"DOUBLE DRIVE" ELEVATOR SYSTEM AND "GIGALIFT" ELEVATOR

Özgür Mert, Yücel Kuloğlu, Adem Çağlar, İlhan Yeter, Serdar Tavaslıoğlu

www.yeterlift.com, www.serdartavaslioglu.com

ABSTRACT

Drive systems of service lifts featuring high rated load or of high speed elevators require over-costing solutions due to the occurring considerable forces. High rated loads are resolved with hydraulic elevators while high speed elevators are resolved to large capacity motors in general. These kinds of solutions cause higher costs in comparison to normal elevators as one might expect. "Double Drive" system brings a solution offer to such problems. It increases drive force without causing increase in cost with double motor run in synchronism, instead of one motor. It redoubles or triples the suspension capability of the elevator through using the pulley of both motors as drive pulley by means of double wrap. It provides a significant improvement in cost when compared to its equivalents.

1. INTRODUCTION

Setting up high rated load elevators or suspending high speed elevators has brought along several problems. We can explain some of the reasons as follows: The first reason is the increase of motor kW value as a result of increase in torque towards elevator drive machine pulley. The increase of motor kW value and the control of the motor effects the costs exponentially when it exceeds a certain value. In order to overcome idleness of the system in high speed elevators during start and stop as well as avoiding rope slipping, suspension between the rope and pulley should be ensured in a more solid way. Moreover, rope pulley pressure caused by the ropes increases as a result of rise in the rated load. Thus, it requires to enhance contact surface between rope and pulley. Due to these reasons, it is needed to increase pulley diameters or number of ropes unduly to decrease pulley surface pressure and to ensure suspension capability in high rated loads. It is even necessary to maximize drive pulley in double wrap implementations while these push up the cost extremely.

A solution to this problem is considered as making hydraulic elevator for high rated loads. However, direct driving systems are used for high rated loads in order that certain numbers of ropes can be used and due to the difficulty in ensuring rope safety number, even though double piston is used in hydraulic elevators. This provides limited solutions as the speed can be very low and running range can be short. Moreover, substantial amount of oil usage occurs as another problem due to the large piston diameters used. When the load gets higher and running range increases, costs pushes up more than enough since the sizes of used materials expands beyond measure and the amount of oil reaches to a large scale.

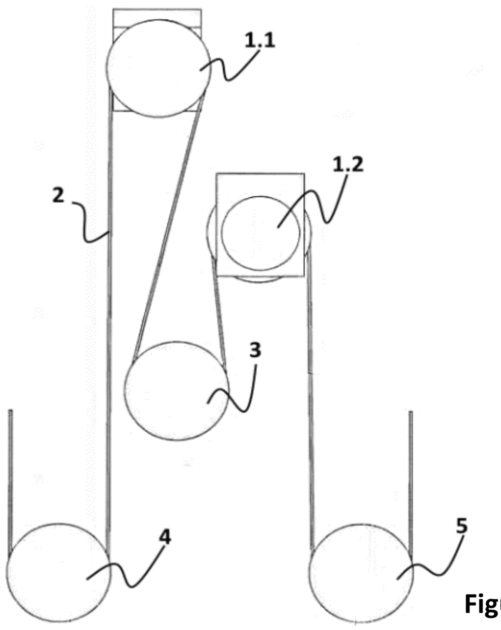
Currently the maximum capacity in medium type synchronous motors for 2:1 is around 6613 lbs, which are used for implementations in the well (MRL). This limits the capacity with maximum 13,227 lbs even a 4:1 rate is used. Since the synchronous machine with rated load above these cannot be used as MRL elevator, either motors with large machines or hydraulic elevators are demanded. A little increase in running rage also brings along many different problems.

When all of these problems were taken into consideration, it was sought to offer a new solution. The developed system was called “Double Drive”. In this system, motor pairs were used as elevator drive group. By using double motor instead of one, higher drive capability was achieved with lower cost. Rope pressures were remarkable lowered by using 4:1, 6:1 and 8:1 systems in elevators and dispatching the pressures towards two motor pulleys while the opportunity of using ropes with less numbers and lower scales and motor pulleys in lower sizes were obtained. Ability to increase rolling angle between 420^0-540^0 also raises the drive capability very much while eliminating the possible rope slipping in high velocities, impact loadings or abrupt halts.

