DESIGNING, ANALYSIS AND MANUFACTURING OF A SCISSOR LIFT PLATFORM

PROIECTAREA, ANALIZA SI FABRICAREA UNEI PLATFORME PENTRU UN LIFT ARMONIC

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In this study, scissor lift platform produced by Konya Saraylı Madeni Eşya, is designed and analyzed through FEM. The design and applying loads are made according to EN 280 standard. Scissor lift platforms must have a stability due to their structure. It is also important that it is light and designed for a specific load. In this study, the design was made in the SOLIDWORKS program and assembled together. Then, a certain load was applied from the upper part of the platform according to the carrying capacity. Then the loads on the truss profile were calculated analytically. The assembly made in the SOLIDWORKS drawing program was imported into the ANSYS program to perform a numerical analysis. The results obtained were compared with each other.

In acest studiu, platforma de ridicare a unuı lıft armonıc produsă de Konya Saraylı Madeni Eşya, este proiectată și analizată prin MEF. Proiectarea și aplicarea sarcinilor sunt realizate conform standardului EN 280. Platformele de ridicare trebuie să aibă o stabilitate datorită structurii lor. De asemenea, este important ca structura să fie ușor de proiectat pentru o sarcină specifică. În acest studiu, proiectarea a fost realizată pas cu pas în programul SOLIDWORKS și apoı asamblată. Apoi, o anumită sarcină a fost aplicată la partea superioară a platformei în funcție de capacitatea de încărcare. Sarcinile pe profilul dat au fost calculate analitic. Ansamblul realizat în programul SOLIDWORKS a fost importat în programul ANSYS pentru a efectua o analiză numerică. Rezultatele obținute au fost comparate între ele pentru valıdarea acestora.

KEYWORDS: scissor lift, platform, SOLİDWORKS, numerical analysis

1. Introduction

Work platforms are used in inaccessible and temporarily accessible areas. Scissor lift platform is one of them. The working principle of scissor lift platforms depends on a hydraulic system. The hydraulic cylinder opens the interconnected profiles in the form of scissors and allows them to rise. Balance and optimum design are important in the design of scissor lift platforms. The scissor lift is designed and manufactured considering the following features;

- height of the scissor lift platform;
- optimum design of the scissors;
- overturn resistant design;
- thickness of truss profile.

2. State of the art

Liu and Sun (2009) [1] stated in their studies that only the static solution was insufficient during the scissor lift design, and that the real operating state and kinetic properties of the mechanism were not shown by neglecting the dynamic solution. In line with this situation, the kinematic and kinetic simulation of the scissor lift were examined through the MATLAB-Simulink program.

Hongyu and Ziyi (2011), [2] in their study, designed a scissor lift using a single cylinder using Pro/ E, and by making force analysis, they revealed the equality between the load desired to be carried and the hydraulic force. In addition, taking into account the hydraulic cylinder speed being 1 m/ min and 5 m/ min, they examined the velocity changes during the elevation of the platform.

Table 1. Platform velocity comparison

Angle Degree	20°	30°	40°	50°	60°
cylinder velocity: 1m/min	0.51 m/min	0.75 m/min	0.96 m/min	1.15 m/min	1.30 m/min
cylinder velocity: 5m/min	9.6 m/min	6.6 m/min	5.13 m/min	4.31 m/min	3.81 m/min

Fig. 3 n-level lift at various stages of deployment

Islam et al. (2014) [3] examined a scissor lift powered by a DC motor using the bond graph method. With the prepared model, they obtained all kinematic values (displacement, speed, acceleration etc.) of the mechanism depending on the torque value of the motor, which is the driving element of the system. Unlike most of the traditional method used in the solution of dynamic systems, it was emphasized that PID control can be used in the solution with the bond graph method.

Bhatt and Pandya (2012) [4] investigated that the overall cost would decrease by performing mechanical control of a lift designed using a ball screw and made their designs accordingly. Later, they analyzed the safety and accuracy of the design by making stress analyzes with the ANSYS program.

