Research Article

Design and Prototype Production of Scissor Lift Platform 25 Tons Capacity

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Abstract

In this study, an innovative 25-ton-capacity scissor lift was designed for the first time, and a prototype was produced in Onder Group Inc. Within the scope of the study, a rolling bearing system was designed instead of the conventional welded scissor-hinge connection system. Static and strength calculations were made using finite element analysis for comparison purposes. As a result of the analysis, it was determined that the stress distribution on the roller bearing system was more homogeneous and at lower values (≈60 MPa) than the welded hinge system. In addition, a detachable (bolted) joint was obtained instead of a fixed (welded) joint with the designed rolling bearing system. With the design analyses carried out within the scope of the study, a particular joint-clamp system was made to expand the surface areas of the welded joints.

Keywords: *Scissor Lift, Finite Element Analysis, Stress Distribution, Bearing System, Welded Manufacturing.*

1. Introduction

Scissor lifts are widely used in many areas, such as aviation, automotive, white goods, the defense industry, and construction [1]. Scissor lift platforms are designed to transfer a product, equipment, and components from one level to another in production lines, warehouses, shipping areas, and systems containing assembly lines [2]. Many designs for converting hydraulic systems determine the capacity of scissor lifts for mechanical movement [3]. However, as the payload and cycles increase on existing platforms, the risks of wear problems, oscillations, and damage increase [4]; for this reason, impact movements occur in the take-off and stop of the platforms at increasing capacities [5]. Since the hydraulic pistons are systemically located under the carrier table (inside the machine), maintenance processes become complicated and lengthy [6]. In general, bushings are used for bearing in scissor platforms. Existing systems do not have a compact assembly/disassembly system but usually have monolithic components with welded constructions. Therefore, assembly/disassembly processes are also difficult. The difference in the materials of the scissors in increasing carrying capacities makes the welded joint difficult. Therefore, the welding strengths of the joined parts cannot reach the desired levels. This study has produced innovative solutions in mechanical design parameters to eliminate the problems encountered in general scissor lifts. System rigidity and optimization have been achieved with electronic components.

2. Materials and Methods

2.1. Materials

In this study, the scissor platform consists of three main parts the welded chassis of the lower table, the welded assembly of the scissor system, and the welded chassis of the upper table [7]. The scissor sections were made of 50 mm sheet metal using S355J0 (St52-3) steel, the lower plate is made of NPU profile using S235JR (St37-2) steel, and the upper plate is made of rectangular section profile using S355J0 (St52-3) steel [8].
Instead of the conventional Teflon-coated steel bushing used in the bearing system, a bushing made of CuAl10Ni5Fe4 aluminum bronze was used. The chemical compositions of the table, scissors, and bushing materials used in the study are given in Table 1, and their mechanical properties are in Table 2.

Table 1 Chemical Compositions of the Table, Scissors, and Bushing Materials Used in the Study (% wt.) [9, 10]

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.

Materials	Ni	Mn	Al	Fe	Cu
CuAl10Ni5Fe4	4.00-6.00	≤ 1.50	8.50-11.00	2.00-5.00	Bal.

Table 2 Mechanical Properties of the Table, Scissors, and Bushing Materials Used in the Study [9, 10]

Materials	Rm (MPa)	ReH (MPa)	KV (J)	A (%)
S355J0	510-680	≥ 355	27	≥ 22
S235JR	360-510	≥ 235	27	≥ 26
Materials	Rm (MPa)	Rp0,2 (MPa)	Hardness (HB)	A5 (%)
CuAl10Ni5Fe4	≥ 640	≥ 270	≥ 190	≥ 15

