HIGH SPEED MAGLEV CONVEYOR FOR BULK MATERIALS

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Abstract

In the U.S.A. today, consumer goods, especially foods, are transported on the average for about 2000 miles (3200 Km) before reaching end users. This is a ten-fold increase over what it was about 100 years ago. A similar change has occurred in the rest of the world, where likewise the population has moved from the country to the cities. This brought with it increased road and rail freight traffic and increased need for transportation fuels, which also need to come from increasingly more distant locations. However, much of the cost and energy used for long distance transportation, especially bulk materials, like crude oil, liquid natural gas (LNG), coal and grain, can be greatly reduced by using maglev freight conveyors, and it can thereby be made simpler, less intrusive, more direct and more consumer friendly. Here described is a lightweight, low cost, high capacity maglev conveyor suitable for transporting 2,000,000 barrels/day of crude oil 1,500 miles (2,400 Km) from Kazakhstan to the nearest port, 100,000,000 tons/year of coal 800 miles (1,300 Km) from New Mexico to California power plants, 10,000,000 bushels/day of corn 1,000 miles (1,600 Km) from Kansas to California or 85,000,000 tons/year of LNG from any unloading dock to inland destinations.

Basic technology

Conveyor

Commonly, a conveyor has an endless belt or chain moving continuously in a closed loop between two points. The belt or chain is adapted to carry freight in one direction, and it normally returns empty. A motor attached to the return roller at the destination end normally supplies driving power.

Maglev

There are three forms of magnetic levitation (maglev), (1) electromagnetic, (2) electro-dynamic and (3) permanent magnets-in-repulsion. The first two are highly complicated technologies, which would require multiple electric windings and controls over the full length of the conveyor and use excessive energy, which makes them unsuitable. The third form, permanent magnets-in-repulsion, does not have wiring, does not use energy for levitation, is very simple and safe to install and, thus, is well suited for levitating conveyor belts or chains. Curiously enough, about 150 years ago railroad scientist Earnshaw experimented unsuccessfully with this idea. He lacked two important ingredients: (1) aluminum, which came into commercial existence 50 years later and (2) ferrite magnets, which came into existence 100 years later.

Long sealed containers as chain links

In order to be able to transport the types and quantities of bulk materials mentioned in 'Abstract' above, it is necessary to use long containers as chain links and move them at high speed. A folding mechanism, U.S. Patent No. 4,024,947, "Bulk Material Conveyor", automatically turns the containers at loading and unloading points into vertical side-by-side position for loading from the top and emptying at the bottom. Fig. 1 shows a cross-section of a container in its guide channel with vertically repelling magnets and lateral guide channels on each side. Attached to the bottom of the container is a platen, which is the secondary to stationary linear induction motors (LIMs) along the way.

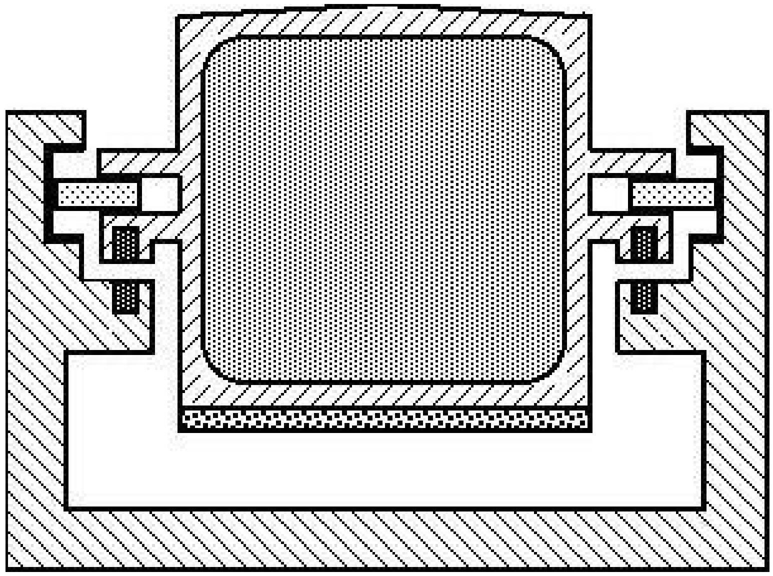

Fig. 1, Container and guide channel cross-section

Elevated guideway

To enable a container string to move at high speed with a minimum of rocking or bouncing requires perfectly aligned guideways, which is not achievable with conventional elevated structures. A new design, U.S. Patent No. 6,301,736 "Elevated Suspended Guideway", in addition to enforcing perfectly straight motion, has the ability to smoothly guide the containers through banked horizontal and vertical curves. This guideway may be mass produced and rapidly assembled.

