Simulation helps LG Industrial Systems develop improved escalators

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The Challenge

The trend towards longer and higher rise in new building construction provides a significant challenge to escalator designers. Traditionally, escalators have been designed based on static loads and torques from physical experiments, these experiments are very expensive and time-consuming to perform. Another problem with the experimental approach is that it is very difficult to capture the actual dynamic operating conditions of the escalator in simplified static tests. Data collected during the experiments is limited to specific locations where sensors can easily be located, raising the risk that they may fail to capture important loading conditions.

In an effort to overcome these problems, LG engineers considered simulating escalator designs on a computer. They investigated several major commercial software packages and selected DADS due to its superior ability to analyze the extremely complex, dynamic mechanical systems involved in escalator design.

The Design

The model of the steps is composed of 58 step bodies and 116 roller bodies and has 523 independent degrees of freedom. In order to consider the elastic effect of chains, rollers are connected by 174 spring and damper elements. All bodies are assumed to be rigid since they do not deform under operating conditions. The frame is fixed to the ground. The upper terminal gear is constrained to the frame by a revolute joint. The lower terminal gear is set to the frame by a translational joint and a spring element to provide proper chain tension force. The upper terminal gear is driven at the angular velocity corresponding to the step velocity, 0.500 m/s.

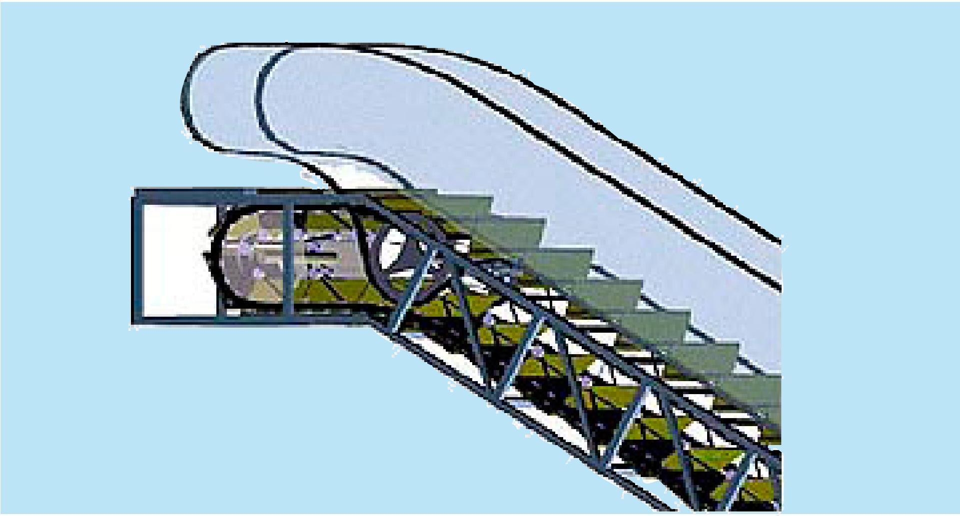
The continuous elastic handrail is modeled by dividing it into 127 discrete rigid bodies resulting in a total of 381 independent degrees of freedom. Two friction contact elements for each handrail body are applied to prevent rotational motion of the handrail. In order to consider the elastic e ffect of the handrail, each handrail body is connected by 127 spring and damper elements, which are connected with spring elements . The rigid bodies used to model the handrail are as small as possible in order to have at least one body in contact at the bending region. The driving pulley is constrained to the frame by a revolute joint and driven at the angular velocity corresponding to handrail velocity of 0.510 m/s. The lower tensioner and the belt tensioner are constrained to make proper tension force on the handrail. To consider the bending resistance of the handrail, bending resistance coefficients corresponding to relative bending angle of each handrail body were determined by experiment and applied to the model.

