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Design Development and Analysis of Escalator

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Abstract

An escalator is a moving staircase conveyor transport device for carrying people between floors of a building. The device consists of a motor-driven chain of individual, linked steps that move up or down on tracks, allowing the step treads to remain horizontal. Escalators are used around the world to move pedestrian traffic in places where elevators would be impractical. Principal areas of usage include department stores, shopping malls, airports, transit systems, convention centers, hotels, and public buildings. The benefits of escalators are many. They have the capacity to move large numbers of people, and they can be placed in the same physical space as one might install a staircase. They have no waiting interval (except during very heavy traffic), they can be used to guide people toward main exits or special exhibits, and they may be weatherproofed for outdoor use. Escalators are one of the largest, most expensive machines people use on a regular basis, but they're also one of the simplest. At its most basic level, an escalator is just a simple variation on the conveyor belt. A pair of rotating chain loops pulls a series of stairs in a constant cycle, moving a lot of people a short distance at a good speed.

In this article, we'll look inside an escalator to find out exactly how these elements fit together. While it is exceedingly simple, the system that keeps all the steps moving in perfect synchrony is really quite brilliant.

Keywords: escalator, sidewalks, travelators.

Introduction

An escalator is a mechanized moving stairway, common in places with a lot of foot traffic or where a conventional staircase would be very long and tiring to climb. Escalators can often be seen in shopping malls, museums, multi-story parking garages, and subway stations, for example. Escalators are often installed in pairs, with an up escalator and a down escalator adjacent to each other, while a single escalator may be changed to go up or down according to the direction of heavier traffic at different times of the day.

An escalator is similar to a conveyor belt, but differs in that it is on an incline and has a surface of stairs rather than a flat belt. Most escalators also include a handrail that moves in conjunction with the stairs. To move from one end of an escalator to the other, a person may simply stand on one step until one reaches the end, or one may climb or descend the escalator like conventional stairs. Many escalators in busy areas are wide enough to accommodate two columns of people, and those who wish to stand conventionally remain on one side of the escalator

Modern escalators are usually inclined at 30°, limited in rise to about 60 feet (18 m), with

floor-to-floor rise of about 12 feet (3.5 m). They are electrically powered, driven by chain and sprocket, and held in the proper plane by two tracks. As the treads approach the landing, they pass through a comb device; a deflection switch is actuated to cut off power if an object becomes jammed between the tread and the comb.

Escalators move at a rate of up to 120 feet (36 m) per minute; larger types have a capacity of 6,000 passengers per hour. If a chain breaks, the release of tension stops the escalator. A safety switch also halts the device if a handrail is broken or comes loose or if a side panel is deflected.

Moving ramps or sidewalks, sometimes called travelators, are specialized forms of escalators developed to carry people and materials horizontally or along slight inclines. Ramps may have either solid or jointed treads or a continuous belt. Ramps can move at any angle of up to 15°; beyond this incline the slope becomes too steep and escalators are favoured. Escalator as shown in fig.1& fig.2

