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NEW CONCEPT DEVELOPMENT FOR CARRYING IDLERS MANUFACTURED THROUGH MECHANIC FORMING AND VALIDATED BY MATHEMATICAL MODELING

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ABSTRACT

The purpose of this work was development a new concept for carrying idlers of belt conveyors for bulk materials in order to enable manufacture through formed plate and with this remove partly or fully the welding process, thus reduce manufacturing time. This study, with parameters based in related standards, was validated for finite element method and the result shown was a new model with minor weight in regards the current models.

Keywords: finite element method, mechanical forming, carrying idlers.

INTRODUCTION

Belt conveyors are equipments that do the continuous movement of materials through the proper belt, which is supported by rolls. These are assembled in carrying idlers that transfer the load to stringers, which are mounted on the ground. The trebles carrying idlers, that transport the iron ore and subject of this work, are robust, with approximate weight of 53 kg. The construction is done through the welding process of angle bars with U-sections bent at 45°. The manner to modify the concept of the carrying idlers was to introduce the sheet conformation, using a single plate for substitute the central angle bar and the U-sections, that are the outriggers of the 45° inclined rolls, and the addition of the screws to connect the central support of the rolls and the angle bars responsible by fixation of the idlers in the stringers.

The dimensions of the new concept were obtained by the standard ABNT NBR 6678 of 2010; the loading supported was determined in accord with the standard DIN 22101 of 1982 that consider the sum of the transported material, the belt and the rolls, taking one meter between trestles. The loading value was 3789,2 N; the failure modes, operational limitations considered and permissible stresses were local or generalized yield, in case to static loading (the permissible equivalent stress was 166 MPa, obtained by F.E.M. SECTION II – 131/132, of 1997) , local or generalized yield, by dynamic loading, or fatigue, where the parameters considered were direct obtained by Ansys library, considering that the criterion assumed was the method of Soderberg and the maximum vertical deflection limit is 3,5 mm (ABNT NBR 6678, 2010).

METODOLOGY

The sequence of steps described in the introduction is shown by the flowchart of Fig. 1.

