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Analysis of stresses and deformations in the chassis of rough terrain forklifts with wheel drive formula 4X4

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Abstract. The outcome of studying the strength and the deformation characteristics of rough terrain forklifts with wheel drive formula 4X4, using a created 3D model applying FEM, is presented herein. The tested chassis design features are described. The external loads of the chassis structure have been estimated throughout two operation modes: handling the load at vertically elevated lifting mast and also featuring load lifted off the ground, using lifting mast in transport mode tilted backwards. Two alternating payloads have been applied for each of the selected modes: featuring rated load and standard size of the centre of gravity, and featuring reduced load at increased height of the centre of gravity. The resulting rates of stresses and deformations of the studied chassis of a terrain forklift with wheel drive formula 4X4, have been calculated, presented and analysed with regard to the two main operating modes both of which entail two loading alternatives determined by the weight and the location of the payload.

Key Words: rough terrain forklifts, chassis, stresses, deformations, estimated strength, FEM.

1. Object and purpose of the study

The object of the study is a chassis of rough terrain forklifts with wheel drive formula 4X4 and lifting capacities of 60, 70, and 80 kN, different in compare with the studied chassis, presented in [10], wich is for the rough terrain forklifts with wheel drive formula 4X2 and lifting capacities of 30, 40, and 50 kN [11].

The purpose of the study is to determine the stressed and deformed state of the structure of a terrain forklift chassis under two typical load conditions. While developing the model, the chassis has been subjected to the loads resulting from the forces of gravity of the main assemblies and units related thereto, such as engine, tanks, box, lifting mast, counterweight, etc.

The main purpose of the study is to identify the critical points in the chassis design based on the results of the strength and deformation analysis.

An FE model of the chassis and the stresses and the deformations thereto have been made using the SOLIDWORKS Simulation Xpress module within SOLIDWORKS 2019 [7].

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2. Load conditions of the chassis of a rough terrain forklift with wheel drive formula 4X4

The chassis, selected for the study, is used in the DV60-80 forklifts series, manufactured by Balkancar Record JSC, with wheel drive formula 4X4 and lifting capacities of 60, 70, and 80 kN. [11].

What the new item about this design is that the rear steering axle constitutes also a drive axle.

The forklift is manufactured in two modifications: featuring hydrostatic and hydrodynamic drive. Both options feature a distribution box between both axles [8, 9].

The chassis features a welded steel structure of sheet material whereto both drive axles, front and rear, are fixed. The two side plates, left and right, constitute the main carrying elements of this chassis. They are also linked to the wings and the transverse shield at the front and to crossbars and plates at the rear, whereto the individual counterweights are fixed. Thus, the result is a box-like enclosed form. The side plates thickness is 30 mm, and the mostly used material for these is steel ST355JR.

The calculations have been made in respect of the two most typical load conditions in the use of these machines [5].

*2.1. **Mode one** – taking the load at vertically elevated lifting mast*

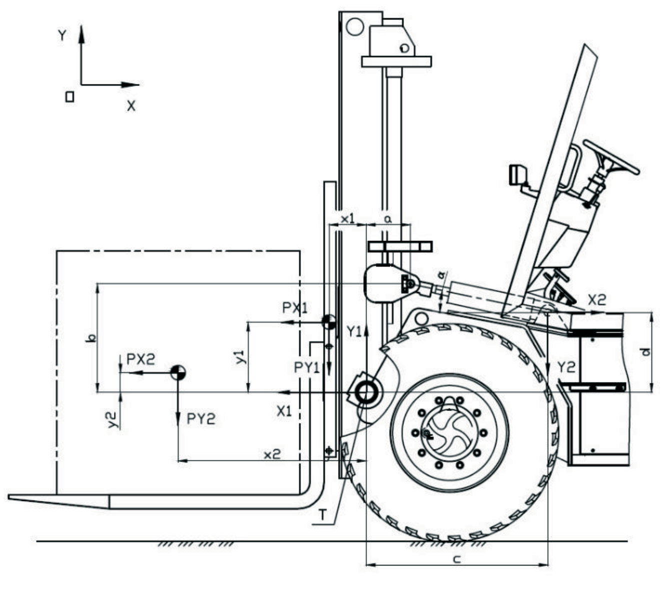

Figure 1. *Mode one: Loading by taking the load at vertically elevated lifting mast*

