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Enhancing Safety Through a New Railway Wheel Design

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Abstract

Due to increases in axle load and the speed of railway freight wagons, wheels have evolved to meet growing braking demands under high levels of mechanical and thermal stress. The most serious failure mode that can occur in a railway wheel is fracture, which carries a high risk of causing derailment. In the 2020s, several critical failure events were observed in the web region of Association of American Railroads standard cast railway wheels, used by a heavy-haul railway operator in Brazil. These events resulted in significant material losses and prolonged interruptions to rail freight traffic. Laboratory test results from the last four failure events revealed the following detrimental factors: poor microcleanliness, surface or subsurface macroscopic flaws in the fracture region of the web, and low web toughness. This article presents technical analyses of a newly designed cast railway wheel, based on previous studies and investigations of wheels that failed in service in Brazil. Additional tests on the rim and especially on the web were conducted to assess the operational safety of this new wheel design. New quantitative requirements are proposed with the aim of improving the operational safety and reliability of railway wheels.

Keywords: operational safety, wheel web, fracture toughness, microcleanliness, rolling contact fatigue, standards

1 Introduction

This article aims to carry out a literature review, especially from Association of American Railroads (AAR) [1], European Standard (EN) [2] standards and the

American Society for Testing and Materials (ASTM) [3] laboratory testing standards. An evaluation of the different existing technical aspects related to modern railway wheels will be performed, focusing on the web. Topics such as types of wheels, chemical composition and microalloyed steel, metallurgical quality, mechanical properties with emphasis on fracture toughness (K_{IC}) [4] and fatigue, as well as in-service failure events and common characteristics of failed wheels will be addressed.

Technical suggestions will be presented based on existing literature and on analysis of defective wheels. Emphasis will be given on the quantitative aspects of failures in webs, as well as suggestions for improvements to the standards identified to date. Additional tests and new quantitative references for quality control in the manufacture of new batches of wheels will also be proposed. A new wheel design was evaluated from the perspective of the parameters proposed in this article.

This work builds upon previous technical analyses [5], in which severe web failure events in heavy-haul railway wheels were investigated from a metallurgical and mechanical perspective. The present paper extends that work by integrating fracture-mechanics concepts, particularly fracture toughness, stress intensity factors, and defect tolerance, enabling a quantitative assessment of critical defects in wheel webs.

2 Standards Review

Currently, railway wheels for use in freight and passenger vehicles have standard references such as: Associação Brasileira de Normas Técnicas - ABNT (Brazil), Rail Industry Safety and Standards Board - RISSB (Australia and New Zealand), AAR (United States, Mexico and Canada), EN (Western Europe), Gosudarstvennyy Standart - GOST (Russia and Eastern Europe). The AAR standard, widely regarded as a technical benchmark though not compulsory in Brazil, will serve as the primary reference for this article. Additionally, relevant information from the European standard EN 13262 will be highlighted.

AAR contains the minimum technical references for the design, manufacturing process, product and quality control in the production of wheels for freight wagons, locomotives and passengers [6]. AAR standard is the main technical reference for the specification of wheels for freight and heavy haul, which can be cast or wrought, heat treated and with a design that includes web low stress level. The S-660 standard [7] outlines the evaluation criteria for different aspects of wheel design. Among them, the standard specifies a numerical method to assist in the analysis of wheel design for adequate performance under normal service conditions. The S-660 standard requires numerical simulation through the finite element analysis method (FEM). The procedure involves a comparative evaluation of the elastic stress of different existing wheel designs assuming parameters such as steel material properties, conditions of application of lateral and vertical loads, thermal load, geometry of the wheel web, and geometry of the rim including new and completely worn wheels. AAR has a comparative database, not available for consultation, containing practical results of wheels with adequate and inadequate performance.

