Design and Analysis of Machine Room less Elevator

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Abstract— In this paper, we present current invention in the field of elevators which relates to an installation structure for mounting an elevator traction machine at a rooftop floor. It removes a conventional machine room separately located at the upper end of a shaft and minimizes an installation space of the elevator traction machine without altering an operating height of elevator. Machine Room Less (MRL) elevator drives offer advantages over conventional traction drives such as a higher energy efficiency, low weight and more design freedom and better utilization of hoist-way space. We cover all the algorithms required to ensure safety of designed elevators and explain it with running example.

Key words: Machine Room Less Elevators, Drives

I. Introduction

Elevators are vertical transport systems that have being used for efficient transport of passengers and goods between different floors (landings). An elevator differs from other hoisting mechanisms in that it runs at least partially on guide rails. The elevator is a mass transit system (conveyor) whose design has evolved rapidly from that of a simple drum and rope traction system to traction less and machine room less systems[11,12,14,15].

Elevator usage has grown exponentially in India but the adoption of newer technologies such as the MRL drive or systems is lagging behind because of additional costs of maintenance and inspection involved as convenience of machine room diminishes. It becomes imperative to establish MRL elevators as a superior choice and provide additional future changes that provide advantage of MRL drive during operation and the convenience of a machine room during inspection and maintenance. Such an elevator drive will provide least cost of maintenance and inspection for the customer over the elevator lifetime. The present invention relates to a machine-room-less installation structure for mounting an elevator traction machine at a rooftop[6-10,13].

This paper is organized as follows. Firstly, literature reviews of IS: 14665 is discussed in section II. Design and analysis of elevator is explained in section III. Algorithms are explained with running example in section IV. Finally we conclude in section V.

II. Literature review

Indian Standard for Electric Traction Lifts provides guidelines for outline dimensions of passenger, goods, service and hospital lifts. This standard was adopted by the Bureau of Indian Standard. This was done with a view to align the Indian Standards with the latest developments in the field of Lifts and also to align the standards with the European Norms on Lifts and Escalators EN 81. Moreover, these standards are published with a view to have a uniform code for electric traction lifts all over the country, where presently different rules are being followed by different states. This standard is one among the series of standards finalized by the Lifts and Escalators Sectional Committee as detailed below:

A. IS 14665 (Part 1) - 2000 Electric Traction Lifts (Guide Lines For Outline Dimension Of Passenger, Goods, Service & Hospital Lifts)[1]

This standard specifies outline dimensions of lift cars for passenger, goods, service and hospital lifts. The corresponding well sizes, pit depth, headroom, machine-room details and type of car and landing doors are also specified.

B. IS 14665 (Part 2 - Sec 1 & 2) - 2000 - Code Of Practice for Installation, Operation and Maintenance [2]

This standard (Part 2/Sec 1) covers the essential requirements, design considerations, testing and precautions to be exercised during installation of passenger and goods lifts operated by electric power, so as to ensure safe and satisfactory performance. It also provides guidance for proper maintenance after installation.

C. IS 14665 (Part 3-Sec 1 & 2)-2000 Safety Rules (Section 1 Passenger & Goods Lifts, Section 2- Service Lifts)[3]

This standard (Part 3/ Sec 1) applies to the construction and safety of new passenger and goods lifts suspended by ropes and employing a guided lift car. This standard does not apply to platform lifts, amusement devices, skip hoists, conveyors or similar apparatus used for raising, piling.

D. IS 14665 (Part 4-Sec 1 To 9) – 2001[4]

This standard describes selection criteria for elevator components.

- Section 1 - Lift Buffers
- Section 2 - Lift Guide Rails and Guide Shoes
- Section 3 - Lift Car frame, Car, Counterweight and Suspension
- Section 4 - Lift Safety Gears and Governors
- Section 5 - Lift Retiring Cam
- Section 6 - Lift Doors and Locking Devices and Contacts
- Section 7 - Lift machines and Brakes
- Section 8 - Lift Wire Ropes
- Section 9 - Controller and Operating Devices for Lifts

E. IS 14665 (Part 5) - 1999 Electric Traction Lifts - Specification (Inspection Manual)[5]

This standard (Part 5) applies to electric traction passengers/goods lifts erected at any place and intended for use by passengers. This standard does not apply to:

1) Service lifts(dumbwaiters)
2) Hydraulic lifts
3) Escalators
4) Cranes

This standard is concerned with inspection of lifts from safety point of view and does not cover performance requirements and corresponding tests.