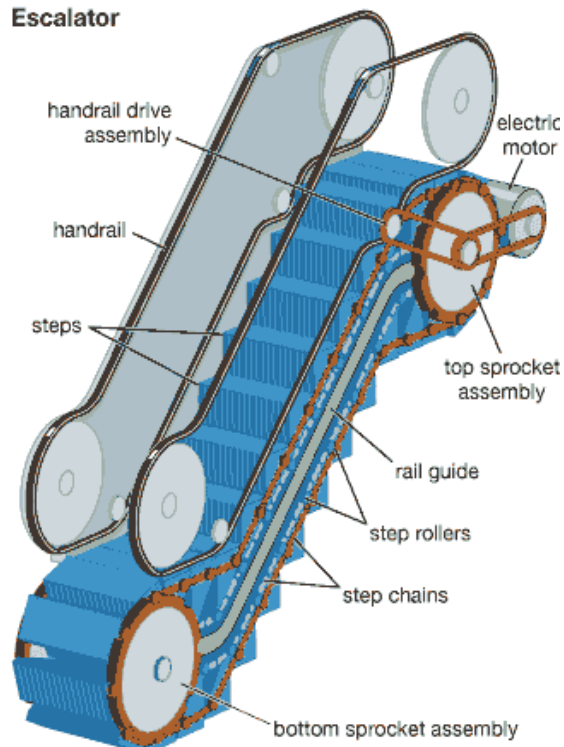


Fig.-1 ESCALATOR

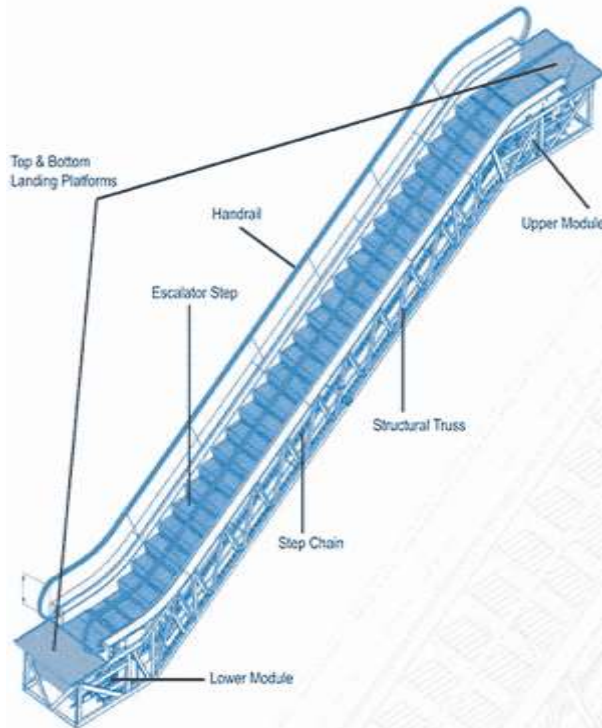


Fig-2 INTERNAL VIEW OF ESCALATOR

Literature Review

There is various type of escalator given below:

Escalators, like moving walkways, are powered by constant-speed alternating current motors and move at approximately 1–2 feet (0.30–0.61 m) per second. The maximum angle of inclination of an escalator to the horizontal floor level is 30 degrees with a standard rise up to about 60 feet (18 m). Modern escalators have single piece aluminum or steel steps that move on a system of tracks in a continuous loop. layout as shown in fig.4



Fig.4 Types of escalator ("Crisscross" "Multiple parallel" "Parallel")

Escalators have three typical configuration options: parallel (up and down escalators "side by side or separated by a distance", seen often in multilevel motion picture theatres), crisscross (minimizes structural space requirements by "stacking" escalators that go in one direction, frequently used in department stores or shopping centers), and multiple parallel (two or more escalators together that travel in one direction next to one or two escalators in the same bank that travel in the other direction).

Escalators are required to have moving handrails that keep pace with the movement of the steps. The direction of movement (up or down) can be permanently the same, or be controlled by personnel according to the time of day, or automatically be controlled by whoever arrives first, whether at the bottom or at the top (the system is programmed so that the direction is not reversed while a passenger is on the escalator).

Working

Escalators, while rather expensive and large, are actually relatively basic machines. The machinery of an escalator is hidden beneath its steps in what is called a *truss*. At the top of the escalator, housed in the truss, is an electric motor which runs the four gears that all escalators have — two *drive gears* on either side at the top and two *return gears* on either side at the bottom. These gears have chains that loop around the gears and run down each side of the escalator. Connected to each step, these chains help the steps make their way up, or down, the escalator.

The handrails that riders use for balance and safety on their ride up or down escalators are powered by the same system that powers the steps. The handrails are essentially long rubber loops connected to the two drive gears at the top of the escalator and powered by the same electric motor that powers the steps

Speed is controlled by a governor, similar in general principle to that used on stationary steam engines. Two heavy metal balls are attached to pivoted levers which are in turn fixed to a vertical shaft, revolving through gearing. The faster the shaft revolves, the more are the metal balls swung out by centrifugal force, and should the lift speed exceed a predetermined figure the governor actuates a brake.

This device was originally designed to serve as a check on the working of lifts controlled by an attendant travelling on them. In the newer types, no attendant is necessary in the lift itself, as the result of introducing a semiautomatic means of operation known as landing control. With this system, human

control is restricted to closing the gates, after which working, including acceleration and deceleration, is automatic.