*2.2. **Mode two** – load lifted 300 mm off the ground, the lifting mast being tilted backwards in transport position*

Calculations involving two positions of the centre of gravity of the load have been made, with regard to each of both load conditions, where C = 600 mm and C = 1370 mm concern the heaviest model representing the series, DV60-80, 4x4; it features lifting capacity of 80 kN [11].

It is known from the theory and the design of forklifts [1, 2, 5] that moving the centre of gravity of the load forward, in respect of the longitudinal axis of the forklift, the rated load should be reduced in order to preserve the machine stability against overturning while handling any load [3, 4, 6].

Therefore, the second purpose of the study has been set – to identify and analyse the stressed state of the chassis structure and its deformed state at various positions of the centre of gravity and using various rates of the payload, which ensure the longitudinal stability of the terrain forklift against overturning [3, 4].

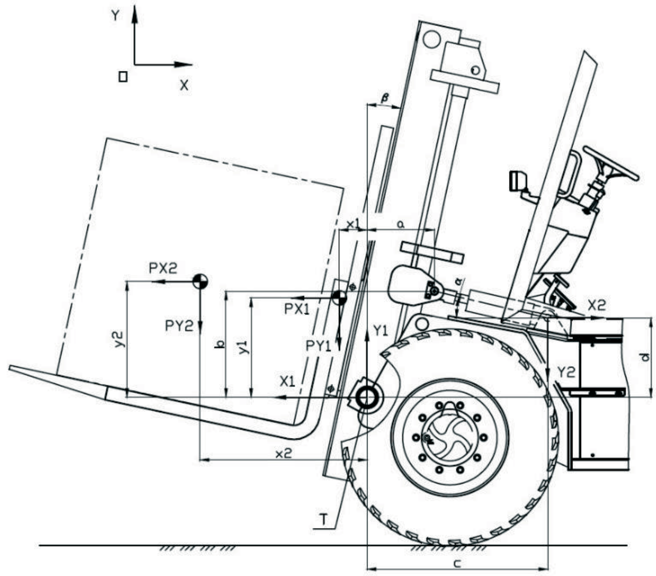

Figure 2. *Mode two: Load lifted 300 mm off the ground, the lifting mast being tilted backwards, in transport position*

3. Studying of the chassis of a rough terrain forklift with wheel drive formula 4X4

3.1. Stresses and deformations in the chassis under the first load conditions featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN

The results of testing the strength under the first load conditions, featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN, are shown in Figure 3 and Figure 4.

