Case Study: **Comtes FHT**

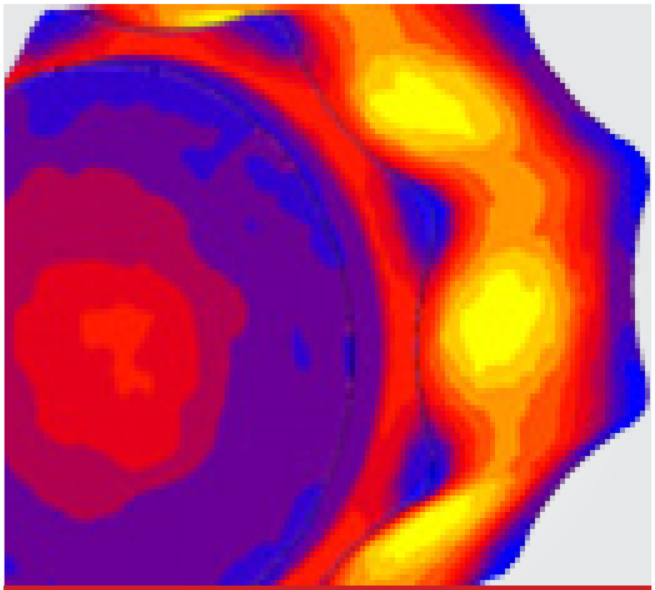
Marc Heat Transfer Analysis Helps Solve Tough Forging Problem

Overview

A leading producer of castings, ingots and forgings, Pilsen Steel, Pilsen, Czech Republic, recently experienced difficulties with ingots cracking in a forging operation. The company contracted with COMTES FHT to investigate and determine the root cause of the formation of longitudinal cracks on a diverse load of 34CrNiM°6 steel ingots in a forging operation. Previously the ingots were cooled after casting in water to between 500°C and 600°C. The ingots were then placed in the forging furnace which is at a temperature of 1100°C to 1200°C. It was unclear whether the root cause of the cracks was heating the ingots or the forging operation.

COMTES used MSC Software's Marc nonlinear finite element analysis (FEA) software to analyze the process of heating the ingots in the furnace, which was suspected as the root cause of the cracks.

The results showed that increasing the temperature of the ingots by 100°C prior to putting them into the furnace reduced thermal stresses to acceptable levels. Pilsen Steel implemented this change and it eliminated the cracking problem.



Marc calculated the radiant heat transfer from the furnace to the ingot then converted the thermal gradients into mechanical stresses on the ingot.

“Marc is a powerful tool for better understanding the physical phenomena involved in a product or process and optimizing performance prior to investing in expensive physical hardware.”

Dr. Filip Tikal, Computer Modeling Specialist, Comtes FHT

Challenge

COMTES FHT was tasked with investigating the root cause of the formation of longitudinal cracks on a diverse load of 34CrNiM°6 steel ingots in a forging operation.

In their current proccess, Pilsen Steel was cooling the formed Ingots in water to between 500°C and 600°C. The ingots were then placed in the forging furnace which is at a temperature of 1100°C to 1200°C.

Once cooled, the Ingots longitudinal cracks contained a series of undesirable longitudinal cracks. It was unclear whether the root cause of the cracks was heating the ingots or the forging operation.

“Marc is the only finite element analysis software I am aware of that is capable of handling all of the complexities of this analysis problem,” Tikal said. “Performing thermal analysis on the complete ingot workload requires determining the radiant heat transfer between the furnace and each of the each ingots with shading effects taken into account. Marc excels at this type of challenging multiphysics problem which is why it is our finite element analysis tool of choice.” Marc is an implicit nonlinear FEA software program that simulates static, dynamic coupled physics problems. Marc eliminates the need for the simplifying assumptions that are required with linear FEA, making it possible to accurate simulate complex real-world behavior under realistic environments and operating conditions.