The advantages of the method are that it saves the passenger's time, and that a single operator can attend to a number of lifts. At certain stations the lift is operated at the upper level by the booking clerk, and an attendant is necessary only at the bottom of the shaft.

Design Process

Definition of the Problem

We are to design escalator using gear which is lighter, smaller and less expensive to manufacture.

It also provides smooth drive and torque characteristics from starting to the designed peak condition.

Need Analysis

There is a great demand of escalator by the society in today's world of growing technology. it offers many advantages like

1. It is very useful in the multistorage building.
2. Escalator are used to move pedestrian traffic in places where elevators would be impracticable

Customer Requirements

1. Power consumption should be minimum.
2. Escalator running should be smoothly.
3. Handrail should be given for the support of passenger.
4. Surface of steps should not be slippery
5. The size should be smallest possible so that it should occupy minimum amount of space.
6. angle of inclination should be 30 to 35 degree
7. The functioning of escalator should be easy to perform without much fatigue
8. It should be economical..

Development of Basic Solution

Requirement	Weight age
1.Smooth drive	.2
2.Minimum noise	.1
3.Economical	.3
4.Efficiency	.2
5.Maintenance	.15
6.Size	.05
TOTAL	=1

Detail Design

In design of a gear drive, the following data is usually given:

1. The Power to be Transmitted
2. The speed of the driving gear
3. The speed of the driven gear or the velocity ratio
4. The centre distance

Designing of gear

- (1) rpm = 1440 , power = 5h.p
 T = TORQUE TRANSMITTED BY SHAFT
 $T = P \cdot 60 / 2 \cdot 3.14 \cdot 1440 = 24.7 \text{ NM}$

(2) MODULE AND FACE WIDTH OF GEAR

V.R. = $N1 / N2 = 1440 / 200 = 7.2$
 LET Dp = PITCH CIRCLE DIA OF PINION ON THE MOTOR SHAFT
 Dg = PITCH CIRCLE DIA OF GEAR ON THE MAIN shaft

Let distance between the shaft
 $L = 500 \text{ mm}$
 $500 = dp / 2 + dg / 2$
 $Dp + dg = 1000$
 v.r. = $dg / dp = 7.2$
 $dg = 7.2 dp$
 $dp + 7.2 dp = 1000$
 $8.2 dp = 1000$
 $Dp = 121.95 \text{ mm}$
 $Dg = 7.2 \cdot 121.95 = 878.04 \text{ mm}$

We know that pitch line velocity of drive
 $V = 3.14 \cdot dg \cdot n / 60 = 3.14 \cdot 878 \cdot 200 / 60 = 9.19$
 $Cv = \sqrt[3]{3 + v} = \sqrt[3]{3 + 9.19} = 2.32$

Let assume that motor pinion is made of forged steel and the gear of cast steel. Since the allowable static stress for the cast steel is less than the forged steel.

Therefore the design should be based upon the gear. Let us take allowable static stress for gear material = 140 N/mm^2

Lewis factor for gear (for 20 stub teeth)
 $Yg = 0.175 - 0.841 / Tg = 0.175 - 0.184 / m / Tg$
 $Yg = 0.175 - 0.841 / m / 878 = 0.175 - 0.00095 / m$

We also known that maximum tangential force on the gear

$Wt = (\sigma) wg \cdot b \cdot 3.14 \cdot yg$
 $Wt = 140 \cdot 0.23 \cdot 10 \cdot 3.14 \cdot m \cdot (0.175 - 0.00095 / m) - 1$
 But, $Wt = p \cdot v =$
 $p \cdot 60 / 3.14 \cdot 0.878 \cdot 200 = p \cdot 60 / 3.14 \cdot 0.878 \cdot 200 = 405.88 \text{ N}$

Putting the value of Wt in above equation of Wt , will get value of m (module) as $N \quad m = 12 \text{ mm}$

2) No. of teeth and pitch circle diameter of each gear

No. of teeth of the pinion
 $Tp = Dp / m = 121.95 / 12 = 10.16$
 No. of teeth on the gear
 $Tg = Dg / m = 73.16$
 Pitch circle diameter of the pinion
 $Dp = m \cdot Tp = 120$
 Pitch circle dia of the gear
 $Dg = m \cdot Tg = 12 \cdot 73 = 876$

