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Optimizing the Geometry of a LHy-M Hybrid Locomotive's Chassis by Resistance Calculations

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Starting from the initial geometry of the LDH 1250 CP locomotive chassis, the work aimed to optimize the geometry in the sense of maximum stresses reduction by geometric changes and the reinforcement of the structure. The optimization resulted from the need to transform the LDH 1250 Hydraulic Diesel Locomotive into the LHy-M Hybrid Locomotive, encompassing hybrid technology, powerful automation elements, as well as ergonomic redundant components that can complement and assimilate the extensive features of the old components of the rolling stock.

Keywords*: chassis, locomotive, hybrid, finite element analysis*

1. Introduction

More than 10 years after the emergence of the first hybrid locomotive, made of a Diesel locomotive, one can speak of extending the use of locomotives of this type, by "hybridization" or by new construction, for the "shunting" application with powers up to 800 Kw. In this context, Romania Euroest SA, together with its partners, proposes an innovative approach to the transformation of LDH 1250 diesel-hydraulic locomotives through the project "Hybrid Shunting Locomotive - Transforming LDH 1250 CP Hydraulic Locomotive in Hybrid Locomotive" [1] (LHy-M) This project comes to meet all railway operators, helping both to reduce operating costs and pollutant emissions. The Diesel locomotive is one of the most complex products due to the number, variety of subassemblies and components and its specific technical regulations on railway safety.

2. The LDH 1250 chassis analysis in the original variant

The geometry of the chassis in the original version is shown in Figure 1. It is noted that the chassis has the maximum dimensions of 12460 x 3081.6 x 550 mm and has many connections (with a radius of maximum 12 mm) or small holes.

Consequently, for finite element analysis, all threads and small holes will be removed from geometry, which will not significantly affect the results of the analysis. The chassis mass in the initial version is 20252 Kg, and the chassis mass in the simplified version is 20177 kg, a 75 kg weight loss, which is 0.375% of the original weight. The characteristics of the LDH, DIN Steel chassis material taken from the SolidWorks library are shown in Table 1.

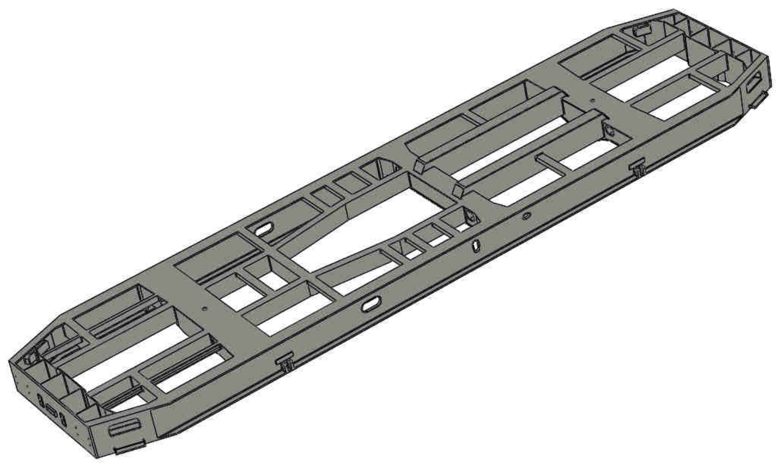

Figure 1. The chassis geometry in the original version

Table 1. The chassis material of the LDA locomotive

Material	1.0037 (S235JR)	
Elastic Modulus	210000	N/mm^2
Poisson's Ratio	0.28	-
Shear Modulus	79000	N/mm^2
Mass Density	7800	kg/m^3
Tensile Strength	360	N/mm^2
Compressive Strength	-	N/mm^2
Yield Strength	235	N/mm^2

From Table 1 results that the yield point of the material σ_c=235 MPa. We consider the allowable stress of the half-value, relation 1:

$$\sigma_a = 0{,}5 \cdot \sigma_c = 0{,}5 \cdot 235 = 117{,}5\ MPa \qquad (1)$$

We will consider the safety factor in relation to the allowable stress, calculated as the ratio of the allowable stress to the maxim von Mises stress, relation 2:

$$C_{\sigma a} = \frac{\sigma_a}{\sigma_{vonMises}} = \frac{117{,}5}{\sigma_{vonMises}} \tag{2}$$

The chassis loads applied to the chassis geometry in the original version are shown in Figure 2 and are centralized in Table 2.

