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A View to The Application of Linear Motors in Vertical Transportation

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ABSTRACT

Linear motors[1] have been considered to be used as propulsion means in different vertical transportation systems[2], as alternatives to conventional systems, in both roped and rope-less configurations. This paper is a summary and collection of points, ideas and comments from different related, albeit not all, texts and sources dealing with the advantages and challenges in this regard, with a conclusion in the end.

GENERAL CONCEPT

Figure1 shows a schematic illustration showing examples of different arrangements for linear motors, replacing propulsion means in conventional passenger elevators.

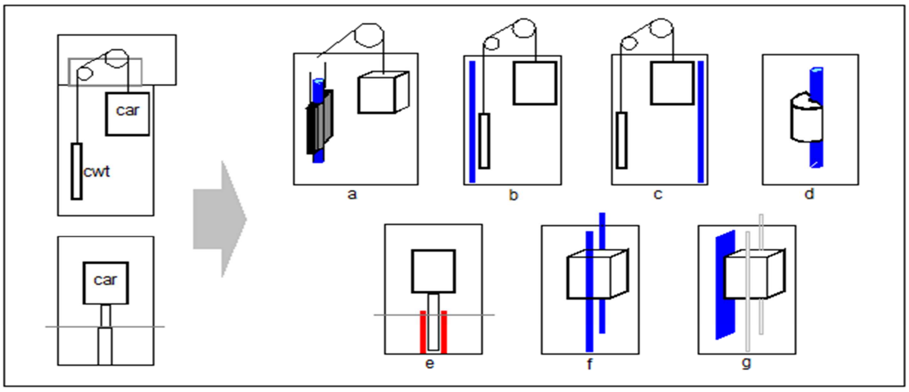

Fig. 1

Roped and rope-less alternatives are shown in blue and red. (Readers may refer to [1-5] for more detailed demonstrations and explanation).

POINTS, ADVANTAGES AND CHALLENGES

Wire rope itself. Extending the length of travel has limitation due to the extra load on the ropes, and also vibration. A limit of 700-800 meters according to ropes weight and safety factor criteria is

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[1] Electromagnetic motors capable of providing direct linear motion, similar in principles to their rotary counterparts. Particularly: Linear Induction Motors (LIMs), Linear Synchronous Motors (LSMs), and Linear Switched Reluctance Motors (LSRMs).

[2] Including passenger elevators and some related mechanisms, as well as other elevating or lifting devices used in different areas.

given in [6], and a 600-750 meters practical limit in [7]. A rise limitation of about 1200 meters is mentioned according to the weight and strength of ropes, car weight and safety factor, as well as vertical oscillations [8]. In gold mining applications, however, achievable depth by a single roped system is around a maximum of 3000 meter, yet not sufficient [9-11].

Ropes elimination consequences. With no ropes, there would be no counterweight leading to savings and improvements in hoistway and car spaces which consequently result in interesting new ideas for vertical
transportation in buildings: Having more than one car in a single shaft with more convenience, and having the movement of elevator cars not limited to a vertical path. These seem to be the most interesting points in the application of linear motor driven elevators, with consequent dramatic changes in building circulation and traffic patterns, according to [12-26] and also [1,2,5,8][1].

On the other hand, in a rope-less elevator, energy and power demand is higher due to the lack of counterweight which offsets a percent of payload in conventional roped systems. Without a counterweight, energy consumption could increase by a factor of three to eight [27]. Such systems would consume four to eight times the power a similar roped elevator's needs [7]. Removing the ropes and counterweight would probably increase power demand and energy losses by approximately 6-7 times [19].Another say regarding linear induction motors is that they are only 60-70% efficient in power use, compared to 90% for conventional rotary motors [13].

Elimination of Driving Unit and Mechanical Parts. In a roped configuration, with no traction machine and machine room, the exerted load on the building is reduced, as well as starting torque and current to overcome inertial forces. Overall mechanical efficiency is improved, and the inherent noise with gearings and pumps is eliminated [1]. In a rope-less system, lack of cables, gears and wheels provides a smoother and quieter ride [25]. Also maintenance requirements are minimal due to the lack of moving parts, cables and hydraulic equipment [26].