III. Design and Calculation of Elevator

In this section, algorithms for designing and ensuring safety of MRL elevators are described. Design of new elevator has to pass all the algorithms for ensuring its safety.

A. *Algorithm 1: Wire Rope Selection*

- Input - Breaking strength of wire rope f(N), Number of wire rope n, Roping k, Maximum load on wire rope w(N)
- Output - Estimated Factor of safety est_fos, Result of design status

1) Initialize Required Factor of safety req_fos from IS:14665
2) est_fos = (f. n. k) / w
3) if est_fos > req_fos then
4) status = SAFE
5) else
6) status = UNSAFE
7) end if

Algorithm for checking factor of safety of wire rope is given in Algorithm 1. Factor of safety for given parameters is calculated in line number 2. Estimated factor of safety is then compared with the IS: 14665 standard value in line number 3.

B. *Algorithm 2: Traction Machine Selection*

- Input – Car side weight t_1(N), Counter weight side weight t_2(N), Traction pulley radius r(m), Speed n(rpm), Coefficient of friction μ, Arc of contact ϴ (radian)
- Output – Estimated torque est_t(N.m), Estimated power est_p(KW), Estimated static load est_sl(N), Result of design status

1) Initialize required torque cat_t(N.m), power cat_p(KW), and static load cat_sl(N) from traction machine manufacturer catalogue
2) est_t = (t1 - t2).r
3) est_p = (2π.n.t)/60000
4) est_sl = t1 + t2
5) if est_t < cat_t and est_p < cat_p and (t1 - t2) <= eμϴ and est_sl < cat_sl then
6) status = SAFE
7) else
8) status = UNSAFE
9) end if

Algorithm for checking traction machine torque, power, traction and static load is given in Algorithm 2. Torque, power and traction calculation for given parameters are calculated and then compared with the standard values from traction machine catalogue values.

C. *Algorithm 3: Car Guide Rail Selection*

- Input – Empty car weight *p*(N), Rated capacity *q*(N), Buckling factor *Ꞷ*, Area *a* (mm^2)
- Output – Estimated buckling stress *est_бk*(N/mm^2), Result of design *status*

1) Initialize required buckling stress cat_бk from guide rail manufacturer catalogue
2) est_бk = 15Ꞷ.(p + q)/a
3) if est_бk < cat_бk then
4) status = SAFE
5) else
6) status = UNSAFE
7) end if

Guide rail buckling stress is validated using Algorithm 3.

D. *Algorithm 4: Car frame top beam member calculation*

- Input – Car side weight p(N), Distance load acting a(mm), Length of member l(mm), Modulus of elasticity e(N/mm2), Moment of inertia ixx(mm4), Section modulus zxx(mm3), Bending moment m(N.mm), Neutral axis to outer fiber distance y(mm)
- Output – Estimated deflection est_δl(mm), Estimated bending stress est_бb, Result of design status

1) Initialize allowable deflection all_δl and bending stress all_бb from IS:14665
2) est_δl = p.a (3l2-4a2)/(24.eixx)
3) m = p.a
4) zxx = ixx/y
5) est_бb = m/zxx
6) if est_δl < all_δl and est_бb < all_бb then
7) status = SAFE
8) else
9) status = UNSAFE
10) end if

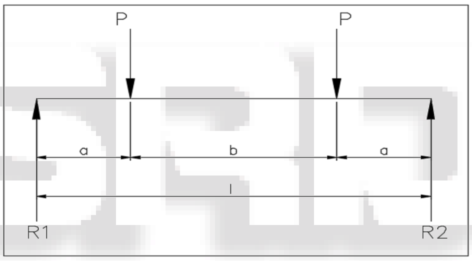

Fig. 1: Car frame top beam member force diagram

Car frame top beam member deflection and bending stress are calculated and validated against deflection and bending stress from IS: 14665 standard values in Algorithm 4. Fig. 1 represent car frame top beam member force diagram.