Solution

Pilsen Steel provided the geometry of the ingot and furnace in the form of 2D drawings. COMTES FHT researchers reproduced the ingot geometry in SolidWorks. Then they created a simple 2D axisymmetric model of a single ingot and the furnace wall. The material model for the simulations was obtained through experimental testing including thermal capacity, thermal conductivity, heat expansion coefficient and phase transformation in the COMTES FHT mechanical testing laboratory.

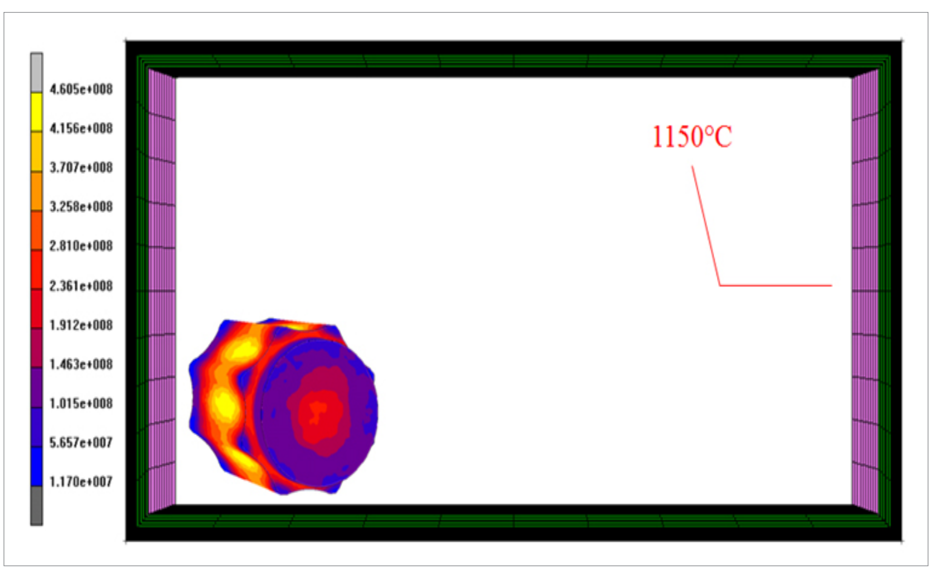
The researchers ran a transient analysis for a period of 5 minutes starting with when the ingot was placed in the furnace. Marc calculated the radiant heat transfer from the furnace to the ingot then converted the thermal gradients into mechanical stresses on the ingot. The results showed very high stresses in the ingot so the 2D axisymmetric model was expanded to a full 2D model also consisting of a single ingot.

The researchers then expanded the 2D model by adding additional ingots to determine the effects of the placement of the ingots in the furnace and of the shading of ingots from radiation heat transfer by other ingots. The actual layout and materials of the ingots in the work load were monitored in the plant for several months to ensure accurate modeling of the ingot placement.

Next, the 2D model was extruded to a 3D model consisting of the furnace and a typical load of ingots. The 3D model provided verification of the 2D analysis as well as more detailed prediction of the location of the cracks which was used for validation by comparing the analysis results with inspection data.

These results confirmed that heating the ingots in the furnace generated thermal stresses that later caused cracks to form during forging. Based on the analysis results, researchers were able to predict which ingots would develop cracks and the location of those cracks. In both the analysis and in production, cracks were primarily seen on ingots placed near the wall of the furnace.

It was clear that the problem was caused by thermal gradients during the heating operation. The temperature of the furnace could not be reduced so the researchers wondered whether raising the ingot temperature would eliminate the cracking problem and, if so, what was the lowest ingot temperature that would eliminate cracks? To answer these questions, COMTES FHT researchers ran a series of analyses while varying the starting temperature of the ingots in 50°C increments.



Key Highlights:

Product: Marc

Industry: Manufacturing

Benefits:

- Realistic Simulation of the Multiphysic behaviour of metal during manfucturing
- Elimination of cracking in final product

A high performance computing (HPC) cluster with 32 cores was used to provide a fast turnaround on this more complex analysis.