However, AAR standard does not determine a minimum or maximum value nor references for stresses and mechanical properties for wheel webs. Properties such as fracture toughness (K_{IC}), mechanical strength (yield or ultimate tensile), toughness (elongation or reduction of area) or even evaluation of metallurgical quality (micro inclusion defects and/or voids) are not specified. Due to this lack of limitations, some values are proposed here, based on the practical experience of a Brazilian railway. The evaluations which based the suggestions were carried out with samples of defective and other reference wheels, including new ones, only for comparative analysis.

In turn, EN 13262 standard specifies the characteristics of the types of wheels on European railways. This standard is applicable only to wrought and rolled wheels, manufactured with vacuum degassed steel, with emphasis on high-speed passenger transport, above 200 km/h (category 1), with heat treatment on the rim. The heat treatment aims to increase the hardness and residual compressive stress in the rim. New wheel models must now comply with EN 13979-1 [8]. EN 13262 determines only the minimum value of mechanical resistance to traction and elongation for samples taken from the wheel web. The other values are not specified. EN 13262 also specifies parameters for evaluating fatigue in the wheel web.

2.1 Chemical composition and microalloying

Both AAR classes, C and D, are heat treated and have a low stress level on the web and compressive circumferential stresses on the rim. They have the same basic chemical composition, but class D has microalloyed carbon steel. The microalloying allows for increased strength and hardness, which can reach up to 415 HB, in addition to the need to maintain operational safety, meeting the aspects of mechanical strength, fracture toughness (K_{IC}), elongation and area reduction required by the standard itself [6].

The ferritic-pearlitic microstructure of steel, typical of railway wheels, can be improved by adjusting the chemical composition and heat treatment [9]. Generally, the increase in strength of steel for railway wheels is obtained by increasing the carbon content. However, this increase reduces its toughness and corresponding operational safety. So, the microstructure and mechanical characteristics of ferritic-pearlitic steel is improved by microalloying the steel [10]. The positive aspect of the microalloyed wheel mainly concerns grain refinement. The EN 13262 standard specifies, for example, the ER8 wheel, widely used in China in high-speed trains because it presents high toughness, but, on the other hand, high wear due to its low wear resistance. Thus, grain refinement by microalloying leads to greater resistance to dislocation movement, being an important tool to increase the wear resistance of the wheel without compromising the safety aspect related to toughness [10].

2.2 Metallurgical quality

Steel manufacturing defects, micro and/or macro inclusions and/or voids, associated with increased operating speed raise the risk of subsurface rolling-contact fatigue (RCF) in the wheel tread [11]. Subsurface cracks are difficult to detect and may lead to severe broken-rim (shattered rim) conditions with catastrophic consequences [12]. Macro-inclusions, around 1 mm, typically occur at depths of about 10–25 mm below the tread surface, whereas micro-inclusions are associated with subsurface fatigue cracking at about 3–5 mm below the tread [13].

To prioritize operational safety and wheel reliability through quality control of the steel used in manufacturing, the AAR standard specifies minimum metallurgical quality conditions. The standard details aspects such as frequency of random sampling for removing test specimens from the wheels, geometry and location of, at least, 6 test specimens removed from the wheel rim, preparation and evaluation of the test specimens. Inclusions larger than 2.5 μm are already considered in the quality calculations. Defects such as voids and inclusions (oxides and sulfides) are evaluated and accounted for (average and worst scenario).

The metallurgical quality control of the steel (microcleanliness) used in the manufacture of wheels is essential for reliability and operational safety. AAR standard does not set a limit for the use of wheels [6], either by time or mileage. The end of the useful life is determined by the geometric condition of the rim and by post-machining ultrasonic tests on the rim (AAR, section G-II). The presence of defects (inclusions and voids) has the potential to reduce the fatigue life of the wheels. Severe web failure events with the presence of macro defects in the region close to the hub were verified in Brazil

2.3 Hardness and Hardness Map

Hardness governs the wear rate of railway wheels [14] and interacts with rolling-contact fatigue (RCF) and residual stresses. For pearlitic steels typically used in wheels, lower wear rates are obtained around 300 HBW (Figure 1), which explains the predominance of pearlite in wheel microstructures and the industry's focus on achieving stable hardness distributions rather than peak values alone [15].

