Porosity in Spray-formed Materials

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Abstract

Porosity in spray-formed materials is an important issue, but the formation of porosity is not completely understood. The paper gives some examples picked from literature, which show some general correlations between process parameters and porosity. To improve the understanding of porosity formation it is necessary to know more about the conditions of the droplets and the deposit at the point of impingement. Determining the impact conditions is a challenge because usually they are not constant with time and some values are difficult to measure. Our experiments show a strong correlation between the deposit surface temperature and the porosity. The average impact angle weighted by the local particle mass flux is also an important parameter.

Keywords: Spray Forming; Porosity, Impact Angle, Surface Temperature, Tube, Billet

1. Introduction

Porosity is an important issue in spray forming [1-4]. Normally, the aim is to reduce the as-sprayed porosity to a minimum and close it in a post-processing step like forging, pressing, HIPing, or CIPing. Generally, spray formed and cast material can have the same kinds of porosity; additionally, so called "cold" and "hot" porosity can occur. These porosities are the most common in spray formed materials. Normally, the presence of these porosities indicates that the thermal conditions for the deposition of the impinging droplets are either too cold or too hot, respectively. Often, it is not easy to recognise the correlation because the conditions at the deposition site are difficult to detect. Typically, the porosity is correlated with the calculated average liquid fraction of the impinging droplets [3]. But, our own results show that the average liquid fraction of the droplets is not the determining parameter for the porosity in spray formed material and this can even reasoned by experimental data from the literature. Early studies on average porosity were published by Doherty and Warner [5]. They spray formed small billets and tubes using IN625 and Cu-6wt%Ti and found that the average porosity decreased for both materials in the same manner if the liquid fraction of the droplets increased (Fig. 1). The results for IN625 and Cu-6wt%Ti were similar, but there was a significant difference in average porosity if a tube or a billet was generated. For instance, a liquid fraction of 0.3 in the droplets lead to an average porosity less than 5% when spraying a billet, but more than 20% for a tube.

From this it can be concluded that the average porosity cannot be described by the liquid fraction in the spray. To get a better understanding of porosity in spray formed materials it is necessary to know more about the conditions at the deposition site.

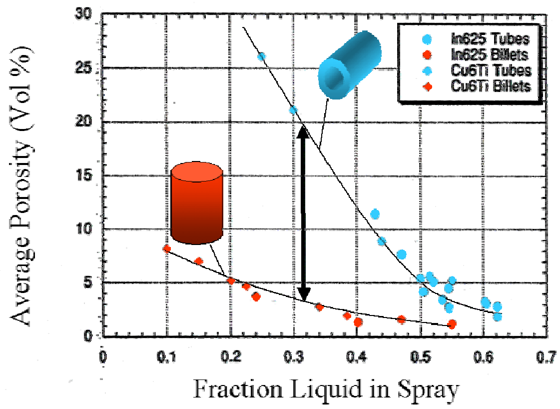

Fig. 1. Average Porosity versus liquid fraction in the spray [5].

2. Experimental and Results

Recent investigations show that the deposit surface temperature is important for the core porosity and the impact angle for the rim porosity. Normally, the porosity in a deposit is not distributed homogenously. Here, core porosity is defined as the porosity deep inside the deposit. Generally, the aim is to keep core porosity to a minimum or at least below a certain limit which depends on the material and the application. The porosity above the limit is defined as rim porosity. To increase the yield and efficiency of the process, the portion of the deposit with rim porosity must be minimized.

Correlation between core porosity and deposit surface temperature

Local porosities of spray formed IN718 (U720) versus the deposit surface temperature are displayed in figure 2. The surface temperatures were measured just before the deposit surface turned into the spray due to the rotation.

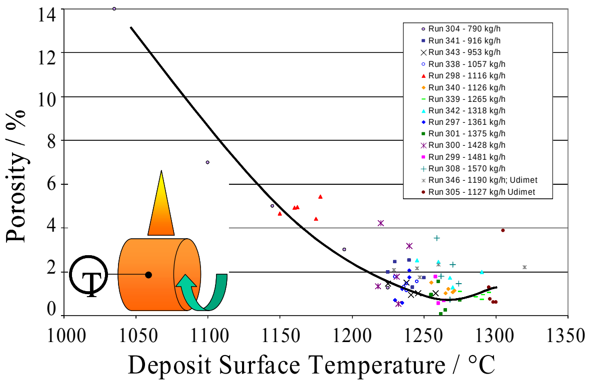

Fig. 2. Local porosity versus deposit surface temperature of a spray formed superalloy ring [6].

Effect of impact angle on porosity

A solely geometric examination of spray formed rings was used to illustrate a correlation between porosity and impact angle. The left part of figure 3 shows a half cross section of the ring. White arrows indicate the trajectory of droplets before they hit the deposit. The dark zone with linear structure is an area with high porosity. The picture on the right side shows the other part of the symmetrical deposit with the local, average weighted impact angle. The impact angle is weighted by the local particle mass flux. Here, 0° impact angle is defined for a droplet trajectory perpendicular to the deposit surface. This comparison obviously shows that there is a correlation between the high porosity zone and the local, average weighted impact angle.

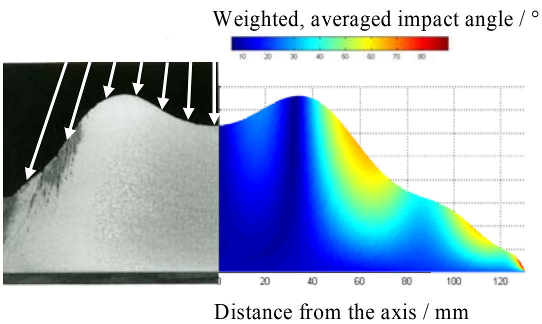

Fig. 3. Half cross section of a spray formed ring (left) and local weighted impact angle (right).

The porosity of six different rings was investigated and plotted versus the local average weighted impact angle as shown in figure 4. It can be recognized that the porosity is not affected if the local average weighted impact angle is below 25°. For higher impact angles the porosity values start to scatter.

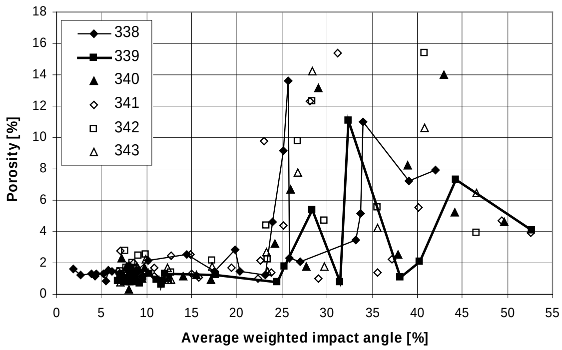

Fig. 4. Local porosity of different spray formed IN718 rings versus averaged, weighted impact angle.

3. Summary

The formation of porosity during spray forming is a complex process and not fully understood today. One reason is that the conditions during the impact of the droplets are not easy to measure or to predict. The latest investigations indicate that the deposit surface temperature – and not the average liquid fraction of the droplets - is a determining parameter for the core porosity. An optimum temperature range for IN718 and U720 has to be found in the range of 1250 °C in order to get the lowest core porosity. The impact angle of the droplet must also be taken into account. A linear structured porosity can be observed if the average weighted impact angle is higher than 25°. Higher values should be avoided to reduce the risk of forming this kind of porosity. Those experimental data and results will be used in the future to develop better models for porosity prediction.

4. References

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