

LMS Virtual.Lab makes the world's first maglev simulation a reality



With soaring oil prices and increasing pollution, the heat is literally on governments and transportation authorities to explore alternative options. The case for maglev technology is clear. Running on electricity, maglev trains can carry people and freight cheaper, faster, quieter and cleaner than trucks and planes. With dedicated guideways, the system does not contribute to urban congestion and the vehicle and track life span lasts 50 years or more with minimal maintenance – much longer than a truck or airplane.

Strictly looking at the cost structure, maglev technology is extremely energy efficient and sustainable. Compared to the European high-speed trains, a typical maglev uses 30% less energy. Compared to traditional transportation, maglev uses 3 times less energy than a car and 5 times less energy than an airplane. And it's quiet as well. At a speed of 240 km/h, a maglev only generates 69dB, a sound level that would completely disappear in a city.

“Many Asian countries are planning new railway services and maglev is really considered the transportation form of the future. This differs from Europe where most countries already have excellent urban and inter-city conventional lines,” states Dr. Hyungsuk Han, Senior Researcher at the Korea Institute of Machinery & Materials (KIMM), the government-run science and technology research institute.

All aboard the Asian maglev revolution

With many Asia cities dealing with constant rush hour traffic and serious pollution, it is no wonder that maglev is taking off in the Far East. First was Shanghai's high-speed maglev railway that zips passengers from the business district to the Pudong International Airport in a nifty 8 minutes. Using Germany technology, the €820 million Shanghai Transrapid maglev took just two years to build and was launched in 2004. World renown for its Shinkansen bullet trains, Japan has a maglev demonstration line in Yamanashi where test trains have reached a speed record of 581 km/h – 6 km faster than the French TGV – as well as the Linimo, the world's first commercial urban maglev constructed for the 2005 Nagoya World Expo.

Creating the future's mainstream transportation systems

Korea is one of the countries that has jumped on board the maglev express with its €285 million urban maglev program which kicked off in 2006. Unlike the high-speed flyers in China and Japan, the government-sponsored Korean maglev project focuses on the 100 km/h medium-to-low-speed range – practically the same as a subway. Driving the project is the Korea Institute of Machinery &

Materials or KIMM, the government-run science and technology research institute responsible for maglev development and system integration. Hyundai-Rotem is building the maglev train and the Korea Rail Network Authority is responsible for constructing the actual guideways.

Running literally at lightening speed, the project has already reached a launch stage in just two short years thanks to a team totaling more than 300 researchers and engineers from 26 industrial, academic and research institutes. Mid-term plans include the 6.1 km urban maglev demonstration line at Incheon International Airport by 2011. If all goes according to plan, the Korean maglev train will go into commercial service in 2013.

The world's first simulated maglev model

In the early project stages, Dr. Han and his team at KIMM conducted a significant amount of research to evaluate and improve existing maglev performance. To do this, Dr. Han and his team turned to LMS Virtual.Lab to help develop a simulated maglev model – the first simulated maglev in the world.

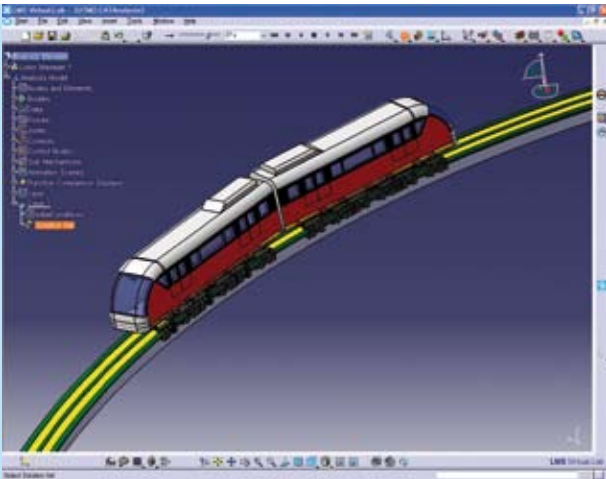
“The fact that maglev simulation requires contact-less interaction between the vehicle and the flexible guideway was the primary challenge. We considered other solutions, but concluded that only

The final design of the Korean maglev: maglev surpasses all other forms of mass transit systems with its comfortable ride and panoramic views.