EN 13262 classifies wheels into models and categories with specific hardness requirements primarily aimed at passenger safety and comfort; for instance, the highest hardness of model ER9 (category 2) is 255 HB, which roughly matches the minimum hardness of an AAR class A wheel, illustrating how AAR wheels, optimized for freight and heavy-haul, generally target higher hardness to improve wear resistance and durability [2] [15].

In practice, what matters is the map of hardness across the wheel: a radially graded rim hardness, often enhanced by rim heat treatment to induce compressive circumferential stress, combined with a web hardness that is adequate for ductility and fracture resistance. An overly hard web does not add service benefit and may penalize toughness. Conversely, an insufficiently hard rim accelerates wear and can alter residual stress evolution under braking. Therefore, hardness mapping should confirm: the expected rim-to-web gradient, absence of local plateaus or valleys linked to processing heterogeneities and consistency with the target microstructure and the wheel's duty (freight vs passenger). In this work, hardness information is used as background to interpret wear/RCF behaviour, but safety-critical acceptance relies primarily on microcleanliness, tensile/ductility, and fracture toughness of the web proposed in Section 5.

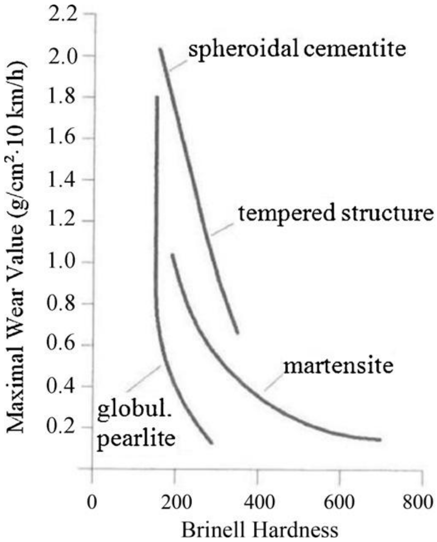

Figure 1: Wear values as function of Brinell Hardness and microstructure morphology [15].

2.4 Fracture Toughness

The first European studies on fracture toughness in wheels were initiated in 1989 with the aim of defining a standard procedure for performing the test on obsolete R7 type wheels. As a result, the current EN 13262 standard was first published in 2004 [16].

According to ASTM E 399, the K_{IC} property determined by this test method represents the material's resistance to fracture in a plane strain condition, where crack propagation occurs with the lowest possible crack opening energy. This value can be used to estimate the defect size for a given material and under fracture conditions.

The location of the test specimens and the test specifications are described in the M-107/M-208 standard [6], class D wheel. All test specimens are taken from the tread region. Therefore, the web region does not have references for mechanical properties according to this standard. In the EN 13262 standard, the K_{IC} test is eligible only for wheels with material R6 and R7 [2], which are used in high-speed transport in category 1.

Studies from the late 1980s indicated that wheels that fractured in service due to residual stress resulting from continuous braking [16] presented K_{IC} between 40 MPa√m and 80 MPa√m. Bench tests showed that wheels with values above 100 MPa√m did not fracture, but they are expected to fracture with resistance around 65 MPa√m and low [16].

Therefore, according to EN 13262, for ER6 wheels the average of the six test specimens must be equal to or greater than 100 MPa√m and no result less than 80 MPa√m. For ER7 model wheels the average of the six test specimens must be equal to or greater than 80 MPa√m and no result less than 70 MPa√m. For ER8 and ER9 models these values must be agreed with the customer and the supplier, as well as whether the test should be carried out or not.

Fracture-toughness testing in AAR and EN 13262 differs mainly by specimen orientation. Under AAR M-107/M-208 (Class D), compact C(T) specimens are cut from the rim in the L–C orientation (load in the longitudinal direction with circumferential crack growth), which targets subsurface circumferential cracking associated with vertical split rim (VSR). In contrast, EN 13262 specifies C–L-oriented specimens taken on the rim side (axial extraction, notch on the flange side), so that the crack propagates longitudinally in the rim. This makes the EN orientation more representative of rim thermal-reversal failures under severe braking (Figure 2).