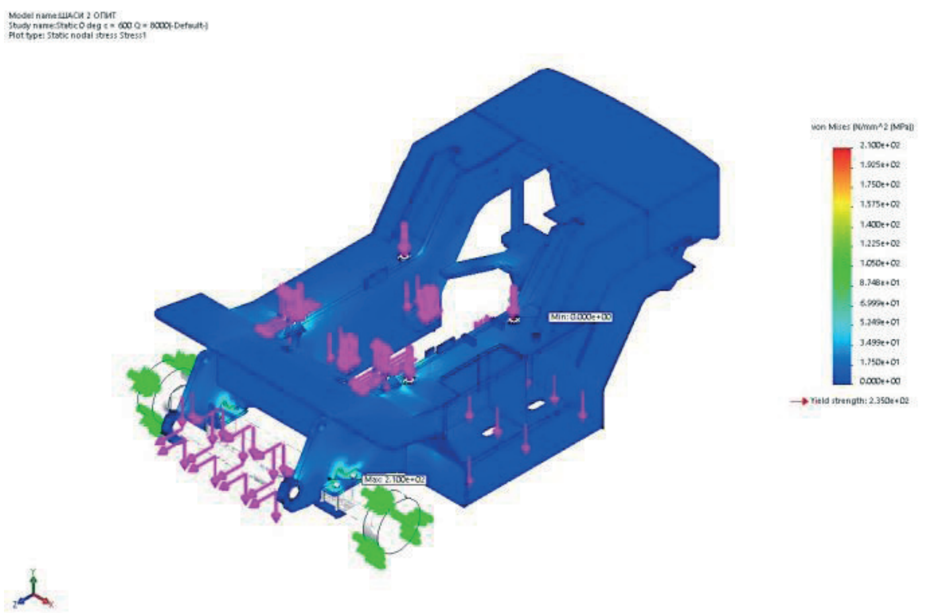

Figure 3. *Stresses in the chassis under the first load conditions featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN*

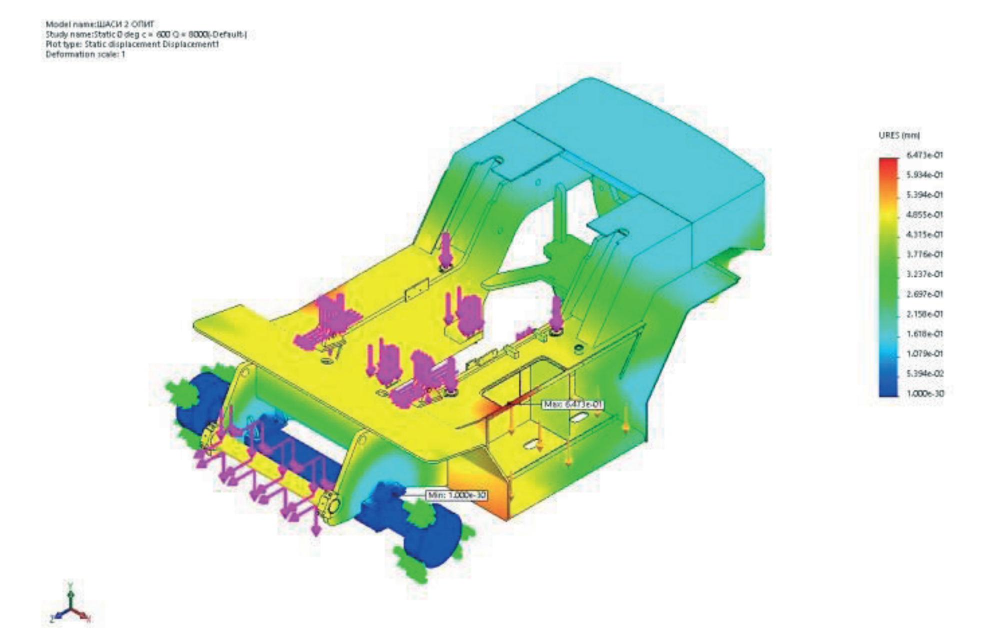

Figure 4. *Deformations in the chassis under the first load conditions featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN*

3.2. Stresses and deformations in the chassis under the second load conditions featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN

The results of testing the strength under the second load conditions, featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN, are shown in Figure 5 and Figure 6.

