Research Article

Conceptual Design And Prototype Production Of Innovative Hydraulic Walking Power Steering Controlled Scissor Lift Platform

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Abstract

Nowadays, more than the workforce is needed to transport heavy tonnage loads. So, movable scissors platforms are used when it is desired to transport loads from one location to another and lift them to a certain level. In this study, for the first time, the concept design and prototype production of the new generation scissor lift platform, which has a hydraulically assisted and automation-managed steering control system that will enable loads up to 6 tons of capacity to be transported and delivered to the appropriate height with precise control, has been carried out within Önder Group Inc. Design Center as a domestic product. Within the scope of the study, an automation-controlled hydraulic steering system was developed, unlike the manual steering control system used in equivalent models. This way, easy driving and control of high-tonnage mobile scissor lifts have been achieved. In addition, with the innovative linear bearing hydraulically driven movable upper table design, the materials placed on the table can be moved left and right precisely without moving the platform, thus providing ease of material assembly and time-saving. Within the scope of the study, static strength calculations were made using finite element analysis of the designed system. As a result of the analyses, it was determined that the *stresses occurring in the system under service conditions affect the components homogeneously and that no plastic deformation will occur in the entire system. Thus, the design can be used safely.*

Keywords: Hydraulic Walking, Power Steering Controlled, Scissor Lift Platform, Conceptual Design, Finite Element Analysis

1. Introduction

In the last twenty years, lifting and transport systems have been used in many areas, especially factories with Industry 4.0 applications [1-4]. Scissor lift platforms are the most commonly used among these systems [5-7]. These platforms allow for lifting a load safely and working at heights challenging to reach by human power. Hydraulic systems generally obtain working power in scissor lift platforms. With the piston movement, the profiles connected are opened in the form of scissors, allowing the platform to rise. Each scissor lift has a specific carrying capacity and can reach a certain height [8].
There are many different designs for converting the hydraulic systems that determine the capacity of scissor lifts into mechanical motion [9-11]. One of these designs is mobile scissor lifts. Movable scissors platforms are preferred when it is desired to transport loads from one location to another and lift them to a certain level. For example, especially in the rail system vehicle sector, these mobile scissor platforms provide convenient transportation and assembly of various equipment during the wagon production stage. These mobile scissor lifts are also designed with multiple models, including manual, electric, and hydraulically driven [12-14]. Due to the light load, the steering control used in these models can be done manually. However, in systems weighing four tonnes and above, ease of use is eliminated due to the difficulty of manually controlling the steering. This study carried out the design and prototype production of a six-tonnes capacity hydraulic walking power steering controlled scissor platform. Within the scope of the study, the power steering control and the analog data received from the steering system were compared with the feedback read from the wheel to ensure that the steering wheel positions were in the same direction. This way, ease of steering control is provided regardless of the platforms' weight, and ease of driving control is achieved for the designed mobile scissor lift. As a result of the innovative conceptual design activities carried out in the project, the sectoral needs for heavy tonnage mobile scissor lift platforms were met.

2. Materials and Methods

2.1. Materials

Within the scope of the study, first of all, the design and assembly of the hydraulically driven power steering system, the movable lower table chassis, the scissor system that provides the mobility of the platform, and the hydraulically driven right-left movable upper table chassis were carried out [15]. Scissor sections were manufactured from rectangular section profile using S355J0 (St52-3) steel, the lower table was manufactured from NPU profile using S235JR (St37-2) steel, and the upper table was manufactured from rectangular section profile using S355J0 (St52-3) steel [16]. The chemical compositions of the table and scissors materials used in the study are given in Table 1, and their mechanical properties are in Table 2.

Table 1: Chemical Compositions of Table and Scissors Materials Used in the Study (% Weight) (TS EN 10025-2:2019)

Materials	C	Mn	P	S	N	Si	Cu	Fe
S355J0	≤ 0.22	≤ 1.60	≤ 0.030	≤ 0.030	≤ 0.012	≤ 0.55	≤ 0.55	Bal.
S235JR	≤ 0.20	≤ 1.40	≤ 0.035	≤ 0.035	≤ 0.012		≤ 0.55	Bal.