The Simulation

The DADS model simulates the operation of the escalator. Output of the simulation includes such critical dynamic characteristics as acceleration, the reaction force of a roller, tension force of a chain, and torque of the upper terminal gear and the driving pulley. Before using the model for real-world design, LG engineers compared its accuracy to physical experiments. They measured the acceleration of an actual elevator step using a low frequency accelerometer and frequency analyzer. Force measurements were made with an experimental set-up comprised of two load cells, jigs to connect chains on both sides of the step, an amplifier, and an analyzer. Experimental torque measurements were taken with a strain gauge type torque sensor, an amplifier, and an analyzer. The torque sensor was set between the motor and the reducer to measure the driving torque more precisely. All results tested were measured as the escalator was rising. Each experiment was performed several times in succession to assure that measurement variations were less than 10%.

The Results

The simulation results matched the experimental results very closely. The step acceleration in the simulation and experiment were 40 gal (cm/sec2) and 45 gal respectively. The 10% error in magnitude could have arisen from excluding the motor and the reducer in the model. The reaction force of a roller rising near the upper terminal gear agreed within 6% of the experimental results. The maximum tension force and the slope of tension force of the chain in the simulation matched those in the experiment within 3%. In order to correlate motor torque, the step and handrails were considered separately. The torque of the upper terminal gear and the driving pulley in the simulation were multiplied by the 24 to 1 reduction ratio. Torque at steady state agrees well with that of experiment within 9%.

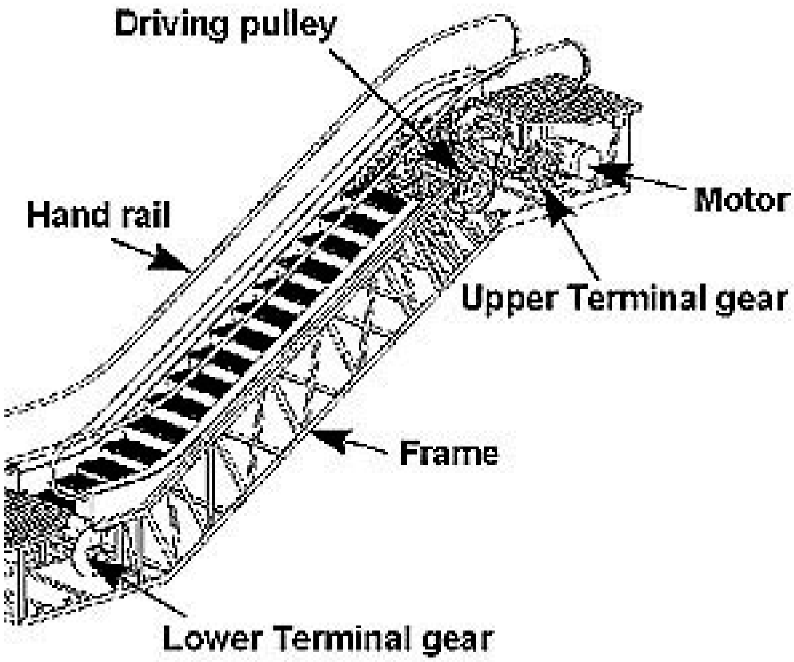


Design Improvements

The validated simulation model has dramatically improved the design process. Since the design can be tested before the prototype is built, the total design time is substantially reduced. Even more important is the ability to tune and optimize the design without the cost of building hardware prototypes. Engineers are able to:

1. develop a more durable structure with lower materials and labor cost
2. reduce energy requirements
3. lower noise and vibrations levels

Based on this success, LGI managers made the decision to expand the number of engineers at the company with access to the DADS simulation model. They assigned LGI engineers to work with LMS CADSI analysts to develop a front end user-interface to DADS that simplifies that process of developing a custom escalator model. This user-interface makes it possible for engineers without experience using DADS, to create their own models simply by entering key design parameters for the simulation. Making simulation available to the company's entire engineering workforce will make it possible to improve and optimize every escalator design while reducing time to market. ■



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