Making the World's First Maglev Simulation a Reality

Looking strictly at the cost structure, maglev technology is extremely energy efficient and sustainable. Compared to European high-speed trains, a typical maglev uses 30% less energy. Compared to traditional transportation, maglev uses three times less energy than a car and five times less energy than an airplane. And it's quiet as well. At a speed of 240 km/h, a maglev only generates 69 dBA, a sound level that would be less than the ambient noise in a city.

"Many Asian countries are planning new railway services and maglev is considered the transportation system of the future. This differs from Europe, where most countries already have excellent urban and inter-city conventional lines," notes Dr. Hyungsuk Han, senior researcher at the Korea Institute of Machinery & Materials (KIMM), a government-run science and technology research institute.

All Aboard the Maglev Revolution. With many Asian cities dealing with constant rush hour traffic and serious pollution, it's 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 Pudong International Airport in only 8 minutes. Using German technology, the €820 million Shanghai Transrapid maglev took just two years to build and was launched in 2004. With its world-renowned 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.

Mainstream Trains of the Future. 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. KIMM is driving the project and is 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 at top speed, the project has already reached a launch stage in just two short years thanks to a team of 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.

First Simulated Maglev Model. In the early project stages, Dr. Han and his team at KIMM conducted significant research to evaluate and improve existing maglev performance. To do this, they 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," adds Han. "We considered other solutions but concluded that only LMS Virtual.Lab Motion allowed us to successfully simulate crucial interaction between the vehicle's electromagnets and the guideway – an extremely complicated procedure."

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 its 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, explains Han. "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 applied to the maglev vehicle and guideway,"

Two-Week Maglev Modeling Project. Even with the KIMM team counting on external help from LMS partner SVD to model the guideway, completing such a complex virtual model while incorporating the new levitation algorithms in two weeks was 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," adds 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.

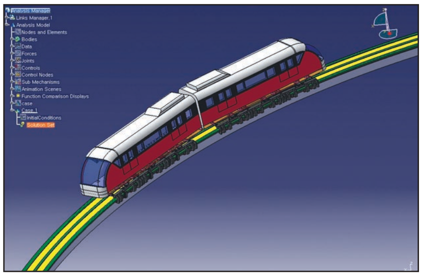

Figure 1. It was very important to find the right balance between creating a sustainable and economical guideway design while maintaining passenger comfort and ride quality.

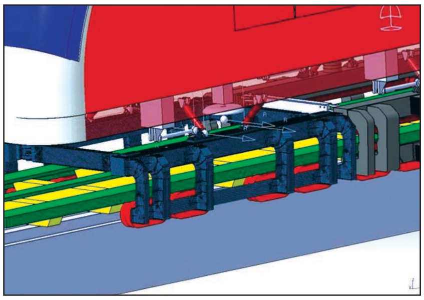

Figure 2. A durability analysis using LMS Virtual.Lab confirmed that the critical electromagnetic mechanism-bogie-guideway interaction was designed to last.

"It was very important to find the right balance between creating a sustainable and economical guideway design while maintaining passenger comfort and ride quality," says Han. "Not only was LMS Virtual.Lab the only simulation software that could handle a complex simulation like the maglev thanks to the user-defined subroutines that could handle the levitation algorithms, we also found that it 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."

Dream Vehicle Becomes Reality. 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 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 damping coefficient on ride quality, the effect of air spring stiffness, the effect of staggering on curving performance and the effect of the bogie mechanism on curving performance.

April 2008 – 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 1-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 Oh Myung, president of Kunkuk University, who started the project when he was deputy prime minister in the Education, Science and Technology Ministry. With completion planned for 2013, Korea will be the third nation 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.