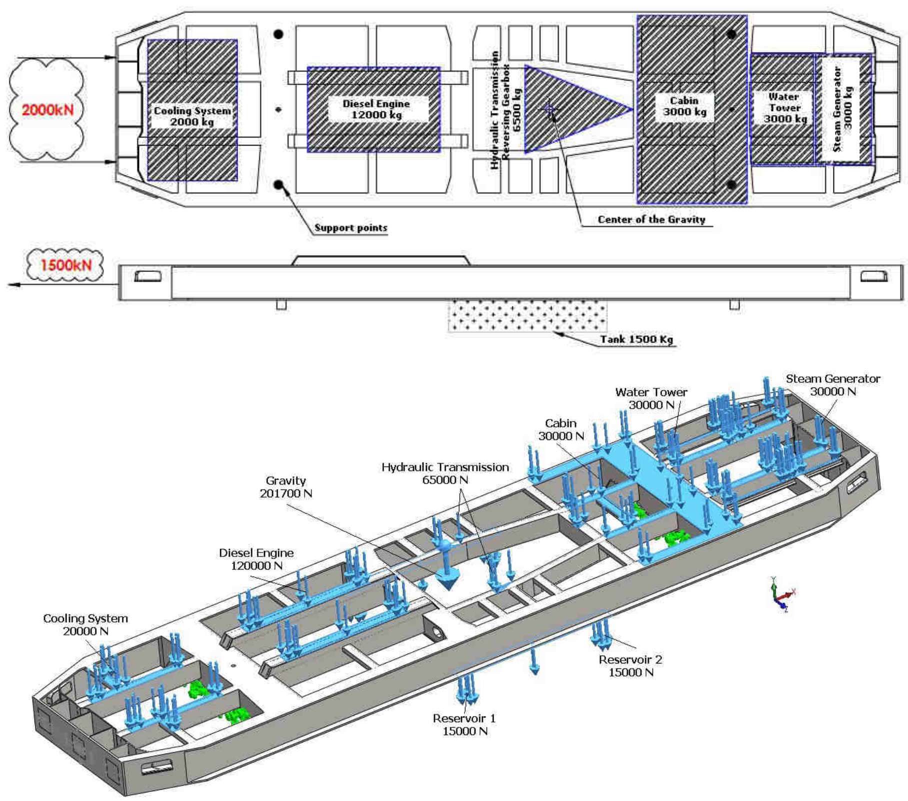

Figure 2. The chassis loads in the original version

Table 2. The chassis loads in the original version

Load case No.	Load Type	Mass	Load	No.	Load Type	Mass	Load
		Kg	N			Kg	N
1	Cooling system ↓	2000	20000	7	Reservoir 1 ↓	1500	15000
2	Diesel Engine ↓	12000	120000	8	Reservoir 2 ↓	1500	15000
3	Hydraulic	6500	65000	9	The chassis	20170	201700

Table 2. The chassis loads in the original version

Load case No.	Load Type	Mass	Load	No.	Load Type	Mass	Load
		Kg	N			Kg	N
	Transmission↓				weight20.17 tons ↓		
4	Cabin ↓	3000	30000	-	**Total vertical load**		**526700**
5	Water tower ↓	3000	30000	10	Horizontal thrust →	-	2000000
6	Steam generator ↓	3000	30000	11	Horizontal thensile ←	-	1500000

The chassis was fixed on the four surfaces, shown in Figure 3. The fixed condition consists in the cancellation of the degrees of freedom of these surfaces.

The chassis geometry in the original version was discretized in 84476 solid finite elements, Figure 4.

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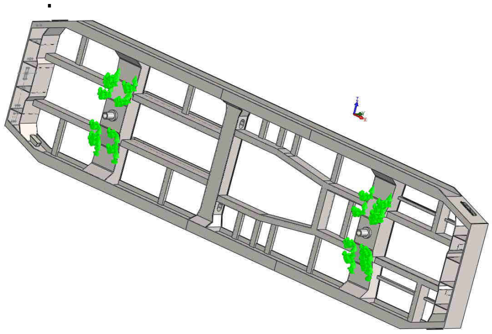

Figure 3. The LDH chassis fixing in the original variant

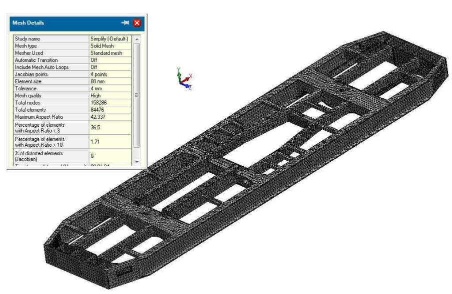

Figure 4. The chassis mesh in LDH original variant

Finite element analysis in the SolidWorks Simulation module was performed on the original LDH chassis in three load variants specified in Table 5, where final results are presented as von Mises stress and maximum displacement. It can be noted that von Mises stress has very high values, located in notch effect, for variants 2 and 3. The Figure 5 and the Figure 6 exemplify the color map of the stress for variant 1.