Electric linear motors

Similar to rotary electric motors, where alternating poles are arranged in a circle, linear motors (LIMs) have their alternating poles in a straight line. Rotary motors are limited to the number of poles, which can fit in a circle, whereas LIMs can be of unlimited length. This technology is quite old. About 25 years ago 16 feet (4 m) long LIMs were successfully tested on vehicles at 250 mph (400 Km/h). About every kind of rotary motor can be emulated in LIM form. However, for this conveyor, only simple single-sided single-speed reversible LIMs are needed. Fig.2 depicts a typical one-sided LIM.

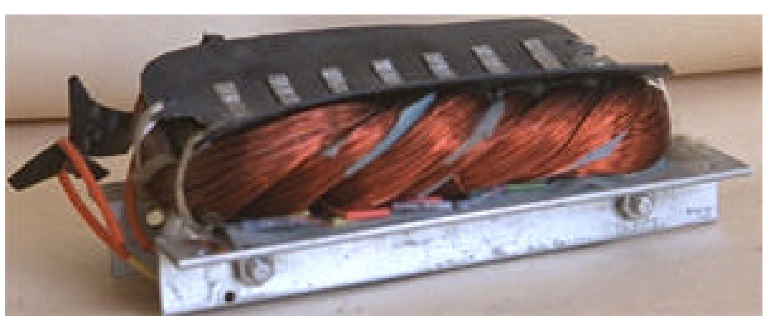

Fig. 2, Typical linear motor

System construction

Layout

At the start, one would first draw a straight line between the pickup and delivery points, and then adjust the route to avoid sensitive areas, communities, lakes and tall mountains, but not straying too far from power sources and locations where service and maintenance facilities might be located.

Erection by helicopter

Concrete footing, towers and guideway spans are so designed that heavy-lift helicopters could do the erection. Fig. 3 shows a helicopter in the process of erecting the guideway.