Abhinay and Rao (2014) [5] stated that the production time can be reduced with the use of scissor lifts in production, and they have modeled and material selection of the scissor lift with a suitable design to meet this need in their studies. They obtained the strain distribution depending on the stress and stresses on the model they designed. As a result, they have designed a scissor lift with a safe design under certain parameters.

3. Design and analysis of the platform

Table 2 shows the characteristics of platform. Scissor lift platform parts are drawn in the SOLIDWORKS program in line with the specified features. The solid model has been created by assembling these drawn parts. After creating the platform in SOLIDWORKS, the file was imported and then analyze it using the numerical code ANSYS. The device has been designed according to EN 280 Standard.

Table 2. Product properties

Product Properties	
Height	8 m
Working Height	10 m
Max Platform Capasity	350 kg

The material properties used are given in ST52 and in Table 3.

Table 3. Properties of the ST52

Mechanical Propesties of The Material	
Elastic Modulus	**Shear Modules**
210 GPa	79000 MPa
Mass Density	**Poisson's Ratio**
7800 kg/m3	0.28
Tensile Yield Strength	**Tensile Ultimate Strength**
315 MPa	520 MPa

The platform weight, calculated in SOLIDWORKS, results in a mass of 330 kg. This value has been added as an additional load to the final calculations in order to make the final solution more accurate. According to the Standard EN 280 a mass of 350 kg was applied to the platform.

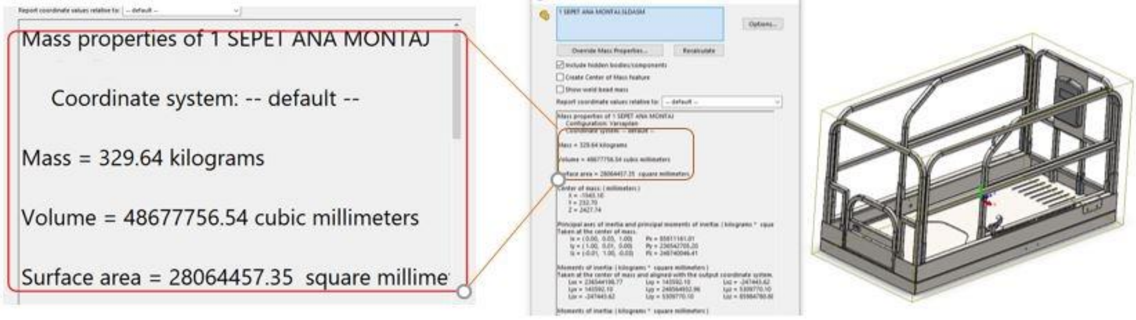

Fig. 1 Calculation of the mass platform

In the present study, the number of profiles as well as the loadings acting on profiles to be used were calculated. For the validation of the results, an analytical study was done in parallel with a numerical study, performed in ANSYS code, in order to evaluate the stress and deformation state in the structure. To have a light structure, instead of actual box profiles (120 x 60 x 6) the author proposed the same profiles, with a thinner thickness (5 instead of 6 mm).

4. Design approach

Scissor lift platform consists of three main components. Scissor lift platform consists of three main components. These components are platform component, scissor component and chassis component. (Figure 2)