A brief maglev history

Floating maglev trains (short for MAGnetic LEVitation) have been a futurist dream for more than 80 years. The original concept can be traced back to a German engineer, Hermann Kemper, who first thought up the idea in 1922. It was only 12 years later in 1934 that he patented it. Decades later in 1966, the concept matured when Dr. James Powell and Dr. Gordon Danby came up with the revolutionary idea to use super-conducting magnets in a vehicle and discrete coils on a guideway to propel a passenger vehicle by generating same polarity magnetic fields.



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LMS Virtual.Lab Motion permitted us to successfully simulate the crucial interaction between the vehicle's electromagnets and the guideway – an extremely complicated procedure,” stated Dr. Han.

Integrated levitation algorithms

Unlike a classic simulation of a car or airplane, the maglev team first needed to calculate electromagnetic forces according to relative position and velocity. In turn, these calculated forces were applied to both the maglev vehicle and the guideway in the model itself. To do this efficiently, the team created their own customized user-defined subroutines, including flexible contact and ordinary differential equations (ODE). The success of the maglev model relied on the calculation's accuracy and the ability to integrate flexible contact subroutines into the LMS Virtual.Lab Motion solver.

“The user-defined subroutines simulated the relative positions and velocities between the guideway and 48 electromagnets. Each electromagnet was divided into about 20-30 segments to accurately calculate forces in vertical and lateral directions. Then the team defined 300 ordinary differential equations related to the electromagnetic forces to calculate lift and guidance forces generated by the electromagnets. Irregular lateral and vertical profiles were defined as well as tangent, transition and circular curve sections. These electromagnetic forces were then both applied to the maglev vehicle and guideway,” explained Dr. Han.

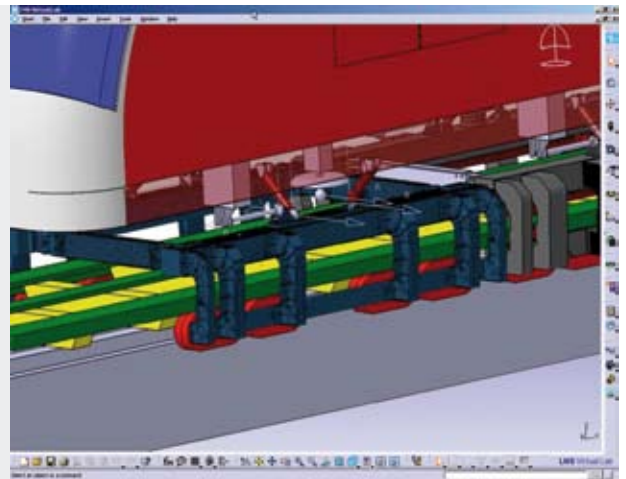
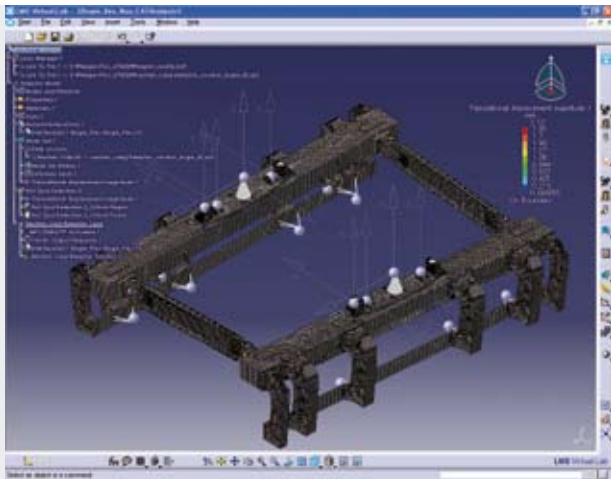
The two-week maglev modeling miracle

Even with the KIMM team counting on external help from LMS partner SVD to model the guideway, whipping up such a complex virtual model while incorporating the new levitation algorithms in a quick two weeks is an amazing feat in itself.

