DEVELOPMENT OF A NEW WELDED CONSTRUCTION OF INTEGRAL TRUCK TYPE TO RAILWAY FREIGHT CAR TRANSPORT

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Abstract. *The railway freight car transport on Brazil needs greater capacity and speed to answer external orders business and internal freight cars transportation. One conception of truck is showing in this work includes some requisites what about costs and weight. The welded construction has careful design to work with dynamic loads, it meet requirements of the American Welding Society. The truck with this structure has primary suspension between bearing and structure. The truck can use appropriate shock absorber to rail car type or Railway Company. This truck assembly standard components of traditional trucks, as axles, wheels, bearings, brake beam, shoes, levers and wear plates. Structural analysis is made for Finite Element method with five loads in accordance of standard for integral welded truck structure, AAR-M213-81 Associated of American Railroads. This truck has some external dimension of the standards, making possible to exchange in any rail freight car. This conception is appropriate to capacities between 80 to 120 tons on the rails and can be used on 1000mm and 1600mm gauges. Initial Conclusion shows the possibility of construction to experimental and functional tests.*

Keywords*: truck structure, welded construction, railway truck development*

1. Introduction

The railway freight car transport on Brazil needs greater capacity and speed to answer external orders business and internal freight cars transportation It is notorious the real necessity of new technology to railway freight cars adapting to particular conditions of each rail road. This design conception is compound of three cast members that take format of "H". This freight car design allows machining in stages of components, spare machining equipment of great capacity. This type of suspension allows that a located step of road set most part over adjacent wheel. It is another innovation over traditional design. Spring group absorb defects of road, as vertical warping, corrugations, depressions, protuberances of rail joints, so that direct prevent impact over self structure and other components like bearings, wheels, rail, adaptors, box wagon. Activation of springs are effective, and contact with rail is maintained in moderated out-of – level and traffic velocity can be increased taking in account truck stability. There is low dynamic overloading and allows bigger load per axis with same stress in mechanical elements. Reference standard requires tests, a minimum of two structures in a static form: Vertical, transversal and longitudinal loading area applied isolated in the same test structure.

This work used also element finite methodology to confirm static results. Actually new generation of trucks considered more developed to railway freight car are according to American line, Swing Motion truck produced by ABC NACO. This truck type brings a support bolster to helical springs, to maintain grading of trucks and brings stops to lateral movement of bolster with lateral

2. Description of main components

For this new design, Structural Truck frame for freight equipments will be manufactured with steel welded plates – USIMINAS Steel SAC 350, Gage of 1600 mm between railhead; nominal bearing support, with dimensions 6.1/2" x 12"; Integral structure in "H" format and Capacity of de 31,5 tons of loading/axis. This truck structure that maintain shape "H" and connection of bolster with lateral are welded and checked according standards well defined.

Superior side was designed with a ring getting around a seat, which form a joint with wagon box. At side of joint disc, over bolster, there are two bearings necessary to oscillation support. There is a clearance between support and structure. This oscillation support can assume different shape, some with rollers to reduce friction in curve travel, others with one spring assembly maintaining constant contact. Inferior side shows four guides slip of bearings adapters. These guides centralize adapters in vertical course of suspension work. "L "sections are positioned by side of these guides and work as bearing to springs seating. Figure 1 presents the assembly. From internal side of each lateral beam, there are guides to slippage of brake beams. These guides receive a section of wear protecting structural elements. Four bearings composed by two bore above bearing guides receive damper of vertical movement. Each end of lateral beam have U section, running as shock shield in main structure at motion of this truck out of box. The grouping of suspension guides is installed after welding and flattening of structure body. Main elements of this structure has a section in form of a box and have two flanges and two webs.

