# Lightweight tubular axle benefit to wheel-rail contact and impact loads

**R.F. Antunes**
*Vallourec OneR&D Be-Je, Belo Horizonte, Brazil*
**P.H.S. Degasperi**
*Vallourec Soluções Tubulares do Brasil, Belo Horizonte, Brazil*
**A.U. Suzuki**
*Vallourec USA Corp., Houston, USA*

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## Introduction

Hollow rail axles have been proposed since the 19th century in the pursuit of greater railway efficiency. A new generation of these axles—specifically designed for heavy haul applications—is now being manufactured from premium seamless steel tubes. These axles are engineered to deliver an infinite service life, comparable to that of solid axles, while offering up to a 40% reduction in weight, equivalent to 250 kg (550 lb) in an AAR G-class axle.

Since 2010, they have been tested and are in regular service with Brazilian railway operators, alongside traditional solid axles, as shown in Figure 1. Both operate under axle loads exceeding 30 tonnes (66,140 lb).

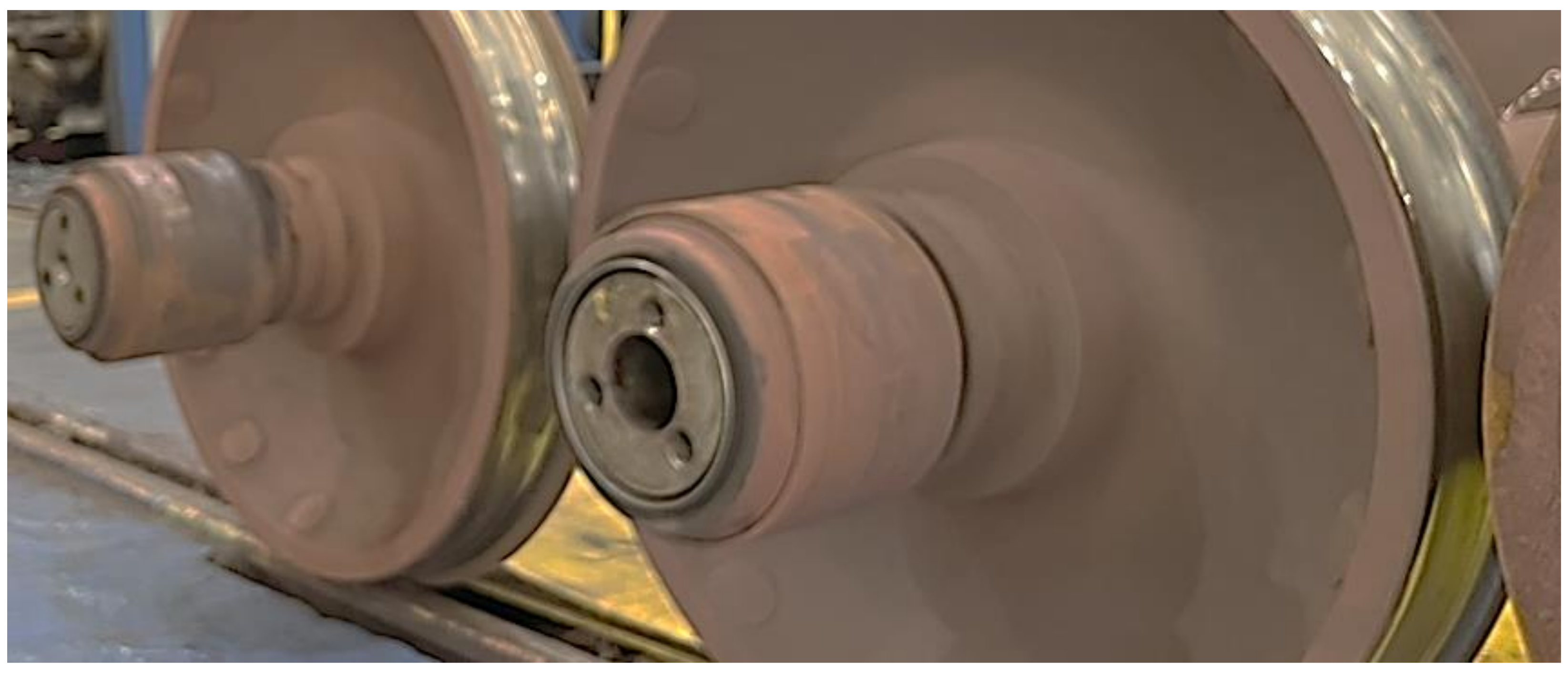