2.2. Mechanical-Automation System Design and Prototype Manufacturing

In this study, first of all, scissor lifts' working and service conditions were investigated, and the problems encountered were determined. The selection and solid modelling of the components that make up the system were carried out in the computer-aided design environment (Solidworks/Part Design). The modelled components were combined in the assembly environment, and the mechanism and clash analyses of the assembled components were performed. After the assembly process, the topology optimizations of the system and components were performed, and the design with the most appropriate cross-section-strength parameters was simulated [11]. Material lists were created according to the designed system, and parts were processed with the laser/oxygen/plasma cutting method. Machining of sheet metals was carried out. Then welded joints of the parts were made. Unlike the existing designs, instead of bushings, a rolling bearing system is designed as a bearing system. Different from standard bearings, a new bearing system has been developed. A particular mounting system has been designed to increase the welding surface area at the junction points of the shears. In addition, aluminum-bronze material bushings were designed instead of classical Teflon steel bushings in the junction details of the scissors, thus minimizing the wear caused by the working frequency. A guiding system has been designed to reduce the oscillations of the upper table in the x-y directions. In order to prevent sudden movement transitions and jolts during starts and stops, a frequency inverter device that enables the motor to run ramped has been integrated into the system.

2.3. Finite Element Analyses

Stress and kinematic analyses were performed using Static Structural and Rigid Dynamics in the mechanical system Ansys Workbench finite element software, the solid modelling of which was created in the SolidWorks [12].

3. Results and Discussion

Figure 1 shows the three-dimensional solid model of the innovative scissor lift platform and the conventional welded hinge-scissor and rolling-bearing solid models. In Figure 2, the product image of the prototype with the roller bearing-scissor system is given. In general, innovative design activities have achieved a significant improvement regarding the size/carrying capacity ratio. Thus, it has been possible to use it in narrower working areas than its counterparts [8]. As seen in Figure 2, a detachable (bolted) connection, which can be assembled and disassembled, provides ease of use and maintenance compared to traditional welded joints (fixed) with the roller bearing system. However, an increase in cycle times and an improvement in wear performance have been observed in practice.

Figure 1: a) Innovative Scissor Lift Platform 3D Solid Model, b) Conventional Welded Hinge-Scissor Model, c) Innovative Bearing Hinge-Scissor Model

Figure 2: Prototype with Innovative Bearing Hinge-Scissor System

Figure 3 shows the total deformation, Von-Mises stress analyses of the scissor platform, and the stresses acting on the bearing ear. The entire configuration of the platform truss is not considered a mechanism but a rigid structure in which the components at the contact points are related links [13]. The minimum yield stress value (235 MPa) of the structural material used as the maximum limit to define the stress state of the platform was taken. As can be seen, with the design innovations carried out, homogeneity has been achieved in the load distributions affecting the components and the whole of the scissor lift platform, and a reduction in the loads acting on the bearing hinge component has been achieved. The results obtained with the FEM analysis showed that the stress does not always occur in the same place, and the stress distribution changes according to the position of the scissors [14]. The FEM results confirmed that the maximum stress value did not exceed the yield stress value.