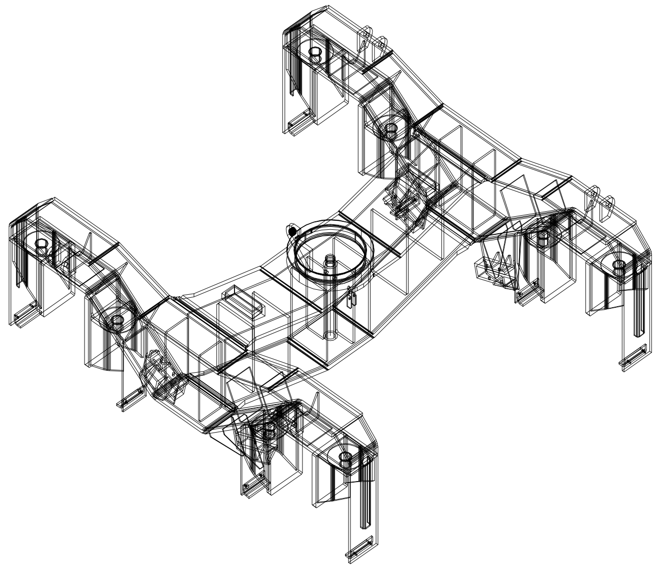

Figure 1. Structure in perspective

Figure 2 shows structure basis. The welded connections are dimensioned to dynamic loading above two millions of cycles. Flanges and webs are continuous, due to an effect of better performance of connections. Internal ribs are installed with purpose of diminishing buckling of element and also to a longitudinal alignment of main elements. At extremity, crossbeam has a width increased and an interval with concordance radius designed to control an increase of stresses in this region compatible with cyclic loading.

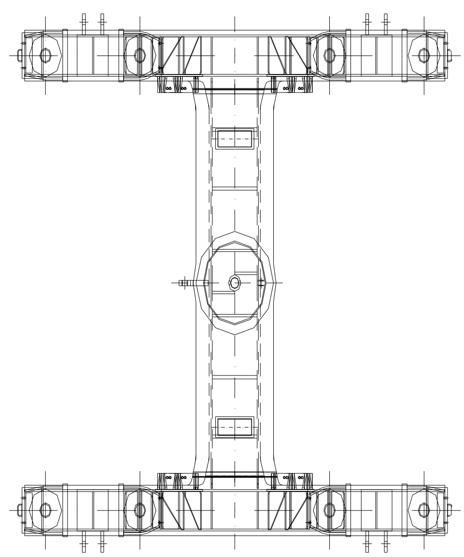

Figure 2. View of structure basis

Figure 3 shows lateral view of mounted truck. Suspension developed is shown schematically in figure 4 and lateral beam in perspective is presented in figure 5. Figure 5 presents lateral designed lateral beam in perspective. Lateral beam shows inferior face with four compartments to helical spring assembly. Inferior and superior flanges are continuous having at center bigger width and shoulder leading to reach webs of central crossbar. Main elements are continuous in the length of lateral beam. This format avoids transversal welding with intension to maintain original metal base strength of the plant mill. Central crossbeam structure is of box type and has main elements in a superior table bent in two local and an inferior table having two bends. It is designed with two webs spaced by internal ribs. The center of crossbeam has circular with ring seat with forming an articulation with box freight car. Contact surface suffer friction and the way of preserve crossbeam structure is by using wear disc and ring, with hardness of 280 to 350 Brinnell. Crossbeam ends receive chamfer to welding connections with lateral beam. Crossbeam is designed with internal reinforcement under pinion plate, elements that distribute received loading to box car.