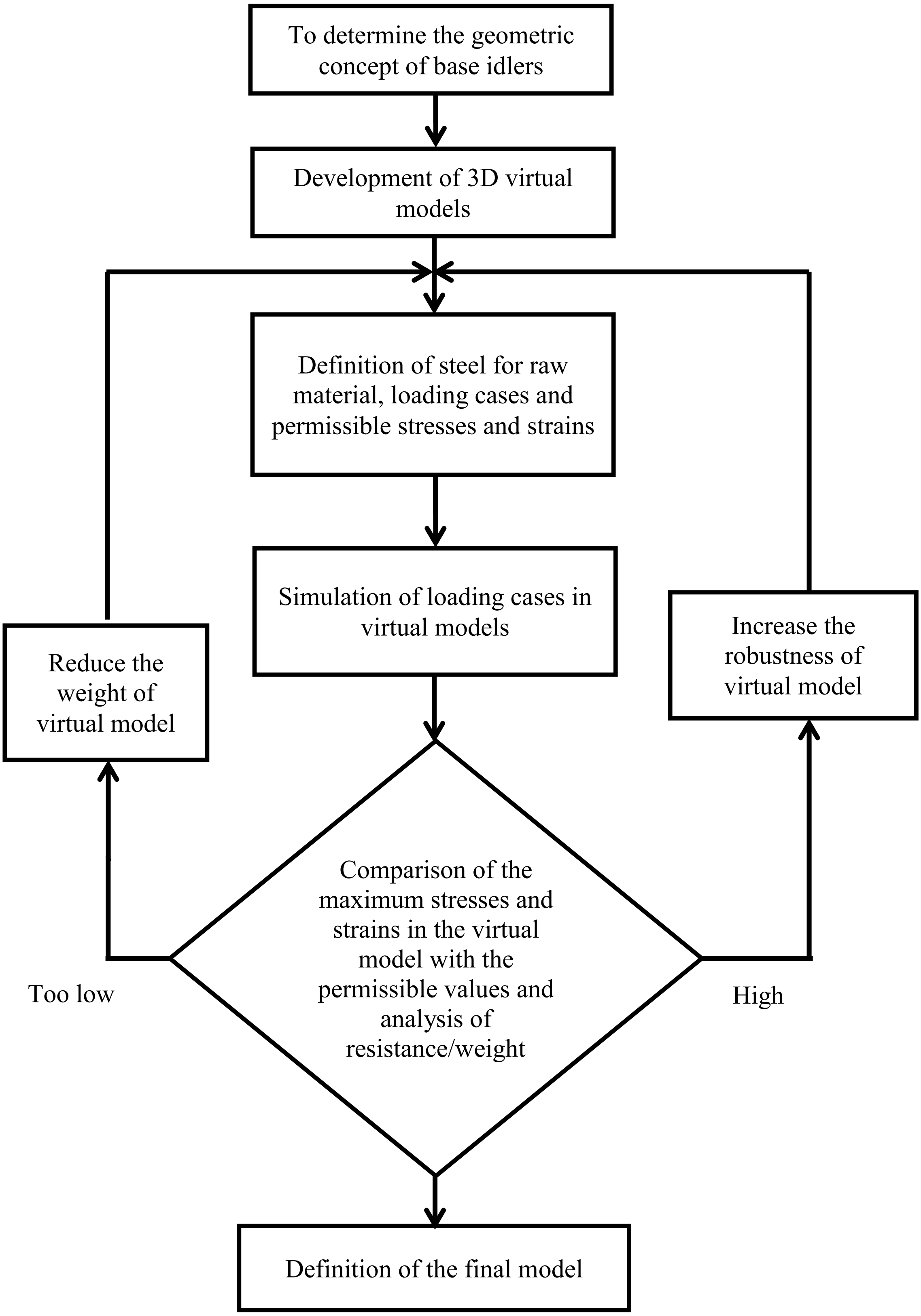

Fig. 1 flowchart of steps study

Geometric concept

The total elimination of the weld filet that connects the angle bars and U-sections was done by formed materials connected through screws. Firstly, because of the similarity to the current base idlers (Fig. 2), and the physical concept related to moment of inertia of rigid bodies, the hypothesis considered was to develop just one formed plate that would substitute the lateral outriggers and the central angle bar.

Fig. 2 Current model of treble carrying idler

In order to have satisfactory resistance, without increasing weight, the section chosen was something similar to the sin, which by its geometry resists the higher loads. The illustration of the section is in Fig. 3.

Fig. 3 New concept section

Classification, main dimensions and building material

After the conceptual definition of the product, its adequacy to the standards was done. According to the identification method of ABNT 6678 standard, the identification of base idlers is: S / CT – 40 / 1400 / 45. The drawing with the normalized dimensions is shown in Fig. 4 and 5.