Using synchronous motors with a capacity of 6613 lbs in 2:1 with a speed of 1.6 m/s, it can be possible to make MRL elevators in long running ranges and relatively faster which feature:
11.000 kg (24.250 lbs) rated load in 4:1*2 system and 0.8 m/s speed
15.000 (33.000 lbs) rated load in 6:1*2 system and 0.6 m/s speed
20.000 (44.000 lbs) rated load in 8:1*2 system and 0.4 m/s speed This provides a great advantage to new type elevator called “GigaLift” when compared to other equivalent elevator types in terms of elevator installation ad cost.

2. DRIVE SYSTEM

For “GigaLift Elevator” using two different types of motor configuration, a different tack was taken to increase drive capability and decrease pressure values. An advantageous drive capability was also obtained through usage of rolling angles between 420^0-540^0 and circulating the cable over two pulley surface. Since suspension capability was increased to full heights, pulley channels can be used as U grooving and with low values of under cut angles together with an increased elevator comfort and expanded cable life span. U channels can be used even in higher rated loads since suspension capability does not pose a problem as can be seen in the two wraps shown in the below drawings. However, additional safety switches were used except from the limit cutters stated in the article 5.5.3 c.2 of EN 81-20 standard due to the extreme increase in suspension capability in these systems. Motor and cable placement are shown for the degrees of 420 and 540 for motor and cable. (Both systems are patent article).

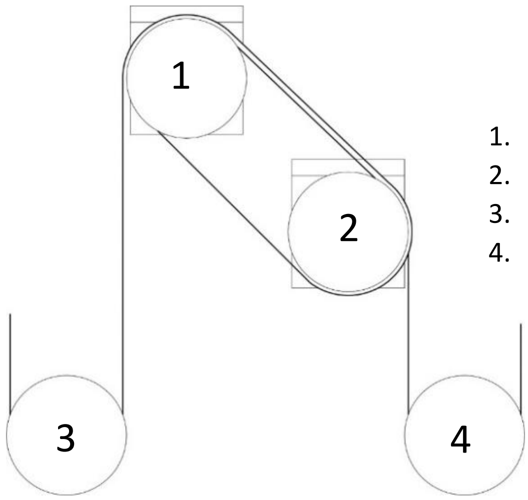


1.1 First motor

1.2 Second motor

2. Ropes
3. Deflection/secondary pulley
4. Car pulleys
5. Counter weight pulleys

Figure 1 Roping with deflection/secondary pulley (420^0-450^0)



1. First motor
2. Second motor
3. Car pulleys
4. Counter weight pulleys

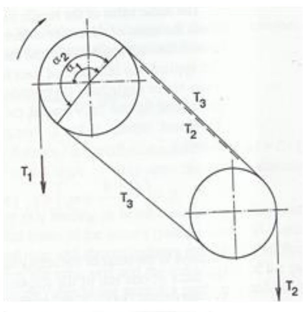


Figure 2 Roping with double wrap (500^0- 540^0)

Usage of both motors as drive pulley and the angle of roping between 420^0-540^0 increase $e^{f\alpha}$ value. This makes it possible to hold high rated loads with smaller pulleys. Arrangement of pulley grooves as U groove and preferring smaller under cut angles provide mechanical synchronization of pulleys on the same cable. When millimetric errors occur in synchronization between motors during stop and start, motors can manage synchronization between each other through small scale cable slipping. Cable pulley pressures are dispatched between each two pulleys.

3. ELECTRICITY CONTROL SYNCHRONIZATION OF SENCHRONUOUS MOTORS

It was required to develop a special software in motor drivers to establish this system. This software was again developed by a local firm and used in the system. Alongside the invertors, motors should also work synchronously. Therefore, motor configuration was designed specially in GigaLift. Driving synchronous motors can only be possible by synchronous invertors. The two drive group should also be driven synchronously with each other. One controller card was used to ensure electrical synchronization and main invertor driving first motor was composed for the synchronous driving of motors while the control of the invertor driving the second motor was connected to main invertor. Two invertor control systems were connected to each other with the electronic communication cables and:

1. All running settings performed in main invertor were transferred to the other invertor automatically.
2. It was enabled that the other invertor drive its own synchronous motor together with the main synchronous motor concurrently according to the commands of main invertor.
3. Motor driving inspections of both invertors are performed independently but current, running, torque, heat, speed, and encoder errors occurring in one of them are used jointly, needed recovery is made and both motor system is stopped at the same time when an error occurs in any of them.
4. In order to ensure encoder unity of both motors independently under load, a system to make matching possible at the same time was developed while it was assured that the directing and encoder settings of motors can be performed independently.
5. A system to check cable tension of both arms in case of a potential mismatch was developed and it was ensured that the system stops when a possible error occurs.