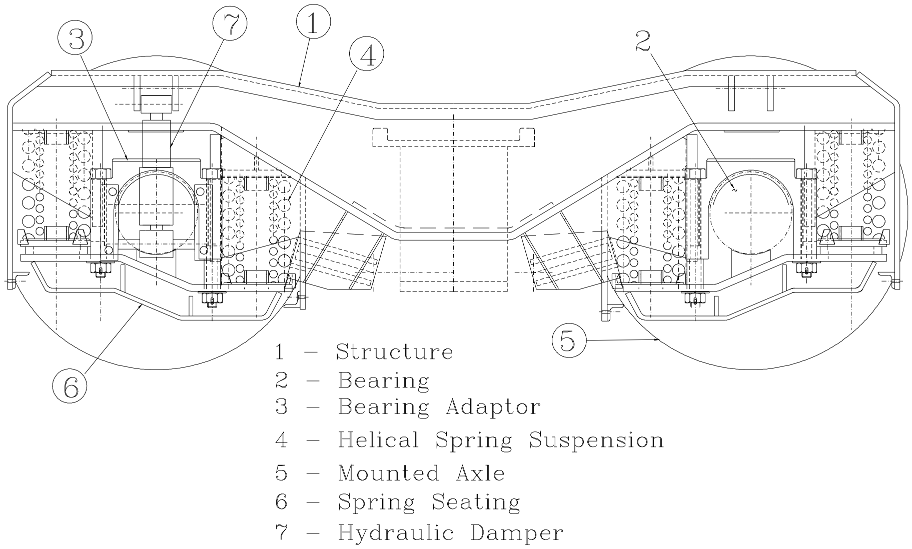

Figure3 - Lateral view of a mounted truck

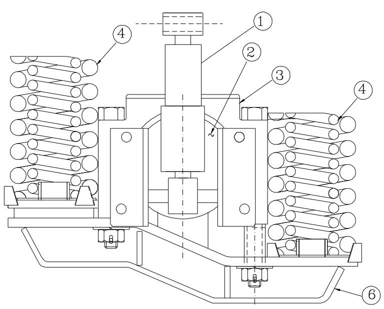

Figure 4 – Suspension assembly,1-damper;2-bearing;3-adaptor; 4-Helical spring;6-spring seating.

3.Design Criteria- Basic Technical Standard

This development design used (Standard AAR,1981). Steel indicated in this norm was ASTM A-441, but for this design Brazilian USI SAC 350 was selected, similar to international standard ASTM A242. Table 1 shows steel properties.

4. Static Tests

Pattern loads according railroad AAR-M213-81 to wagons with 120 ton of Gross weight to wagon, with 30 ton to each axis. This design was adapted using above standards, to an amplified load of 31,5 ton /axis, and table 2 gives main parameters. Limits indicated strain, according railroad standard AAR M-213.81 are destined to trucks with gage of 1435mm and steel ASTM A-441. This new project used gage of 1600mm and steel USI-SAC 350. Two corrections were made, due to gage size and steel material. Recommended longitudinal static load of 528633 N must provide a limit dislocation 2,36 mm. Figure 7 shows longitudinal loading and respective reactions. Figure 8 presents schematic drawing to transversal loading. According to standards an allowable dislocation of 2.44 mm was obtained to a loading of 166937 N.A vertical static load of 795732 N applied at joint, gives a limit dislocation of 4.17 mm. Structure supports a limit loading of 5,22 times the nominal loading, of 2904700 N, applied at pinion center, and do not presents generalized yielding or rupture.