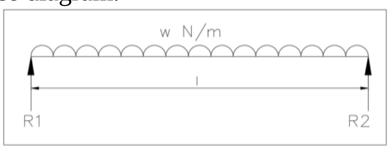

Fig. 2: Car frame bottom beam member force diagram

E. *Algorithm 5: Car Frame Bottom Beam Member Calculation*

- Input – Uniformly distributed load (Car side weight) w(N/mm), Length of member l(mm), Modulus of elasticity e(N/mm2), Moment of inertia ixx(mm4), Section modulus zxx(mm3), Bending moment m(N.mm), Neutral axis to outer fiber distance y(mm)
- Output – Estimated deflection est_δl(mm), Estimated bending stress est_бb, Result of design status

1) Initialize allowable deflection all_δl and bending stress all_бb from IS:14665
2) est_δl = [(5/384).w.l4]/(e.ixx)
3) m = w.l2/8
4) zxx = ixx/y

5) est_ϭb = m/zxx
6) if est_δl < all_δl and est_ϭb < all_ϭb then
7) status = SAFE
8) else
9) status= UNSAFE
10) end if

Algorithm 5 checks car frame bottom beam member deflection and bending stress. Car frame bottom beam member force diagram is given in Fig. 2.

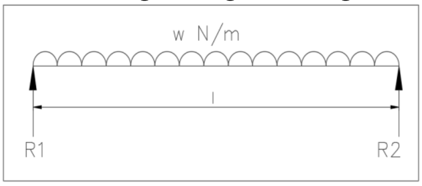

Fig. 3: Car frame platform force diagram

F. Algorithm 6: Car Frame Platform Calculation

- Input – Uniformly distributed load (Car side weight) w(N/mm), Length of member l(mm), Modulus of elasticity e(N/mm2), Moment of inertia ixx(mm4), Section modulus zxx(mm3), Bending moment m(N.mm), Neutral axis to outer fiber distance y(mm)
- Output – Estimated deflection est_δl(mm), Estimated bending stress est_ϭb, Result of design status

1) Initialize allowable deflection all_δl and bending stress all_ϭb from IS:14665
2) est_δl = [(5/384).w.l4] / (e.ixx)
3) m = w.l2/8
4) zxx = ixx/y
5) est_ϭb = m/zxx
6) if est_δl < all_δl and est_ϭb < all_ϭb then
7) status = SAFE
8) else
9) status= UNSAFE
10) end if

Algorithm for checking car frame platform member deflection and bending stress are presented in Algorithm 6. Fig. 3 represent car frame platform force diagram.

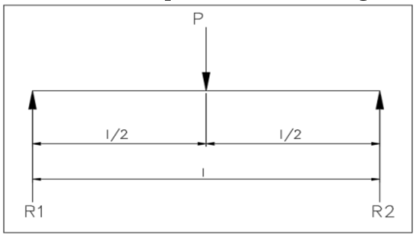

Fig. 4: Counter weight frame upper member force diagram

G. Algorithm 7: Counter Weight Frame Upper Member Calculation

- Input – Counter weight side weight p(N), Length of member l(mm), Modulus of elasticity e(N/mm^2), Moment of inertia ixx(mm^4), Section modulus zxx(mm^3), Bending moment m(N.mm), Neutral axis to outer fiber distance y(mm)
- Output – Estimated deflection est_δl(mm), Estimated bending stress est_ϭb, Result of design status

1) Initialize allowable deflection all_δl and bending stress all_ϭb from IS:14665
2) est_δl = (p.l^3) / (48.e.ixx)
3) m = p.l/4
4) zxx = ixx/y
5) est_ϭb = m/zxx
6) if est_δl < all_δl and est_ϭb < all_ϭb then
7) status = SAFE
8) else
9) status= UNSAFE
10) end if

Algorithm for checking counter weight frame upper member deflection and bending stress are shown in Algorithm 7. Fig. 4 gives counter weight frame upper member force diagram.