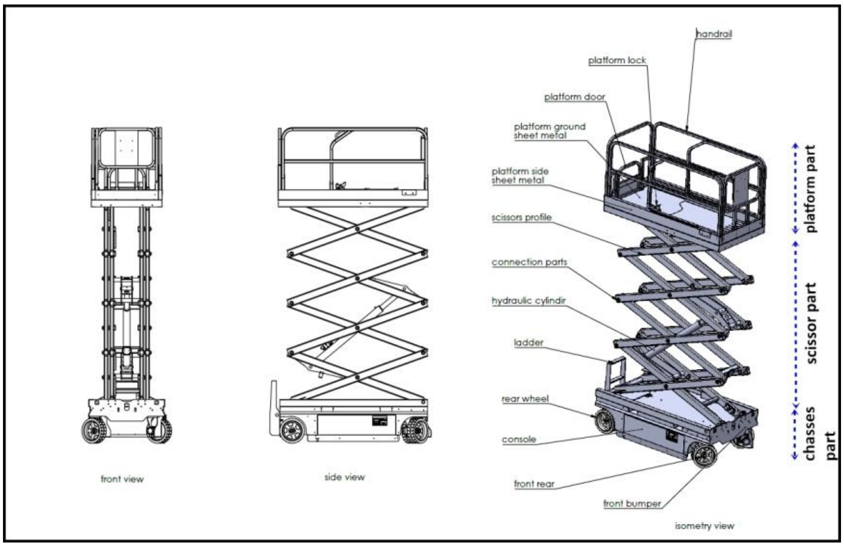

Fig. 2 Explanation of the parts of the platform

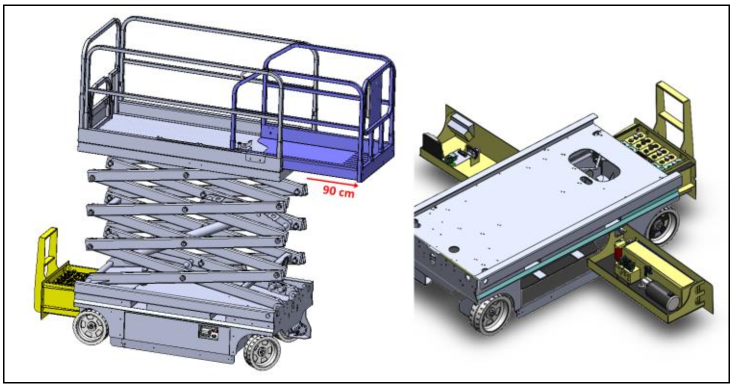

Fig. 3 Design differences made for balance and consoles made for easy access

The battery component is designed behind the scissor lift. Thus, when the upper platform shown in figure 3 is opened forward, it will create a balance. As a result of the design, the openable platform was decided to be 90 cm. In addition, it is important that the battery part should be separated from the console in order to not get dust and to not get wet due to eventually puddles existing on the move. (Figure 3)

Oil tank, oil filter, electric motor, charger, electrical automation and some other equipment are placed in consoles. Consoles with easy access to these equipment are important. In addition, since the company aims to export to 3rd world countries, it will be easier to send spare parts instead of service in case of any breakdown. Consequently, it will be easier to produce and assemble the whole chassis in our company. (Figure 3)

5. Calculations

We use "X" shaped profiles when determining the platform height. In the table below one can find the horizontal and vertical heights of a profile between 5 and 60. In figure 4 it is determined the way to evaluate the number of X-shaped scissors which will be used to reach a height of 8 meters.

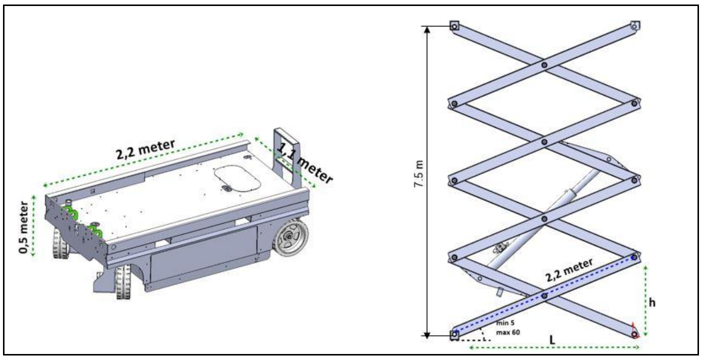

Fig. 4 Chassis general view and scissors dimensions view

If we want the footing height of 8 meters when it is opened, we need to use a 4-level scissors system. The chassis height is equal to 0.5 meters. In order to obtain a height of minimum 8 m an angle θ = 60º has been adopted. (4 . 1,905) m + 0,5 m = 8,12 m.
Where;

$$\cos\theta = \frac{L}{2,2} \quad (1)$$

$$\sin\theta = \frac{h}{2,2} \quad (2)$$

Table 4. Scissor lift link positions

Angle(°)	Lenght(L) m	Height(h) m
5	2,191	0,192
10	2,167	0,382
15	2,125	0,569
20	2,067	0,752
25	1,994	0,930
30	1,905	1,100
35	1,802	1,262
40	1,685	1,412
45	1,556	1,556
50	1,415	1,685
55	1,261	1,802
60	1,100	1,905

