Thought leadership
White Paper

On board with Eaton.

Hydraulic systems for faster, safer tilting trains

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Reduced travel time has always been a major goal throughout the transportation industry. Straight line speed is already maximised and / or limited for either safety reasons or fuel consumption efficiency. Cornering, however, presents an additional challenge to the rail industry. Roads can be banked to allow ground transportation to travel faster when travelling around bends and an aircraft can bank more steeply to turn in a reduced radius For traditional trains to safely and comfortably negotiate a corner at higher speeds, the amount of banking to the track has to be increased significantly. This poses problems when lower speed freight and passenger trains have to share the same track and any increase in the amount of the tilt would become inappropriate for them to safely operate.

When travelling at higher speeds without increasing the bank of the train track, passenger comfort is severely affected due to the increased centrifugal force. When cornering the human body will be forced against the seat, armrest or the side of the carriage. Safety is also impacted as packages and luggage will slide around the passenger compartment, fall from overhead compartments, and have the potential to inflict injury. Any passengers that are standing or preparing to disembark at the next station can lose their balance and fall, again either injuring themselves or other passengers.

The solution of laying dedicated banked track for high speed rail service was used for the Japanese bullet train service and by France's TGV (Train à Grande Vitesse). Many other operators do not have the luxury of doing so due to populous built-up areas, natural restrictions of tunnels or narrow width cut-outs on mountain sides. Tilting train carriages offers a different solution and has been in operation since 1973 with the first public service in Japan on a JNR (Japan National Railways) line. It was not fully implemented worldwide as the expense of the technology did not justify the reduced travel times. Today the benefit from increased train cornering speed is now significant enough for the many companies operating in today's competitive markets to re-consider the technology. Having a tilt of just eight degrees can increase train cornering speeds of up to 30%, while still maintaining a comfortable ride sensation.

Initially (passive) mechanical tilting methods were used, involving a time delay before the tilting could be implemented, and the poor ride quality was rejected by passengers. Computer controlled (active) tilting systems are now the most widely used mechanism today. The ability to sense the severity of the corner from the front power car or predict the amount of tilt needed from forward looking sensors has virtually eliminated passenger motion sickness.

During the long history of the development of train tilting systems, many types of technologies have been designed, prototyped, implemented and then scrapped. Although the primary goals of these systems were met; increased cornering speeds, reduced travel times and improved passenger comfort, reliability was still a concern. Political concerns have caused government programs to be halted as broken down trains and rail delays are quickly picked up by the media.

As the tilt mechanisms are normally mounted on each train and carriage bogie; torsion due to twisting can result in driving instability if they are not properly synchronised. This potential issue has been solved with hydraulic isobaric technology where cylinders installed on different bogies of the same carriage are fed with the same pressure.

Modern rail tilt systems are hydraulically operated; with high pressure oil pumped through a series of valves and manifolds to cylinders that lift and lower one side of the carriage at a time.

The system also has to operate at extremes of temperatures ranging from -40ºC to +100ºC. Periodic inspection, often visual, has to be easy and quick to perform.

The life of the hydraulic pump is also an issue for train reliability. Steps should be taken to minimise the amount of hours that the pump operates at high pressure. Continuously operating pumps also generate noise, affecting the passenger's sleep and comfort. Eaton's history in this arena dates back to 1970 when the revolutionary Fiat test train was equipped with an active tilt system with speeds of up to 260 km per hour. Further collaboration resulted in the ETR 401, which over a 295 km journey, reduced the travel time by 20% from 3 hours and 30 minutes to 2 hours and 50 minutes.

Continuous development has changed the construction, particularly with electrification of rail systems. Not only are tilt mechanisms fitted to the train bogies, but they are now incorporated on the pantograph equipment, with a counter tilt system to keep the brushes in contact with the overhead electrical supply lines. A smart solution lets the pantograph system bleed air through a specifically designed manifold block.

On each rail bogie, of which there are two per carriage, Eaton use two powerful vertically mounted hydraulic cylinders with fully integrated magnetostrictive* linear sensors. These sensors precisely measure the cylinder extension and let the train control system calculate the most comfortable tilting angle while maximizing the speed. A similar construction is used on the pantograph for a higher level of reliability.

A typical Eaton train configuration employs a single power unit placed under the floor of the carriage, driving both bogie mounted cylinders in unison. This synchronises the tilt distance and avoids any torsion on the carriage body, as the cylinders are controlled together, effectively being driven in parallel. The use of a single power unit is more reliable and performs better than a more complex system that employs individual control and power units to each bogie.

The robust centralised power unit uses an open-frame, modular concept with aluminium manifold blocks to reduce weight to improve the train's efficiency and to meet weight limits imposed by technical specifications. Shock and vibration from the train track to the power unit's structural frame is minimised by dampers, again to enhance reliability.

At the heart of the hydraulic system is an electrically powered high reliability pump. To prolong pump operating life, an automatic circuit activates the pump for accumulator charging: after the accumulator has reached the requested working pressure the pump is put at low pressure. As a consequence, when the train is on straight track portions, the pump working time at high pressure is reduced to a minimum. This also has the benefit of reducing noise for passenger comfort. When operating in cold environments during winter or at high altitudes, an oil tank and electrical heater keeps the viscosity of the oil at the correct level. During extended operation, an air to oil heat exchanger is used to cool the fluid. By maintaining the temperature of the fluid within a restricted window, the hydraulic components last longer assisting reduced service times and costs.

A lightweight aluminium manifold assembly contains the servo valves that control the tilt cylinders and include a filter for the returning oil. In the event of a valve failure, the redundant valve arrangement allows operation to continue and improves system reliability. In an emergency, valve units can be activated to discharge the oil from the tilting cylinders, bringing the train back to a vertical position if required.

The open frame structure of the power unit allows for enhanced access for service personnel. Visual checks can be performed quickly, accurately and thoroughly, with any necessary manual adjustments made faster, reducing any potential train departure delays. The air-oil heat exchanger unit location and design assures better cleaning during routine service, again improving operator costs.

Conclusions

The challenges facing the rail industry are to make rail travel as reliable, efficient, safe and comfortable as possible. Driven by regulations and increased globalization, train builders and railway operators must find ways to reduce downtime, increase productivity and enhance safety and security to drive profitability and make the industry more sustainable.

The use of train tilting systems enables trains to comfortably corner at higher speeds, on existing rail networks, to reduce travel times. Eaton's extensive experience and hydraulic product portfolio allows the company to offer proven solutions, and offer full, local technical support when needed. Eaton also offer maintenance programs to maintain tilting system at maximum efficiency.

Eaton understands the need for rail solutions that work reliably and safely. Providing products to the rail industry means helping our customers build better and safer trains, while enabling railway operators to operate competitively with products designed for maximum reliability. Our focus on energy efficiency and safety means our customers can rest assured that they'll be able to meet stringent regulations and drive the industry towards a sustainable future. With technical expertise and project management capabilities, plus a broad portfolio of electrical and hydraulic solutions, Eaton can help minimize risk and ensure secure rail projects.

If you would like to understand more about how Eaton can help you deploy tilting mechanisms on existing rail system or new rail programs, visit our website or talk to our team of applications specialists using the contact information below (tba)

*Magnetostriction (cf. electrostriction) is a property of ferromagnetic materials that causes them to change their shape or dimensions during the process of magnetization Eaton 1000.

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