Connection diagrams of the system can be seen below.

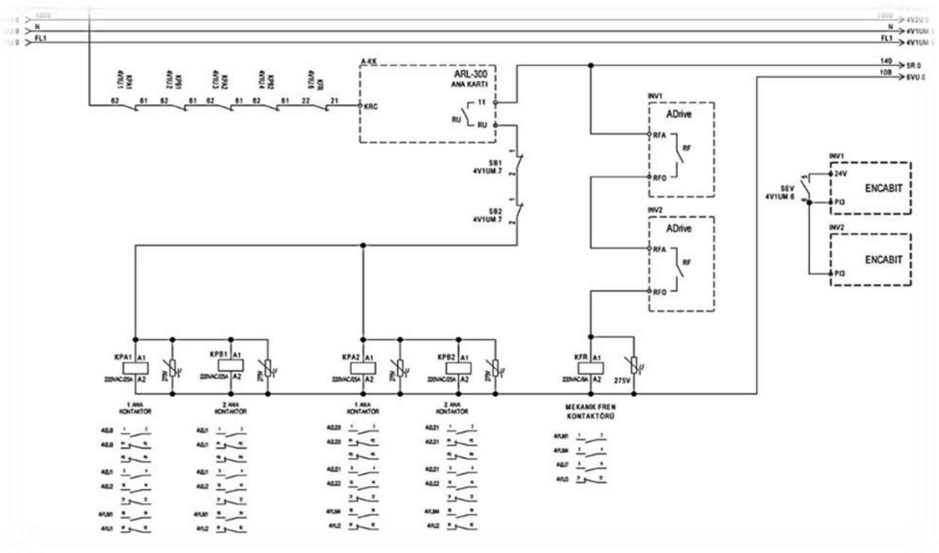


Figure 3. Contactor Circuits

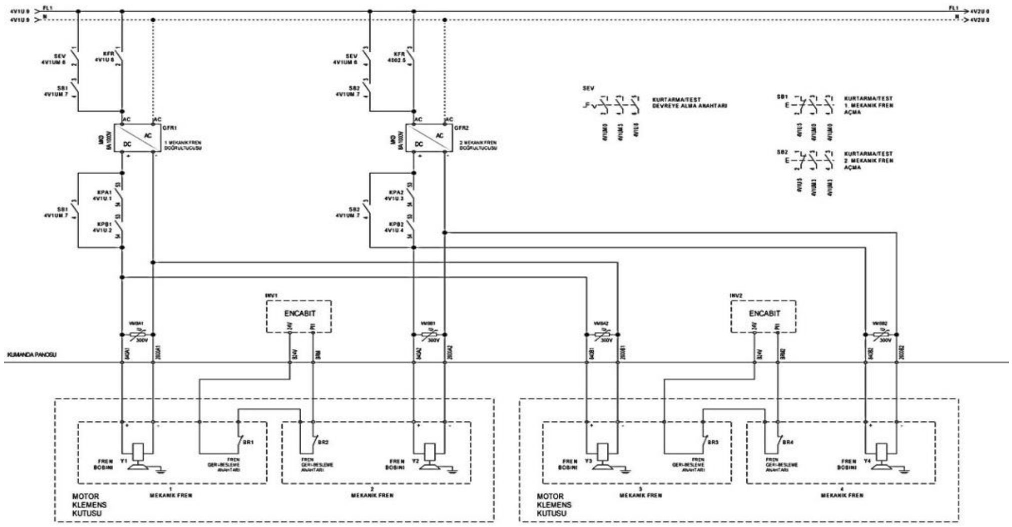


Figure 4. Double Mechanical Brake Connections

Adjustments required for encoder connections and invertors connections to each other were executed and it was ensured that the system runs synchronously, directly connected to each other and under control. Support of Arkel R&D was received for this studies.