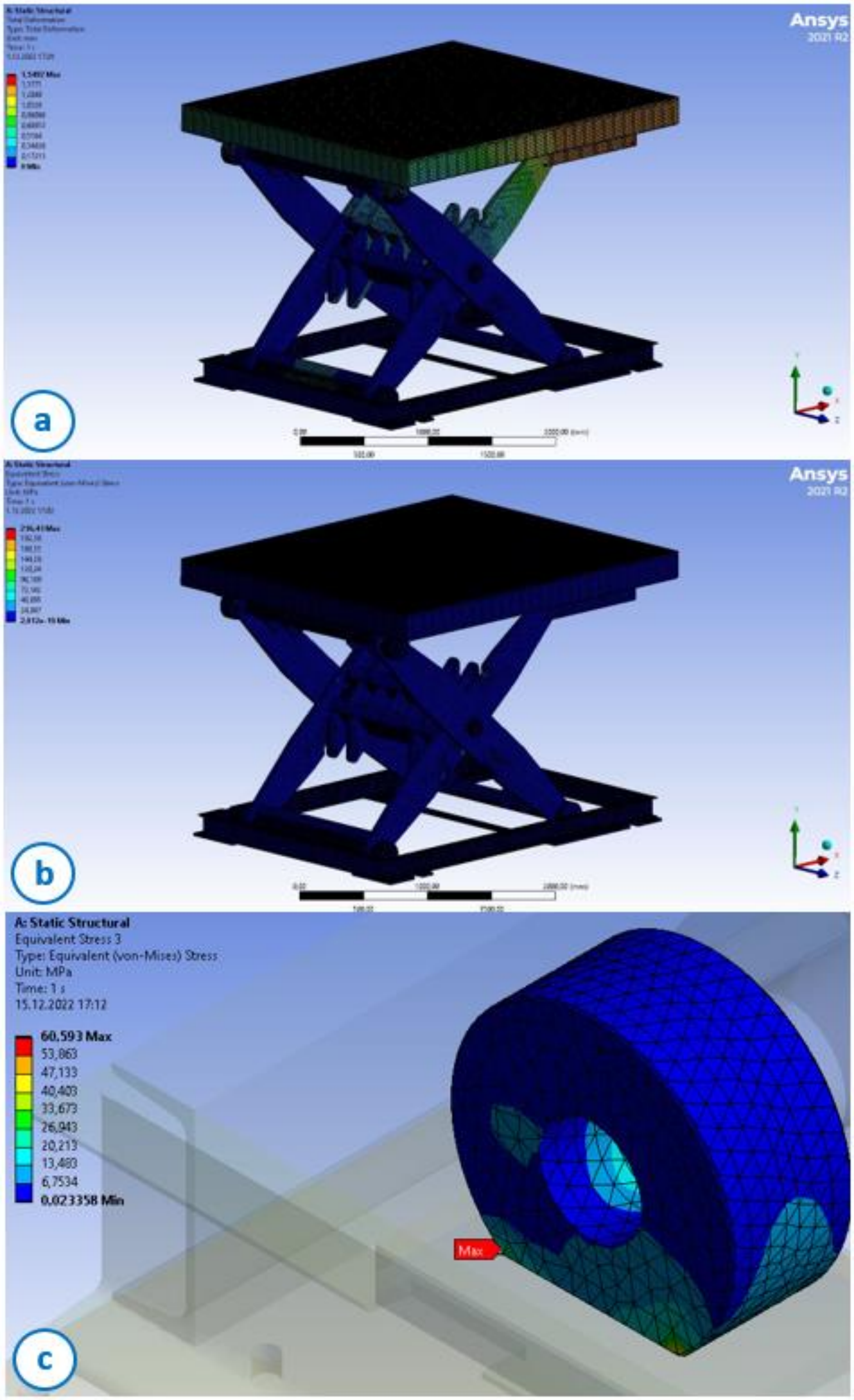

Figure 3: a) Total Deformation Analysis of Scissor Lift Platform, b) Von-Mises Stress Analysis of Scissor Lift Platform, c) Von-Mises Stress Analysis of Bearing Hinge System

In Figure 4, models of the innovative connection assembly clamping system and aluminum bronze bushing bearing assembly and guiding system are given. In Figure 5, these systems are shown on the prototype. Thanks to the design of the hydraulic cylinder connection assembly with a scissor-shaped clamping system, the welding surface area has been increased at the joint points of the scissors. Thus, by increasing the weld strength, damages (tears) in the weld area are prevented in practice [15].

Using aluminum bronze bushings instead of conventional Teflon steel bushings in the bearing of the central components of the scissors, the wear caused by the operating frequency was minimized [16]. With the guiding system designed using aluminum bronze, the oscillations of the upper table in the x-y directions and the platform's oscillations in the whole system are reduced [17].