Power that can be transmitted = $Wt \cdot v = 405.8 \cdot 9.19 = 3729.302 \text{ N}$
 Torque transmitted by the driven shaft
 $T = P \cdot 60 / 2 \cdot 3.14 \cdot 200$
 $T = 3729 \cdot 60 / 2 \cdot 3.14 \cdot 200 = 178.13 \text{ Nm}$

(3) Now $N = 400 \text{ rpm}$
 $Tp = 30.48$
 $Tg = 219.51$
 $Dp = 121.92$
 $Dg = 878.04$
 There for torque transmitted by driven shaft
 $T = 89.09 \text{ Nm}$

(4) Now $N = 800 \text{ rpm}$
 $Tp = 121.45$
 $Tg = 878.04$
 $Dp = 121.95$
 $Dg = 878.04$
 Therefore torque transmitted by driven shaft
 $T = 44.4 \text{ Nm}$

(5) Now $N = 1000 \text{ rpm}$
 $Tp = 121.95$
 $Tg = 878.04$
 $Dp = 121.95$
 $Dg = 878.04$

Therefore torque transmitted by driven shaft
 $T = 35.61 \text{ Nm}$

Sno.	System of gear teeth	Mim no, of teeth in pinion
1.	14½° composite	12
2.	14½° full depth involutes	32 (bevel gear)
3.	20° full depth involutes	18 (bevel ring gear)
4.	20° stub depth involutes	14

We are working on 20° full depth involutes because it has a strong teeth to take have load pressure angle 14½° to 20°

Min .no, of teeth

Sno	Particular	14½° comp.& full Depth involutes system	20° depth involutes system	20° stub depth involutes system
1.	Addendum	1m	1m	0.8
2.	Addendum	1.25	1.25	1
3.	Work depth	2 m	2m	1
4.	Min.total depth	2.25	2.25	1.80
5.	Tooth thick	1.508	1.508	1.508
6.	Mim clear	0.25	0.25	0.2
7.	Fillet radio at the	0.4	0.4	0.4

Min.teeth

Assumption: - dia and teeth of both gears we are taking would be same

Propeller gear 32 – T1

Crone gear – 18 T2

VELOCITY RATIO

$$G = T2/T1 = 18/32 = 0.5625 \%$$

$$\text{MODULE (m)} = D/T = D1/T1$$

T	T
m=1.25,T=18,D=22.5	m=1.25,T=32,D=40
m=1.375,D=24.75.5	m=1.375,D=44
m=1.75,D=31.5	m=1.75 ,D=56
m=2.25,D=40.5	m=2.25,D=79
m=2.75,D=49.5	m=2.75 ,D=88

If m= 1.25

D= 40

D=22.5

Design considerations force gear drive

1. The power to be transmitted
2. the speed of the driving gear
3. the speed of driven gear
4. the control distance

Necessary with of pinion if p=500 & n=1800 rpm

$$T = P \pi 60 / 2 \pi N = 500 * 1000 * 60 / 2 \pi 1800 = 2852 \text{N-m}$$

$$\text{Tangential load } W_t = T/D_p = 2652 / 0.1212 = 49200 \text{N}$$

$$\text{Normal load on teeth } W_n = W_t / \cos \phi = 44200 / \cos 22.5 = 47840 \text{ N}$$

Since normal pressure 175 N per mm of teeth

Number of teeth on each gear

$$T_p = D_p / m = 80 / 5 = 16 \text{ Ans}$$

$$T_g = D_g / m = 100 / 5 = 20 \text{ ans}$$

Checking the gear for wear

$$K = (\sigma_e s)^2 \sin \theta / 1.4 [1/E_p + 1/E_g]$$

$$= (630)^2 \sin 14 \frac{1}{2} / 1.4 [1/84000 + 1/84000] = 1.687$$

$$\Theta = 2 T_{eg} / T_{eg} + T_{ep} = 2 * 160 / m / 160 / m + 102.4$$

$$m = 1.22$$

$$W_n = D_{pb} Q k / \cos \theta p^1 = 80 * 22 * 1.22 * 1.687 / \cos 38.66 = 4640 \text{ N}$$

