Hot Isostatic Pressing – HIP‘17 Materials Research Forum LLC
Materials Research Proceedings **10** (2019) 18-23 doi: http://dx.doi.org/10.21741/9781644900031-3

Hot Isostatic Pressing in the Automotive Industry: Case study of Cast Aluminum Alloys for Rims of Car Wheels

Anders Eklund[1,a] and Magnus Ahlfors[1]

[1]Quintus Technologies AB, Quintusvägen 2, SE-72166 Västerås, Sweden.

[a]anders.eklund@quintusteam.com

Keywords: HIP, Aluminum Alloys, Castings, Wheel Rims, Automotive

Abstract. Cast aluminum alloys are good candidates for weight saving in many industries, i.e automotive, aerospace, sporting goods and other high-performance application. When HIPing of aluminum alloys is performed the fatigue properties of the casting is greatly improved. That is especially true for rims of car wheels that suffer from high porosity and high scrap rates. After HIP, zero porosity is found and scrap rates drop with 50-90%.

Introduction

Cast pores are potential crack initiation sites for aluminum alloys and is considered the main influence of poor fatigue properties. Also, the microstructure influences the mechanical behavior of cast alloys, like inclusions, dendrite spacing and grain size. By controlling the cooling rate during solidification of castings, it is possible to control and modify the alloy microstructure and thereby optimizing the mechanical properties. In Fig. 1, AlSi7 cast aluminum alloy is seen before and after HIP. The internal porosity is completely eliminated, but surface connected pores are still visible on the tested samples. The remaining surface pores will disappear after the final painting step.

Figure 1. Material before HIP (in the middle) and after HIP (top/bottom).

Materials Research Proceedings **10** (2019) 18-23 doi: http://dx.doi.org/10.21741/9781644900031-3

Production route for rims for car wheels

Two different production routes have been considered for the manufacturing of rims for car wheels. In Fig. 2, the HIP is used to treat the aluminum alloy directly after solidification to eliminate porosity and improve the machined surface quality to lower the scrap rate, see Fig. 3. The best way to control the cooling rate is achieved with a HIP-system equipped with uniform rapid cooling (URC™), see Fig. 4. Uniform rapid cooling was introduced in the 1980's for enhancement of the productivity making it possible to double the production due to shorter cycle times. Another advantage was the better control of the cooling rate, which makes it possible to optimize the pressure-temperature ratio which enables optimization of the material properties.