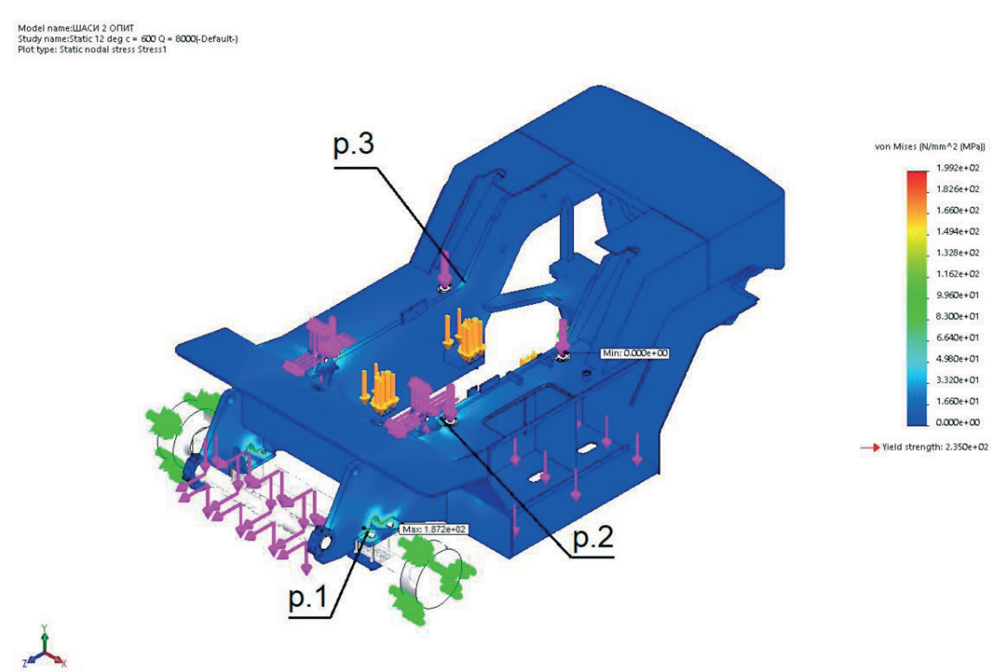

Figure 5. *Stresses in the chassis under the second load conditions featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN*

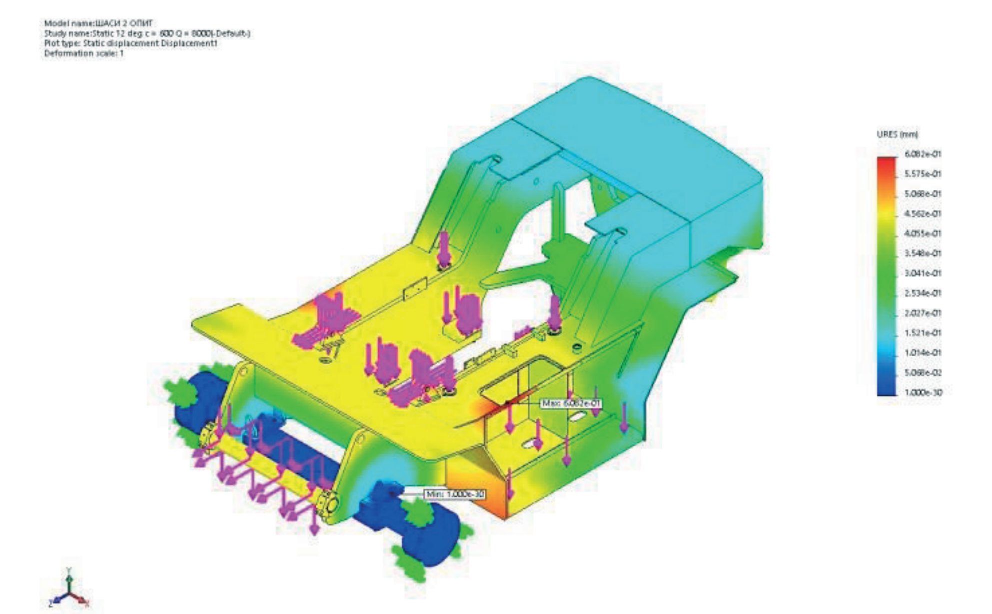

Figure 6. *Deformations of the chassis under the first load conditions featuring a standard centre of gravity at C = 600 mm and a rated load of Q = 80 kN*

3.3. Stresses and deformations in the chassis under the first load conditions featuring an increased centre of gravity of the load at C = 1370 mm and a reduced load of Q = 45 kN

The results of testing the strength under the first load conditions and featuring increased centre of gravity are shown on Figure 7 and Figure 8.