On the other hand, these eliminations will result in challenging issues: These would be safety and braking system for a rope-less elevator, and emergency operations and passengers rescue.

More complicated safety system [1], operation in the event of power failure [25,28], emergency stop problems in either direction, and feasibility of manual release for passengers [19], are issues considered and mentioned in this regard.

Other Challenges. Some other points also exist in the application of linear motors.

Technical issues. Maintaining the distance (air gap) between stationary and moving parts, i.e. between the rotor and the stator, is of importance in the systems with linear motors.
Attractive forces exist in there and such issue leads to changes in performance and speed, as well as loosening of the fixing bolts. Utilizing rolling guides, or a tubular motor instead of a flat one can help [2]. Attraction force working across the air gap tends to pull the secondary and primary parts against each other, which can be eliminated in perfectly symmetrical motors [29].

Utilization of linear motors causes the presence of a magnetic field in the car and also in the hoistway. CIBSE Guide D mentions a linear motor mounted directly on the lift car would expose the occupants to intense magnetic fields and, possibly, high noise levels [30]. Ishii states that the high leakage flux in superconducting magnets having no magnetic core, may disturb the surroundings (people) [8].

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[1] Since some similar sources are referenced in different sections, references numbers may not be in numerical order hereafter.

Different environmental effects on such systems would be another issue. Questions and doubts regarding fire hazard, environmental impact upon drive mechanism, and oscillation in event of an earthquake, have been mentioned in [28]. Sensitivity of the system to dust is pointed out in [31].

Finally, thermal efficiency is another issue in linear motors. The properties of the motor depend on the temperature of its parts and temperature conditions would change motor conditions during the move [29]. In case of high duty cycles or in locked rotor conditions (moving element stopped), overheating can occur in linear induction motors [26].

Cost and Financial issues. A part of cost related issues is due to the power and efficiency problems previously mentioned. Another part relates to the production costs as well as maintenance and inspection. Miravete states that production costs problem due to the high motor length [31]. Another say is that the capital and operating costs of rope-less elevators would take decades to pay back through rents gained on the space they would save, equipment costs will also be high due, in part, to the need for full height linear motors [32]. Similar concerns are mentioned in [29,33].

OTHER AREAS OF APPLICATION

Areas for the use of linear motors in vertical transportation cover more fields and ideas, examples of those are as follows.

Otis offer a system which provide a combined movement path for elevator cars, in which vertical ride is by means of ropes (like a conventional traction elevator), and horizontal transport by linear motors [32].

Linear induction motor driven elevators, as well as linear electric actuators for doors and hatches, are of interest to be used on US Navy. Low maintenance and reducing shipboard manning play a role here [34]. Another example with 150% overload capacity and speed of 0.75 meter per second is mentioned in [26].

Elevators door mechanism is another example for the application of linear motors. Again low maintenance is a factor here, as door related problems are the cause of up to 40% of service calls [35]. More examples and applications can be found in [31,36,37].

Application in different environments would be another use for linear motors. Linear synchronous motor based systems can be used as freight elevators and vertical platform lifts in industrial areas [26]. Automatic baggage handling systems and leisure riders are other examples [31].

A low-rise linear switched reluctance motor elevator to serve a few levels, as a low cost solution for improving seniors mobility in their own homes, has been considered [38].

CONCLUSION

Application of linear motors in vertical transportation has been a subject over many years. They offer interesting advantages, and at the same time impose number of problems and challenges. Important point here is the conflict which exists and makes it not easy to have a quick comparison and decision regarding the replacement of conventional elevators and lifting systems: Extended travel height is an advantage, but having a linear motor along the whole shaft is costly – Maintenance is supposed to be lower, but in another term could be higher – mechanical efficiency could be higher, but power consumption is also higher in rope-less applications, and overall efficiency is a challenge – Savings would be in high rise buildings space, but costly maintenance and operation would exist, and so on. It can be concluded that application of linear motors in vertical transportation in the near future would be confined to specific areas and especial buildings, e.g. in especial industrial or army applications, or in a futuristic architectural design, where specific characteristics or necessities play a dominant role, and the overall positive points compensate for negative issues. However, such systems seem to have a strong potential to be alternatives to conventional elevators on a commercial scale, no matter if not in the next few years.

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