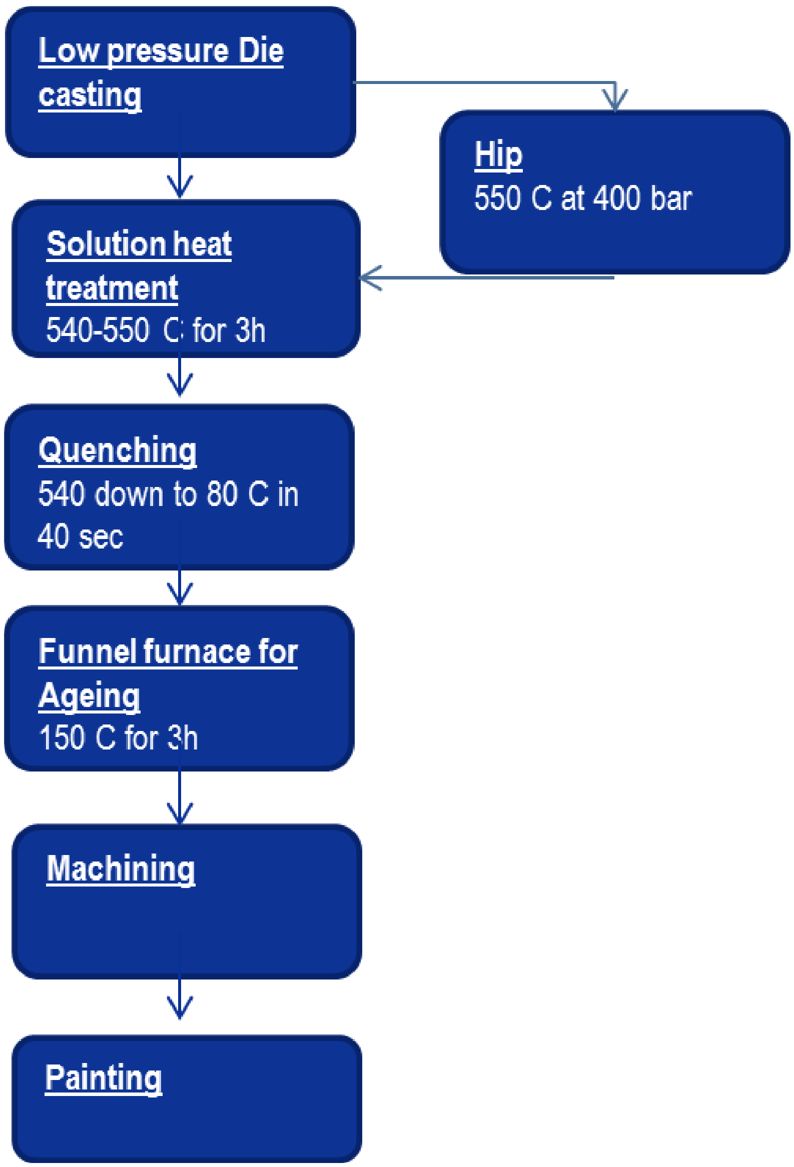

Figure 2. Possible production route for HIP after casting.

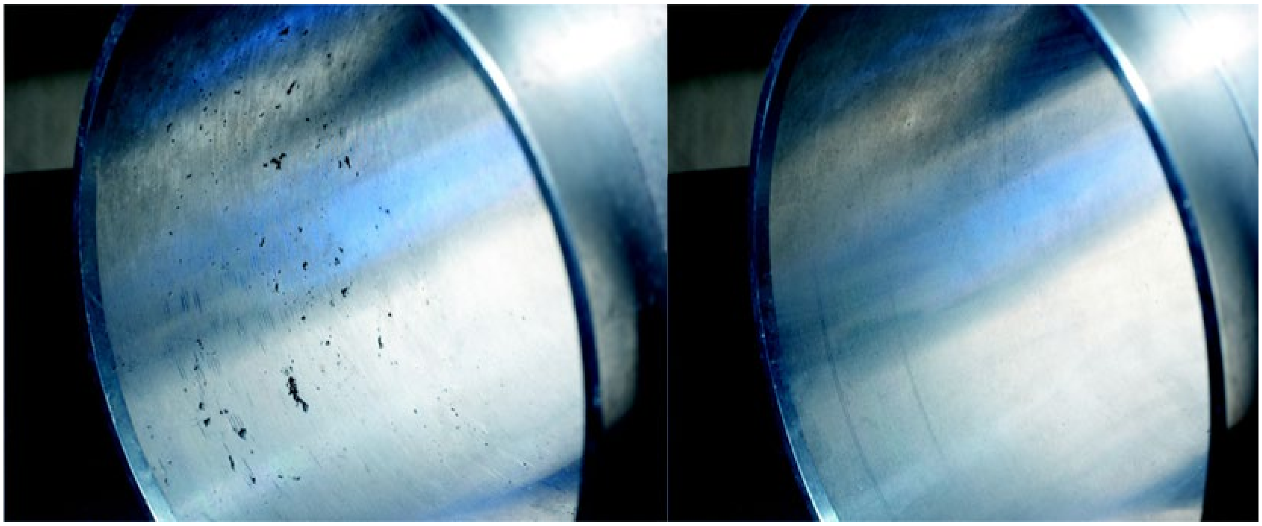

Figure 3. Improved machined surface quality, before HIP (left), and after HIP (right).

