DESIGN OF DRIVING SYSTEM FOR SCISSOR LIFTING MECHANISM

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ABSTRACT: This article describes structural design of manipulation equipment designed for swapping battery system. Battery charging is more time consuming compared to filling a gas tank. One solution is a battery swapping. The main drawback of this solution is a handling problem with heavy accumulator blocks.

KEY WORDS: swapping battery, manipulation equipment, lifting equipment

1 INTRODUCTION

The electric vehicles had made great progress within the last ten years. Under the term electric vehicle we know any transport device that uses electric motor. They are propelled by one or more electric motors and require a continuous supply of electricity. Power source is the biggest problem. Traction line is costly and restrictive. Batteries are a low power and are large and heavy. Therefore the vehicle has a short driving range. Version with battery pack needs to restore electric power source. The battery charging is more time consuming compared to filling a gas tank. Frequent rapid-charging also reduces the battery life and capacity. One solution is a battery swapping system.

Our department cooperates with the company KOVALSYSTEMS, Ltd. to develop an automatic battery swapping station. This station is intended for commercial vehicles of company Greenway. Nowadays the process of batteries' changing is carried out by a forklift and a human operator (fig.1). Our innovation is based on replacement of the forklift by special automatic manipulator.

Figure 1. The current status of the charging station [6]

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This mechanism will work with battery blocks that weight 1000 kilograms. Required total time for whole operation is less than 3 minutes.

2 LIFT MECHANISM

A scissor lift relies upon the elongation of a collapsible mechanism to provide vertical elevation in ratio to a rotational or linear input.

These devices are widely utilized and are capable of lifting significant loads safely and efficiently. Scissor lifts owe their mechanical capability to the pantograph. A pantograph is a series of linked parallelograms with hinged intersections that allow the operator to elongate the mechanism while maintaining the integrity of the geometric figure. The structural components of the pantograph serve as opposing line segments within adjacent parallelograms. Geometric changes are therefore uniform across the mechanism.

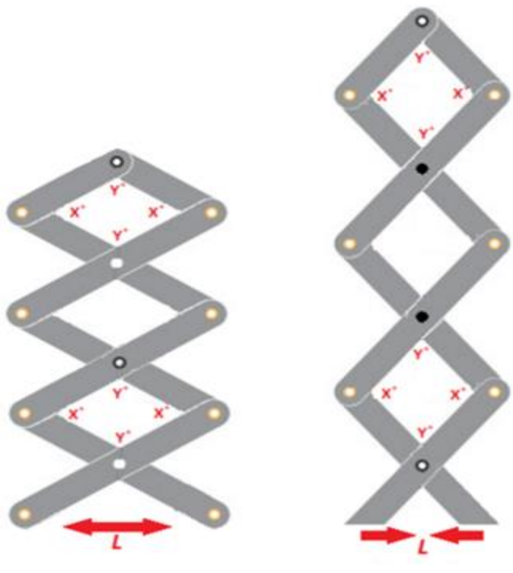

Figure 2. Schematic diagram of scissor lift [1].

True vertical lift is accomplished by using components of equal length. As L (the length of the base) increases, the pantograph contracts, and X deceases while Y increases. As L decreases, the pantograph extends, and X increases in contrast to Y (fig.2). [1]

They can be made of different materials [19] and by different processes hydroforming [12], bending [13], milling [11],[14] orbital deformation [17][18].

3 DRIVING SYSTEM FOR SCISSOR LIFTING MECHANISM

Extension is achieved by applying pressure to the outside of a set of supports located at one end of the mechanism, elongating the crossing pattern. This can be achieved through hydraulic, pneumatic, electro-mechanical or simply muscular means. Pure linear electric motors are improper shape and size. It is problem by construct plan. Drive system of the lifting scissor mechanism consists of an electromechanical system, which contains electric motor and linear power transmission unit in the form of a screw mechanism. [5]

At the beginning it was necessary to define the basic requirements on the lift mechanism. We will calculate with maximum load mass, which is approximately 1400kg. Whole mechanical structure will be oversized 40% with respect to safety. Lift height will be at least 1800mm. The time necessary for load lifting from minimal to maximal height will be about 15-20sec.

We used software Autodesk Inventor for dynamic simulations of lifting. One of important output parameters is driving force. This force is then used in the formula (1). The resulting values were used in the selection of a suitable electric motor.