The forces on the truss profile vary according to the angle. In Table 4, calculations have been made accordingly. With the SOLIDWORKS program, the weight of the platform was calculated as 330 kg. According to the EN 280 standard, a load of 350 kg is applied to the platform.

Total mass is calculated m = 350 + 330 =580 kg. Weight G = 580 . 9,81 = 5690 N

$$N = \frac{G}{4} \cdot sin\theta \quad (3)$$

$$Q = \frac{G}{4} \cdot \cos\theta \quad (4)$$

$$M = \frac{GL}{4} \cdot cos\theta \quad (5)$$

Table 5. Normal force, shear force and bending moment

Angle(°)	Normal Force(N)	Shear Force(N)	Bending Moment(N.m)
5	123,900	1416,952	3105,137
10	246,946	1400,878	3035,086
15	368,143	1373,993	2919,707
20	486,495	1336,581	2762,873
25	601,149	1289,212	2570,508
30	711,250	1231,885	2346,987
35	815,804	1165,170	2099,659
40	913,245	1089,635	1836,253
45	1005,850	1005,850	1564,720
50	1089,635	914,668	1293,889
55	1165,170	815,093	1027,506
60	1231,885	711,250	782,375

The bending moment and shear force at different angles are calculated in table 5.

$$\sigma_N = \frac{N_{(\theta)}}{A} \quad (6)$$

$$\sigma_M = \frac{M_{(\theta)}}{W_x} \quad (7)$$

$$\sigma_{total} = \sigma_M + \sigma_N \quad (8)$$

Table 6. Normal and bending stresses

Angle(°)	Normal Strees (MPa)	Bending Stress (MPa)	Total (MPa)
5	0.07575	60.213	60.289
10	0.15098	58.855	59.006
15	0.22508	56.617	56.843
20	0.29744	53.576	53.874
25	0.36754	49.846	50.214
30	0.43485	45.512	45.946
35	0.49877	40.716	41.214
40	0.55835	35.608	36.166
45	0.61497	30.342	30.957
50	0.66619	25.090	25.757
55	0.71237	19.925	20.637
60	0.75316	15.171	15.925

When we apply a load on the platform, bending moments and axial forces will occur. To find the bending moment, we need to find the flexural sectional modulus. In the equation below:

b = 60 mm (width), h =120 mm (height), t = 5 mm (thickness) where;

$$I_x = \frac{b \cdot h^3 - (b-2t)\cdot(h-2t)^3}{12} = \frac{60 \cdot 120^3 - (60 - 2\cdot 5)(120 - 2 \cdot 5)^3}{12} = 309{,}41 \cdot 10^4 mm^4 \quad (9)$$

$$W_x = \frac{309{,}41 \cdot 10^4}{60} = 51{,}56 \cdot 10^3 mm^3 \quad (10)$$

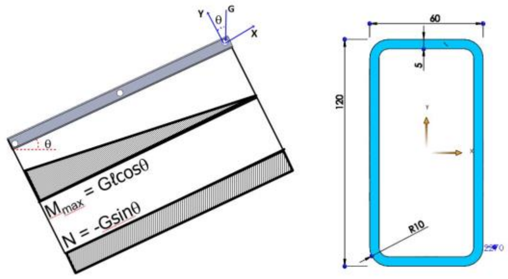

Fig. 8 Cross section of the link

Where the yield limit for structural steel is, according to the standards, σ_y = 315 MPa
According to the scissors standard, a safety factor of 4 has been taken into account.

$$\sigma_{allowable} = \frac{\sigma_Y}{c} = \frac{315}{4} = 78\, MPa. \quad (11)$$