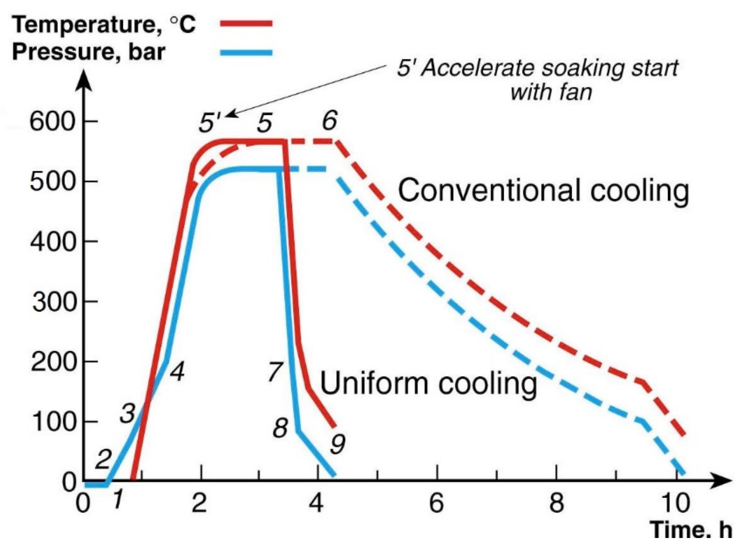

Figure 4. Typical HIP cycle times without and with rapid cooling.

The second possible production route can be seen in Fig. 5. Here, the HIP will replace even more process step, i.e. the solution heat treatment (SHT) and the quenching, by utilizing the possibility the combine HIPing and heat treatment, HPHT. The latest developments in HIP technology, Uniform Rapid Quenching (URQ), have made it possible to achieve cooling rates up and over 2000 °C/min. The same quench rates as you experience in oil- and water bath quenching. The advantage with HPHT, is that the HIP pressure is maintained during the complete HIP cycle until the final step when the HIP is opened for the removal of your parts, see Fig. 6.

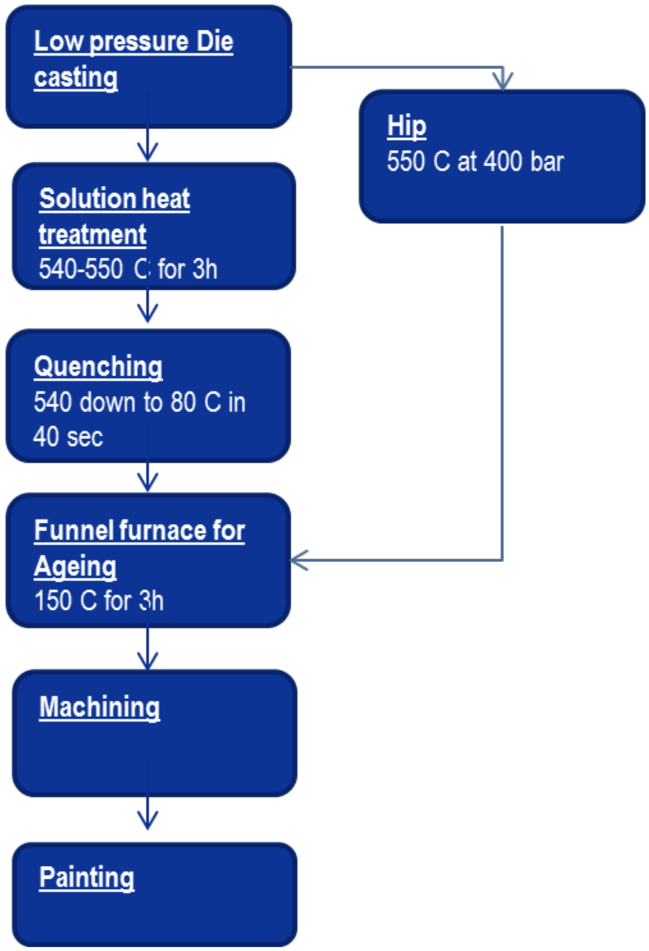

Figure 5. Possible production route for HIP removing SHT and Quenching.