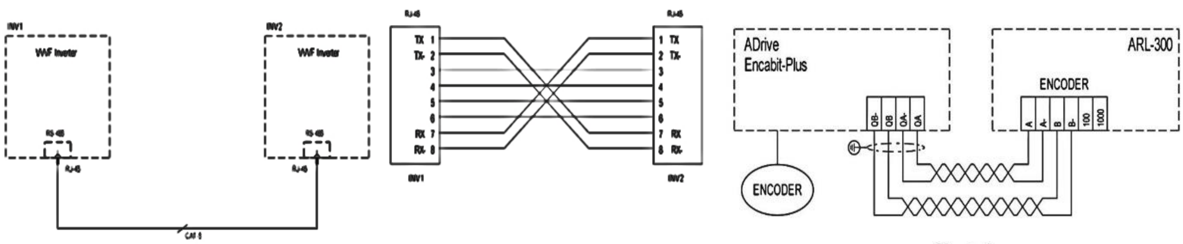


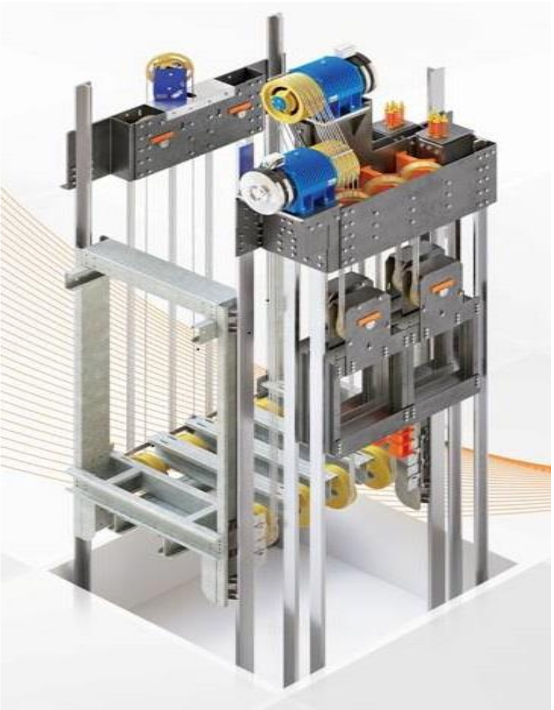
Figure 5 Serial Port and Encoder

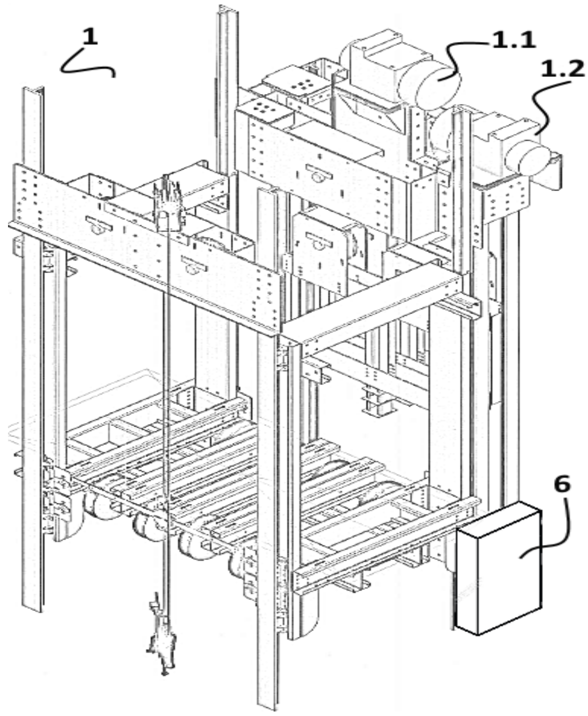
OA > A
OA- > A-
QB > B
QB- > B-

4. MECHANIC STRUCTURE

As a result of expansion of the car area in elevators with higher rated load, bending of rail neck reaching towards the suspension with suspension system increases the loads extremely during the loading. Tilting of car during the loading with forklift can also cause damage on suspension. Moreover, it is a problem to find sliding brake blocks in adequate capacity for higher rated loads. These problems are solved through using 4-rail system in GigaLift. A wide suspension trestle was created in the center with 4-rail system, the car was placed on it so that a more balanced structure was established. Thus, the effect of forces occurring at threshold during the loading on the car suspension and railing neck. It also minimized the tilting and railing neck suspension. Usage of such trestle as a suspension also gave a place for the positioning of hoist systems. All load was given to pulleys in basement hoisted unwrapping system so that the occurring of suspension forces was prevented. Ropes with adequate strenght solve the suspension problem.