Figure 2: Wheel rim fracture in C-L orientation [16].

Regarding the magnitude of K_{IC}, AAR states that for class D wheels, the minimum is 49.4 MPa√m [6]. In EN 13262, the minimum K_{IC} value is 70 MPa√m for ER7 type wheels. The technical guidance of EN 13262 to wheels with greater fracture toughness and, consequently, greater operational safety is evident.

2.5 Tensile and Charpy Impact Test

According to M-107/M-208 standard [6], the reference of the minimum values of the mechanical properties of steel is only for class D wheels. AAR standard does not specify reference values for impact tests. The reference values for the tensile tests of the web and rim of EN 13262 and the values for the Charpy impact tests (type A test specimen) are provided in the standard.

2.6 Fatigue

Residual stresses have a marked influence on the rolling-contact fatigue life of railway wheels, affecting crack initiation and growth under service loads [17]. AAR does not specify technical information related to the fatigue life of the wheels. This evaluation is only performed with the theoretical finite element analysis (FEA) in section G, S-

669 standard [18]. In this case, the result of the evaluation with S-660 standard is used as a reference to also evaluate the fatigue and vibration aspects, with analytical and specific acceptance criteria. The S-669 standard was adopted in 2011 for application to locomotive wheels, but in the 2020 revision the standard also included wagon wheels in its scope [18], leaving only its item 5.6 (vibration analysis) exclusive to locomotive wheels. The S-669 standard only applies to new wheel designs that have not yet been approved according to AAR standards.

This standard used the Sines criterion [19] to evaluate the combination of static or residual stresses with the superposition of alternating stresses. The standard concluded that these stresses vary in a reasonably linear function of the orthogonal static stresses. The purpose of the Sines criterion is to understand the ways in which static and alternating loads combine to cause failure and thus design suitable components without excessive material.

EN 13262 determines that for any type of wheel, the web area must meet stress variations with a minimum of 10^7 cycles [2], without any type of crack initiation and with a probability of 99.7%. The sample must be the wheel itself and must undergo 10^7 bending cycles in the web region. The test must be instrumented by measuring the bending efforts of the web in the radial direction.

3 Description of Web Failure Events

In the 2020s, 14 failure events were recorded in a heavy-haul railway company. The events occurred in the web of AAR wheels, class D, Cr-Mo microalloyed, with a minimum hardness of 380 HB, cast, multiple service life (M-W), with parabolic web. These events caused significant material losses, in addition to the long interruption of rail freight traffic.

The failure events analysed in this study correspond to the same heavy-haul operational cases previously documented [5]. In the present work, these cases are re-examined with emphasis on fracture toughness and defect criticality, rather than only metallurgical and mechanical compliance.

After these 14 failure events, wheels showed the following points of concern:

- 100% from the same manufacturer.
- 93% from the same model – AAR, CD-38, class D, Cr-Mo microalloyed, with a minimum hardness of 380 HB, cast, multiple life (M-W), parabolic web.
- 86% from the same year of manufacturing - 2014.
- Two wheels from the same batch.
- 100% from the same web failure region (between 200 mm and 220 mm from the centre of the wheel) - Figure 3.
- 93% with nucleation on the front face.

For this article, only the four most recent cracked or broken events were fully analysed with the laboratory tests. In addition, eight other wheels were analysed for comparison. So, the test values of the eight reference wheels were used as a comparative criterion for the four failed wheels. The reference values are identified as typical values in this article. A total of 11 wheels from freight wagons were studied and one additional wheel from a locomotive.

Failure analyses were performed in a laboratory in Brazil to assess the root cause and the chemical and mechanical conditions of the wheels. The test specimens were collected in accordance with the AAR standard, and additional tests not specified in the AAR were performed on test specimens collected from the web and rim. These observations are consistent with the sensitivity of wheel rolling-contact fatigue life to residual stresses reported in the literature [17].