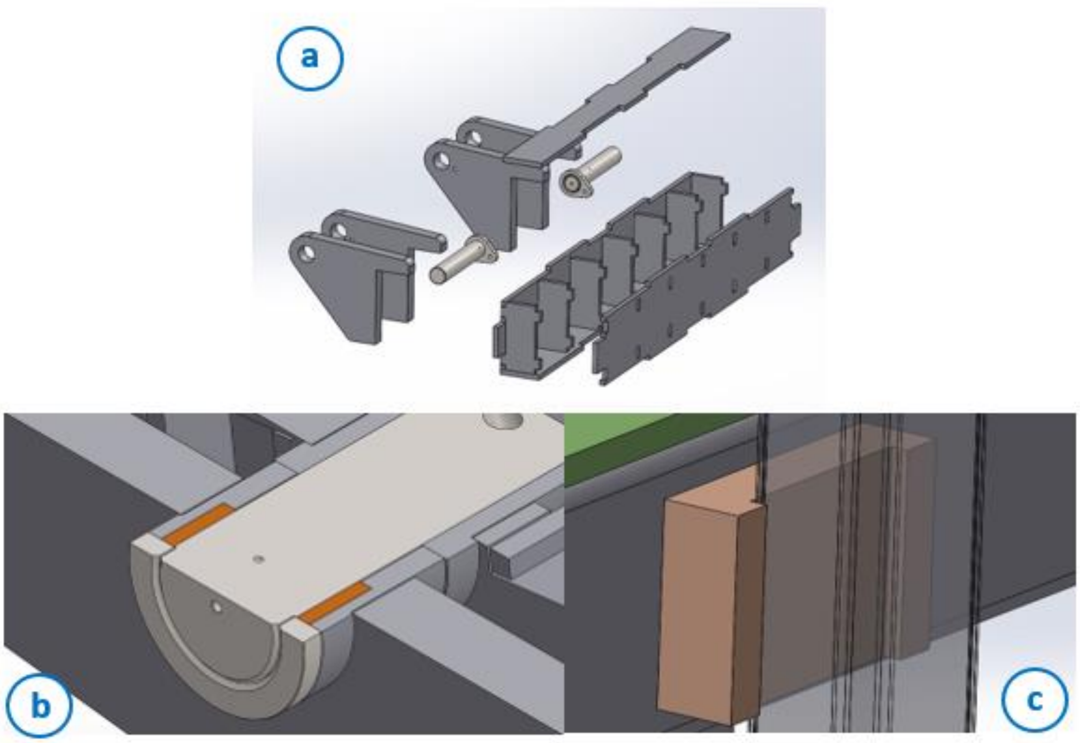

Figure 4: Solid Models of a) Innovative Connection Assembly Clamp System b) Aluminum Bronze Bushing Bearing Assembly c) Aluminum Bronze Guiding System

Figure 5: Prototype with Innovative Clamp, Bushing Bearing and Guiding System

Figure 6 shows the solid model of the innovative eyebolts design. Figure 7 shows the image of the upper table with eyebolts on the prototype. With the innovative eyebolt design, the movement of the platform from the upper table is ensured, thus providing ease of transportation, especially in installations under the working floor (lift shaft) and in maintenance processes [18].

