Engineering Strength to Survive the Storm

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In the fall of 2007 two major hurricanes hit the Gulf of Mexico and tipped moored oil rigs. As a result of this, the mooring systems were redesigned to address the severity of these storms and provide an increased level of safety to keep the rigs afloat. The world's leading provider of mooring systems approached Eagle Alloy, Inc. to produce the redesigned mooring socket, part of the oil rig mooring system. The socket is a 400 pound low carbon, low alloy steel casting, and one rig may use 40 sockets. During initial production, cracks appeared during riser removal and were located in the vicinity of the riser contact. Weld repair was allowed but very costly and time consuming. The customer requested that the finished castings must be delivered to the gulf in the spring of 2008 to retrofit the oil rigs before the upcoming hurricane season.

For those foundries that do not have MAGMASOFT® casting process simulation, when time is short and a problem is large, a group of foundry engineers may get together and brainstorm many possible solutions for a symptom (shrink, inclusion, cracks, etc.) of the problem. Those possible solutions are taken to the shop floor and tried, either in combination or one by one. This can be expensive and time consuming and a valuable opportunity for education is lost. Once the problem is solved, the team disbands and everyone is off to the next issue. This is not the approach that Eagle Alloy, Inc. uses to tackle their issues.

Eagle Alloy, Inc. has utilized MAGMASOFT® since 2007 in the development of rigging systems for a large range of steel alloys, all cast with the shell mold and shell core process. When they were initially asked to quote the part, there was some concern if the casting and its rigging would fit within their process constraints. Using MAGMASOFT® in the quoting phase, they identified that it was a part that could be produced, and the part was quoted and awarded. The production rigging system for the mooring socket was developed, and the initial castings were produced. They recognized that while the rigging system produced a casting free of inclusions and shrink as predicted, there were other root causes for the cracks. They turned to the engineering services at MAGMA Foundry Technologies to provide assistance for two suspected root causes for the cracks, segregation and thermal stresses.

The root cause of the crack was found by methodically investigating all the possible causes which included segregation, hot tear, and high thermal stresses. The initial simulation used the rigging geometry and process parameters that produced the crack. Using this one version, all the possible causes were investigated and quantitative information was given to make changes that would directly impact the root causes for the crack formation.

The systematic approach began with the two issues that can occur during solidification, segregation and hot tearing. A baseline simulation of the segregation of carbon, silicon, and manganese showed there to be very low amounts of segregation through the casting and riser contact. In addition, it was shown that the the riser and riser contact were slightly larger than necessary. This presented an opportunity to decrease the size of both which improve the yield and reduced the amount of segregation. Hot tears can be common causes for what could be perceived as cracks in steel castings. If the cracks produced by hot tearing are not immediately visible upon shakeout, they may open and propagate during additional processing such as riser removal or heat treatment. It was determined that both segregation and hot tearing were not the main root causes for the cracks.

The primary root cause for the cracks was found through the evaluation of the stresses created in the casting during cooling. The casting geometry and rigging is symmetrical, but the entire system was filled through one side riser. The asymmetrical filling of the system produced a "cold side" and a "hot side" at the end of the filling with substantial and lasting effects through solidification and cooling. The maximum principal stress results confirmed a localized region of tensile stress at the riser contact, and these stresses were higher on the hot side. Additionally, the maximum principal stress vectors showed the direction of the tensile stress to be perpendicular to the crack. All these factors showed that the thermal stresses created during cooling led to the creation of the crack in the casting.

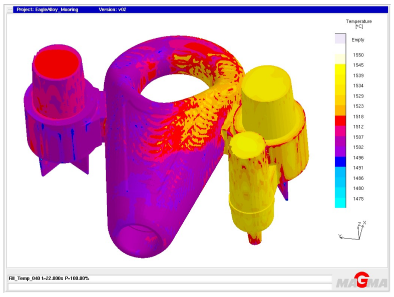

Illustration 1: Temperature Distribution at the End of Filling with the Original Pouring Process

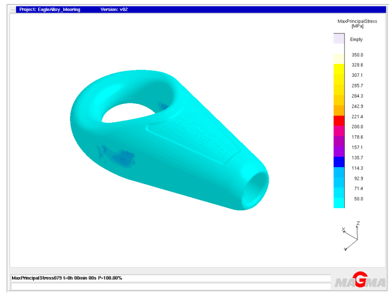

Illustration 2: Residual Maximum Principal Stress at the Cold Riser

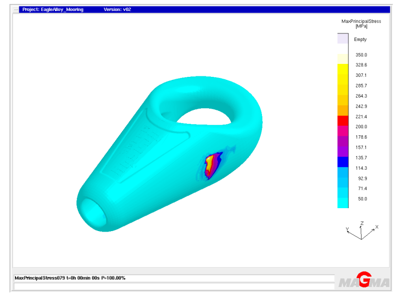

Illustration 3: Residual Maximum Principal Stresses at the Hot Riser

Using the information found in the initial evaluation, the tooling and metallurgical engineers at Eagle Alloy, Inc. and the project engineer at MAGMA discussed several options regarding possible changes that could be made cost-effectively while still creating a robust and manageable process. Various suggestions included insulating the riser contacts during solidification and cooling, leaving the risers on during heat treatment, changing the riser contact shape and size, and other modifications to the pouring process. The easiest process change, pouring through both risers, was investigated. This pouring created a more balanced temperature distribution and was easily implemented in the foundry. The stress simulation during the cooling of the casting still showed a region of higher tensile stress, but the values were equal on both sides. The change to the process was then made in the foundry, and castings were produced with the risers removed prior to heat treatment. The amount of cracks was significantly reduced and when visible, they were smaller in size. However, this was still unacceptable. The engineers at both MAGMA and Eagle Alloy again discussed the possibilities for process changes. With the single riser pour method, removing the risers after heat treating had still produced occasional cracks at the riser contacts. It was determined that the dual riser pour method should continue but additional processing changes were made, and today's castings are free of cracks.

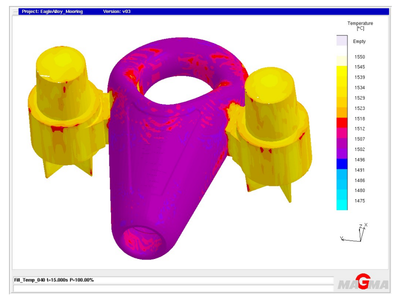

Illustration 4: Temperature at the End of Filling, Double Pour

The initial simulation provided information that clearly identified the root causes for the crack. Once the root cause was identified, the team of engineers used the information from this simulation for discussion and to make selective changes to the rigging and process parameters that directly impacted the root causes for the crack. A second version showed the impact of the change to a process parameter and a third version showed the effects of a rigging change. In those three versions, not only was a robust design and process developed that eliminated the crack, but all the people involved clearly understood what was causing the crack and why the changes made eliminated the crack. Through the comprehensive use of MAGMASOFT® casting process simulation, Eagle Alloy, Inc. met the deadline for casting delivery. In August and September of 2008, two major hurricanes hit the Gulf of Mexico in rapid succession. The rigs using the sockets cast at Eagle Alloy remained upright and safely moored.