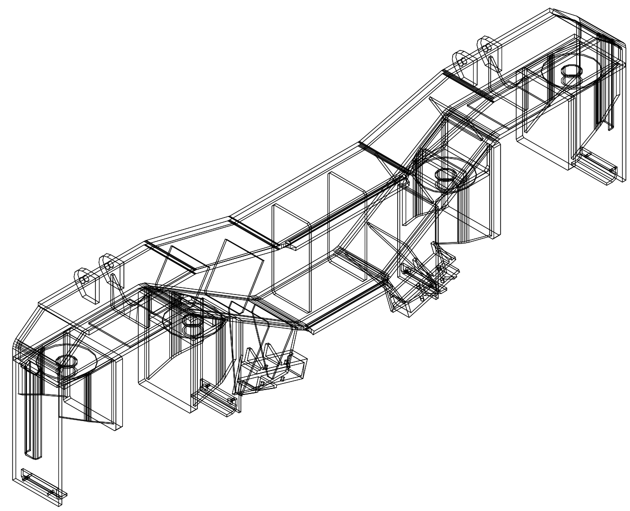

Figure 5 – Lateral beam in perspective

Table 1- Steel Properties with ASTM A-441 and Brazilian steel USI SAC 350

Steel Properties	(Standard AAR M213-81)	USI SAC 350 (Steel used to truck structure in Brazil)
Rupture strength	Thickness until 19mm 485 MPa, (minimum)	thickness 6 to 50,8 mm 500 to 650 MPa
	Above 19mm 460 MPa (minimum)	
Yielding strength	Thickness until 19mm 345 MPa (minimum)	Minimum 350 MPa
	Above 19mm 315 MPa minimum	
Minimum elongation (base 200mm)	18%	16%
Charpy impact energy	15 lb.feet at 0°C	Minimum 26 J
Carbon content %	0,22 max	0,20 max
Manganese content %	0,85 – 1,25	0,60 – 1,50
Phosphorus content %	0,04 max	0,06 max
Sulfur content %	0,05 max	0,02 max
Silicon content %	0,40 max	1,50 max
Cooper content %	0,20 min	0,20 min
Alloy element %	Vanadium 0,02 min	Nb 0,05 max;- Ni 0,20 max

5.Preliminary Results

5.1 Static loading.

Maximum stress at each individual loading cant exceed 0,30 times limit of yielding strength according railroad standards AAR M213-81. Stress under loading combination cant exceed 0,38 times limit of yielding resistance. USI-SAC 350, main mechanical characteristics obtained were: Yielding strength $\sigma_y \geq 350$ MPa and rupture strength $500 \leq \sigma_r \leq 650$ Mpa.

5.2 Fatigue allowable stress at structural elements.

Allowable stress imposed of 141 MPA is already very lower than fatigue strength of 250 MPA. Operational structural stresses presents variations. Empty wagon presents loading 0.10 to 0.28 times maximum stress corresponding fully freight car and change depends on structure types. Structure of mine freight car has 120 ton of net weight. This design is developed to 126 ton of maximum net weight over rails.

5.3 Limit fatigue stress according AWS Standards (American Welding Society, 2000)

This standard divides joints types in 6 categories, letters A to F. This category is known to use graphics of fatigue stress. With this graphic taken from standards, to a B category, and a life 2 x 10^6 de cycles, an allowable welding stress would be of 115 MPa. This refers to a class of traction strength corresponding to 60000 psi(lbf/pol^2). This design was specified a class of 70000 psi (483 MPa). Applying this corresponding correction: Allowable normal strength 115 x 70000 / 60000 → σ_a = 134,2 MPa. So, shear allowable stress at plane stress state, with allowable normal strength obtained above: $\delta_a = \sigma_a / 2 = 67{,}2$ MPa .

