For most airports, a passenger boarding bridge is not just a system to enhance passenger comfort on the way from the terminal to the plane, but a strategic safety element. ThyssenKrupp Airport Systems has installed more than 3,000 passenger boarding bridges, also called fingers, at airports around the world. The drive-system frame of the passenger boarding bridge (known as the bogie) supports 50 metric tons (55 tons) of structure while providing the forward, backward and lateral movements needed to dock to the aircraft.

ThyssenKrupp recently used ANSYS simulation tools to develop a new bogie design by evaluating the performance of many design iterations while taking nonlinear material properties and contacts into account. Parametric analysis and shape optimization delivered the required safety margin with the least material possible. The end result is a part with 33 percent higher allowable load limits that keeps manufacturing costs under control by using 10 percent less material than the original part.

**STRATEGIC SECURITY ELEMENT**
ThyssenKrupp Airport Systems is a business of over 400 people focused on building, installing and maintaining passenger boarding bridges. Its three production facilities are located in Spain, China and the United States. The company’s bridges consist of glass and steel side-walls with one, two or three tunnels to service planes with multiple entrances. A column supports a substantial portion of the complex structure’s weight and connects with the moving frame using a roller just below the rotunda. The lift-and-drive system incorporates a telescopic frame joined to the tunnel structure near the entrance to the aircraft. The bogie supports the lift system and uses motor-driven wheels to provide forward, backward and lateral movement for the bridge. The bogie includes a lift jack opening that is used when replacing the wheels. A cabin on the end of the passenger boarding bridge connects the tunnel to the aircraft.

**MOVING TO SIMULATION-BASED DESIGN**
The bogie originally used in ThyssenKrupp passenger boarding bridges was designed in Germany 20 years ago using hand calculations. The limitations of manual
design methods meant that prototypes had to be constructed and tested in evaluating each design iteration. Testing identified problems with early design iterations but provided limited diagnostic information, so engineers had to rely on intuition to modify the design. The time required for physical testing limited the number of load-case scenarios that the engineering team could evaluate. Historically, it took 18 months to iterate to a bogie design that met specifications.

Recently, ThyssenKrupp Airport Systems integrated simulation into its design process. The team still regularly uses hand calculations, but finite element analysis is now the primary tool to evaluate proposed concept designs. This simulation takes the actual geometry of the part into account so engineers can more accurately determine the response of the structure to realistic loads while examining detailed diagnostic information. Simulations address complex physics that are far beyond the capabilities of hand calculation, such as nonlinear material properties, nonlinear contact conditions and plastic deformation. The technology gives the design team the ability to accurately predict real-world performance, making it possible to postpone prototype building and testing until the latter stages of the design process, when the build-and-test method is used to validate the simulation results.

ThyssenKrupp Airport Systems uses ANSYS Workbench, ANSYS DesignModeler and ANSYS Mechanical. Workbench provides an integrated environment to substantially reduce the time required to prepare models for analysis — including defining loads, constraints and contacts. DesignModeler delivers a fully parametric environment for defining and editing design geometry so that design engineers can evaluate many different design variations in a short time. ANSYS Mechanical offers the ability to analyze the wide range of physics — stresses, deformations, vibration characteristics, reaction forces and residual strains — required to determine performance of a passenger boarding bridge.

**REDESIGNING THE BOGIE**

Recently, the decision was made to redesign the bogie using simulation as an integral part of the design method. As a first step, the original CAD geometry was transferred into DesignModeler. At the same time, physical tests were carried
out to validate material properties and determine loads based on the original design. Engineers used ANSYS Mechanical to evaluate the stress behavior of the original part and the effects of design changes, such as increasing the radii in high-stress areas. The team decided to change the material from cast iron to steel, because steel provides better control over material properties, and then began to redesign the part from scratch.

ThyssenKrupp engineers then created a new design in DesignModeler. The model of the previous design used all solid elements because of the complex geometry of the cast part. It had a total of 1.3 million nodes. The model of the new design with a combination of shell and solid elements used only 300,000 nodes. Running this analysis with all solid elements would have taken about 12 hours per load case. The use of shell elements reduced the solution time to three hours per load case.

Engineers added constraints and loads to the model and simulated its behavior. One of the more complex load cases involves jacking up the bogie to change one wheel. When the jack rises, the bogie flexes under bending loads, and the load is transferred along the lift jack opening. ThyssenKrupp engineers used a nonlinear contact to maintain the contact at the right location as the part flexes.

Using ANSYS DesignModeler, the engineering team reproduced stiffness and other behaviors of this complicated component while defining many load cases and taking nonlinear material and contacts into account. It performed stress and buckling analyses, to determine if interior ribs were required, then validated the forward, backward and lateral movements of this part. The interaction between the wheels and the apron surface was analyzed for different combinations of material stiffness and contact conditions.

ITERATING TO AN OPTIMIZED DESIGN
Once the analysis identified the part’s problematic zones, engineers added and removed material manually; they also used the shape optimizer within ANSYS Mechanical to improve the geometry. An envelope of the initial volume was defined to determine the location of the fixed points where the bogie attaches to the wheels and lift. Loads and fixed supports were applied. The software approximated the initial structure as a large volume. Material was then reduced at locations with low stresses, resulting in a more optimal structure.

The resulting optimized design weighs 10 percent less than the original design while providing an allowable load of 80 metric tons (88 tons), 33 percent more than the previous-generation design. Engineers ordered a prototype of the new design and performed component-level physical testing that verified the simulation results.

Confident in the design results, rather than prototyping just the drive system, engineers went ahead and built a complete bridge with the new bogie design. Testing showed that the design worked perfectly, so it went into production only three months after the beginning of the design process — reducing design time by almost 89 percent from the hand-calculation build-and-test method used for the original design.

Overall, the use of ANSYS simulation tools drastically reduced the time required to bring the new design to market. In just a few months, ThyssenKrupp engineers thoroughly evaluated the bogie’s behavior under many different load-case scenarios, far more than could have been physically tested. The result is a very reliable product that far exceeds design specification at a manufacturing cost equal to the previous design.

Design time was reduced by almost 89 percent from the hand-calculation build-and-test method used for the original design.
- Model of original bogie design (left) and new bogie (right)

- Global displacement results for new design

- Stress analysis results with mesh for wheel-replacement load case for new bogie design

- Linear buckling analysis results for operating load case for new bogie

- Stress simulation of original bogie

- Stress simulation for internal components of new bogie

- Previous-generation bogie design

- New bogie prototype during testing