

# COMPARATIVE ANALYSIS OF POROSITY IN ALUMINUM WELDED JOINTS BY OPTICAL AND SCANNING ELECTRON MICROSCOPY

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**Abstract:** The quantification of microstructural parameters is one of the main concerns of modern materials science. In the case of aluminum welded joints the variation and distribution of pores size is surely the main aspect, since that, depending on these characteristics, the material can be safely used or not. Several techniques can be used for this quantification, but the main purpose of this work is a comparative analysis of the quantification of pores size by optical microscopy coupled with automatic image analysis and scanning electron microscopy (SEM). The results show that, depending on the focus of the analysis, one technique can be more adequate than the other.

**Key words:** automatic image analysis, optical microscopy, scanning electron microscopy, welded aluminum, porosity quantification.

## 1. INTRODUCTION

Many applications of structural components frequently involve the use of fusion welded joints. Welding is usually associated to local fusion, and eventually local vaporization of metals and alloys, phenomena which can generate residual porosity in the welded joints. However, depending on the characteristics of this porosity (size and distribution of the pores), it can be acceptable or not from the viewpoint of the extent of this risk associated to these characteristics. Hence, a quantitative measurement of pores size is one of the most important steps in the acceptance or rejection of welded components [1].

Several techniques can be applied for the identification and measurement of particles, pores and other discontinuities that can be found in metals and their alloys and among these methods are optical microscopy coupled with automatic image analysis and scanning electron microscopy [2].

In this work a statistical comparison between results of pores sizes measurements is carried out. It shows that each technique yields different ranges of pores sizes, depending on the focus of the technique.

## 2. MATERIAL AND METHODOLOGY

Two commercial purity aluminum (AA 1050) samples were welded by GTAW process each one with a different gas protection: sample 1 was welded with argon as protective gas, while sample 2 was welded with a gaseous mixture of argon and helium as protective medium. Specimens for metallographic analysis were cut and subjected to conventional preparation: grinding and polishing. After polishing it was observed in optical microscope and SEM for images capture and measurements of the largest dimension of each pore. Then they were polished again and new observation and measurements were performed and this procedure was repeated once more, thus involving three steps of polishing and observation/measurements. The average value of pore largest dimension was calculated as well as a t Student statistical analysis was determined, comprising minimum and maximum values for around 95 % confidence.

## 3. RESULTS

*Sample 1 – AA 1050 - Argonium as gaseous protection*

Figure 1 shows an example of the aspect of pores size quantification in an optical microscope by automatic image analysis software, while figure 2 presents a view of pores size quantification in a scanning electron microscope (SEM), both in concern to sample 1.

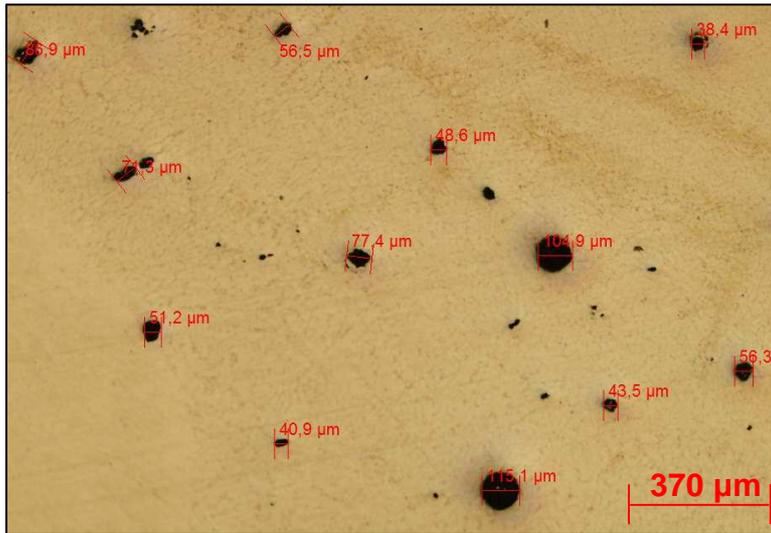


Fig.1. Pores size quantification, optical microscope aspect: sample 1.

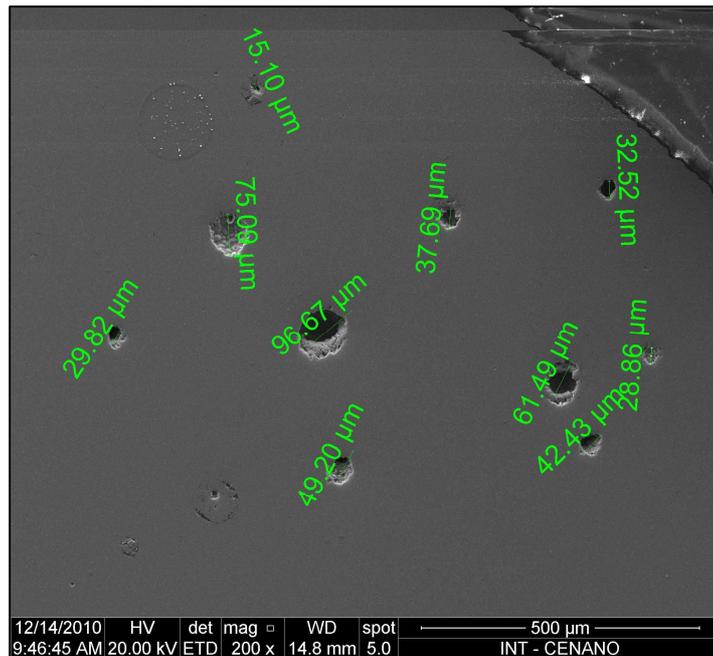


Fig.2. Pores size quantification, SEM aspect: sample 1.