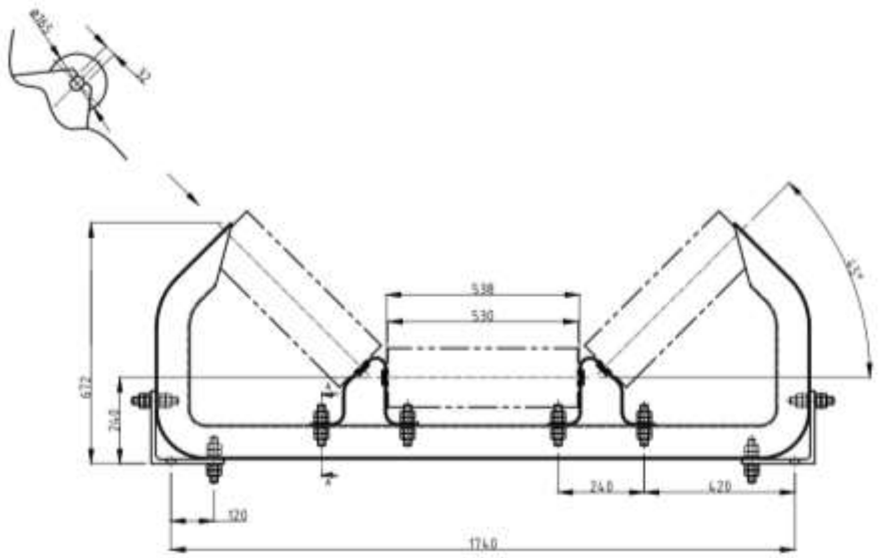

Fig. 4 Drawing of the base idlers with normalized dimensions

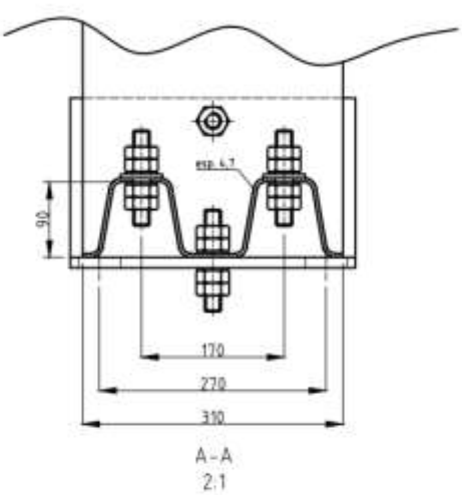

Fig. 5 View of the transverse section

The selected steel to build the base idlers was the ASTM A-36, because of its good conformability and market offer for large scale production. The yield stress of the steel is 250 MPa and the possible values for the rupture stress are 400 up to 500 MPa.

Loading cases

The input data of operational conditions are the following:

- Capacity: 5.000 t/h
- Belt velocity: 2,5 m/s
- Belt width: 1400 mm
- Ore density: 2400 kgf/m³
- Granulometry: 50 mm
- Material rest angle: 20º
- Load trestles spacing: 1 m

- Rolls inclination of load trestles: triple a 45º
- Belt: Goodyear EP 220
- Number of canvas: 3
- Covering: Stacker, top 10 mm, under 3 mm
- Load roll: Ø165 x 530 mm, shaft Ø 40 mm. Ball bearing code 6308

According to DIN 22101 the transverse section of carried material and its elements is illustrated by Fig. 6.

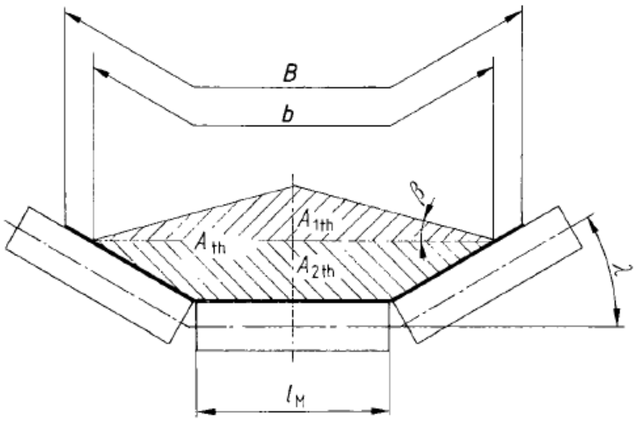

Fig. 6 Transverse section of ore, belt and rolls

The calculation of weight ore is done through below equations:

$$A_{1th} = [l_M + (b - l_M) \cdot \cos\lambda]^2 \cdot \frac{\tan\beta}{4}$$

$$A_{2th} = [l_M + \left(\frac{b - l_M}{2}\right) \cdot \cos\lambda] \cdot \frac{b - l_M}{2} \cdot \sin\lambda$$

$$B \leq 2000\,mm \quad b = 0{,}9 \cdot B - 500\,mm$$

The calculation results for the section area of carried materials are:

$A_{1th} = 0{,}0743\,m^2$
$A_{2th} = 0{,}1975\,m^2$
$A_{thtotal} = 0{,}2718\,m^2$
Load $C = A_{thtotal} \times \rho$
$C = 0{,}2718\,m^2 \times 2400\ kgf/m^2$
The belt weight is obtained with the equations as follow:
Weight housing (Goodyear catalogue):
$P_{c1} = P_{car} \times 1$
$P_{ci} = 6{,}1\,kgf/m^2 \times 1{,}4\,m = 8{,}54\ kgf/m$

