

# Deliberating the Significance of Heavy Spots on Rail Wheels: Optimizing Balancing and Extending Operational Life

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## ABSTRACT

This paper aims to optimize rail wheel balancing and extend the operational lifespan of rail wheels through enhanced production process control. The study offers a novel contribution, as previous research has not extensively investigated the impact of manufacturing-induced eccentricity on rail wheel imbalance. Utilizing NX for geometric modeling and MATLAB for simulation, the research visualizes and quantitatively analyzes key scenarios in which imbalance occurs. The findings indicate that eccentricity introduced during the fixation of rail wheels on boring machines results in significant imbalance, characterized by heavy and light spots. A distinct wheel-axle assembly condition was simulated with a fixed eccentricity of 0.06 mm, representing a realistic manufacturing tolerance. Quantitative analysis revealed substantial variations in the required counterbalancing mass depending on the angular position of the wheel mounting. The study proposes practical strategies to minimize these imbalances, thereby improving wheel longevity and enhancing the durability of associated components such as bearings and suspension springs. Although the proposed implementation may initially appear challenging, a thorough assessment suggests that it is feasible within existing manufacturing lines. Overall, the proposed methodology is expected to significantly improve rail wheel reliability, reduce maintenance demands, and enhance passenger comfort.

Keywords: Balancing mass, Optimization, Rail wheel, Heavy spot marking

## 1 INTRODUCTION

The rail wheel balancing is most critical in railway operations, as imbalances can lead to excessive vibrations, wear, and reduced service life of the rail wheel and associated components. The occurrence of light or heavy spots on rail wheels, whether due to manufacturing tolerances, material heterogeneity, or operational wear, necessitates the implementation of counterbalancing strategies. This paper aims to analyze and quantify the imbalances using NX modeling [1] and proposes practical solutions to address them.

### 1.1 Background

Rail wheels experience static and dynamic loads during operation, making their balancing critical to minimizing wear on rails and wheels, reducing noise, and ensuring passenger comfort [2]-[6]. Traditional methods for balancing involve adding counterweights, but an in-depth analysis of the impact of light and heavy spots on the rail wheel is still underexplored, in relation to rail wheel balancing. The most common methods for

balancing being adopted are the application of lead-based adhesive tape and welding of external counter-balancing weights [2].

### 1.2 Objective

The objective of this study is to evaluate the impact of light and heavy spots on rail wheels and propose optimized balancing techniques using wheel set assembly process control. By visualizing imbalance scenarios, this work seeks to offer actionable insights for railway engineers and manufacturers.

## 2 METHODS AND MATERIAL

### 2.1 NX modeling

NX software is used to model/design a simplified semi-finished rail wheel, 3-D model, excluding the fine features, like curvatures and fillets. The exclusion of fine details is done for simplicity and also this does not obscure the purpose of this work.

The simplification is limited to curvatures and fillets but the basic dimensions are maintained exactly, as denoted in table 1. The basic dimensions are adhered to the actual solid forged wheel (rough turned) for FIAT bogies, from drawing number MI006615 [7].

The finished wheels are modeled with the dimensions as per solid forged wheel (Finished Turned) for FIAT bogies, from drawing number

LW0215 [8]. The static balancing of the finished wheel is governed by the drawings and is specified in terms of wheel residual unbalanced moment should be less than 50 gm-m.

The NX modeling has been done for FIAT bogies wheels, and it is equally applicable for other models of rail wheels.

Table 1. Wheel nominal dimensions

Model	Hub internal diameter (mm)	Hub outer diameter (mm)	Rim internal diameter (mm)	Rim outer diameter (mm)	Web thickness (mm)
Solid forged wheel (rough turned) for FIAT bogies	184	245	800	918	14
Solid forged wheel (Finished Turned) for FIAT bogies	196	245	800	915	14

## 2.2 Machining operations

The boring of semi-finished wheel is carried out after holding the wheel tread of semi-finished wheel, see figure 1(a), these machines have self centering mechanism but still this may be out of center due to wearing and tearing of parts, even though properly maintained. This will add to eccentricity in the central bore. Now, this wheel

with eccentric central bore in relation to the outer periphery is press fit mounted on concentric axle and sent for the tread profile turning machine for turning the tread to specified profile, see figure 1(b). During this process the wheel set is kept concentric to the central axis of the axle and material is removed from the outer surface of the tread.