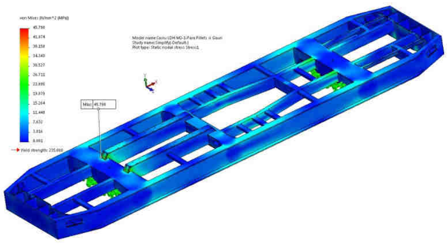

Figure 5. The von Mises stress for the variant 1 $\sigma_{von\ Mises}$=45,79 MPa

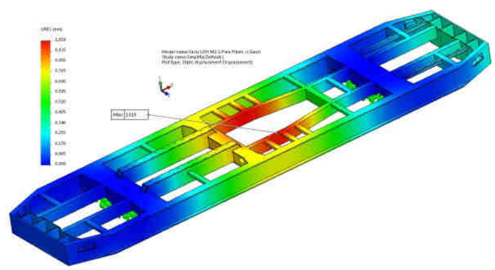

Figure 6. The von Mises stress of the variant 1 δ=1,019 mm

3. The LDH 1250 chassis analysis in the enhanced variant

The chassis geometry in the enhanced version, Figure 7, shows that the chassis has the maximum dimensions of 12955 x 3082 x 550 mm and the mass 42316 Kg. The consolidation consisted of the applying of the plates with 50 mm thickness on the entire length of the top and in the local changes (ribs, etc.) in critical areas. The chassis geometry in the reinforced version was discretized in 72721 solid-state finite elements, Figure 8.

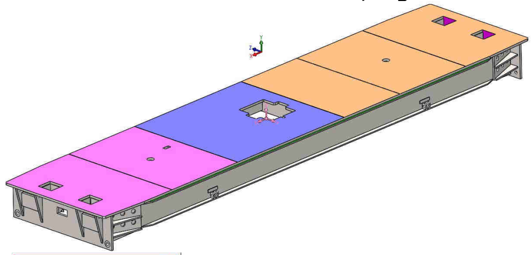

Figure 7. The chassis geometry in the enhanced variant

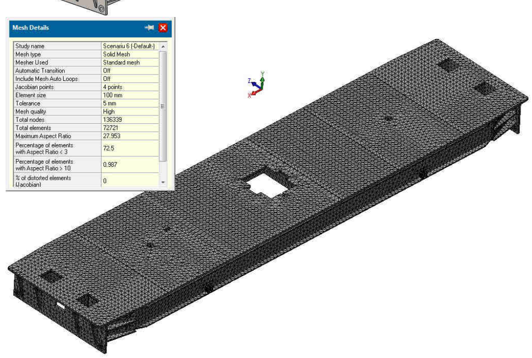

Figure 8. The chassis mesh in enhanced variant

The chassis loads in the enhanced variant are presented in the Table 3 and in the figures 9 ÷ 18.

Table 3. The chassis loads in the enhanced variant

Load case No.	Load Type	Mass	Load	Figure
		Kg	N	
1	Upper plate 1 ↓	6000	60000	Figure 9
2	Upper plate 2 ↓	7000	70000	
3	Upper plate 3 ↓	4000	40000	
4	Rezervoire 1 ↓	1500	15000	Figure 10
5	Rezervoire 2 ↓	1500	15000	
6	Bogies weight 4 x 5 t ↓	20000	200000	Figure 11
7	The forces on the 4 lifting eyes 4 x 18 t ↑	-72000	-720000	Figure 12
8	The forces on the 4 holes 4 x 18 t ↑	-72000	-720000	Figure 13
9	The forces on a surface 100 x 100 mm 36 t ↑	-36000	-360000	Figure 14
10	The forces on two surfaces 100 x 50 mm 36 t ↑	-36000	-360000	Figure 15
11	The force on a surface 100 x 50 mm 36 t ↑	-36000	-360000	Figure 16
12	The own weight 42.3 tone ↓	42300	423000	Figure 17
13	Traction power 400 KN ←	-	400000	Figure 18