8 Brake blocks can be used in 4 railings as well. Thus, it solve the problem of finding a progressive safety gear block for these capacities. Brake blocks were overlapped on 4 suspension joists. Therefore, the effect of brake blocks on railings was diminished and the damage to be caused on the railings during braking with greater loads was minimized. Brake arms were connected to each other with rigid materials, delay or decrease of the force from mechanism arm was prevented.





The greatest challenge in 4-rail systems is to transmit the tractive force created by regulator to brake blocks concurrently and in equivalent force. If this problem is not solved, buckling is seen on suspension and car upon every braking in 4-rail system. GigaLift used a special system to transmit tractive force to the brakes concurrently. It placed the regulator on the center of the suspension and located the traction arm at an equal distance to the brakes. Thus, the movement is transmitted to the both sides concurrently and with equal force. Tractive force of the regulator was doubled by means of lever arms and thus, it facilitated the engagement of 8 brake block. However, the regulator rope diameter and regulator gap were increased and the tractive force was raised to 600 N in order to avoid disruption in brake arm force. Performed test showed that the brake blocks got involved smoothly and concurrently, that there was no delay as well as no bending in suspension. All brake blocks contacts were connected in series and it was ensured that the machines stopped with the contact getting involved first. In case of a loosening in ropes during this process, dual rope loosening contacts were placed on the motors.

5. CONTROL OF THE PERFORMED DEVELOPMENT USING CALCULATION METHOD

Efforts will be spread on to perform status control in two elevators by using calculation method. For the first status, a service elevator with 6:1 hoisted, working with 3000 kg rated load motor on 2:1 will be addressed and the same system will be calculated with two motors featuring the same capacity, using Double Drive method. Railing and car calculations should be performed separately for these elevators. The purpose here is to show that an increase can be made in the same system capacity through a second motor and an addition of a little rope. Formulation given in the standard will be used for the calculation of rope.

$N_{equivalent} = N_{equivalent\ (t)} + N_{equivalent\ (p)}$

Where;

$N_{equivalent\ (t)}$ Equivalent number of traction sheaves

$N_{equivalent\ (t)}$ Equivalent numbers of deflection sheaves.

V - channels	V-channel angle	36°
	$N_{equivalent\ (t)}$	16
U – undercut channels	U- angle (ß)	80°
	$N_{equivalent\ (t)}$	3.0

$$N_{equivalent\ (p)} = K_p \cdot (N_{ps} + 4 \cdot N_{pr}) \qquad K_p = \left(\frac{D_t}{D_p}\right)^4$$

Car on 6:1 hoist and 5 pulleys at a time in the counter weight are used. Rope cycle was performed as to be straight roping and backwards roping was not formed. However, the deflection pulley between the two drive pulleys should be taken as reverse press.

Calculation

Dt =	**400**	mm
Dport =	**400**	mm
dr =	**10**	mm
Nps =	**10**	Adet
Npr =	**1**	Adet
Neş(t) =	**3**	
Kp =	**1**	

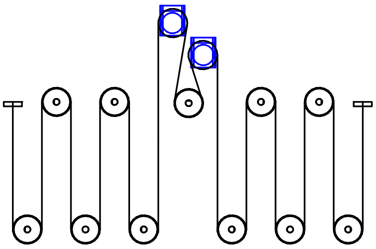
$N_{equivalent} = K_p \cdot (N_{ps} + 4 \cdot N_{pr})$

$N_{equivalent} = N_{equivalent\ (t)} + N_{equivalent}$

Neş =	**17**

$$S_f = 10^{\left(2{,}6834 - \frac{\log\left(\frac{695{,}85 \cdot 10^6 \cdot N_{eşdeğer}}{\left(\frac{D_t}{d_r}\right)^{8{,}567}}\right)}{\log\left(77{,}09\left(\frac{D_t}{d_r}\right)^{-2{,}894}\right)}\right)}$$

Sf =	**22,65**



EN 12385	**1770 N/mm2**	
Rope Diameter	**wo 819W**	Pawo F7S
mm	**kN**	kN
6		
6,5	**31,5**	
8	**46**	44,6
9	**58,8**	56
10	**70,3**	69,5
11		83,1
12		98,9

In this situation, 1 reverse roping pulley is formed. As hoist ropes, 0.39 inches (10 mm) special ropes were used. Calculation of safety factor and rope values for this situation were given up. Rope numbers and safety factors were calculated according to the loads for both elevators. For the first elevator 17.636 lbs rated load and for the second elevator 33.000 lbs rated load were calculated by taking the rope and pulley losses into account.