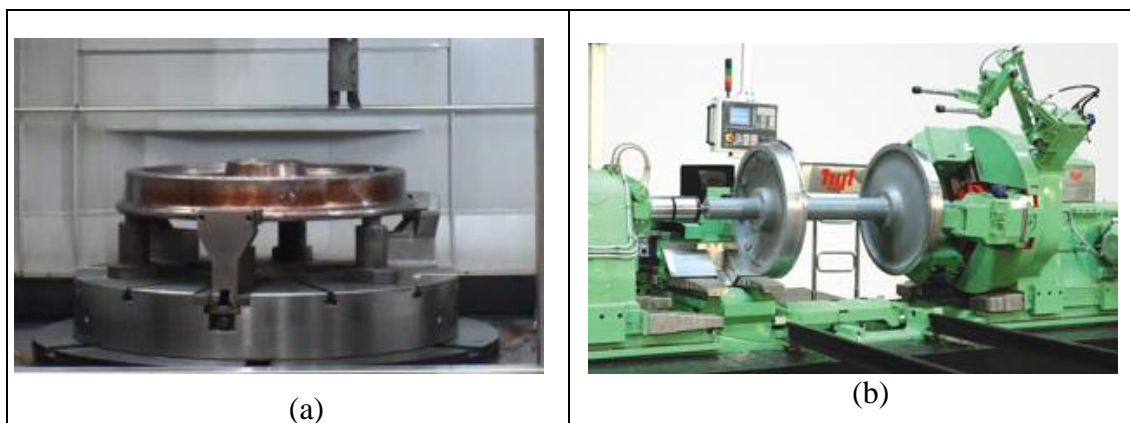


Figure 1. Machining operations (Image: Courtesy internet)

The key observation, here, is that the wheel set is although rotating about the central axis but the path followed by the inner surface of rim profile is not concentric due to the eccentricity of the semi-finished wheel. So, the material from this semi-finished wheel is removed in un-even surface thickness, from the outer radial surface. But the eccentricities at the hub outer surface and rim inner surface are not addressed. This not addressed

material is in the shape of an arc and the associated material contributes to the un-balance mass on both sides of the wheel web, at the hub and rim better visualized by figure 2. The central web being symmetrical does not add to any unbalance.

## 2.3 Visualization of eccentric material

The related functions of NX software are used to isolate the eccentric material, and the finally visualized in figure 2. Here, the eccentricity of 0.06 mm has been used, herein; this value for eccentricity will be used in all generated models.

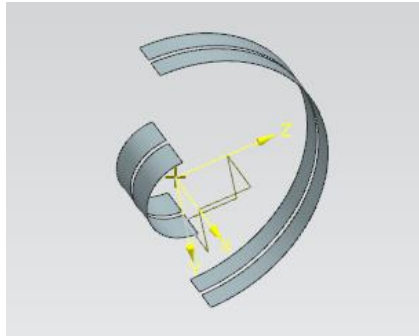


Figure 2. Un-balancing material within wheel

## 2.4 Scenarios and parameters

The study considers multiple scenarios of finished wheel as:

The semi-finished simplified 3-D model is modeled into two categories one perfectly concentric, fully balanced (Perfect), and other with eccentricity of 0.06 mm (Eccentric). The perfect semi-finished wheel is not given any marking and the eccentric semi-finished wheel is given a “RED” marking regarding the angular position of the heavy side (Positive z-axis). From these two

categories of semi-finished models the final finished models (The final finishing operation is done on the profile turning machine) are prepared.

Further, the finished wheel models are prepared from above two categories and a total of five models are created. The mass of all the models remains same and is equal to 234.56 kg, but the mass centers of these are observed to be changed.