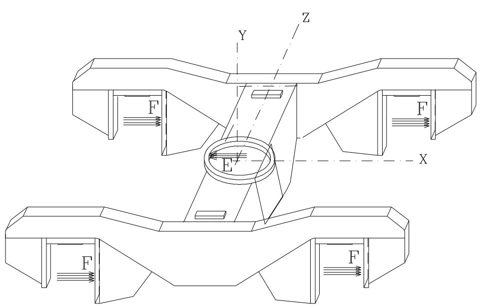

Figure.7 Longitudinal load direction

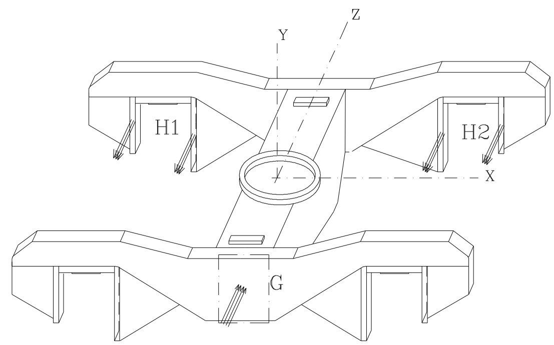

Figure 8 – Transverse loading

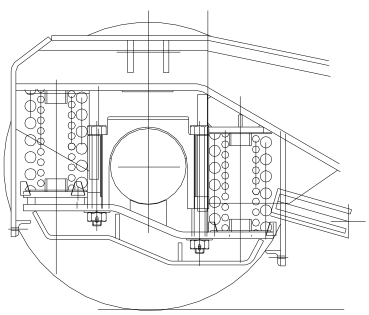

Figure9 – Truck suspension

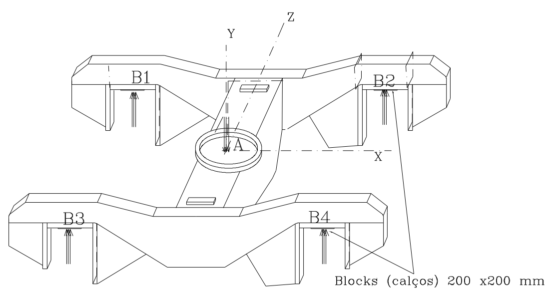

Fig.10- Vertical loading direction applied at joint application.

Table 4 – Design requirements

Loading direction	Application site	Loading N	Allowable stress Steel, MPa	Allowable stress Welding, MPa	Deflection m
Longitudinal	bolster	528633	141	127,4	0,00236
Transversal	lateral	166937	141	127,4	0,00244
Vertical	Side bearing	795732	141	127,4	0,00263
Vertical	Joint	795732	141	127,4	0,00417
Vertical	Joint	2904700	650 localized	490	Not defined
Longitudinal	bolster	528633	141	127,4	0,00236

Our conclusion is that allowable shear stress is the less than 0,30 of rupture stress and 0.40 of yielding stress. Welding electrode AWS E-7018 G or similar presents a minimum yielding stress of 380 MPa and minimum rupture stress of 490 MPa. In this Project, shear allowable stress value was taken into account James F. Lincoln foundation standards, Cleveland Ohio,USA. Also, fatigue stress due to welding with intermittent stresses were calculated based, in formulas from AWS. Maximum normal stress,,lateral bending stress, combination of lateral and vertical combination , and flexure were calculated and attends all standards.

6.Design evaluation

Deflection at structure of 2,26 mm was less than normalized value of 4.17 mm. Also longitudinal deflection at bolster having both ends fixed was calculated with Y = 0,00171m = 1,71 mm. This value is less than 2,36 mm indicated by railroad standard AAR M213-81Transversal Deflection acting at lateral beam: value calculated was Y_t = 0,00095m = 0,95mm, less than 2,44 indicated by railroad standard AAR M213-81Strength limit loading has vertical direction, applied at joint, which value is 5,22 times nominal loading of 2904700 Normally, freight car in motion has disturb of straight uniform motion in vertical and horizontal dislocations. One of freight car functions is attenuate transference of dislocations to truck box Height of step "h" will resolve in combined dislocations with road strain, suspension, mounted axle, smaller part was given to truck box. To this freight car conception proposed, there is a primary suspension that absorbs vertical acceleration,as schematic concept. At normal conditions, relation between dynamic overloading at conventional truck and this new conception is 2.16 times. This dynamic overloading difference enable increase of load capacity without overloading bearings, freight car structure and box truck. Passing through a curved road, it requires the truck to turn under it box. The support of box over pinion basis reacts a resistant torque in function of this turn This reaction is a lateral force at front external wheel to the curve. This lateral force is unwanted because it consequence results in wear of wheel spindle and railroad by metallic friction. Others variables were also considered, for example, railroad roughness between railroad and wheel, vertical side of flange angle, level of railroad wear and time of lateral force duration. In this design relation L/V was calculated in function of joint wear. External right front wheel was critical, that which receives impulse from railroad when describing a curve.