Covering Weight:

$$P_{c2} = P_{rev.} \times esp \times B = 1{,}13\ kgf/m^2 \times 13 \times 1{,}4\,m = 20{,}56\ kgf/m$$

Belt weight:

$P_{c2} = 20{,}56 + 8{,}54 = 29{,}1\ kgf/m^2$
$C_c = (P_c + C) \times ac \times kc = 432{,}11kgf$

Inclined rolls load, in each roll:

$C_1 = (P_c + C) \times ac \times kl = 122{,}66\,kgf$

The work load of ore, belt and rolls are divided in three parts for analysis in the rolls as following in Fig. 7, 8 e 9. The equations for the first case are:

Loading case I:

$C_{mc} = (C_c/2 + P_c/(3 \times 2) + P_r/2) \times g$
$c_{mc} = 2248{,}0\ N$

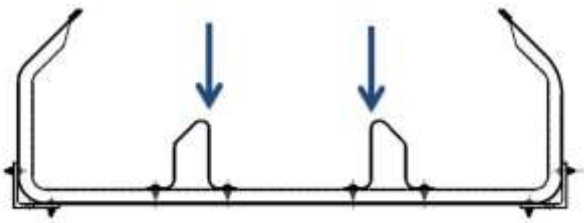

Fig. 7 Loading case direction I

Loading case II

$C_{m1} = (C_1/2 + P_c/(3 \times 2) + P_r/2) \times \sin(45°) \times g$
$C_{m1} = 510{,}58\ N$

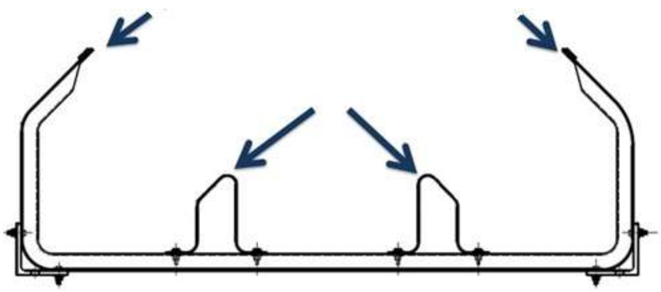

Fig. 8 Loading case direction II

Loading case III

$C_{mc2} = (C_1 + P_c/3 + P_r) \times \cos(45°) \times g$
$C_{mc2} = 1021{,}2\ N$

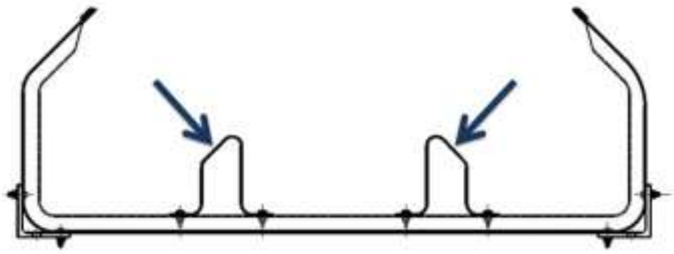

Fig. 9 Loading case direction III

The structure mesh has 10 mm parameter that results in 59.416 elements connected by 121.801 nodes (Fig. 10).

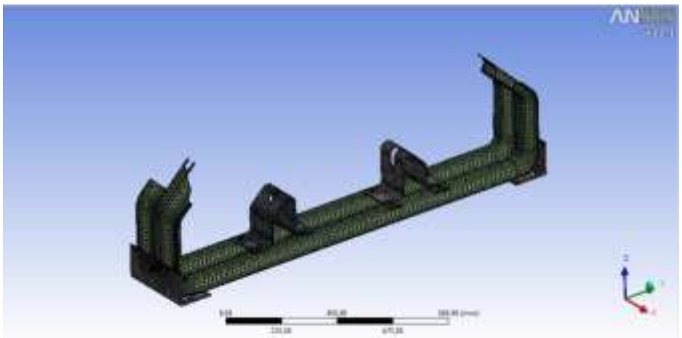

Fig. 10 Structure with the mesh

The boundary conditions considered were the fixation of base idlers in the stringers as in Fig. 11.