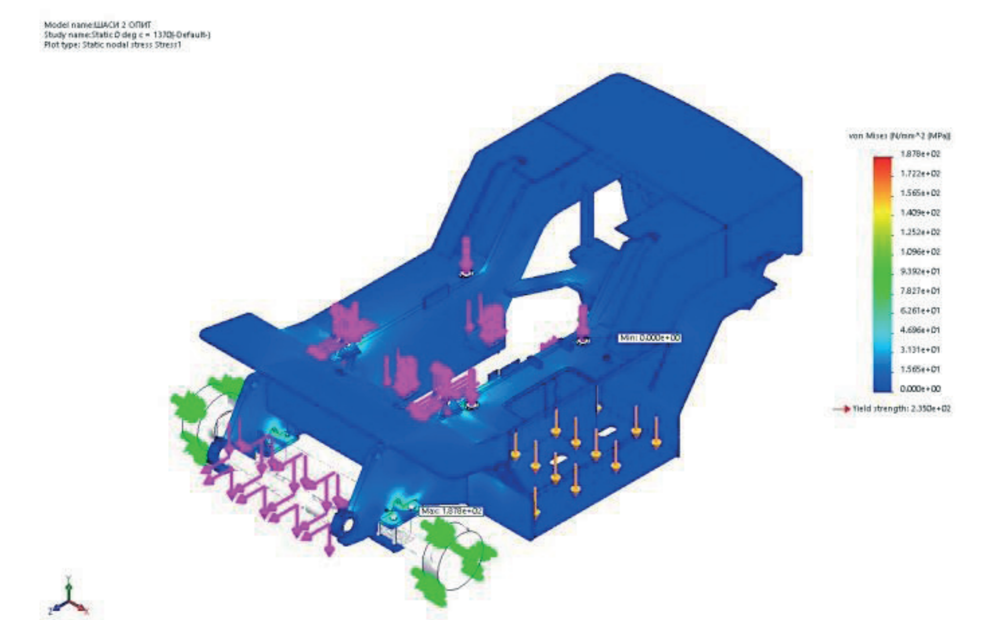

Figure 7. *Stresses in the chassis under the first load conditions featuring an increased centre of gravity at C = 1370 mm and a reduced load of Q = 45 kN*

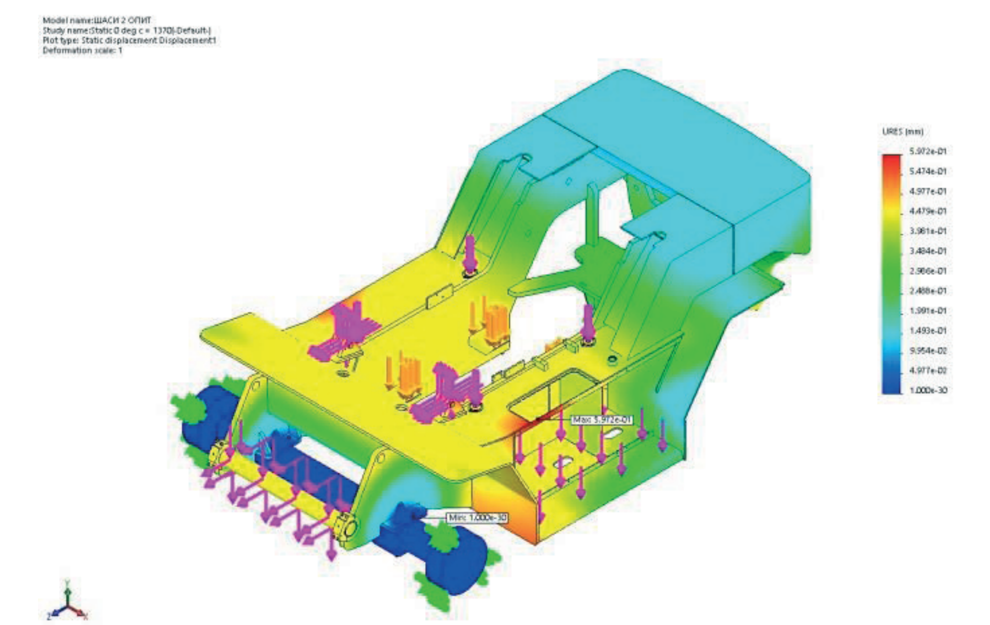

Figure 8. *Deformations of the chassis under the first load conditions featuring an increased centre of gravity at C = 1370 mm and a reduced load of Q = 45 kN*

3.4. Stresses and deformations of the chassis under the second load conditions featuring an increased centre of gravity at C = 1370 mm and a reduced load of Q = 45 kN

The results of testing the strength under the second load conditions and an increased centre of gravity are shown in Figure 9 and Figure 10.