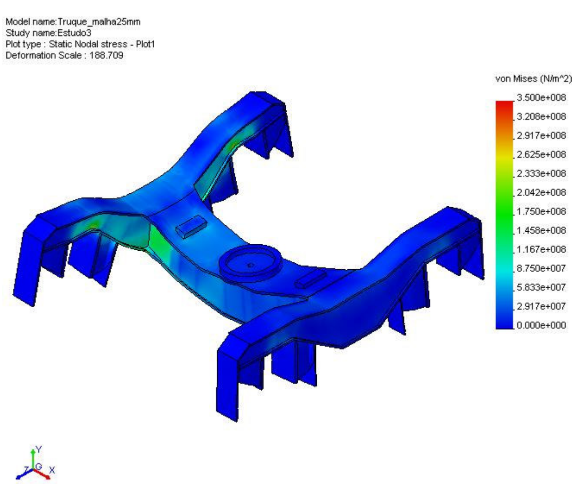

Figure 17 – Loading application at lateral bearing

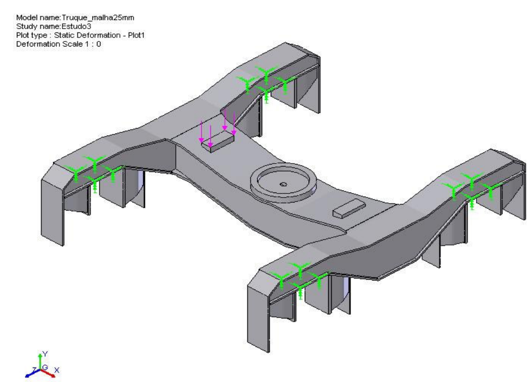

Figure 18- Stress results obtained

Load application in vertical direction and reactions are placed in inferior blocks at ends of laterals, regions of suspension. Figures 17 and 18 presents finite element results of lateral bearing loading and level of stress obtained. Table 7 shows results found according standard AAR M 213-8.

7. Results obtained by Finite Element Method

In this project also was used a software COSMOS to determine stress distribution through all structure Drawing were prepared so that assembly behaves like one unique entity. Basic mesh adopted was of 25 mm, but with refine at regions of section changes. Vertical loading at lateral bearing presented stresses slightly over allowable, but in a not operational applicable situation. This deviation of 4 MPA represents 2,8%, allowing a construction of this format. Dislocations are very smaller than specified, as in tab. 5, whose values oscillate around half of allowable values. Small strain means rigidity in structure assembly. Table 6 presents comparison between results obtained with specifications and Table 9 gives comparison of results between Finite element method and strength of materials. Results processing were very concise and predictable. Some regions with connections in angles and others with section changes had higher local stresses, and graphical format could present all levels of stresses at these regions. Load normalized applied was of 795732 N, distributed at basis of joint with diameter of 406 mm(Table). Direction of loading is vertical (fig.). Reaction will impinge in the same form through four blocks of region, central of suspension. Allowable stress in structural steel was 141 MPa and allowable vertical dislocation is of 0,00417 m, which demonstrate validation of design and reliability of this new structure

Table 5– Results obtained in function of load application

Load application	Loading N		Stress MPa		Dislocation M	
	Specified	Used	Allowable	Found	Allowable	Found
Nominal vertical at joint	795732	795732	141	max 133	0,00417	0,00263
Vertical limit of strength	2904700	2909470	650	max 600	Not specified	0,0066
Vertical on lateral journal	795732	795732	141	max 145	0,00263	0,00133
Longitudinal at suspension side	528633	528633	141	max 130	0,00236	0,00215
Transversal at structure	166937	166937	141	max 91	0,00244	0,0011

Table 6 Comparison of results- Finite element method and strength of materials

Loading direction	Loading point	Loading	Stress (Mpa)		Dislocation (mm)	
			Finite elements	Strength of materials	Finite element	Strength of materials
Longitudinal	Bolster	528633	130	119,4	2,15	1,71
Transversal	Lateral	166937	91	86,3	1,1	0,95
Vertical	Lateral journal	795732	145	-	1,33	-
Vertical	Joint	795732	133	-	2,63	-
		556456	-	107.5	-	2,26
Vertical	Joint	2904700	Aprox. 650	385	6,6	-