Table 2: Mechanical Properties of Table and Scissors Materials Used in the Study (TS EN 10025-2:2019)

Materials	Rm (MPa)	ReH (MPa)	KV (J)	A (%)
S355J0	510-680	≥ 355	27	≥ 22
S235JR	360-510	≥ 235	27	≥ 26

Hydro motors provide the forward and backward mobility of the platform. Here, the hydro motor that meets the appropriate torque power was selected based on the calculations considering the platform weight and capacity. Technical details of the selected hydro motor are given in Table 3.

Table 3: Technical Details of the Selected Hydro Motor

Max. Displacement, cm^3/rev [in^3/rev]	724.3 [44.2]
Max. Speed, rpm	775
Max. Torque, daNM [lb.in]	cont.: 130 [11500] int.: 148 [13100]
Max. Output, kW [HP]	40 [54]
Max. Pressure Drop, bar [PSI]	cont.: 200[2900] int.: 240 [3480]
Max. Oil Flow, lpm [GPM]	150 [39.6]
Min. Speed, rpm	5
Permissible Shaft Loads, daN [lbs]	Pa =1000 [2250]
Pressure Fluid	Mineral based- HLP (DIN 51524) or HM (ISO 6743/4)
Temperature Range, °C [°F]	-40/140 [-40/284]
Optimal Viscosity Range, mm^2/s [SUS]	20/75 [98/347]
Filtration	ISO code 20/16 (Min. recommended fluid filtr. of 25 microns)

In the platform's hydraulically driven right-left moving upper sliding table, a linear rail-car bearing system was used, taking into account the platform weight and carrying capacity and ensuring the sliding table's rigid movement. Table 4 gives the technical specifications of this system.

Table 4: Technical Specifications of the Linear Rail-Car System

Height Including Rail, mm	42
Hole Center (WidthxLength), mm	72x52
Overall Length, mm	97.40
Overall Width, mm	90
Carrying Capacity (Static), kN	83.06
Carrying Capacity (Dynamic), kN	38.74
Distance Between Rail-Hole Center, mm	80
Rail Base Width, mm	28

2.2. Mechanical-Automation System Design and Prototype Manufacturing

This study aimed to determine the problems encountered by examining the operation and maintenance requirements of scissor lifts. Selection and solid modeling of the components in the system were carried out in the computer-aided design environment (Solidworks/Part Design). The components resulting from the modeling were combined during the assembly process, and clash analyses were performed with the created mechanisms. The system's mechanical design determined safe working conditions by calculating the hydraulic cylinder, hydro motor, pump, and electric motor power required to carry and lift the six-tonnes capacity load. After the assembly, topology optimizations were carried out to design the system and components with the most appropriate cross-section and strength parameters [17]. Material lists were prepared per the designed system, and parts were produced using traditional manufacturing methods (laser/oxygen/plasma cutting). In addition, sheet metal machining was completed, and component welded manufacturing was carried out.

A power scheme suitable for the calculated engine power was created for the automation control system. Position information is obtained by receiving feedback from the first potentiometer connected to the steering system. Here, the analog information received from the second potentiometer on the hydraulically driven wheel rotation system was compared in the PLC software to ensure that the steering wheel and the wheel were in the same direction. A control circuit diagram suitable for controlling the machine has been drawn. At this stage, panel assembly was carried out using appropriate cabling methods. Appropriate PLC programming was made for the produced panel and integrated into the control system. The mechanical parts of the produced prototype and the automation system used in this prototype are given in Figure 1.