From Table 6 the maximum strength which will occur (at an angle of 5^o) is:

$$\sigma_{total} = \sigma_N + \sigma_B = \frac{N}{A} + \frac{M_{max}}{W_x} = \frac{Gsin\theta}{1700} + \frac{G\ell cos\theta}{51{,}56 \cdot 10^3} = 0{,}07575 + 60{,}213 = 60{,}289\, MPa \quad (12)$$

The condition:

$\sigma_{max} \leq \sigma_{allowable}$ (60,289< 78 MPa) is accepted, so our design is safe. (13)

6. Analysis

The load applied to the platform was determined and the connections were made. Revolute, fixed and translational connection types are used in connection types.

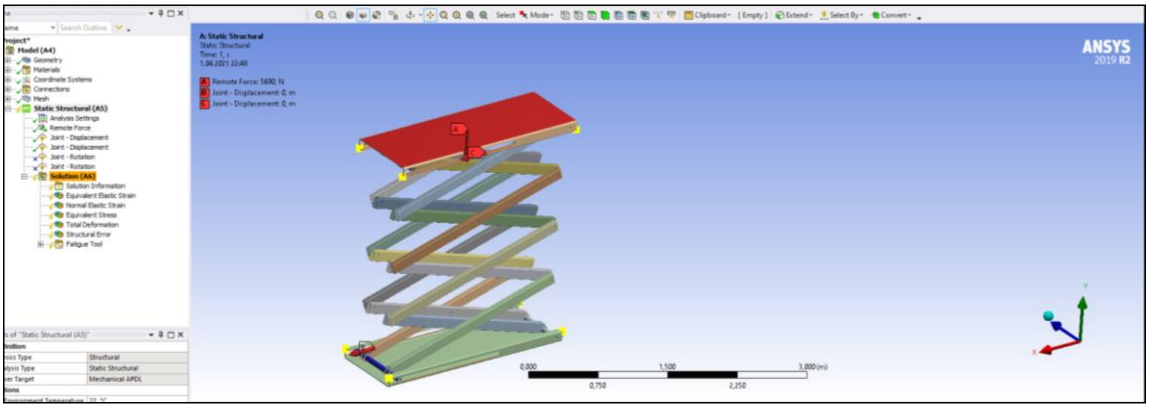

Fig. 5 The load applied to the platform

The mesh was created as in Figure 6. The upper and lower tables were considered as a rigid.

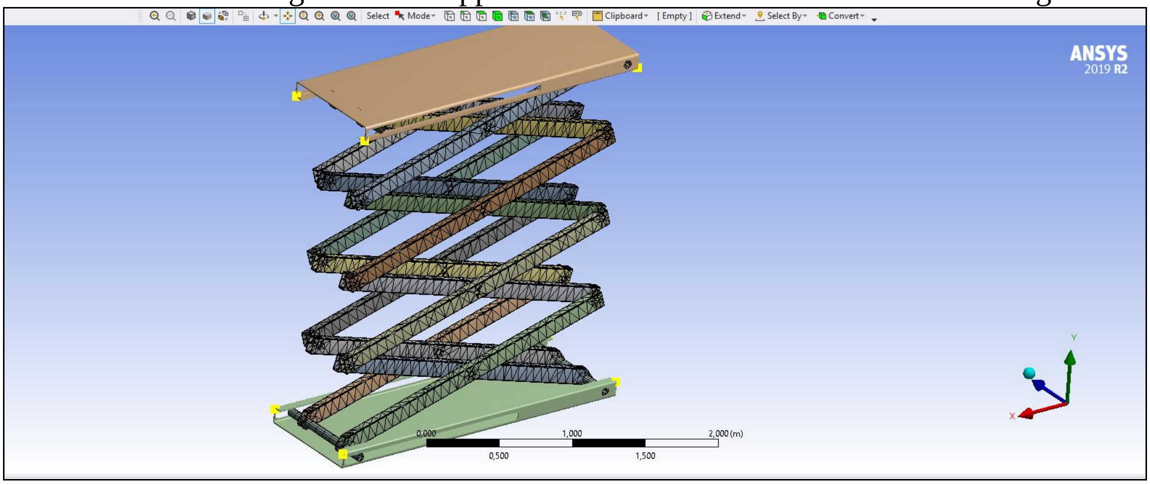

Fig. 6 Meshing of the scissors platform

As a result of the calculations, the total stress value and the value obtained from the numerical analysis are very close.