The simulation showed that the cracks originated in areas where high thermal stresses were generated as the ingots were heated.

COMTES researchers next ran a number of additional analysis runs that evaluated the impact of adjusting the temperature of the ingots prior to inserting them into the furnace.

Results/Benefits

The results showed that raising the ingot temperature to 700°C completely eliminated the cracking problem. COMTES FHT researchers worked with Pilsen Steel engineers to modify the soaking process used to cool the ingots after casting to provide assurance that ingots would be at least this temperature when they were placed in the furnace.

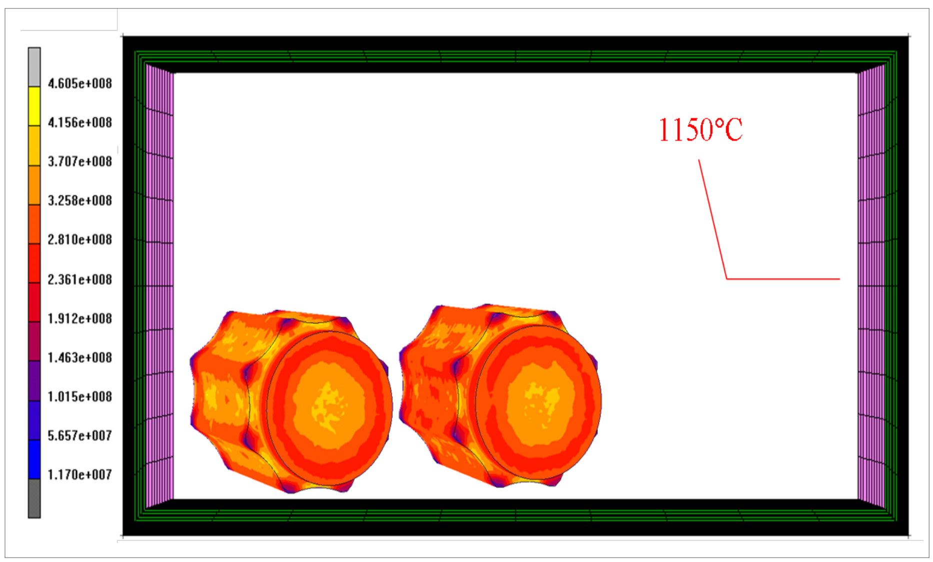
As predicted by the analysis, when these changes were implemented they eliminated the cracking problem.

About Pilsen Steel

Pilsen Steel produces steel, ductile and grey-iron castings, ingots and finished machined forgings for a wide range of industries such as power generation and shipbuilding as well as for further processing by rolling mills. The company performs the complete production process under one roof including steel making, casting, forging and round and finish machining. Two thirds of the company's production is exported. Pilsen Steel delivered the wheel shaft and other castings totaling more than 200 metric tonnes for the London Eye Ferris wheel. Pilsen Steel is also the world's leading producer of wind turbine shafts and one of the largest suppliers of large crankshafts for 4-stroke diesel engines.

About COMTES FHT

COMTES FHT offers a wide range of services to metal producing and metalworking companies including physical testing, material analysis, computer simulation, process design and development, and prototype manufacturing. COMTES FHT's customers include steelmakers, rolling mills, forge shops and nonferrous metal producers. The company's capabilities include fracture-toughness testing, high- and low-cycle fatigue testing, high temperature testing, strain measurement, material analysis with electron microscopes, electron backscatter diffraction (EBSD) analysis and energy dispersive X-ray analysis (EDX) analysis of chemical composition. COMTES FHT cooperates with industrial partners primarily in Europe and participates in research and development projects with research institutes and universities all over the world. COMTES FHT employs more than 65 researchers, technicians and other employees.



For more information on Marc and for additional Case Studies, please visit **www.mscsoftware.com/marc**

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