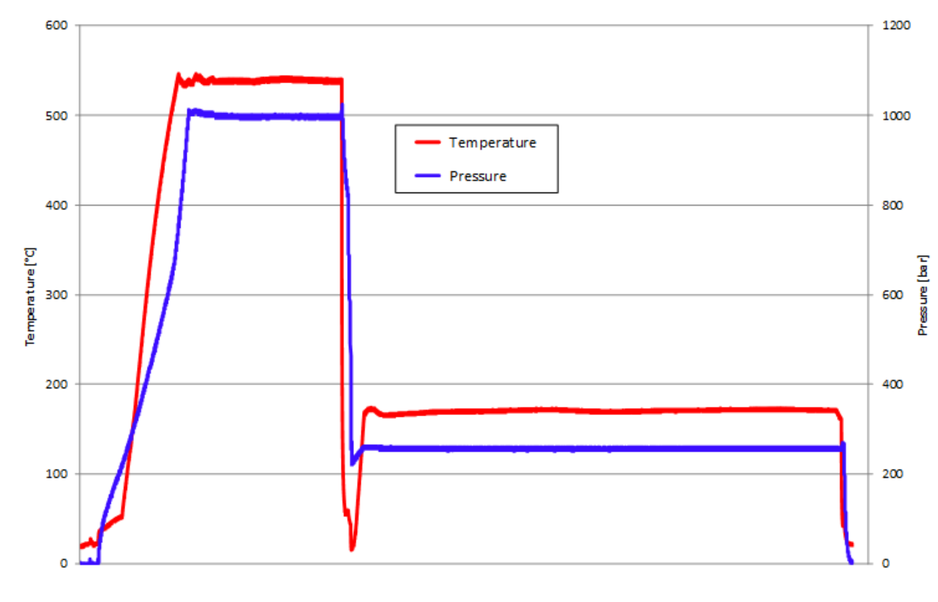

Figure 6. HIP log curve at 1000 Bar and 538° C with a following T6 heat treatment at 168° C and 260 Bar for 6 hours.

Materials Research Proceedings **10** (2019) 18-23 doi: http://dx.doi.org/10.21741/9781644900031-3

Many advantages are found when HIP and Heat Treatment is combined in the same cycle. Cost savings due to lowered energy usage and lowered scrap rates due to the elimination of porosity. The material properties are enhanced, especially fatigue life and elongation, but also hardness can be increased by modifying and optimizing the microstructure. The influence of HIPing on the fatigue life can be seen in Fig. 7. The average fatigue life increases from less than 20k cycles to well above 140k cycles for the same stress load, before failure.

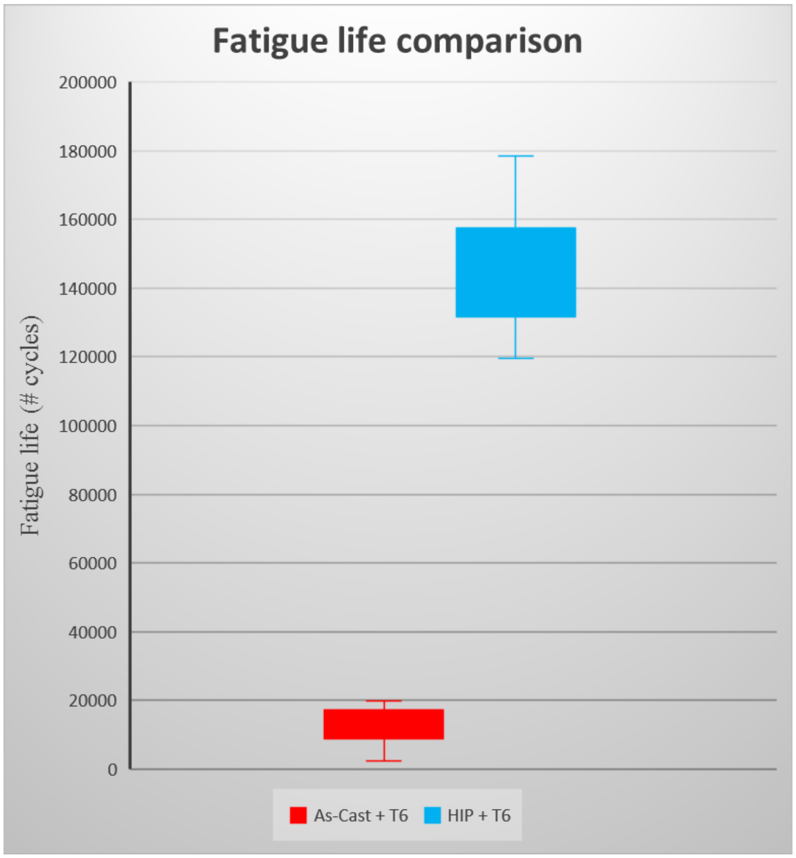

Figure 7. Fatigue life comparison with and without HIP at the same load stress.