8. Final Considerations

This designed structure meets requirements of reference standard AAR-21381 from American Association of Railroad, and calculation showed that all structure extension presents acceptable levels of stress. The Brazilian steel adopted was USI SAC 350 due to market convenience. The corresponding stress corrections in function of a bigger mechanical strength were realized.Using strength materials and numerical calculation, results showed that a development of a integral welded structure is technical viable to Brazilian railway freight car transport. It was shown also that: a) Structure is rigid, sections and dimensions are defined, properties of area, inertia, linear dimensions are stable to levels of tested loading; b) Internal stresses values are close to others once strain and dislocation levels are of same magnitude; c)Structure design was developed without grooves or strong variation of sections that could present nodes with high stress level in relation to normal stress; d)Fatigue strength**.** It was assured infinite life in relation to stress level in steel elements and also at welded connections. Stress criteria at welded connections depends on base metal, electrode at welding, penetration deep of cast region, level of inspections and mainly joint format and position of joint in relation to structure axle. All stress criteria meets American Welding Society, standard AWS D1.1-2000, also Welding AWS Publication and Design of Welded Structures from Lincoln Foundation, USA. Values to allowable stress at welded joints attend minimum value between all above recommendation.

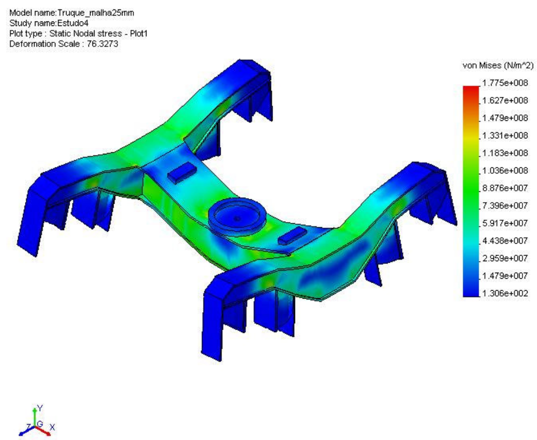

Figure 20 Reactions due to vertical load at joints.

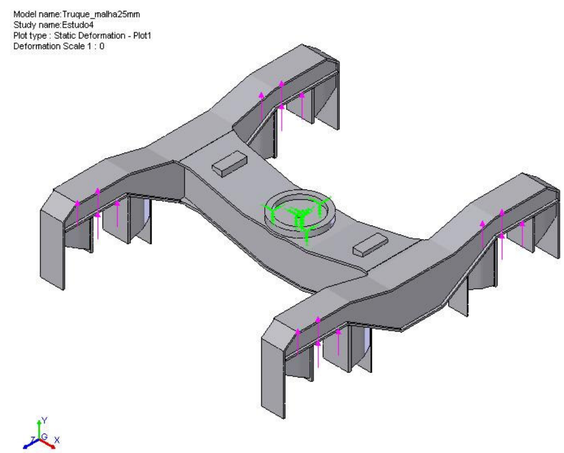

Figure 21 Vertical loading at lateral bearing

So, fatigue strength was considered at allowable stress at welding and most of pieces and welded fillet were designed to attenuate concentration stresses; e)Introduction of primary suspension. It was incorporated a primary suspension system through helical springs between mounted axle journal and structure. It was installed near each wheel, a damper with capacity of actuating loading adjustment. This system decreases dynamic load intensity between 20 to 30%. It was possible an increase at nominal capacity of loading by shaft taking in accounting reduction of dynamic loading at rail, wheel, journal and bearing. All structure was also benefit by reduction of dynamic loading; f)Advantages of this design was increasing operation speed once Higher efficiency of suspension associated to geometry stability that allows bigger speed and operation safety; g)Reduction of structure weight – After calculation and finite element technique used, there was a initial weight reduction by truck of 160 kg; h)Reduction of structure weight Calculation indicates a reduction of 160 kg per truck, which can increase with a weight reduction at local points of smaller stress concentration using finite element method; i)Manufacturing Costs The developed structure spares assembly machining once it is possible using gages at production line so that it can offer functional tolerance of structure. Welding disposition, properties of steel used, thickness of plates permit spare thermal treatment of stress relieve; j) Changeability with components of others truck models This structure allows operate with same mounted axle and brake components of traditional truck.

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