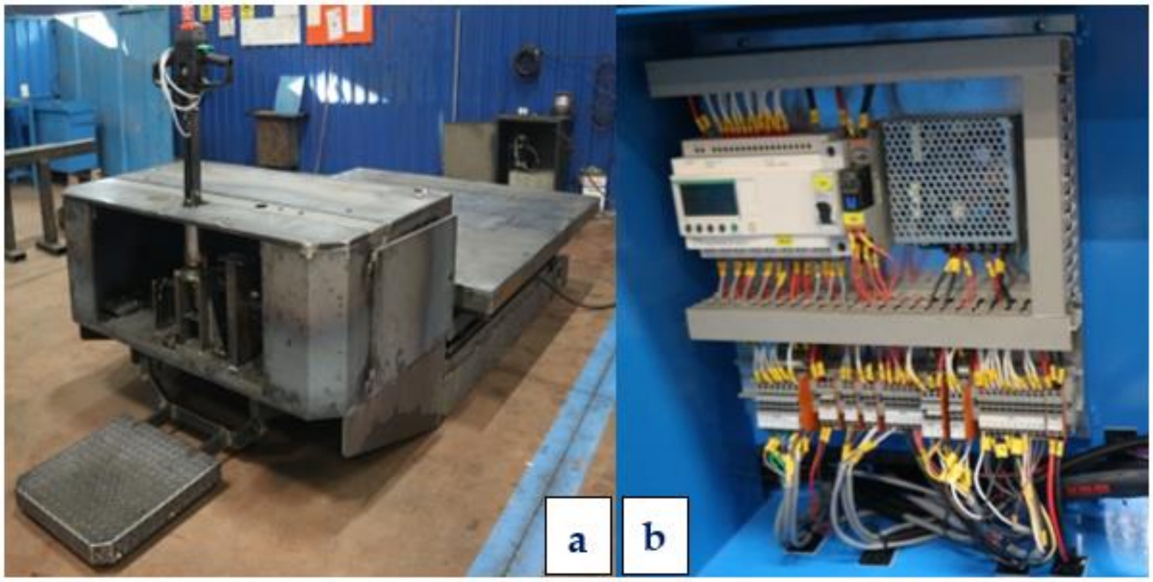

Figure 1: a. Mechanical Parts, b. Automation System of Produced Prototype

2.3. Finite Element Analyzes

Mechanical system analysis, whose solid modeling was created in the SolidWorks environment, was carried out in the SolidWorks Simulation - Static Analysis module [18-20]. Von Mises and deformation analyzes were applied to verify that the developed innovative linear bearing hydraulically driven moving upper table design would operate safely under service conditions. The weight and carrying capacity of the platform were taken into account to ensure the rigid movement of the hydraulically driven right-left moving upper sliding table. In this context, the designed system was evaluated as a rigid structure that connects the contact points of the components.

3. Results

Figure 2 shows the innovatively designed mobile scissor lift's prototype visual and operator stand model. A collapsible operator stand has been built in front of the machine for the ergonomics of operator control and its suitability for comfortable use of the power steering.

Figure 2: a. Prototype Image, b. Operator Stand Model of Mobile Scissor Lift Platform

Figure 3 shows the right and left movement of the upper table. This movement is realized by linear bearing and hydraulic drive.