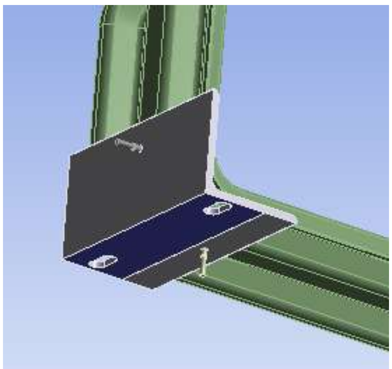

Fig. 11 Boundary conditions, purple coloration region

The placement of loads in the virtual model is shown in Fig. 12.

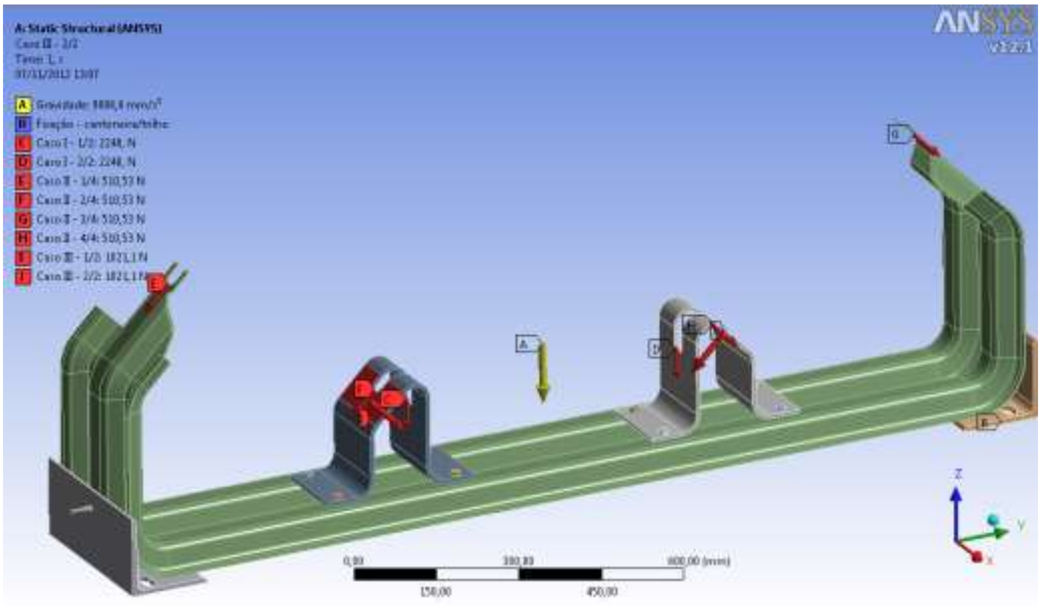

Fig. 12 Loads disposing

Permissible stresses and strains

The two possible failures considered are:

a) Plastic deformation, in case the stress exceeds the yield stress;

b) Fatigue fracture.

The maximum permissible stress for uniaxial was obtained as the standard F.E.M determines 1997 Section II – 131/132, for cases which the ratio between yield stress and rupture stress (σ_E/σ_R) is inferior to 0,7, where for the steel A-36, with minimum rupture stress is 400 MPa, takes maximum value of 0,625, the equation is:

$$\sigma_a = \frac{\sigma_E}{1{,}5}$$

For combined stresses the formula adopted becomes:

$$\sigma_{cp} = \sqrt{\sigma_x^2 + \sigma_y^2 \cdot \sigma_x \cdot \sigma_y + 3\tau_{xy}^2} \leq \sigma_a$$

But when the triple stress state occurs the Von Mises criterium must be followed, accordance with the formula below:

$$\sigma_{misses} = \frac{\sqrt{2}}{2}[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 + 6 \cdot (\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2)]^{\frac{1}{2}}$$

Even the resultant stress that acts in the structure is minor than permisible stress, the material can flow, this is due cyclic loadings. This failure is called fatigue fracture and occurs in cases of fluctuating loadings, as Fig 13. Among the criterion to evaluate the limits for cyclic stresses, the Soderberg method was chosen, because it is more conservative.