The perfect semi-finished model gives two models: (a) Perfect finished model with no eccentricity (b) Eccentric model with eccentricity, the mass center of this model was at point (0, 0, 0.1607). This observation can be interpreted as that from a perfect semi-finished wheel we may prepare a perfect balanced wheel or eccentric wheel, i.e. un-balanced wheel. It will depend upon the machine settings, accuracy and sensitivity of the wheel boring machine, on which the work is being carried out.

Now, from the eccentric semi-finished model three options can be possible: (a) Centered with the semi-finished model (coordinates (0, 0.06)) and will be eccentric with mass center at (0, 0, 0.1607); (b) if we adjust the wheel center at (0, 0) we again get the perfect balanced finished wheel with mass center at (0, 0, 0); (c) if adjust the wheel center at (0, 0.12) again we get the finished eccentric wheel with mass center at (0, 0, 0.4821). The figure 3 presents the finished wheel models prepared from the eccentric semi-finished models.

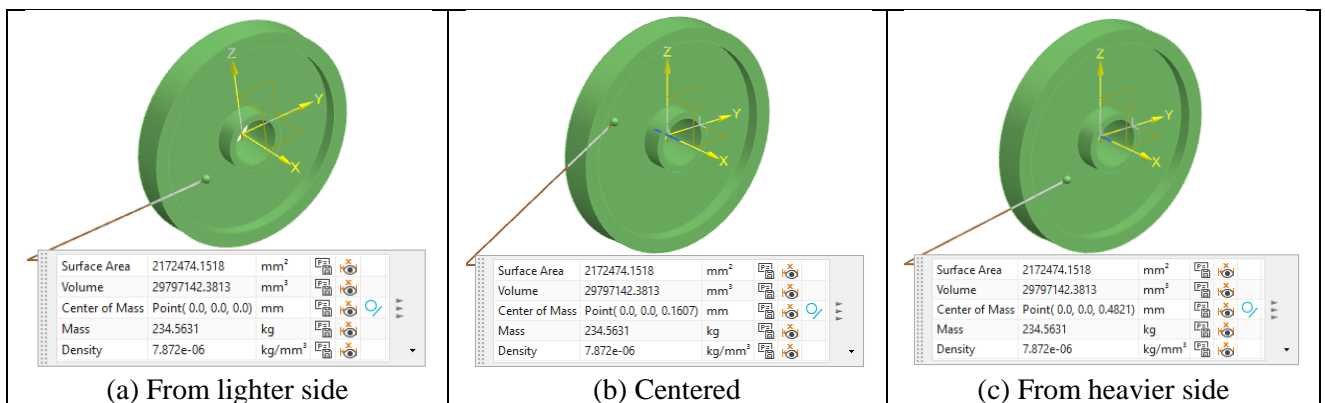


Figure 3. Finished wheel models from semi-finished eccentric model

From above observation the interpretation can be made that even if the semi-finished wheel had eccentricity, still by adjusting the boring center in the wheel boring machine we can get perfectly balanced wheel, only subject to process control and if we know the line of light-heavy point in the wheel. If we move to heavy side we will get increased eccentricity and if we move towards the light side we get towards the perfection. This

directly dictates the requirement of external counter balancing weights.

So, the use of light & heavy spots on the rail wheel can help to mitigate the requirement of external balancing masses which are just an add-on cost. By controlling the angular positioning of the semi-finished wheel and the eccentricity of specific wheel boring machine, the adequate markings can be done at the loading stages which will align and

position the wheel with respect to the cutting tool so that boring is done with minimal eccentricity.

Although some trial and error may be required initially, it can be adjusted and established as a benchmark once optimized and any deviation in the balancing of the wheel set later on, will be indication of flaw in the process control.

One more indirect benefit of controlling and managing wheel boring in accordance to light and heavy spots is that, the process will result in increased life of wheel as the amount of material removed during the wheel profile turning will be less, and more material will be available for operational life. This will add to more tool life also, along with low scrap handling.