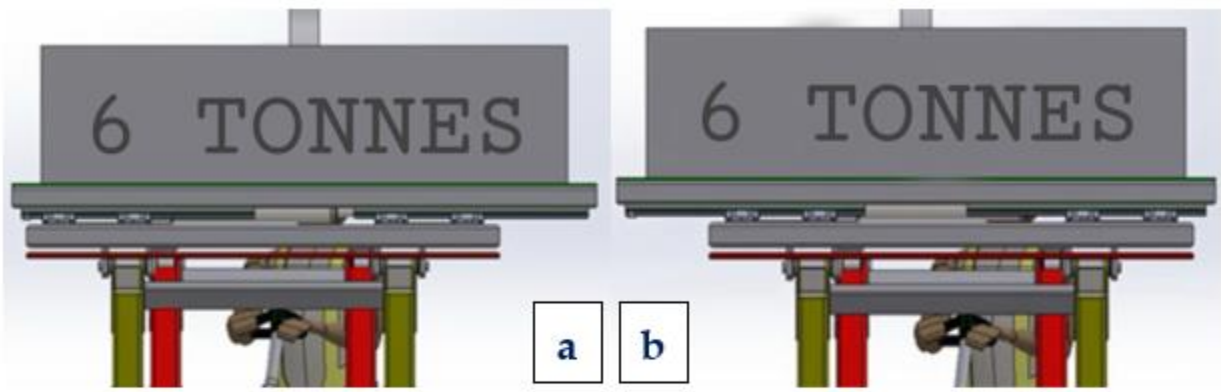

Figure 3: Precision Movement of Upper Table Under Load, a. To the Right, b. To the Left Direction

Figure 4 shows the linear rail–slide system used in table movement. Thus, the materials placed on the upper table are moved to the right and left precisely without moving the platform, thus providing ease of material assembly and saving time.

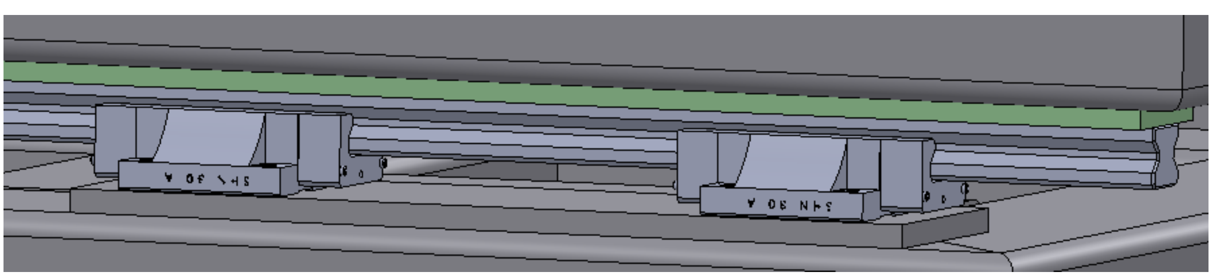

Figure 4: Linear Rail–Slide System Used on the Upper Table

Figure 5 shows the 3D model and visual of the power steering used in the prototype. Within the scope of this study, the analog data received from the power steering control and the steering system was compared with the feedback read from the wheel to ensure that the steering wheel positions were in the same direction. This way, ease of steering control was achieved regardless of the prototype's weight, and ease of driving control was achieved on the mobile scissor lift.

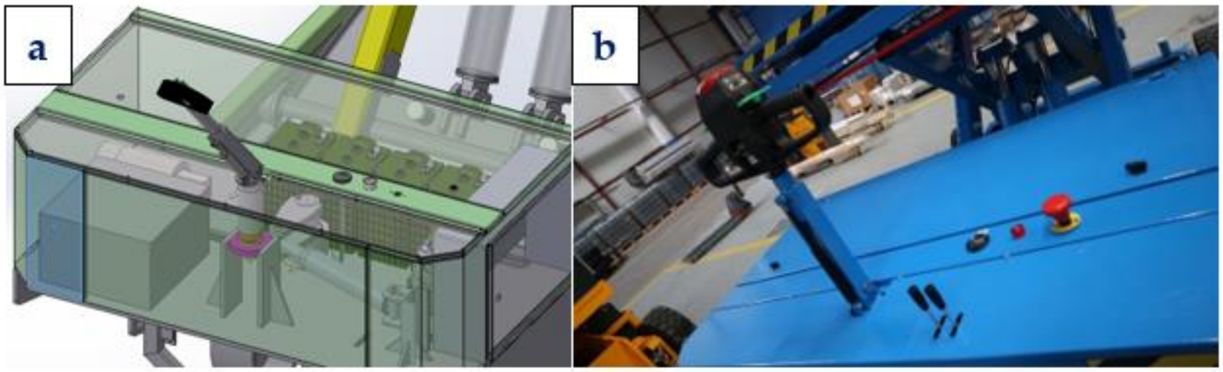

Figure 5: a. 3D Model, b. Image of Power Steering Used in the Prototype

Figure 6 shows the location of the hydro motor system used on the front wheels of the platform on the prototype and the solid model of the hydro motor-wheel connection. With this system used, smooth speed operation is achieved by taking advantage of the incompressibility of hydraulic fluids.