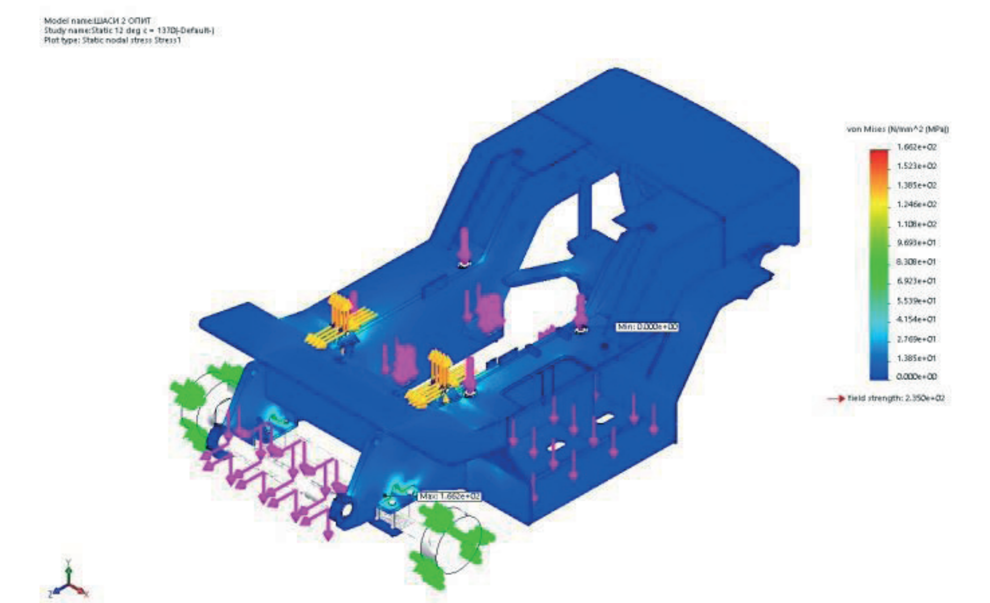

Figure 9. *Stresses in the chassis under the second load conditions featuring an increased centre of gravity at C = 1370 mm and a reduced load of Q = 45 kN*