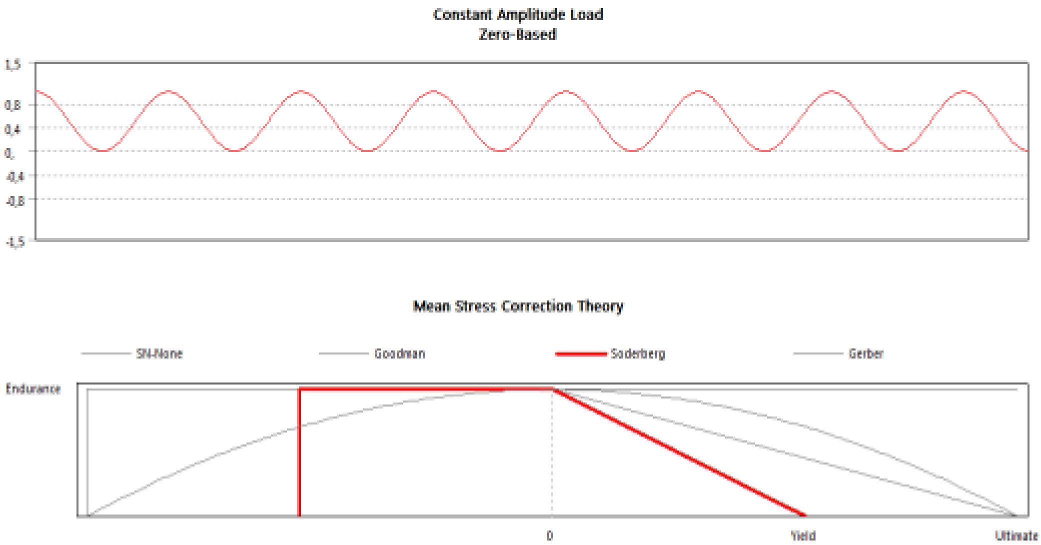

Fig. 13 Loading model and fatigue criterium

The maximum deflection according to the standard ABNT NBR 6678 must be:

$$f_I = \frac{A_I}{500} = \frac{1740}{500} \therefore \; f_I = 3{,}48\,mm$$

Where:
f_I is the deflection value;
A_I corresponds the distance between supports.

RESULTS

The results obtained by the simulation showed values below the standard of the base study. It was verified a maximum deflection of 1,47 mm. in the central region (Fig. 14), the maximum stress criterion of Von Mises 112.75 MPa (Fig. 15) and theoretically infinite life (Fig. 16).