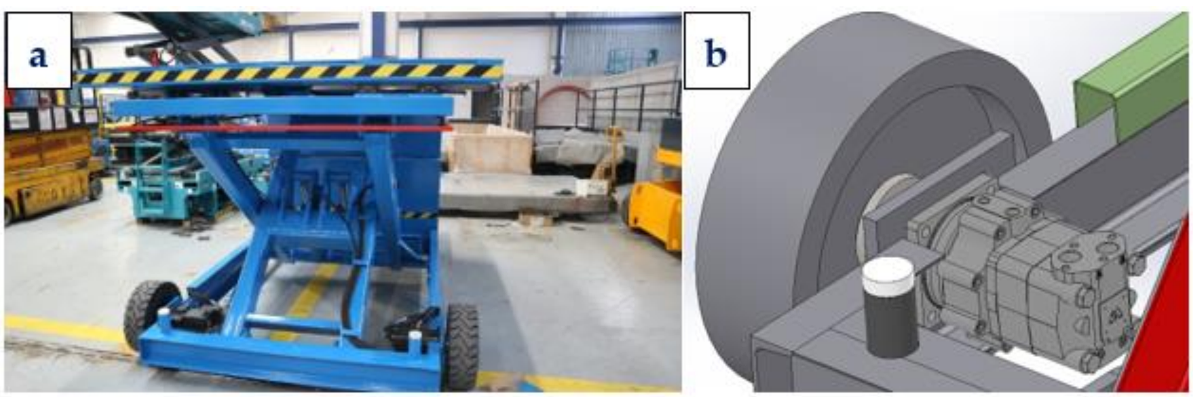

Figure 6: a. Location of the Hydro Motor System on the Prototype, b Hydro Motor-Wheel Connection Model

Von Mises and total deformation analysis results of the sliding upper table are given in Figure 7. Upon reviewing the outcomes of plastic deformation, it was identified that the maximum displacement of 0,161 mm fell within acceptable boundaries. Upon scrutiny of

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stress results, it was observed that an average maximum stress of approximately 87 MPa was evident, significantly below the yield strength of the chosen materials (235 MPa). Consequently, the system has the potential to operate with a safety coefficient of about 2.7, ensuring a lack of plastic deformation under service conditions.