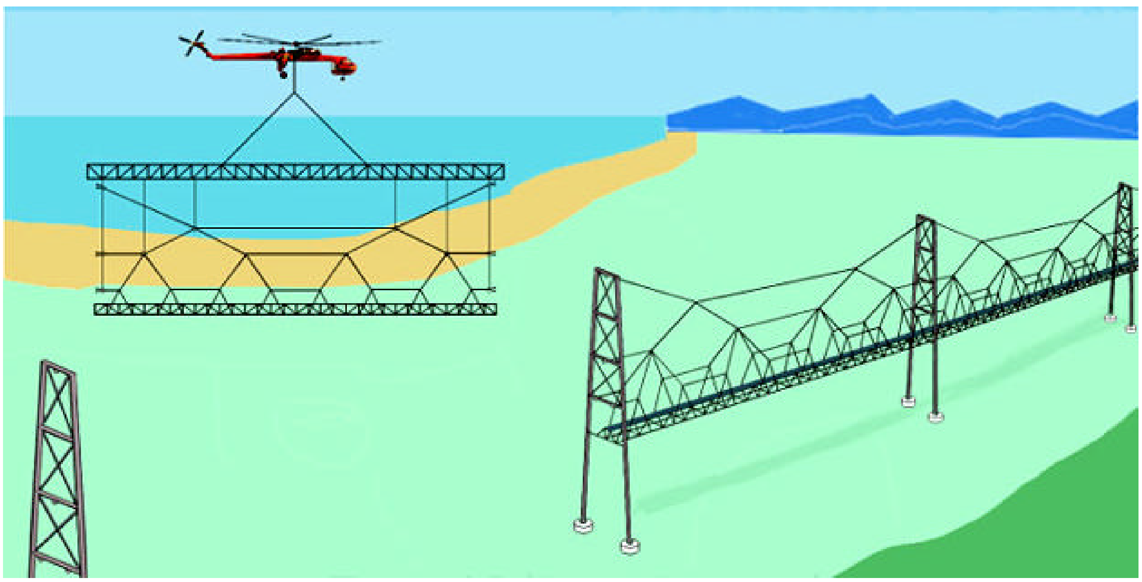

Fig. 3, Erection by helicopter

Power supply

For the grain, coal and oil applications, mentioned in 'Abstract' above, the pickup points would be located at much higher elevations than the delivery points. The loads would, thus, travel downhill and exert pushing forces. Depending on the combined total resistance to forward motion of all moving parts, it might be that little or no propulsion power is required during normal operation. However, when a conveyor is empty and there is no downhill pushing help from the load, then the power requirement would be high. Furthermore, during startups and reversing of motors for braking, substantial booster power would be required. In laying out the system, one should consider finding outside power supplies for power stations at 100-mile (160-Km) intervals. These stations would have standby generators and several LIMs for each direction. However, frequency converters are also required. The speed of a conveyor equals two times pole pitch times frequency. For high speeds the frequency may need to be several hundred cycles per second, but during startup it would need to be quite low.

Controls

The main controls would consist of an on-off relay. There would be sensing devises and monitors at intervals along the full length of a conveyor. Communication lines would connect a control center with line inspection and service providers, as well as crews of daily air patrols. Emergency shutdowns would be executed when conditions call for it.

System operation and maintenance

Startup and shut down

Operators would have checklists, security checks and inspection routines much like airline pilots. LIMs can overheat during starting. If containers hover too long over a heavily straining LIM they may melt or its contents may catch fire. Stresses and strains on containers are in continuous flux due to location and temperature. Starting and stopping distances must be equal on both sides. This is difficult to enforce where the loaded side goes downhill and is hard to stop.

Operation

Different bulk materials have different characteristics and may require special treatment. - For instance, crude oil comes out of the ground at a temperature of ~140°F (60°C) and it is partly volatile and also releases trapped gas. Strict fire safety would be required with oil. - Grain is sensitive to extreme temperatures, but would benefit in transit from ventilation with warm dry air, but it should not get rained on. On a 1000-mile (1600-Km) run there is almost always a section where it rains and another where the sun shines. The solution would be to have remotely controlled vents on grain containers. - Coal needs to be 100% crushed, which means nothing larger than 3/8-inch (10-mm). This prevents load jamming during loading and emptying of containers. - LNG is obtained by cooling natural gas to about -260°F (-130°C). This liquefaction causes volume shrinkage of 620 to one at atmospheric pressure. In transit LNG temperature needs to be maintained to prevent regassification.

Maintenance

Design of the system includes an allowance of 20% shutdown time for maintenance. A quantity of spare containers are kept at a maintenance facility at all times and routinely rotated with an equal number from the operating line, which will then be checked and serviced. This way all containers would rotate offline at regular service intervals. Similarly, there would also be routine checking of the elevated guideway.

Design considerations

High speed is more economical

If containers, as shown in Fig.1, would have interior dimensions of 10 x 10 inches (25 x 25 cm) they could transport 1,000,000 barrels/day of crude oil at 60 mph (100 Km/h). Furthermore, with a wall thickness of 3/8-inch (9 mm), the aluminum containers could withstand longitudinal tension of 150 tons, which would occur at the crest of a 5,000-foot (1,500-m) mountain pass. Economically it means that for every ton-mile of crude oil there would be 1.4 ton-mile of container weight, empty returns included. Airfreight, just for comparison, has 5 ton-miles of plane weight for every one ton-mile of freight, not counting possible empty return flights.

With speed doubled, but with the same carrying capacity, container interior dimension would come down to 7 x 7 inches (18 x 18 cm), and crest tension from 150 tons to 75 tons. The load-to-container weight ratio would remain about the same. However, with only one-half of the moving weight per unit of distance, guideways and levitation magnets could be reduced in size by one-half. More importantly, the conveyor's total moving weight would also be halved, which would be, for a 1,000 mile (1600 Km) long conveyor, from 240,000 tons to 120,000 tons. With a factor of resistance to forward motion during starting (three-times running resistance) of around 0.0006, combined LIM thrust would need to be 144 tons for the 60-mph (100 Km/h) system, and 72 tons for the 120 mph (200 Km/h) system. One 12-foot (~ 4 m) LIM can produce one-ton of thrust.