Torque:

$$M_K = F_Q . \frac{d_2}{2} . tg(\Upsilon . \varphi') \qquad (1)$$

M_k - torque (Nm),

F_0 - axial force (N),

γ - lead angle of thread (^{0}),

φ' - angle of friction

Lead angle of thread:

$$\gamma = arctg\left(\frac{s}{\pi \cdot d_2}\right) \qquad (2)$$

s – thread pitch

3.1.Variant 1

There were designed 3 main conceptions. The difference between them lies mainly in location of linear motor and the type of constrains between the elements.

The first version has an electric motor located horizontally at the bottom base and it is connected between two main shafts of the bottom arms (fig 3). The orientation of this motor doesn’t change during the lifting process. Both arms are connected to the frame by sliding units.

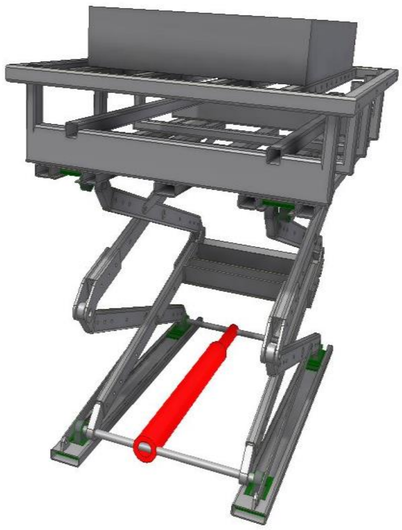

Figure 3. Design of Variant 1.

From the simulation results we can see the necessary driving force in the process lifting. When scissor mechanism is at maximum load, the required driving force is about 280 000N (fig.4).

Requirements for the electro-mechanical driving unit:

torque - 240Nm;
rotational speed (15sec) - 288Rpm.

Suitable electro-mechanical driving unit made by company Nord:

- SK32100-132SH / 4: power 5,5kw
torque 238Nm;
rotational speed 203Rpm.

Total lifting time is 21 seconds.

- SK93672.1-132SH / 4: power 5,5kw
torque 240Nm;
rotational speed 218Rpm.

Total lifting time is 20 seconds.

These engines are large, and the location of the engine influences the design of the scissor mechanism. The problem occurs in the transmission of the forces. The mechanism must be symmetrically loaded and two sliding elements should move equally. Otherwise, blocking may occur.

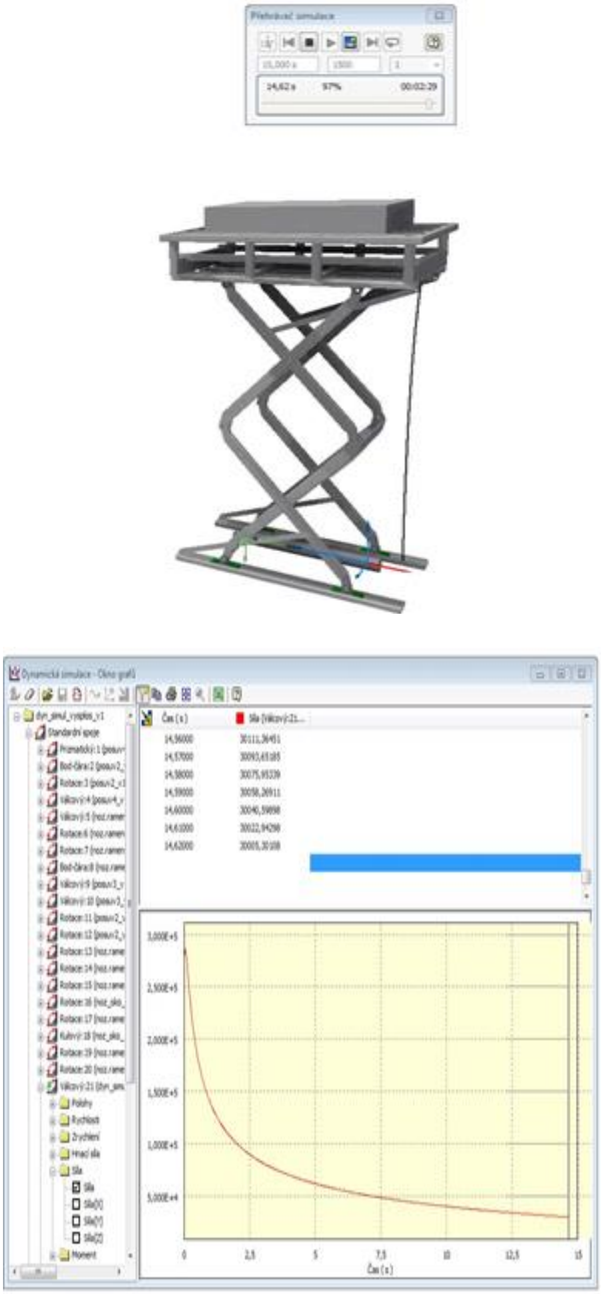

Figure 4. Dynamic simulation design of scissor mechanism (variant 1).