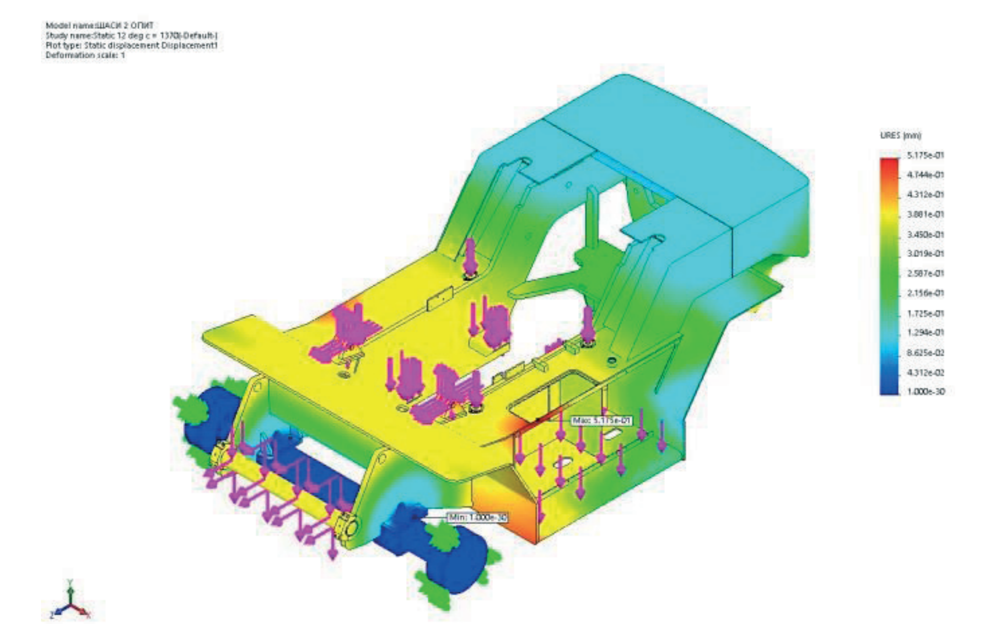

Figure 10. *Deformations of the chassis under the second load conditions featuring an increased centre of gravity at C = 1370 mm and a reduced load of Q = 45 kN*

3.5. Results analysis

Based on the obtained results concerning a 4x4 forklift chassis, the following conclusions and assumptions could be drawn:

1) The critical points in the structure, where the highest stresses have been ascertained at both load conditions, could be reduced to three, similarly to the design of forklifts featuring two-wheel drive: Point 1 – underwing plate mounted on the drive axle; Point 2 – front upper section of the horizontal plate within the bracket of the tilting cylinder; Point 3 – the rear section of the carrying side plate within the passage where the counterweight is hung (Figure 5).

2) The estimated maximal static stresses are σ_{Max} = 187 MPa within the underwing plate, p. 1, under the second loading conditions – transport position. This value has also been confirmed by the conducted strain measuring tests of a chassis of this class of machines at the testing laboratory of Balkancar Record JSC. Pursuant to [3], the dynamism coefficient of chassis and lifting mast of rough terrain forklifts, featuring pneumatic tyres, is C_d = 1.9. The maximum stress value multiplied by the dynamism coefficient results in the highest stress value of 355 MPa. Considering the fact that the yield limit regarding the ST 355 JR steel, whereof the chassis components have been made, is 355 MPa, pursuant to [3] up to 5% excess of the stress is allowed, which is why it may be assumed that the construction possesses the necessary strength.

3) There is a considerable difference regarding this design in the values of the maximal static stresses regarding both load conditions. When the load is being lifted, the values are 40-50 MPa lower than the ones expressing lifting mast tilted backwards – transport position. This shows that operation at both load conditions of the forklift substantially affects the stresses. In order to equalise the stresses values under both load conditions, the front part of the chassis should be strengthened – in this case, the thickness of the underwing plate should be increased from 20 mm to 30 mm.

4) Regarding the calculations entailing an increased centre of gravity and a reduced load at both load conditions, the registered stresses have been 12% lower compared to the ones obtained by calculating the rated load and centre of gravity. These results are analogous to the calculations

regarding the first chassis and confirm the conclusion that concerning a forklift optimally designed for rated load and centre of gravity, compliance with the loads chart specified by the manufacturer shall ensure not only the required stability but also the strength and the reliability of the forklift structure.

5) The achieved results regarding the stresses at the other critical point of the chassis structure, point 3, could be decreased by enlarging the rounding radius, i.e. by applying smoother passage between the top and the bottom section of the side plate.

6) The proposed 3D model of the chassis of a rough terrain forklift with wheel drive formula 4X4, involving application of FEM, using [missing text] for calculating the stresses and the deformations at randomly applied static and dynamic impacts observed during operation, allows to make a full analysis of the strength and deformation characteristics of the studied object.

4. Conclusion

The resulting values of the stresses and the deformations in the chassis of rough terrain forklifts with wheel drive formula 4X4, have been calculated, presented and analysed using the created 3D model applying the FEM under two main operation modes, each of which has undergone two alternatives of loading determined by the value and the location of the payload.

A real assessment of the strength and the deformations of the chassis of rough terrain forklifts with wheel drive formula 4X4, has been made by analysing the obtained numerical results, and changes to the chassis structure have been proposed, which determines the practicality and the applicability of this study.

Acknowledgments

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