and force-tracking controller of nonlinear lateral vibrations in passenger rail vehicle using magnetorheological fluid damper,” Journal of Intelligent Material Systems and Structures, vol. 29, no. 2, pp. 279-297, 2018. doi: 10.1177/1045389X17721051

[37] S.K. Sharma and A. Kumar, “Ride comfort of a higher speed rail vehicle using a magnetorheological suspension system,” Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi- body Dynamics, vol. 232, no. 1, pp. 32–48, 2018.

[38] V. Singla, R.C. Sharma, and J. Singh, “Fault diagnosis of bearing for wear at inner race using acoustic signal,” International Journal of Mechanical Engineering Research and Development, vol. 1, no. 1, pp. 40-46, 2011.

[39] P. Sivakumar, P. Srihari, & N. Haribabu, “Optimization of Liquid Cold Plates Using

Computational Fluid Dynamics, International Journal of Engineering Trends and Technology, vol. 27, no. 5, pp. 274 – 277, 2015.

[40] K. Swathi, & P. Srihari, "Heat Transfer Enhancement in a Tube Using Rectangular Strip Inserts," International Journal of Applied Engineering Research, Research India Publications, vol. 10, no. 20, pp. 41532-41544, 2015.

[41] Vashist, A., Sharma, R. C., Taneja, S. (2012). Productivity improvement by defect analysis in Indian automobile industry, International Journal of Mechanical Engineering Research and Development, 2(2), 734-741.

[42] A. Vashist, R.C. Sharma, S. Taneja, "Productivity improvement by fixture modification," International Journal of Mechanical Engineering Research and Development, vol. 4, no. 3, pp. 54-62, 2014.