When force effect is asymmetric, rotational speed is only 144Rpm, but the driving force must be very high. The comparison between symmetric and asymmetric force effect we can see in figure 5.

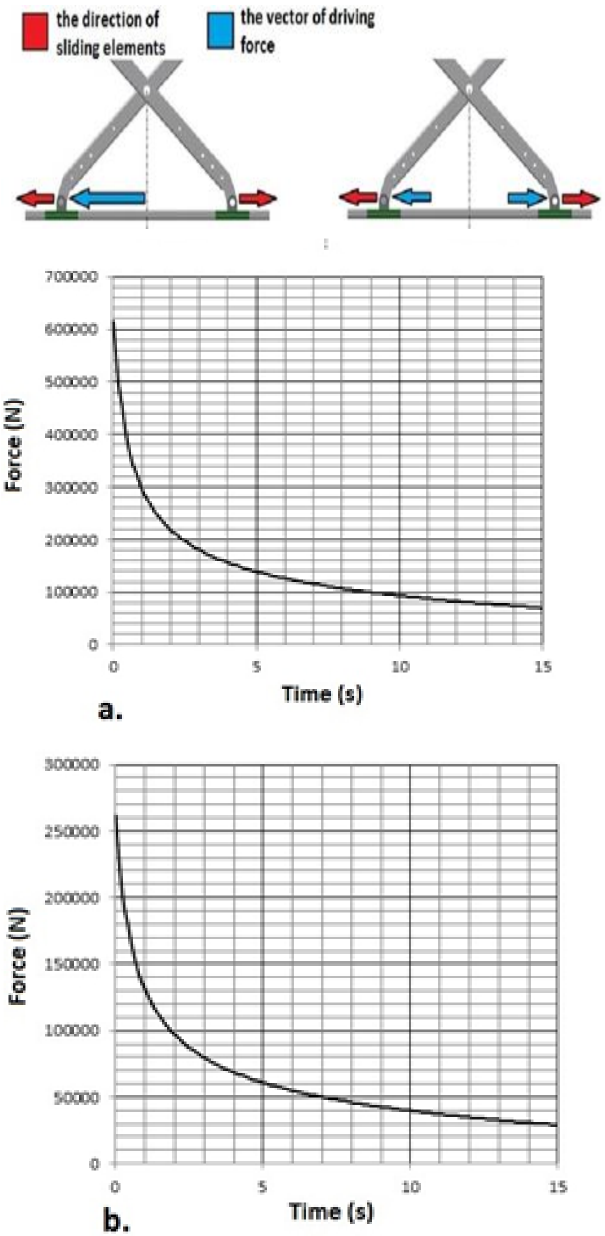

Figure 5. Comparison of asymmetric force effect (a) and symmetric force effect (b).

3.2.Variant 2

By the second version we considered the most frequent location of the power unit, inside of the scissor mechanism. It is generally connected diagonal between bottom shaft and the shaft in the middle of scissor arms. The plane of attachment of the power unit is variable depending on the position of the lifting mechanism (fig 6).

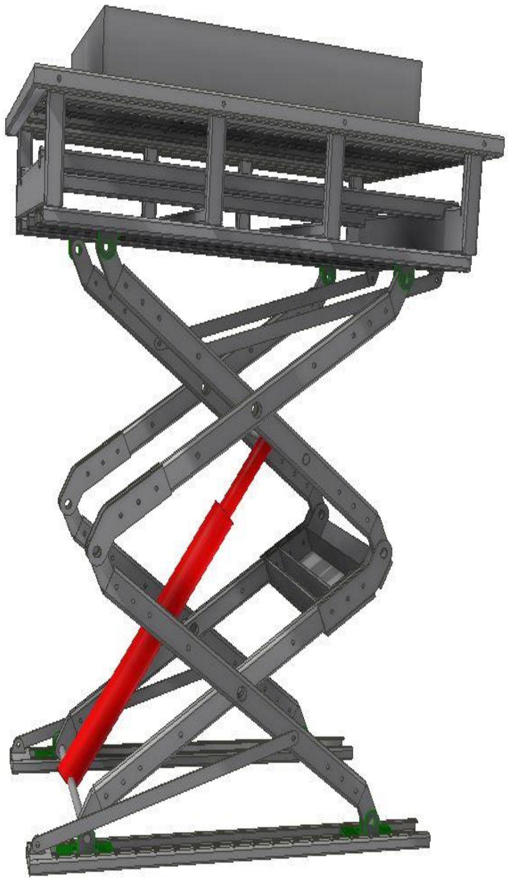

Figure 6. Design of Variant 2.