Another way to describe the improvement of HIPing for rims of car wheels is to study the development of elongation through the production process, see Fig. 8. Every time the Al-alloys is going through a process step, the elongation decreases due to mechanical or thermal impact of the wheel. Especially, the solution heat treatment and ageing make the large drop in elongation, but also machining and painting makes a lowering in elongation. The threshold for approval in this case is 3% elongation.

One clearly see that HIP increases elongation dramatically and thereby adds a cushion so the threshold value is out of reach, and consequently a drastic drop in scrap rate due to being too low in elongation values.

Materials Research Proceedings **10** (2019) 18-23 doi: http://dx.doi.org/10.21741/9781644900031-3

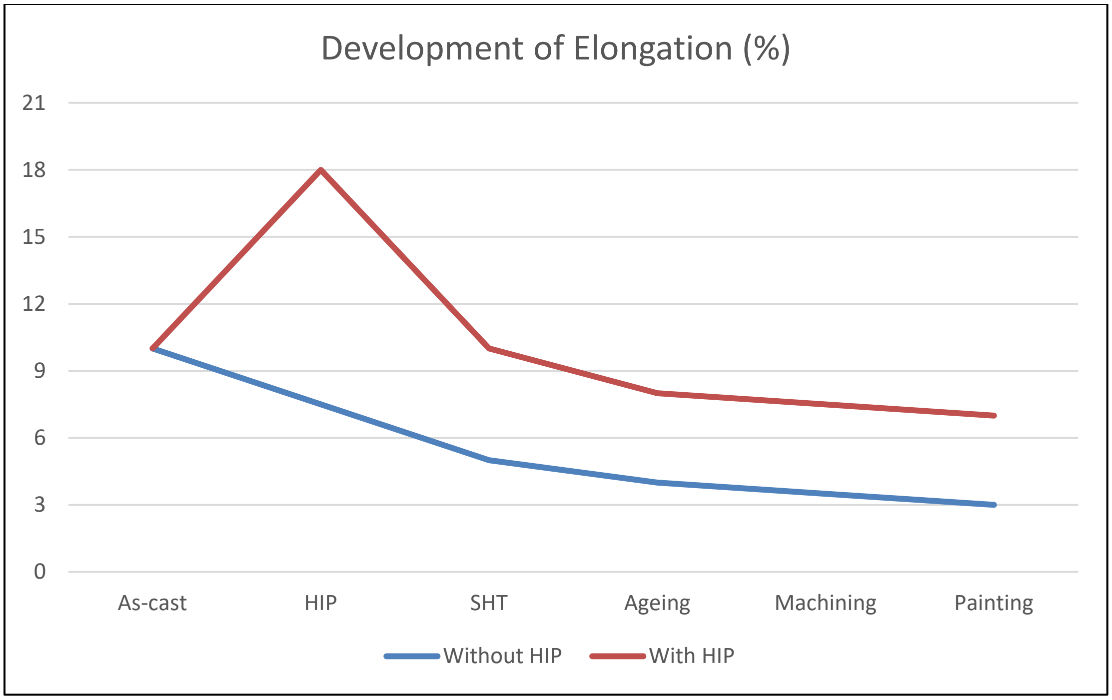

Figure 8. Development of elongation during manufacturing.

Summary and Conclusion

The automotive industry is always looking for weight reductions so the cars will be lighter and save fuel. Aluminum alloys have been used for making the rims of car wheels lighter for many years. If HIPing and a combined heat treatment step is introduced, the material properties can be optimized, especially fatigue life and elongation. The scrap rates will be reduced, and other cost savings as lesser energy usage as well as reduced material usage can be seen.