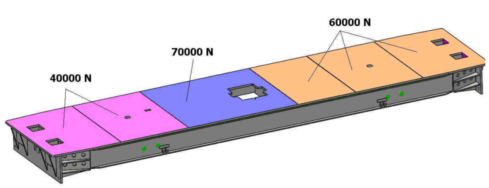

Figure 9. The loads on the upper plate

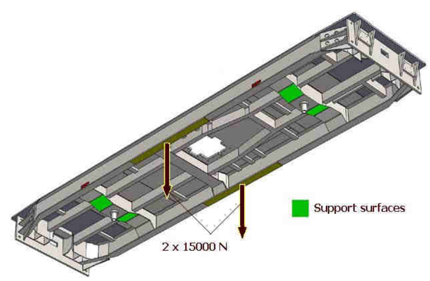

Figure 10. The loads on the reservoir

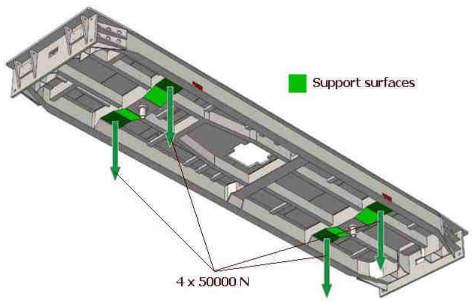

Figure 11. The bogies weight

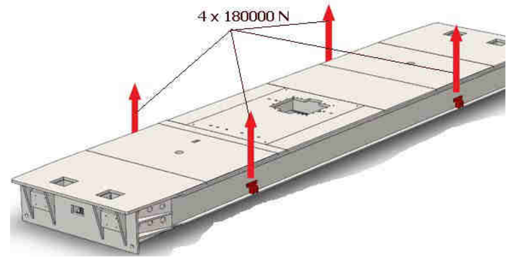

Figure 12. The forces on the 4 lifting eyes

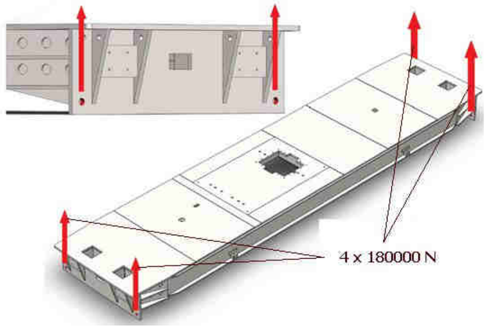

Figure 13. The forces on the 4 holes

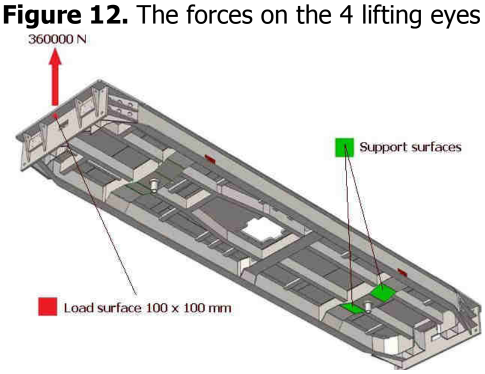

Figure 14. The forces on a surface 100x100 mm

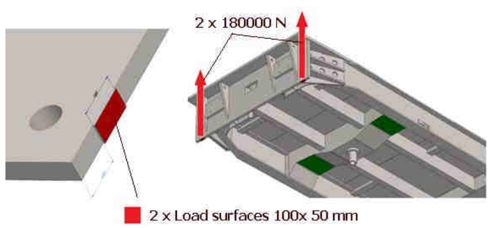

Figure 15. The forces on two surfaces 100 x 50 mm

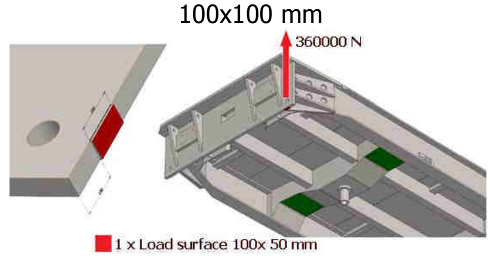

Figure 16. The force on a surface 100 x 50 mm

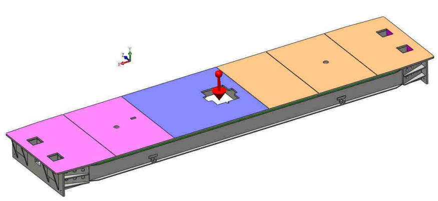

Figure 17. The own weight

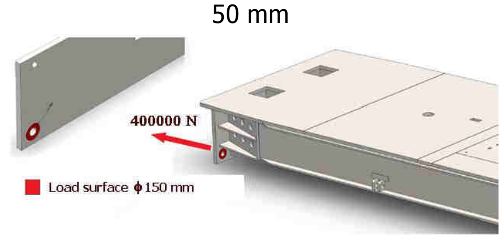

Figure 18. Traction power 400 KN

The fixing of the chassis was done in four variants shown in Figure 19 ÷ 22.