From the simulation results we can get the value of necessary driving force in the lifting process. When scissor mechanism is at maximum load, the required driving force is about 185 000N (fig. 7).

Requirements for the electro-mechanical driving unit:

torque - 180Nm;

rotational speed (15sec) - 365Rpm;

Suitable electro-mechanical driving unit made by company Nord:

- SK92772.1-132S/4: power 5,5kw

torque 186Nm;

rotational speed 282Rpm;

Total lifting time is 19 seconds.

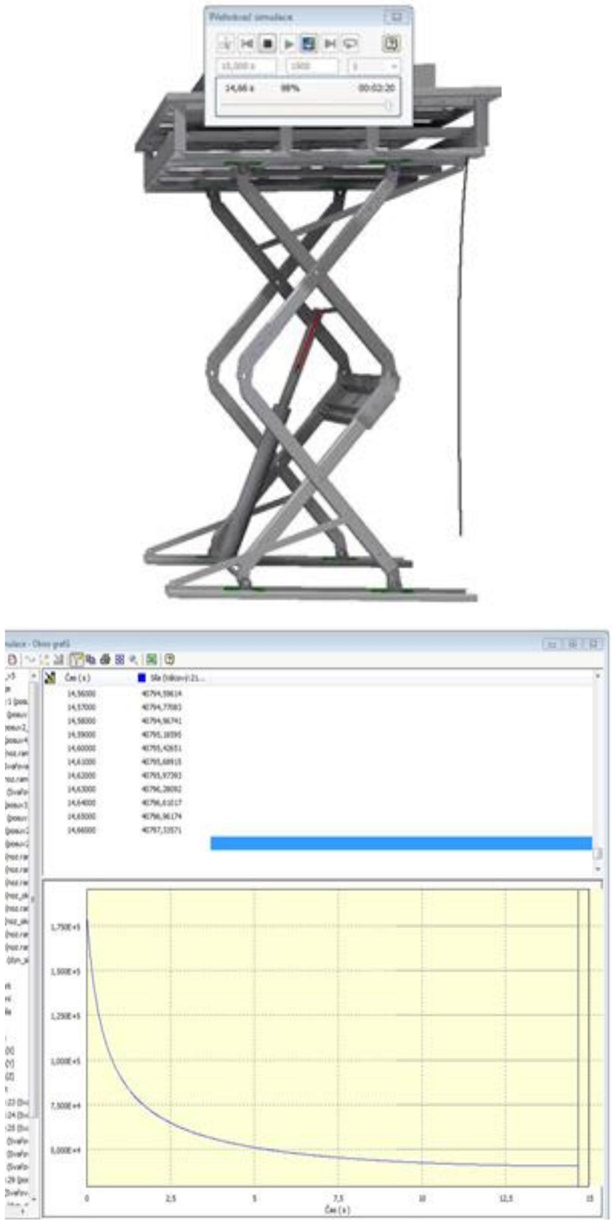

Figure 7. Dynamic simulation design of scissor mechanism (variant 2).

By the variant 2 the torque can be reduced and it is smaller than by the variant 1. Its value dropped from 238Nm to 186Nm. One the other hand the rotational speed will increase from 203Rpm to 282Rpm.

Suitable electric motors are quite large and the location is problematic. In practice are used mainly hydraulic cylinders due to high generated forces. Their location has a great effect on the design of the lifting mechanism. The driving motor is placed in the interior of the scissor system. The problem of this variant are space limits.

3.3.Variant 3

Variant 3 is structurally the most difficult. It includes auxiliary arms, which are connected to the ball screw. They transmit acting force to the sliding elements (fig. 8).