Figure 1. G-class axles on freight car wheelsets: Solid (left) and Tubular (right).

This study focuses on the theoretical influence of axle weight reduction on wheel-rail impact forces under wheel-flat conditions, where peak loads may trigger wayside monitoring alarms. Additionally, the effect on bearing life was evaluated.

## Experimental work

Figure 2 presents a diagram adapted from [Bezgin et al., 2023], illustrating a railway wheel with a wheel flat in a scenario that excludes Hertzian contact effects. In this model, Fs represents the static force (gross rail load function) and Fi the impact force. These forces were calculated for two scenarios, using different axle weights—solid and tubular—based on the corresponding formulae from the same reference. The diagram also includes representations of masses (m) and stiffness values (k), along with reaction forces Rs and Ri, which were introduced here to support the subsequent analysis in this study.

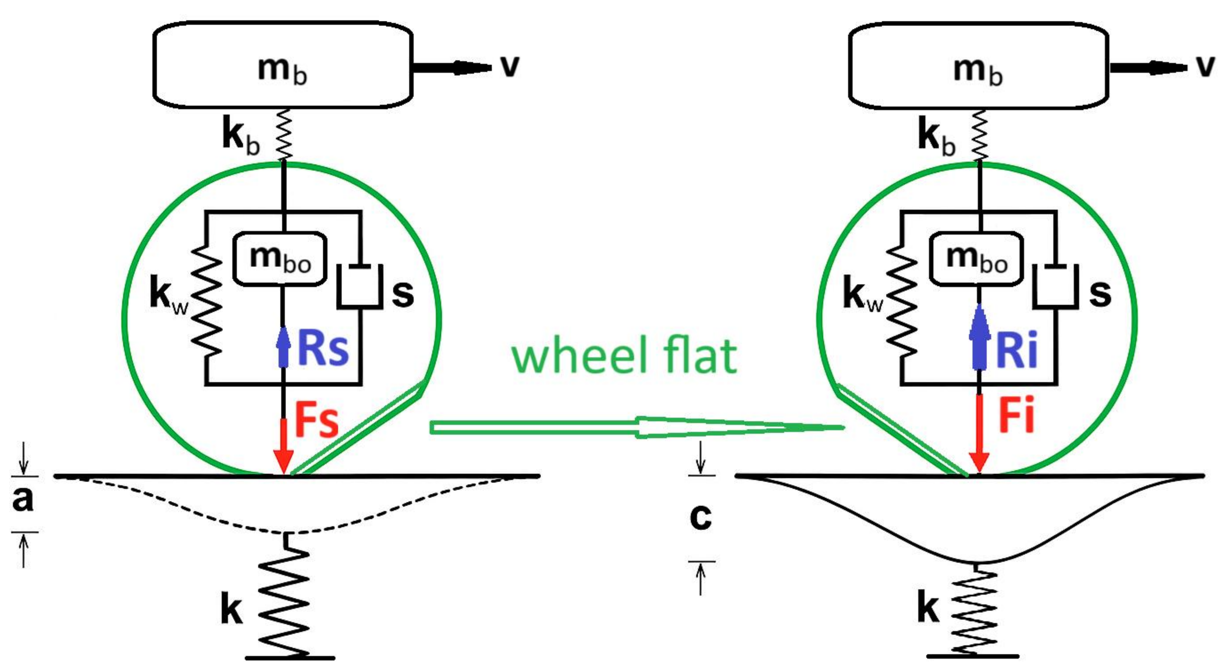


Figure 2. Wheel flat force diagram: Static (Fs, left) and Impact (Fi, right).