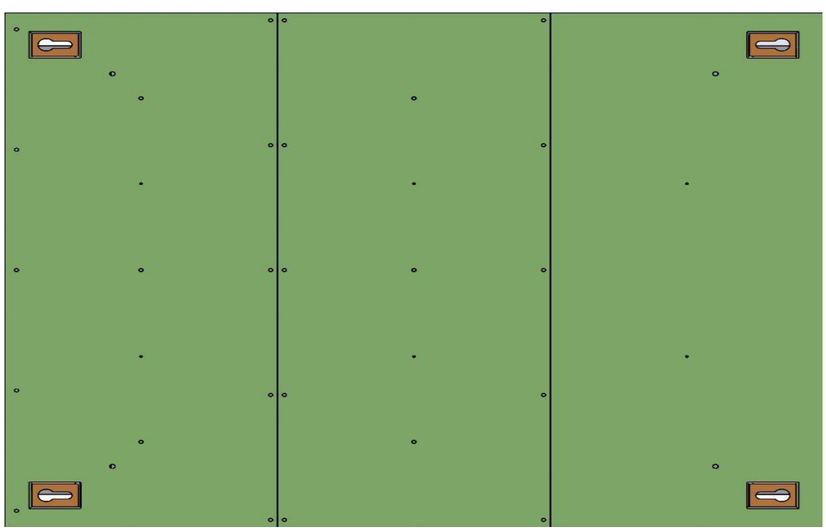

Figure 6: Model of Innovative Eyebolts Design

Figure 7: Appearance of Eyebolts Design on Prototype

Another innovation designed within the scope of the study is integrating a frequency inverter device into the system. Sudden movements in the scissor structure and platform in the longitudinal (Y) and lateral (X) directions become irregular, especially as the height of the platform increases. In this case, irregularities can significantly affect the scissor lift's centre of gravity position and stability. If the loads on the platform move periodically (such as the shaking of molten metal in the transported casting ladles) or regularly apply a significant force in the horizontal plane, the resonance of the platform can be stimulated. So, it may be one of the mechanisms or contributing factors of platform tipping [19]. In the study, to minimize these risks, the rigidity of the platform against sudden movement transitions and jolts was increased with the frequency inverter device added to the system, and the ramped operation of the motor was ensured [20]. Thus, new advantages have been obtained from using the inverter in hydrostatic systems, such as increasing efficiency, controlling acceleration, and improving operational safety [21]. In Figure 8, frequency-time graphs of non-inverter and inverter electric motors are given comparatively.

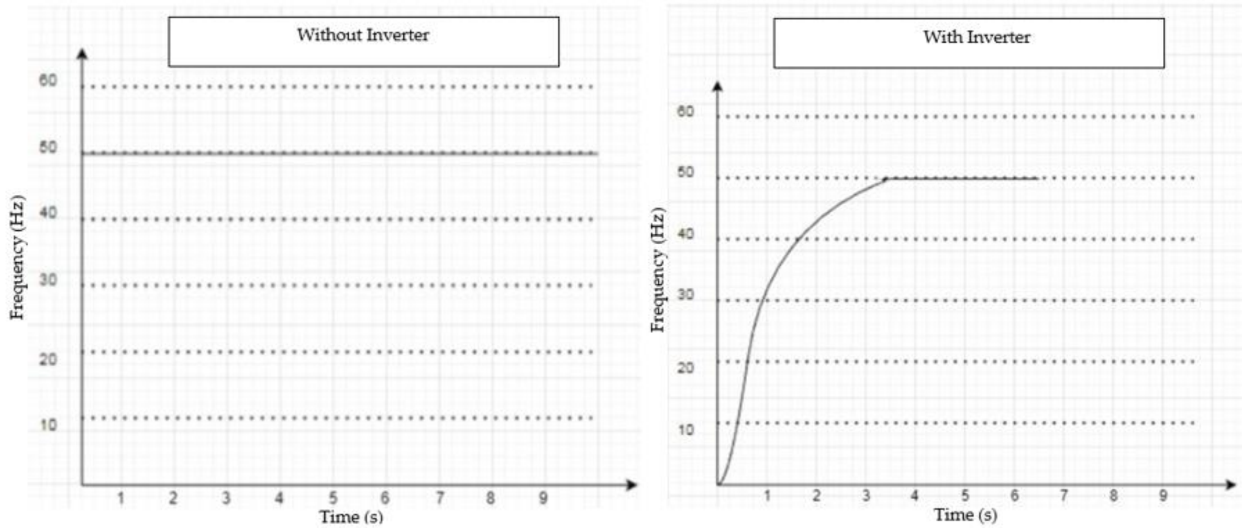

Figure 8: Frequency-Time Graph of Electric Motor a) Without Inverter, b) With Inverter

4. Conclusions

In this study, an innovative scissor lift platform with a capacity of 25 tons was designed, and a prototype was produced. The results of the study are presented below:

• As a result of the innovative design activities carried out in the project, vibration-free transportation of high-tonnage molten metal was ensured, especially in industrial areas for heavy industry such as the casting sector. Thus, different usage areas were created to ship high-tonnage products.

• Especially the platform, which is mounted under the working floor (in a pit), has made it more accessible to perform maintenance operations.

• An increase in periodical maintenance times has been achieved thanks to the bearing system design. However, by increasing the number of cycles, service life has been improved.

• Thanks to the bolted joint design used in the different connection parts of the scissor platform system, the assembly/disassembly of the platform is carried out in a short time.

• As a result of the innovative design activities carried out, the carrying capacity of the platform has increased. Thus, developing new projects to design platforms with higher carrying capacity was possible.

• At the end of the study, it was included in the product range as an innovative product of the enterprise, and especially international customer demands were met.

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