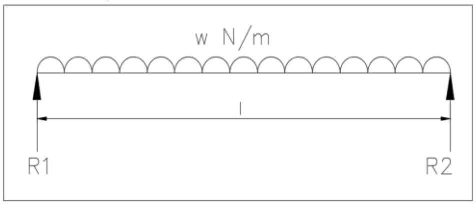

Fig. 5: Counter weight frame bottom member force diagram

H. Algorithm 8: Counter Weight Frame Bottom Member Calculation

- Input – Uniformly distributed load (Counter weight side weight) w(N/mm), Length of member l(mm), Modulus of elasticity e(N/mm2), Moment of inertia ixx(mm4), Section modulus zxx(mm3), Bending moment m(N.mm), Neutral axis to outer fiber distance y(mm)
- Output – Estimated deflection est_δl(mm), Estimated bending stress est_ϭb, Result of design status

1) Initialize allowable deflection all_δl and bending stress all_ϭb from IS:14665
2) est_δl = [(5/384).w.l4]/ (e.ixx)
3) m = w.l2/8
4) zxx = ixx/y
5) est_ϭb = m/zxx
6) if est_δl < all_δl and est_ϭb < all_ϭb then
7) status = SAFE
8) else
9) status = UNSAFE
10) end if

Algorithm for checking counter weight frame bottom member deflection and bending stress are given in Algorithm 8. Fig. 5 represent Counter weight frame bottom member force diagram.

I. Algorithm 9: Car Buffer Selection

- Input – Empty car weight p(N), Rated capacity q(N),
- Output – Estimated maximum load on car buffer est_p(N), Result of design status

1) Initialize required load rating cat_p from buffer manufacturer catalogue
2) est_p = 2.(p+q).9.81
3) if est_p < cat_p then
4) status = SAFE
5) else
6) status= UNSAFE
7) end if

Algorithm for checking load rating capacity for car buffer is given in Algorithm 9.

J. Algorithm 10: Counter Weight Buffer Selection

- Input – Empty car weight p(N), Rated capacity q(N),

– Output – Estimated maximum load on counter weight buffer est_p(N), Result of design status
1) Initialize required load rating cat_p from buffer manufacturer catalogue
2) est_p = 2(p+q/2)9.81
3) if est_p < cat_p then
   status = SAFE
4) else
   status= UNSAFE
5) end if

Algorithm for checking load rating capacity for counter weight buffer is given in Algorithm 10.

IV. EXPERIMENTATION

For better understanding we maintain following running example.

A. Running Example

Consider 10 persons MRL elevator with speed = 1 m/s and roping = 2:1

Estimated values for considered example are given in TABLE 1 in appendix section. Given example satisfy all the conditions given in algorithms, so design of this MRL elevator can be approved.

V. CONCLUSION AND FUTURE WORK

MRL drives offer best operating parameters including costs, energy efficiency, and ride quality. When compared to other types of drives for high rise applications and are being preferred to hydraulic drives in low rise applications. Machine Room Less drives represent current pinnacle of elevator drive technology and have made other traction drives obsolete. However MRL drives currently in use have few disadvantages including less seismic safety, eccentric haulage of cabin, difficulty and increased costs of inspection and maintenance. Now it is done for passenger elevator same algorithm can be evaluated for goods or freight elevators. In this paper, we tried to simplify designing process of MRL elevators by providing several algorithms.

APPENDIX

Components Name	Parameter	Estimated value	Standard value
Wire rope	Factor of safety	12.50	10.00
Traction Machine	Torque (N.m)	346.88	360.00
	Power (KW)	4.32	4.50
	Traction calculation	1.29	1.40
	Static load (N)	16100.00	22000.00
Car guide rail	Buckling stress (N/mm^2)	68.27	370.00
Car frame top beam	Deflection (mm)	0.59	1.00
	Bending stress (N/mm^2)	43.64	90.00
Car frame bottom beam	Deflection (mm)	0.51	1.00
	Bending stress (N/mm^2)	40.81	90.00
Car frame platform	Deflection (mm)	0.43	1.00
	Bending stress (N/mm^2)	34.19	90.00
Counter weight upper frame	Deflection (mm)	0.12	0.60
	Bending stress (N/mm^2)	26.49	90.00
Counter weight bottom frame	Deflection (mm)	0.04	0.60
	Bending stress (N/mm^2)	9.16	90.00
Car buffer	Load rating (N)	34923.00	40000.00
Counter weight buffer	Load rating (N)	28252.00	40000.00

Table 1: Estimation for Running Example

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