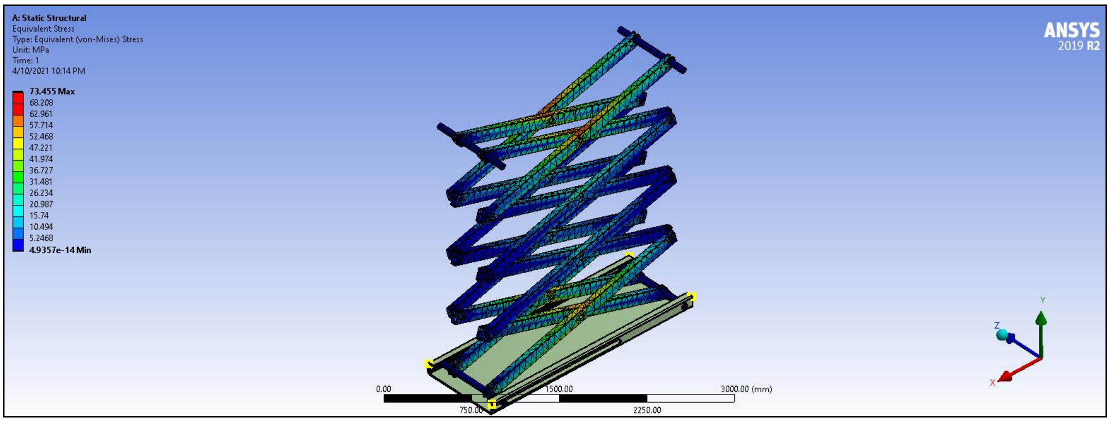

Fig. 7 Equivalent elastic Von-Mises stress analysis

The scissor lift platform was designed and analyzed and Konya Saraylı Eşya and was produced. This company produced for the first time that type of scissor lift platform.

Fig. 8 Finished product images

6. Results and conclusions

It has been seen that the stress values are very close as a result of analytical analysis and numerical analysis. It has an average of 60 MPa. Average safety coefficient was determined as 4 in the most critical places. As a result of tests with different thicknesses, it was decided to use a 120 x 60 x 5 mm profile instead of 120 x 60 x 6 mm. As the company aims to export, the product parts can be disassembled and made detachable. The platform will provide faster and material-oriented service in case of possible malfunction in remote countries. As a result, I believe the scissor lift platform is a new approach to the market, as well as the design's success.

7. References

[1]. Liu, T., Sun, J. 2009. Simulative calculation and optimal design of scissor lifting mechanism. Chinese Control and Decision Conference (CCDC),June, 2009, Guilin, China

[2]. Hongyu, T., Zhang, Z., 2011. Design and simulation based on pro/e for hydraulic lift platform in scissors type. Procedia Engineering, 16(2011): 772-781.

[3]. Islam, M. T., Yin, C., Jian, S., Rolland, L. 2014. Dynamic analysis of scissor lift mechanism through bond graph modeling. International Conference on AIM, 8-11 July,2014, Besançon, France

[4]. Bhatt, J.M., Pandya, M.J. 2013. Design and analysis of an aerial scissor lift. Journal of Information,Knowledge and Research in Mechanical Engineering, 02(02): 452-455.

[5]. Abhinay, M., Rao, P., S. 2014. Design and analysis of an aerial scissor lift. SSRG-IJME

8. Remarks

b = profile width [mm]
c = safety factor
G = weight [N]
FEM = finite elements method
h = profile height [m]
I_x = second moment of area [mm^4]
L = length [m]
M = bending moment [Nm]
m = total mass [kg]
N = normal force [N]
t = profile thickness [mm]
Q = shear force [N]
σ_n = normal stress [MPa]