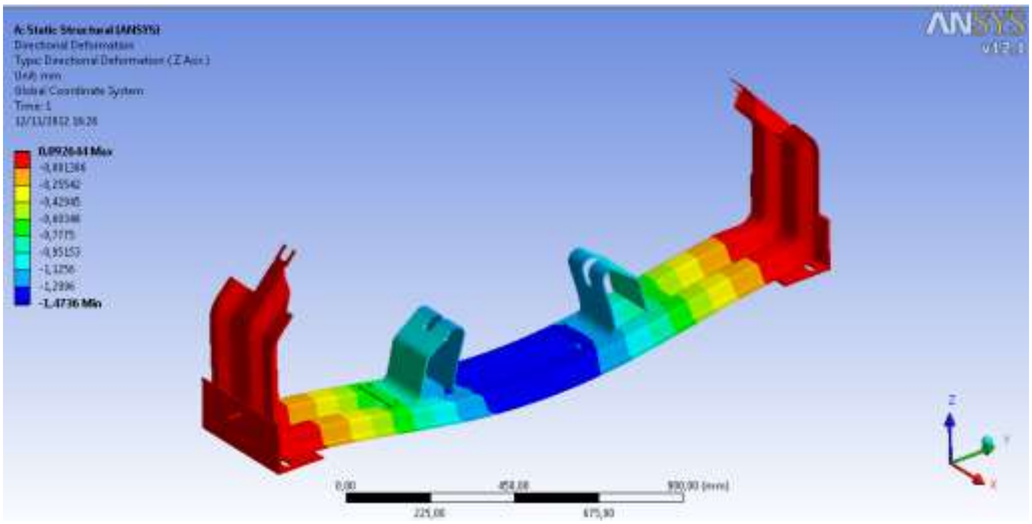

Fig. 14 Deflection regions in the structure

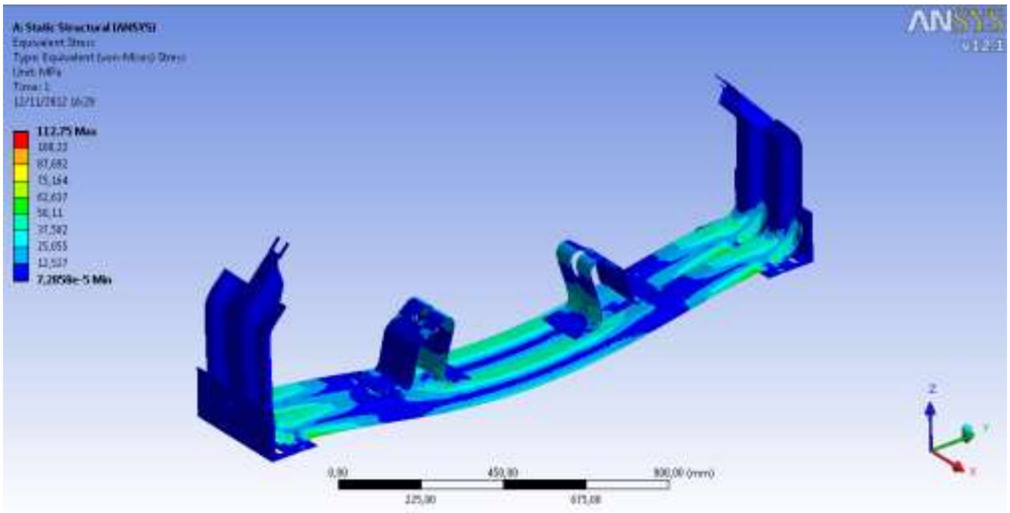

Fig. 15 Distribution of the Von Mises stresses

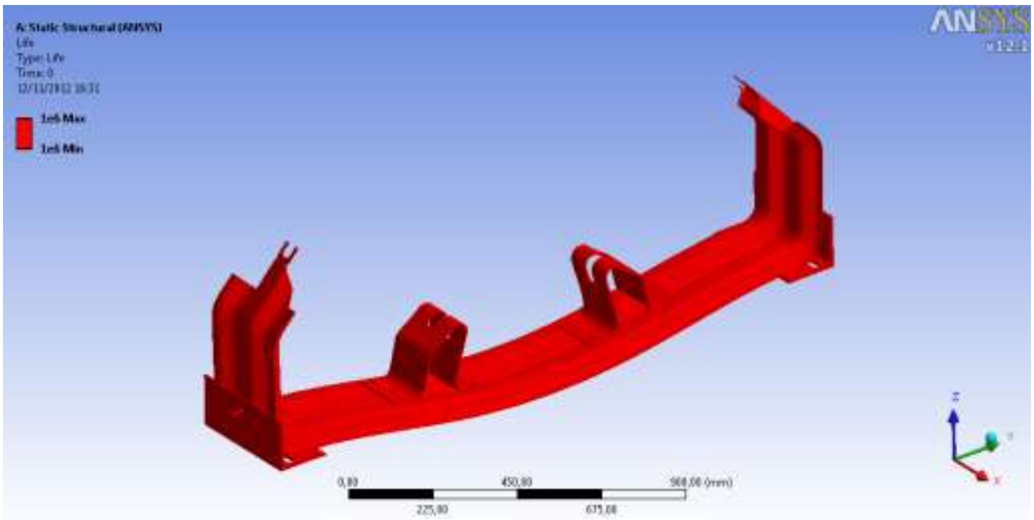

Fig. 16 Infinite life regions

CONCLUSION

The objective has been reached, as a result a model with new characteristics and able to be manufactured by a different method in comparison to the current methods. Adjustments must be done to attend the operational conditions, as well as field tests.

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