### 2.5 Optimal angular positioning of wheel

The bored wheel in accordance to above controlled process can now be assembled in the coupled balancing position which requires the minimum balancing mass, i.e. the wheels heavy points are at 90° with respect to each other, when press fitted on the axle. The requirement of external balancing mass in relation to the angular positioning of the wheel with respect to each other; is presented in figure 4. This has been calculated and presented in the plots, using the MATLAB software [9]-[13]; based on the assumption that 16 gm un-balance is present on both the wheels of the LHB bogie axle.

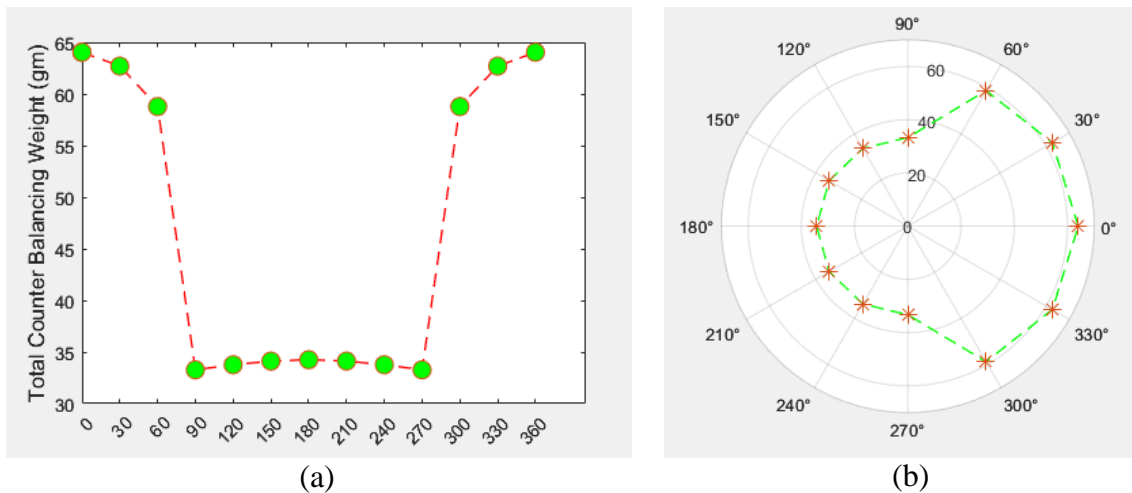


Figure 4. Requirement of counter balancing mass w.r.t. angular position of un-balance in wheel

### 3 RESULTS AND DISCUSSION

The three finished models from the eccentric semi-finished model, were parted into half from the mid-plane along z-axis to evaluate the mass of two parts so that requirement of external counter

balancing mass can be approximated by the simple difference of masses on two sides. The table 2 presents the obtained requirement of counter balancing mass. The figure 5 presents the half model of finished wheel from the positive z-side, which gives increased unbalance.

Table 2. Counter balancing mass requirements

Model	Mass of negative z-side (kg)	Mass of positive z-side (kg)	Mass difference (kg)	Required counter balancing mass (kg)
To lighter side	117.28155241	117.28155241	0	0
Centered with hole	117.25808740	117.30501718	0.0469	0.0469
To heavier side	117.19593999	117.36716607	0.1712	0.1712

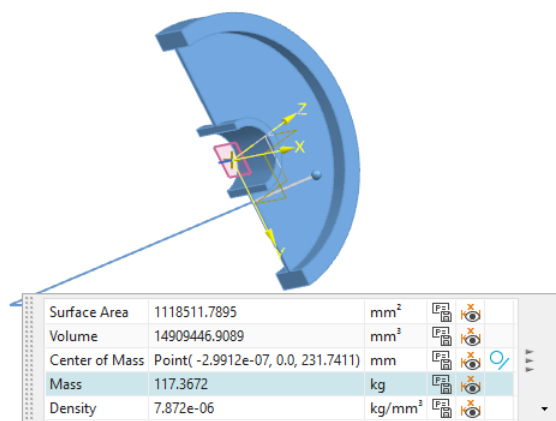


Figure 5. Half of the finished wheel model from the heavier side

The results of Table 2 indicate that even from the unbalanced semi-finished wheel, a better-balanced and a worst-balanced finished wheel can be produced. The only factor controlling this is process control from the initial positioning of the semi-finished wheel on the wheel boring machine and knowledge of the eccentricity of boring for the machine. Then, controlling the press fitting process so that the wheels are press fitted in the coupled balance position, so that minimum counterbalancing is required.