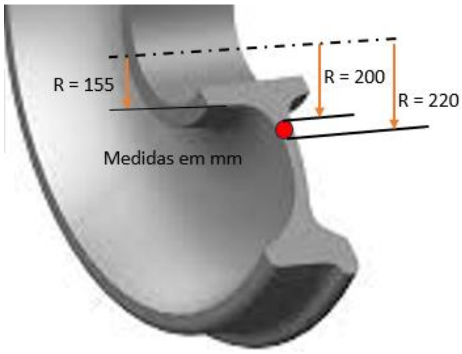

Figure 3: Typical location of web failures [20].

The web tensile test and the specification of the test specimens were based on the European standard EN 13262 and the K_{IC} test of the web was based on the annex A4 of ASTM E 399 standard, with the test specimen as the Compact test specimen C(T) classification.

The metallurgical quality test (microcleanliness) was based on M-107/M-208 standard, which specifies the removal of at least 6 test specimens with a minimum area of 167 mm² each, equidistant from the rim, every 3 months. The evaluated field of each test specimen is 0.70 mm².

In the metallurgical quality test carried out in Brazil, 10 test specimens were removed from the rim and another 10 test specimens from the web, which is not specified by the AAR. Inclusions larger than 2.5 μm were recorded in both cases. A total field area of 2 mm² was evaluated on the rim and on the web.

Additional studies through extensive laboratory analysis have been initiated in the last four events. Laboratory test results from these events (3 CD-38 wheels and 1 CK-36 wheel) led to the following analyses.

4 Results

4.1 Metallurgical Quality

At least one rim field for each wheel presented results significantly above the AAR reference for the worst field, i.e., above 0.750% including oxides and voids or 0.750%

sulfides. The average of the 10 rim fields evaluated for each wheel was significantly above the AAR reference, i.e., above 0.100% including oxides and voids.

Comparing the rim quality values of broken or cracked wheels with references of other eight wheels, evaluated by the same method, the defective wheels results were worse than the typical values. For web quality evaluations, not referenced in the AAR, only the typical reference of the other wheels was used. Similarly, both the worst field and the average were above typical values.

As an example, in a web cracking event that occurred in 2024 in Brazil on a loaded wagon in a heavy haul railroad using an AAR wheel, cast, type CD-38, class D, with approximately 60 mm of remaining rim (70% of the total), the web's metallurgical quality of the samples was analysed. The total value (area fraction in %) of voids and inclusions was 30.45% (AAR rim reference for worst field: maximum of 0.75% for oxides + voids or sulfides).

4.2 Macroscopic, Surface or Subsurface Flaws

Oxide inclusions, mainly silicon, were observed in all four events. In one of them, a coarse subsurface void was also observed.

4.3 Low level of toughness, impact, elongation, reduction of area

For the evaluations of the web tensile tests, not referenced in the AAR, only the typical reference of the other wheels was used. In two of the four wheels, values of tensile strength limits, elongation and area reduction showed to be different from the typical values. One of the four wheels presented the rim impact value, not referenced in the AAR, below the typical value of the typical reference.

4.4 Low fracture toughness

In the results of the rim fracture toughness tests, all values were below the minimum recommended by class D. For the fracture toughness evaluations of the K_{IC} web, not referenced in AAR, only the typical reference of the other wheels was used. Three wheels were evaluated and only one reached the typical reference value.

5 Proposal for Additional Wheel Testing

As a technical strategy to increase operational safety and reliability in AAR standard railway wheels, the authors suggest the manufacturers or railways perform the following tests on a random wheel in each run:

5.1 Web metallurgical quality test by optical microscopy

- Samples: 10 test specimens taken equidistant from the external/internal surfaces of the web and 55 mm ± 10 mm from the external diameter of the hub, region indicated in Figure 4.
- Considering defects larger than 2.5 µm.

• Geometry of the test specimen according to practical requirements of laboratory tests in the country.
• Proposed values for the average and worst field of 0.70% and 2.00%.