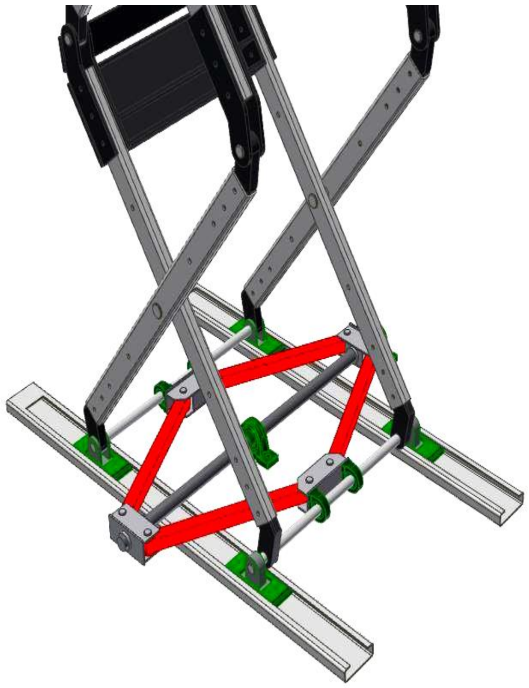

Figure 8. Design of Variant 3.

From the simulation results we can see the necessary driving force in the process lifting. When scissor mechanism is at maximum load, the required driving force is of about 280 000N (fig.9).

Requirements for the electro-mechanical driving unit:

torque - 180Nm;
rotational speed (15sec) - 260Rpm;

Suitable electro-mechanical driving unit made by company Nord:

- SK92772.1-112MH/4: power 4kw
torque 190Nm;
rotational speed 201Rpm;

Total lifting time is 20 seconds.

- SK92772.1-132SH/4: power 5,5kw
torque 184Nm;
rotational speed 285Rpm;

Total lifting time is 14 seconds.

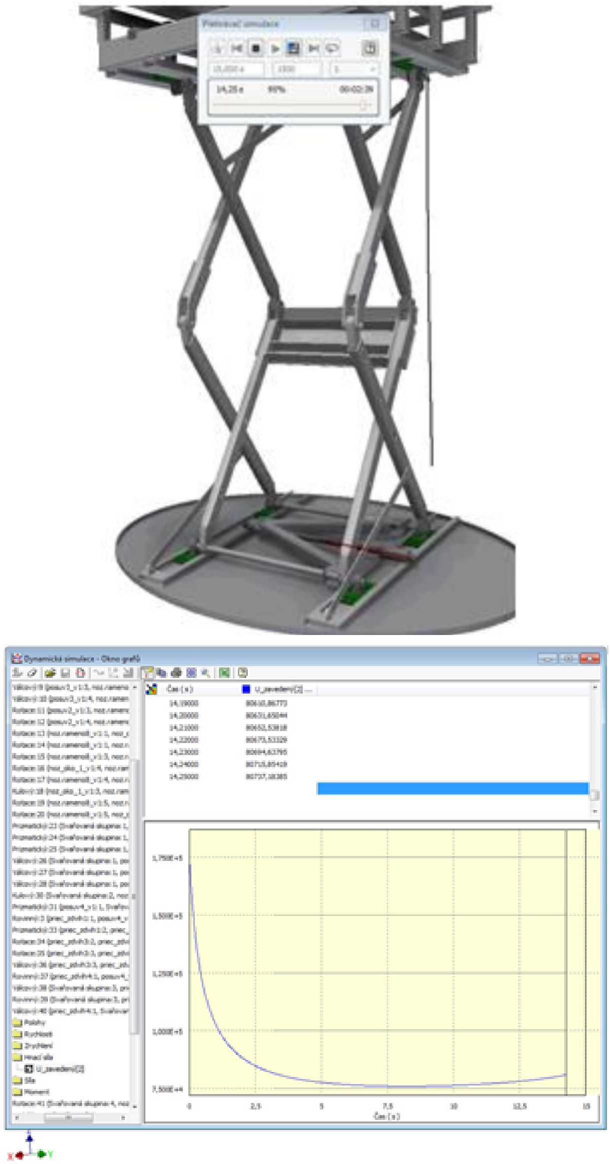

Figure 9. Dynamic simulation design of scissor mechanism (variant 3).

Engines are again relatively large and heavy. But it is not so important, because motors are not inside the scissor construction. They are located horizontally at the bottom base.

4. CONCLUSION

Nowadays the number of electric vehicles continuously grows. Their use is versatile, from industry to civilian use. The largest problem is with the power supply. This caused the short range as well. Therefore it is important to find way how to recovery the energy source. Battery charging is still quite long process. Battery swapping system is only a temporary solution, but it is currently the fastest one. As one is able to compete with fossil fuels.

Therefore we decided to further research on this system in cooperation of the company Kovalsystems.

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