From row three of table 2, the critical observation is that the requirement of balancing weight is more the 4 times if the wheel is generated from the heavy spot side; compare with row 2.

The practical implementation of above methodology, is based on the identification and marking of the light and heavy spots on the rail wheel, and then manufacturing the wheel set. Testing this wheel set for relative angular position and value of external balancing weights and the heavy spot; after that making the adjustment in the process of wheel boring and press fitting of the wheel set assembling. This may take few cycles of operations before getting it fine-tuned to manufacture the wheel sets which will not need any external balancing weights.

Practitioners implementing this process control are invited to share their findings to support further refinement of the approach.

#### 4 CONCLUSIONS

This study presents an unexplored arena related to unbalancing of the rail wheels and simulates the same using NX modeling and MATLAB programming. The study has demonstrated criticality of addressing light and heavy spots in

optimizing rail wheel balancing. Through detailed CAD simulations and scenario analysis, the study provides a framework for manufacturing better balanced rail wheels and wheel sets. Future work need to focus on experimental validation and the integration of deliberated process control for improved balancing of wheel, wheel set and improved wheel life. The future working and refining this approach shall mitigate the requirements of any external balancing weights.

#### CONFLICT OF INTEREST

The author declares no conflicts of interest.

#### AUTHORS CONTRIBUTION

JSK conceptualized, analyzed, drafted, prepared, read, edited, and approved the manuscript.

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#### REFERENCES

- [1] NX 12 for Engineering Design, <https://me5763.github.io/lab/assets/books/NX-12-for-Engineering-Design.pdf>. Accessed 01 January, 2024.
- [2] Chao L, Chao Z, et al (2012) Non-repair dynamically balanced device of wheel set in vehicles, *Advanced Materials Research*, Vol. 510, pp.431-436.
- [3] Wang Y, Kang H, et al (2011) Influence of dynamic unbalance of wheelsets on the dynamic performance of high-speed cars, *Journal of Modern Transportation*, Vol. 19(3), 147-153.

- [4] New T, Pimsarn M (2021) Railway axle and wheel assembly press-fitting force characteristics and holding torque capacity, *Applied Sciences*, Vol. 11, 8862.
- [5] Taneja S (2020) Effect of tyre unbalance on performance of vehicle, *International Journal of Mechanical Engineering and Technology*, Vol. 11(12), pp.12-18.
- [6] Pintao B, Mosleh A, Vale C, Montenegro P, Costa P (2022) Development and Validation of a Weigh-in-Motion Methodology for Railway Tracks, *Sensors*, Vol. 22, pp. 19769.
- [7] Section 6 - List of Drawings, <https://www.scribd.com/document/664185101/Drawings-Section-6>. Accessed 10 December 2023.
- [8] FIAT Bogie <https://rskr.irimee.in/sites/default/files/flat%20bogies.pdf> Accessed 09 January 2025.
- [9] Kushawaha J S (2025) MATLAB-Assisted Dynamic Analysis and Balancing Optimization in Railway Wheel Sets, *Journal of Novel Engineering Science and Technology*, Vol. 4, No. 01, pp.39-43.
- [10] Hunt B., Lipsman R. et al (2001) *A guide to MATLAB for Beginners and Experienced Users*, Cambridge University Press, New York.
- [11] Otto SR, Denier JP (2005) *An Introduction to Programming and Numerical Methods in MATLAB*, Springer, USA.
- [12] Chapman S J (2008) *MATLAB: Programming for Engineers*, Fourth Edition, Thomson, Canada.
- [13] *MATLAB: The Language of Technical Computing* (2005) MATLAB Programming, MathWorks Inc.