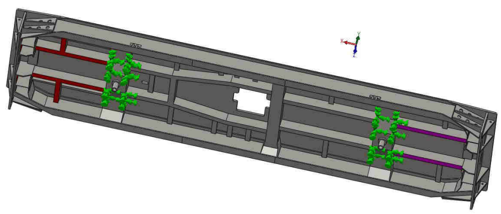

Figure 19. The fixing of the enhanced chassis on four surfaces

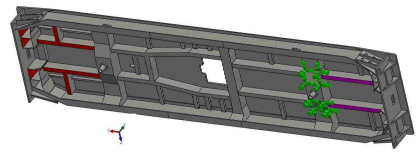

Figure 20. The fixing of the enhanced chassis on two inclined surfaces – variant a

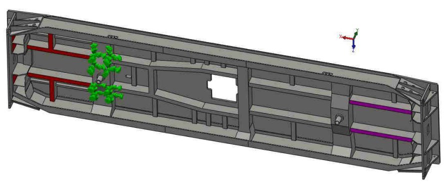

Figure 21. The fixing of the enhanced chassis on two inclined surfaces – variant b

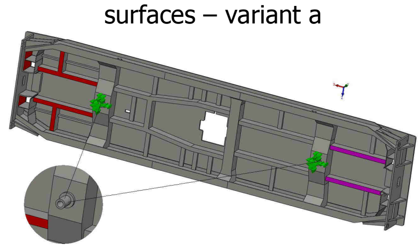

Figure 22. The fixing of the enhanced chassis – on two cylindrical surfaces

The enhanced chassis calculations are presented in Table 4. Loading scenarios 1-6 are required by ITS rail rules that meet the essential requirements for the structural subsystem of the railway vehicle component that are the subject of an EC or NNTR declaration of conformity.

Table 4. The enhanced chassis calculation

No.	Study	Restraint figure	External loads from Table No. 3
4	Initial loads	Figure 19	Load case No. 1,2,3,4,5,12,14
5	Script 1	Figure 19	Load case No. 1,2,3,4,5,6,7,12
6	Script 2	Figure 19	Load case No. 1,2,3,4,5,6,8,12
7	Script 3	Figure 20	Load case No. 1,2,3,4,5,6,9,12
8	Script 4a	Figure 20	Load case No. 1,2,3,4,5,6,10,12
9	Script 4b	Figure 21	Load case No. 1,2,3,4,5,6,10,12
10	Script 5	Figure 19	Load case No. 1,2,3,4,5,6,11,12
11	Script 6	Figure 22	Load case No. 1,2,3,4,5,12,13

4. Summary results

The Table 5 centralizes the results of both analyses: chassis in the original variant and enhanced chassis variant.

Table 5. Results

No.	Study	Geometry	Loads	Finite elements number	von Mises Stress MPa	Displa-cement mm	Safety Factor
Initial geometry							
1	Variant 1	The LDH chassis in original variant 12460 x 3082 x 550 mm	Only vertical loads Load case No. 1 ÷ 9 from Table 2	84476	45.79	1.019	2.57
2	Variant 2		Vertical and horizontal loads; Load case No. 1 ÷ 9, 10 from Table 2	84476	2717	37.544	0.04
3	Variant 3		Vertical and thrust loads; Load case No. 1 ÷ 9, 11 from Table 2	84476	1014	9.975	0.12
Enhanced geometry							
4	Initial loads	The chassis in the enhanced variant 12955 x 3081.6 x 550 mm	See table 4	72721	130.021	1.432	0.90
5	Script 1			72721	97.148	0.365	1.21
6	Script 2			72721	71.541	2.48	1.64
7	Script 3			72721	108.756	32.386	1.08
8	Script 4a			72721	103.133	29.664	1.14
9	Script 4b			72721	104.692	31.594	1.12
10	Script 5			72721	162.697	47.949	0.72
11	Script 6			72721	255.089	3.962	0.46

5. Conclusions

On both chassis geometries, vertical loads combined with traction power or thrust power were been applied. For the original version, applying only vertical loads, the chassis stresses are low compared to the admissible stress of 117.5 MPa.

For the enhanced version, the script 5 and 6 are most critical, the safety factor calculated being subunit.

The weight of the enhanced chassis is double that of the initial. The present numerical analysis using finite elements represents a national novelty in the railway industry, being for the first time applied in the technical project and the technical documentation for the certification of the conformity of a locomotive subject to modernization.

The technical specification and technical design have been approved by the Regulatory Authority - ONFR and is in the testing phase for certification according to national NNTR standards.

6. Acknowledgments

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