“This was the first time that a full vehicle multi-body dynamic model containing interaction between an electromagnetic mechanism and flexible guideways was completed to this functional extent. Other firsts were a full vehicle curving simulation including the bogie steering mechanism as well as the bogie durability analysis,” added Dr. Han.

Once the model was available, the team put it through its paces to improve the overall maglev experience. KIMM investigated classic key attributes using LMS Virtual.Lab Motion such as ride quality, vibration, and durability. Covering all the process steps and required technologies to perform an end-to-end design assessment, LMS Virtual.Lab Motion allowed the researchers to examine atypical simulation aspects such as levitation stability and curve negotiation – a tricky design aspect since the bogie mechanism needed to include steering capabilities to negotiate a small radius curve. The team also counted on the LMS Virtual.Lab suite to optimize the design to answer mission critical questions like the cost associated with the guideway specifications and the levitation control system.

“It was very important to find the right balance between creating a sustainable and economical guideway design while maintaining passenger comfort and ride quality,” adds Dr. Han. “Not only was LMS Virtual.Lab the only simulation software that could handle



A durability analysis using LMS Virtual.Lab confirmed that the critical electromagnetic-mechanism-bogie-guideway interaction was designed to last.

a complex simulation like the maglev thanks to the user-defined subroutines that could handle the levitation algorithms. In the end, we also found that LMS Virtual.Lab significantly reduced our CPU processing time – an important factor when you are calculating 48 electromagnets, each divided into 20-30 segments using 300 equations. The streamlined processing set-up allowed us to create this working model in two weeks time.”

The dream vehicle becomes a reality with LMS Test.Lab

To validate the world’s first maglev simulation, KIMM counted on a LMS Test.Lab configuration to confirm the accuracy of the calculations against the actual maglev prototype model, the UTM2. KIMM engineers measured the dynamic responses like the Frequency Response Function (FRF) of the secondary suspension and mission-critical electromagnet control system of the actual maglev prototype and used this information to cross-check the simulation model’s accuracy. For example, the engineers compared the resonance between the vehicle and the

flexible guideway and sampled a selection of vibration modes on the guideway and the bogie mechanism as well as operational vibration modes of the bogie, curve negotiation, ride and vertical and lateral gaps.

LMS Test.Lab was also used to complete several critical design ride and handling variation studies including the effect of the damper damping coefficient on ride quality, the effect of air spring stiffness on ride quality, the effect of staggering on curving performance and the effect of the bogie mechanism on curving performance.

April 2008: almost ready to “levitate”

Thanks to the success of the simulated urban maglev using the LMS Virtual.Lab platform and the validation of the simulated results with LMS Test.Lab, KIMM gave the green light to launch. On April 21, 2008, the first official Korean maglev pulled out of the National Science Museum and continued down the guideway to the Expo Park on the approximately one-kilometer line in Daejeon. Since 2005, the Korean

government has already invested about €6.4 million in maglev infrastructure including guideways, bridges and station buildings. “I was overwhelmed to see this first maglev test drive – 20 years after we started the plan,” said the President of Kunkuk University Mr. Oh Myung, who started the project when Deputy Prime Minister in the Education, Science and Technology Ministry. With completion planned for 2013, Korea will be the third nation on the planet to run maglev trains for revenue service, following China and Japan respectively. The completed urban maglev train will stop at six stations, including the Water Park Station, an access point for visitors to the 2014 Asian Games. “LMS Virtual.Lab was the only simulation solution that let us incorporate levitation algorithms to model electromagnetic forces that truly reflected real-life performance. This allowed us to create the most realistic simulation possible,” concluded Dr. Han. “The fact that it could handle other mission critical factors like guideway specification costs and the levitation control system not to mention the LMS Test.Lab validation process all contributed to the successful launch of the Korean maglev.” ■



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