Other Calculation

Angle = 30 degree

Velocity = 1 m/sec

Step width = 1000 mm

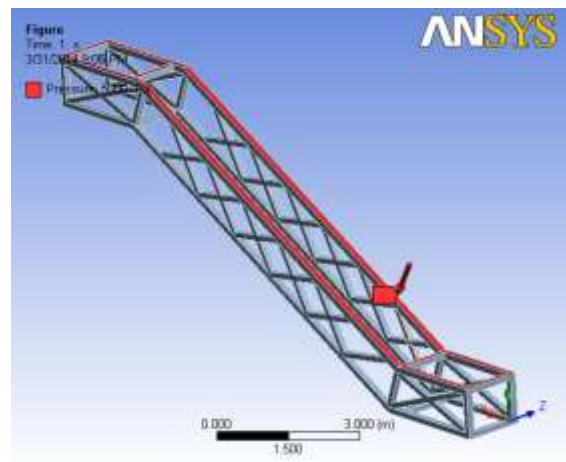
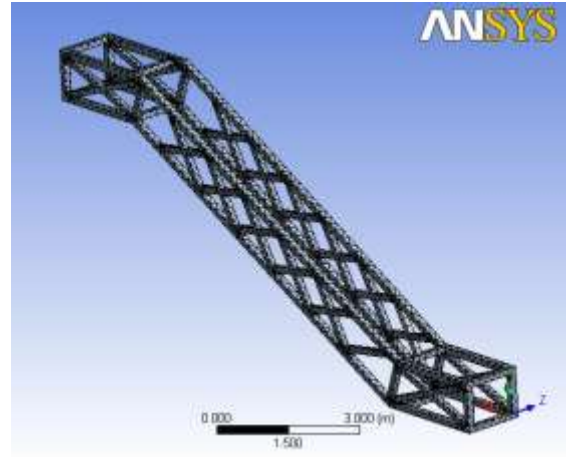
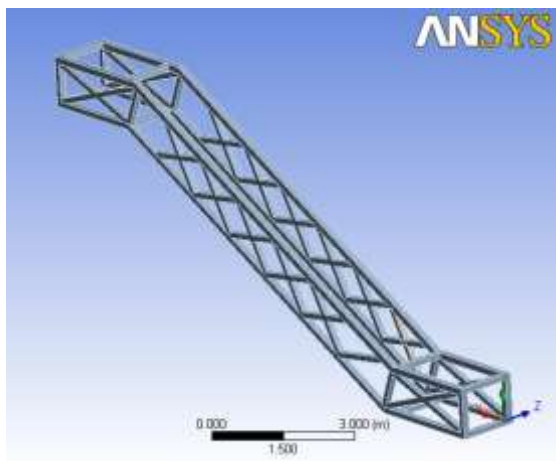
Speed desired = 90 feet/min.
 Sprocket dia. ~ 20 inch.
 Circumference of sprocket = $20 * 3.14$
 $= 62.8''$
 Speed in inch. = $90 \text{ fpm} * 12 \text{ inch./feet}$
 $= 1080 \text{ inch./min.}$
 Revolution per minute of sprocket = 1
 rotation*velocity/circumference
 $= 1080 / 62.8$
 $= 17.19 \text{ r.p.m}$

Assume total passenger load = 20000 N
 Total stairs load = 2000 N
 Total load on escalator = 22000 N
 No. of stairs = 15
 Area of one stairs = $1 * 0.4 = 0.4 \text{ m}^2$
 Total area = $15 * 0.4 = 6 \text{ m}^2$
 Stress produced = load / area
 $= 22000 / 6$
 $= 3666.6 \text{ N/m}^2$

Strain produced = stress / E
 E = Modulus of elasticity
 Material used for escalator is aluminium

E for aluminium = 70 GN
 So strain = $3666.6 / 70 \text{ GN}$
 $= 5.2 * 10^{-8}$

Anslys Drawing



Conclusion

- i. Detailed description about the Escalator is given in the paper
- ii. Literature survey on Escalator has been carried out.
- iii. Work to be carried on Escalator been clearly defined.

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