Elevator 1

Rope control			
The biggest load received on			
P =	**3500**	Kg	
Q =	**8000**	Kg	
H =	**400**	Kg	
n =	**7**	Number of rope	
i =	**6**	Sling rate	
Fmax= gn. [(P+Q+ H) /(n.i)] (N)			
Fmax =	**2780**	**N**	
Control of rope safety coefficient			
Tmin =	**70300**	**N**	
S= Tmin/Fmax > Sf			
S =	**25,29**	**> Sf =**	**22,65**

Elevator 2

Rope control			
The biggest load received on			
P =	**4500**	Kg	
Q =	**15000**	Kg	
H =	**600**	Kg	
n =	**11**	Number of rope	
i =	**6**	Sling rate	
Fmax= gn. [(P+Q+ H) /(n.i)] (N)			
Fmax =	**2988**	**N**	
Control of rope safety coefficient			
Tmin =	**70300**	**N**	
S= Tmin/Fmax > Sf			
S =	**23,53**	**> Sf =**	**22,65**

With the addition of 1 motor and 4 ropes to the same system, its capacity was doubled. Rope friction values and drive capability should be examined in this situation. Apart form these calculations, rope extension calculation should be done in hoisted elevators.

Tensile control must be done for the preferred rope.

σ=E*ε , ε=L/Lo , σ=E*L/Lo , L=(F*Lo)/(E*A)

d =	**10**	mm	
Lo =	**30000**	mm	
x =	**0,49**		It can be 0.49 or 0.44.
%L = (Fmax.Lo)/(E.A)			
%L =	**0,37**	**< %1**	L% value should not be over 1%.

d = Rope diameter

x = Rope void ratio x = 0,49 6x19 For ropes , x = 0,44 8x19 I For ropes

Lo = Rope length (mm)

E = 63000 N/mm2 Elasticity module for steel rope

A = (π.d2.x)/4 mm2 Real area of rope

There is a rope extension calculation and "f" friction value calculation made below.

Calculation of rubbing value

β =	80	Undercut angle	
γ =	36	Channel angle	
v =	2,5	m/s	

u value for suspension mechanism study

$$\mu = \frac{0{,}1}{1 + \frac{v}{10}}$$

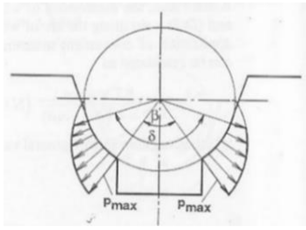
μ = 0,08

For U channels

Rubbing value f calculation

$$f = \mu \cdot \frac{4 \cdot \left(\cos\frac{\gamma}{2} - \sin\frac{\beta}{2}\right)}{\pi - \beta - \gamma - \sin\beta + \sin\gamma}$$

f = 0,137



$$dN = \frac{D \times d}{2} \times d\alpha \times \int_{\frac{\beta}{2}}^{\frac{\delta}{2}} p \times \cos\phi \times d\phi$$

For the used under cut angle, friction value in U groove was given above. f value resulted in small number since a small under cut angle was chosen. According to this value, drive factor e^{f} and rope pressure calculation should be performed. Rope pressure calculation should especially be made for drive motors with small pulley and service elevators. When the rope pressure falls short, either the pulley surface (pulley dimension should be extended) or rope number should be increased.