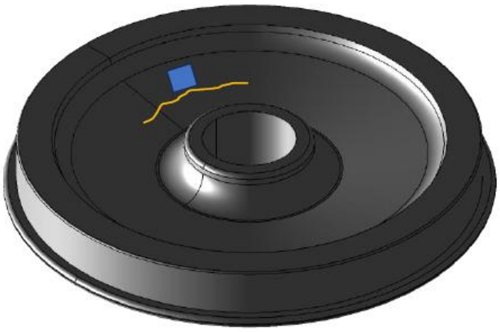

Figure 4: Location of K_{IC}, impact and metallurgical quality test pieces [20].

• AAR standard does not have a reference for evaluating the web metallurgical quality, but it should have.

If the proposed web microcleanliness limits (average 0.70%, worst field 2.00%) had been used for batch quality control, the lots containing the four cracked/fractured wheels and the three mate wheels would not have been approved.

By contrast, new forged AAR K-36, D-38, and D-42 wheels tested by the same method meet those limits, with worst-field 0.25%–1.52% and average 0.15%–0.65%.

5.2 Rim metallurgical quality test by optical microscopy

• Samples: 10 test specimens collected in accordance with the practical requirements of laboratory tests, including worn wheels not covered by AAR.
• Consideration of defects larger than 2.5 µm.
• Test specimen geometry in accordance with the practical requirements of laboratory tests.
• Criterion for the average and worst field of 0.40% and 1.00%.
• AAR standard has a reference for rim metallurgical quality.

If the proposed rim microcleanliness limits (average 0.40%, worst field 1.00%) had been applied to batch quality control, the lots containing the four cracked/broken wheels and the three mate wheels would have been rejected. In contrast, new forged AAR K-36, D-38, and D-42 wheels tested by the same method comply with these limits (worst-field 0.25%–0.85%; average 0.19%–0.35%).

Details regarding specimen extraction, metallurgical quality assessment and standard mechanical testing follow the procedures previously reported [5], with additional fracture-mechanics testing and analysis introduced in the present study.

5.3 Web tensile tests according to EN 13262

The quantity, location and geometry of the test specimens are in accordance with the European standard EN 13262. AAR standard does not have a reference for evaluating tensile tests on the web.

If the proposed web property thresholds (yield strength ≥450 MPa, ultimate tensile strength ≥950 MPa, elongation ≥11.0%, area reduction ≥13.0%) had been applied to batch quality control, the lots containing the two cracked/broken wheels and the three mate wheels would have been rejected. By contrast, new forged AAR K-36, D-38, and D-42 wheels meet these thresholds: yield strength 458–626 MPa, ultimate tensile strength 958–1014 MPa, elongation 11.0–15.0%, area reduction 13.6–25.4%.

5.4 Web fracture toughness test

- Comply with ASTM E 399 with Annex A4 - Compact C(T) test specimen.
- Location: sample taken equidistant from the external/internal surfaces of the web and 55 mm ± 10 mm from the external diameter of the hub (Figure 4). The orientation adopted for specimens taken from the web was R–C orientation, corresponding to radial loading and circumferential crack growth.
- Proposed minimum K_{IC} fracture toughness of 44.2 MPa√m.
- AAR standard does not have a reference for evaluating fracture toughness K_{IC} tests on the web.

If the proposed web fracture-toughness limit ($K_{IC} \geq 44.2$ MPa√m) had been applied to batch quality control, the lots containing the three cracked/fractured wheels and one mate wheel would have been rejected. In contrast, new forged AAR K-36, D-38, and D-42 wheels tested by the same method comply, showing K_{IC} = 45.5–58.5 MPa√m.

5.5 Impact test

- Comply with ASTM E 23 [21], type A test specimen.
- Location: minimum of three samples taken from the rim (EN 13262) and minimum of three samples taken equidistant from the external/internal surfaces of the web and 55 mm ± 10 mm from the external diameter of the hub (Figure 4).
- AAR standard does not have a reference for evaluating impact tests on the web and rim. EN 13262 refers only to the rim with tests in accordance with EN 10045-1 [22] which is compatible with ASTM E 23.