High speed requires high quality guideways

As already indicated in 'Layout' above, there may have to be curves for social reasons and definitely also for crossing mountains. But whatever the reason, the faster the conveyor goes, the more precise must be its guideway alignment. Fig. 4 shows an enlarged close-up of the patented elevated guideway shown in Fig. 3. The loaded conveyor and empty return line are attached side-by-side to the top of a rigid triple triangular truss guideway, which can be curved and banked with great precision.

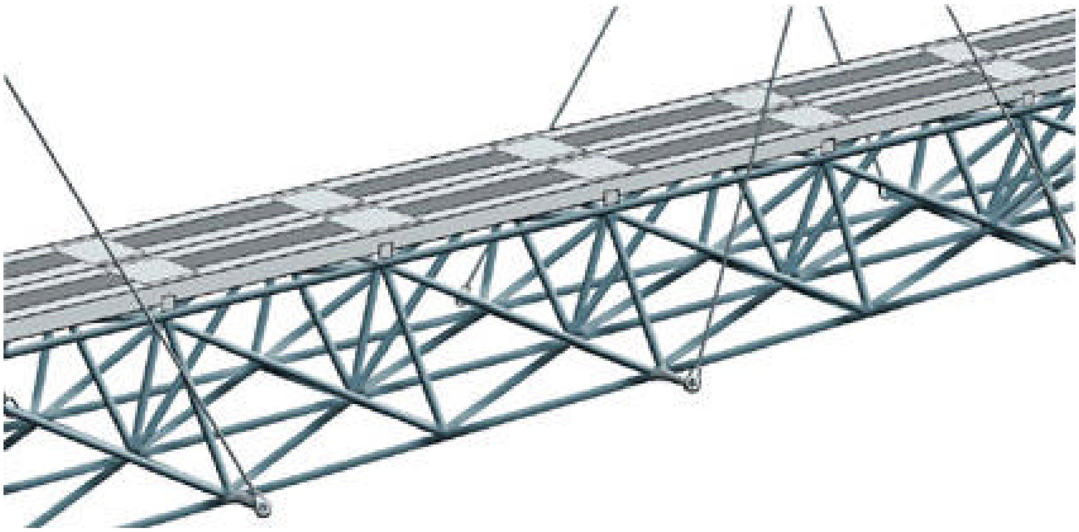

Fig. 4, Precision guideway

LIM efficiency

The four dark areas with white spots, in Fig. 1 above, represent permanent magnets magnetized vertically. The upper two magnets are attached to the container and the lower two to the guideway with poles facing each other vertically in repulsion. The gap between them depends on the size of the magnets and the weight of the container. The design criterion is to select the right magnet size so that containers don't touch bottom when full and not ride unnecessarily high when empty.

The white area with black squares in Fig. 1, attached to the bottom of the container, is a platen designed to convert the magnetic flux emitted by the stationary LIMs along the way into propulsion force. However, much like in rotary electric motors, the gap between primary (LIM) and secondary (platen) must be as small as possible for high efficiency. Depending on other factors as well, but a 1/4-inch (6 mm) gap may only result in 70% LIM efficiency versus 90% with a 1/8-inch (3 mm) gap. The design challenge then is to guide the containers, full or empty, over the LIMs with the smallest possible gap, but never let them touch.

Conclusion

Several voluminous financial feasibility studies were made about this maglev conveyor technology, and compared with conventional transportation means. One such study concluded that about $10,000,000/day could be saved by using a maglev conveyor instead of the 830 miles (1,300 Km) long hydraulically pumped Alaska pipeline. Another study compares present costs of conventional railroads with maglev technology. It likewise concludes that over 50% of present cost could be saved. As described above, basic components of maglev conveyors have been built and successfully tested. A working scale model has also been built. Design of a complete system is at hand and may soon be implemented.