Next, to estimate the influence of the reduced weight on bearing life when using a tubular axle, the results of impact forces for solid ($Fi_{So}$) and tubular ($Fi_{Tu}$) axles were applied to a widely known equation for bearing life prediction, L10, as defined in [ISO 281:2007]. In this equation, C represents the dynamic load rating, and P is the equivalent radial load—taken here as the impact force Fi previously obtained.

$$L10_{Tu}/L10_{So} = [(C/P_{Tu})^{3.33}]/[(C/P_{So})^{3.33}] = (Fi_{So}/Fi_{Tu})^{3.33}$$

Equation 1. Bearing fatigue life ratio for roller bearings.

## Results

The impact force results were obtained using a selected set of parameters consistent with the current application of tubular axles: a wheel diameter of 965 mm, a static wheel load of 159 kN, and a maximum train speed of 80 km/h. A wheel flat of 50 mm was assumed, while the vehicle-track equivalent stiffness was kept constant, matching the value used in the reference study. For an equivalent G-class tubular axle (7 × 12 journal) with a 1.6 m broad gauge, the reduction in static wheel force (Fs) was approximately 1.23 kN. In addition to the force variations, the key figures are summarized in Table 1.

| Parameter | ID | Unit | Solid Axle | Tubular Axle | Variation |
|---|---|---|---|---|---|
| Wheel diameter | D | mm *(in)* | 965 *(38")* | | - |
| Flat length | l | mm *(in)* | 50 *(2")* | | - |
| Train speed | v | km/h *(mph)* | 80 *(50)* | | - |
| Static Force | Fs | kN *(kip)* | 159.0 *(35.74)* | 157.8 *(35,47)* | -0.8% |
| Impact Force | Fi | kN *(kip)* | 312 *(70,14)* | 310 *(69,69)* | **-0.6%** |

Table 1. Wheel-Rail Impact Force Comparison: Solid vs. Tubular Axles.

Regarding the transmission of impact forces to the car bogie and car body through the bearing, the next set of results was derived using Equation 1. Since the bearing life (L10) equation has a cubic relationship with the radial bearing load, even a small reduction in force results in a larger increase in estimated bearing life. In this case, the analysis indicates a life extension of approximately 2%, far above 10,000 km in a typical 5-year bearing lifespan.

## Conclusions

This initial theoretical approach demonstrated that wheelsets equipped with tubular axles, as opposed to solid ones, exhibit reduced impact forces caused by wheel flats—primarily due to their lighter weight. Although the reduction is modest, at only 0.6%, it should not be underestimated.

Firstly, the impacts on the rail caused by wheel-flats are monitored by wayside systems which detects when "hammering" loads reach operational thresholds that trigger alarms. Even a small reduction in recorded impact forces can help prevent unnecessary stoppages.

Secondly, from a fatigue perspective, any decrease in stress amplitude contributes to delaying crack initiation and propagation. This impact reduction also influences the reaction forces transmitted to the bearing. The calculated proportional decrease in reaction force results in a +2% extension in bearing life, that may correspond to extra months in its full life.

Note that the advantages of reducing the gross rail load are cumulative, benefiting both maintenance and operation. Looking ahead, more sophisticated mathematical models or experimental studies could be employed to validate these findings or explore alternative scenarios to enhance railway efficiency with this technology.

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**For further information please contact:**
Ronaldo Antunes, Vallourec OneR&D, ronaldo.antunes@vallourec.com
Alberto Suzuki, Vallourec USA Corp., alberto.suzuki@vallourec.com

vallourec

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