If the proposed impact energy limits (web ≥ 8 J, rim ≥ 8 J) had been applied to batch quality control, the lots containing one mate wheel and one cracked wheel would have been rejected (due to web < 8 J and rim < 8 J, respectively). Among new forged AAR K-36, D-38, and D-42 wheels tested by the same method, one falls outside the web limit.

5.6 Summary of additional testing proposal

Summarizing, the tests and limits proposed by this work are listed in Table 1. The use of the limits described there would have prevented the failures discussed in the previous sections. Part of the dataset was previously reported values are reanalysed here under a fracture-mechanics framework [5].

Test - 18,3ºC~26,6ºC		Location	Unit	Value
Metallurgical quality	**Average**	Plate	%	Máx. 0.70
	Worst field			Máx. 2.00
	Average	Rim	%	Máx. 0.40
	Worst field			Máx. 1.00
Tensile	**Yield 0,2% offset**	Plate	MPa	Mín. 450
	UTS			Mín. 950
	Elongation (50,8 mm)		%	Mín. 11.0
	Area reduction			Mín. 13.0
Fracture toughness	**K_{IC}**	Plate	MPa√m	Mín. 44.2
Impact	**Charpy**		J	Mín. 8
		Rim	J	Mín. 8

Table 1: Additional testing proposals and limits [5].

6 Evaluation of a wheel under development

In the development of a new CD-38, class D, M-W, AAR wheel design, a comprehensive evaluation of various technical aspects was conducted. The results presented in Table 2 were benchmarked against the reference values proposed in this article and AAR standard.

Based on the results of the sample analyses, it was found that the new wheel does not meet the maximum average metallurgical quality of the web and rim, the minimum elongation strength of the web and rim, the area reduction of the rim, and the fracture toughness of the web and rim. With these results, the wheel returned to the development project.

7 Conclusions

This work sought to present a broad bibliographic review with different technical aspects and failure events in cast wheel webs manufactured in Brazil, according to the AAR standard, used in freight wagons in heavy haul.

For the case under study, the boundary conditions that coincide in the failure events and the deleterious characteristics identified in the laboratory analyses were presented. The implementation by wheel manufacturers of the tests described here and not covered by AAR and EN 13262, depending on the type and manufacturing process, is understood as an opportunity to manufacturers improve wheel quality, increasing operational safety.

Therefore, some additional tests on the rim and, mainly, on the web were suggested. Quantitative limits for these tests were also proposed with the aim of performing safety quality control in the manufacture of new batches of wheels and new design.

Test - 18,3ºC~26,6ºC		**Location**	**Unit**	**Ref. Value**	**New design**
Metallurgical quality	**Average**	Plate	%	Máx. 0.70	**0.85**
	Worst field			Máx. 2.00	1.37
	Average	Rim		Máx. 0.40	**0.44**
	Worst field			Máx. 1.00	0.59
Tensile	**Yield 0,2% offset**	Plate	MPa	Mín. 450	524.4
	UTS			Mín. 950	1005.5
	Elongation (50,8 mm)		%	Mín. 11.0	**10.6**
	Area reduction			Mín. 13.0	16.4
	Yield 0,2% offset	Rim	MPa	Mín. 792	872.8
	UTS			Mín. 1102	1188.6
	Elongation (50,8 mm)		%	Mín. 14	**8.7**
	Area reduction			Mín. 30	**8.7**
Fracture toughness	**K_{IC}**	Plate	MPa.√m	Mín. 44.2	**39.8**
		Rim		Mín. 49.4	**42.9**
Impact	**Charpy**	Plate	J	Mín. 8	9
		Rim		Mín. 8	13

Table 2: New CD-38, class D, M-W, AAR wheel design evaluation [5].

A new wheel model under development was evaluated according to AAR normative requirements and the new parameters proposed in this article. The wheel failed the evaluation and was returned for design review, enhancing safety through a new railway wheel design.

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