Elevator 1

e^{fa} Calculation

I Rubbing value
α wrapping angle of ropes to traction sheave

α =	180 =	180 derece =		3,14
	for U groove		for V groove I	
efα =	1,539		=	1,534

Rope pressure control
for Undercut U and V groove
Safety surface pressure

Pem = (12,5+4v)/(1+v)
Pem = 6,429

Rope pressure on pulley

P = (8.Fmax.Cos(β/2)) / (DT.d.(π-β-γ-Sinβ+Sinγ)) <Pem

P =	5,922	< Pem=	6,429

Elevator 2

e^{fa} Calculation

f Rubbing value
α wrapping angle of ropes to traction sheave

α =	440 =	2,44*3,14 =		7,675
	for U groove		for V C groove	
efα =	2,868		=	2,844

Rope pressure control
for Undercut U and V groove
Safety surface pressure

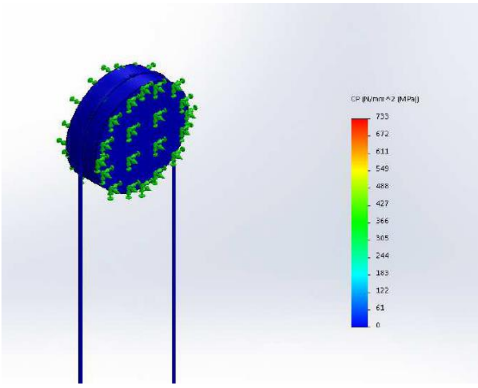
Pem = (12,5+4v)/(1+v)
Pem = 6,429

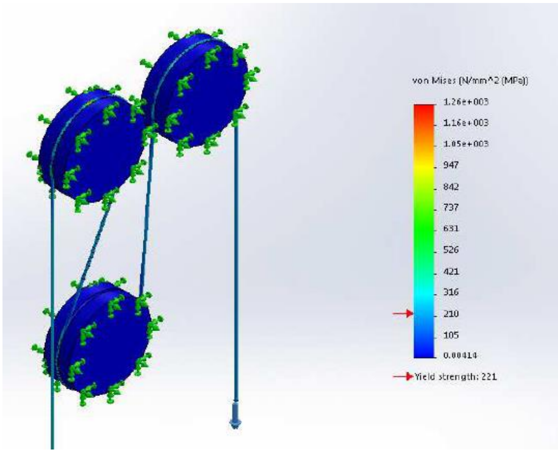
Rope pressure on pulley

P = (8.Fmax.Cos(β/2)) / (DT.d.(π-β-γ-Sinβ+Sinγ)) <Pem

P =	6,365	< Pem=	6,429

As can be seen from the calculations, when a small f value is achieved, $e^{f\alpha}$ value in 180^0 roping angle does not provide a good result for drive capability but since the roping angle is 440^0, drive capability is found as twice as much. This provides an adequate value. This kind of value on a pulley with that dimension for a load in such like level can only be found in high roping angles or low angled V groove. In low angle V grooves, vibration occurs in the elevators during high motor rotations. Although the load is doubled, the rope pressure occurs on the pulley stays under the safe surface pressure. When we controlled this situation with a modeling on Solid, we achieved the very approximate results. The load was doubled but since the force was divided between the two pulleys in Double Drive system, approximate pressure values were achieved.





Normal drive and Double Drive values of the system were analyzed. With the addition of one motor and 4 ropes to the system, its capability was doubled. By the way, the values remained under all safety values. The required additional cost also remain under the equivalent elevators to be made normally.

6. ADVANTAGES OF THE SYSTEM

Advantages of the system can be listed in short as follows:

1. Large motor force required for the high rated loads was solved economically by using double motor.
2. It was ensured that the two motors able to work correspondently by forming “mechanical synchronization” though ropes by using rope circulation types of motors and groove features.
3. Since the pulley of both motors were used as drive pulley, large roping angle was ensured, drive capability was increased, and it became possible to keep and run the elevator with lower pulley angles safely.
4. Pulley surface pressures decreased extremely and the elevator became safer as the rope pressure was dispatched to the pulleys.
5. As the electrical motor speeds could be arranged, it became possible to carry rated loads with higher speeds when compared to hydraulic elevators.

6. Running range for high rated loads stopped being a problem and higher floors become reachable faster since the frictional driven system was used.
7. Its cost is much more lower than the equivalent hydraulic elevators.
8. Moreover, by means of the developed 4:1, 6:1, and 8:1 hoisted systems, load capacity can be increased to a level that even hydraulic elevators have difficulty to reach.
9. Through the usage of “Double Invertor” featuring a new software developed in elevator control board, the problem of inter-motors Electrical Control Synchronization and the elevator became available to be driven with double motor.

7. RESULT

As can be seen from the calculations, Double Drive system provides a great convenience with wide roping angle, double driving pulley, opportunity to carry more loads with smaller pulleys and ability to stop as well as offering improvement in terms of cost. It creates many beneficial usage opportunities not only for large service elevators but also high speed elevators in terms of both safety and comfort. As for the cost studies which are really important factor for these kinds of elevators, it can be accepted as a preferable solution since it meets both capacity and speed increase with low cost elements. We expect to see that the performed study be improved further, made beneficial to our sector, and be diversified as a drive type.

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