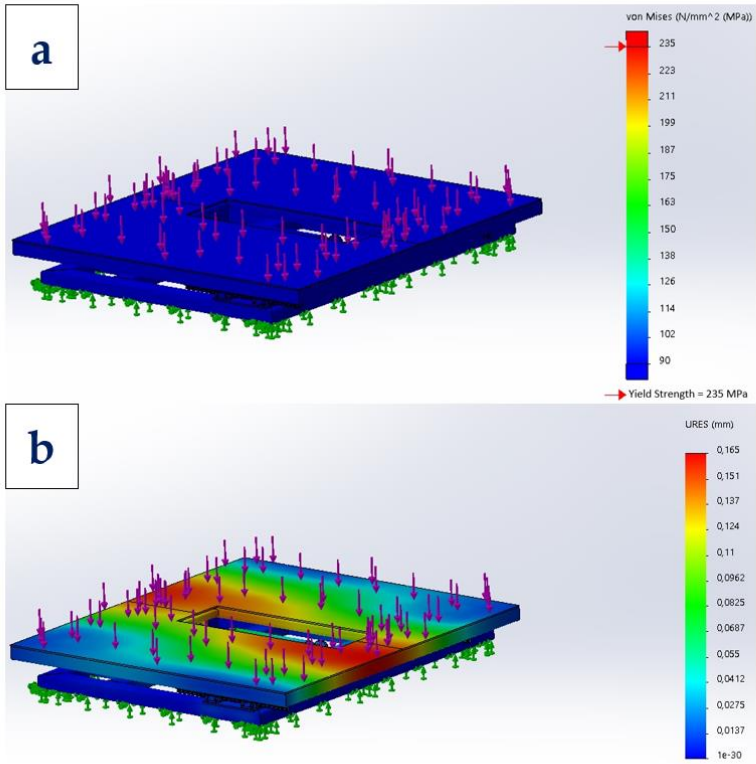

Figure 7: a. Von-Mises Stress, b. Total Deformation Analysis of the Sliding Upper Table

Within the scope of the study, total displacement analysis in the direction of right movement was also examined in order to simulate the service conditions during the right-left movement of the upper table. Figure 8 shows the total deformation analysis result of the sliding top table for the right open position. It was evaluated that the maximum plastic deformation in the table for the determined right open position was 0.183 mm and that this value was quite acceptable for a steel construction.

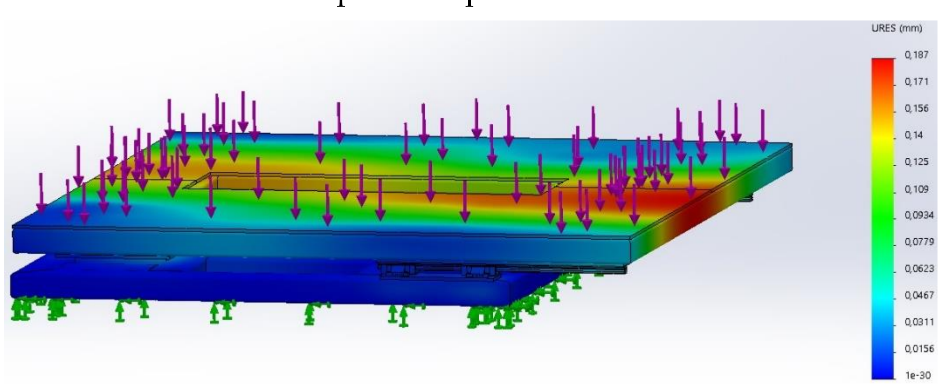

Figure 8: Total Deformation Analysis of the Sliding Upper Table for Right-Open Position

4. Discussion and Conclusion

This study carried out the design and prototype production of a mobile scissor platform with a six-tonnes capacity hydraulic walking steering system. The results of the study are presented below:

- As a result of the study's innovative design activities, the ease of transportation and assembly of various equipment has been provided during the wagon production phase in the rail system vehicles sector. Thus, different usage areas have been created to ship high-tonnage products, and the sectoral needs of heavy-tonnage mobile scissor lift platforms have been met.
- Within the study's scope, thanks to the linear bearing hydraulically driven movable sliding table placed on the upper table, the materials placed on the table can be moved left and right without changing the platform's position. With the new design, the moving parts can be moved precisely. Thus, an effective assembly process is achieved.
- Ergonomic comfort of the operator and ease of machine use are achieved thanks to the design of the opening-closing operator stand in front of the power steering.
- In heavy tonnage systems, controlling the platform with manual steering connections creates difficulty for the operator. With the automation-controlled hydraulic steering system designed within the scope of the study, the steering of the moving scissor lift has been facilitated, and precise position adjustments can be made in the assembly area.
- After the successful production of the prototype as a result of the innovative conceptual design activities carried out within the scope of this study, it was determined that the study has a high potential to create new designs for different sectors.
- The prototype produced with this study was introduced into the product range as an innovative product of the company, especially rail systems, vehicles, etc. National and international customer demands were met in different sectors.

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