Figure 3 shows a plot of pores size variation in an optical microscope by automatic image analysis software, for sample 1. Table 1 (sample 1) show the values of pores size variation which was plotted in figures 3.

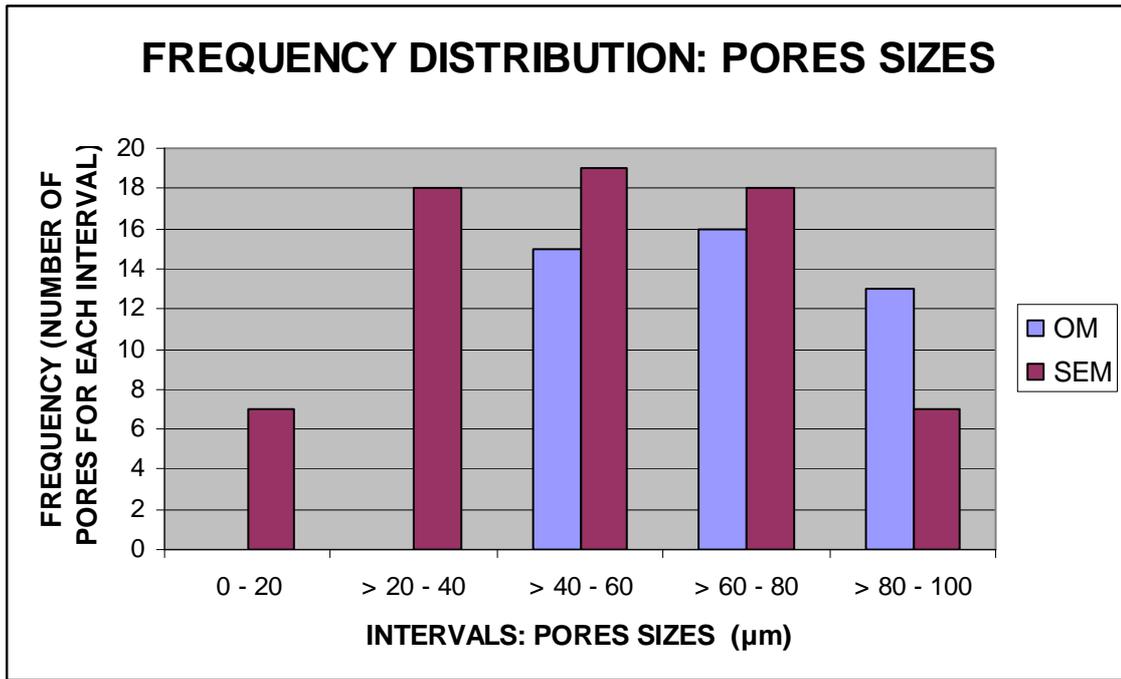


Fig. 3 - Pores size variation, optical microscope (OM) and SEM: sample 1.

Table 1. Pores size variation plot: optical microscope (OM) and SEM, sample 1.

Size (µm)	OM	SEM
0 - 20	0	7
> 20 - 40	0	18
> 40 - 60	15	19
> 60 - 80	16	18
> 80 - 100	13	7

Sample 2 – AA 1050 - Gaseous mixture of argonium and helium as gas protection

Figure 4 shows an example of the aspect of pores size quantification in an optical microscope by automatic image analysis software, while figure 5 presents a view of pores size quantification in a scanning electron microscope (SEM), both in concern to sample 2.

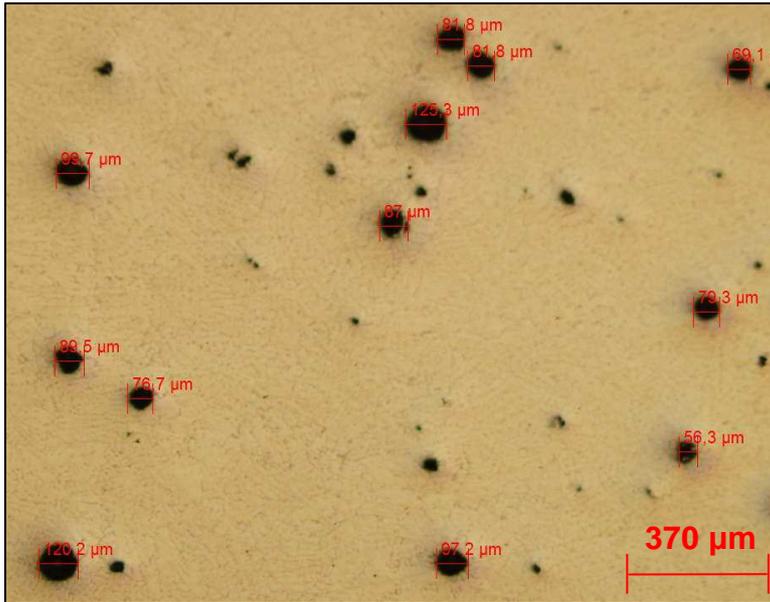


Fig.4. Pores size quantification, optical microscope aspect: sample 2.

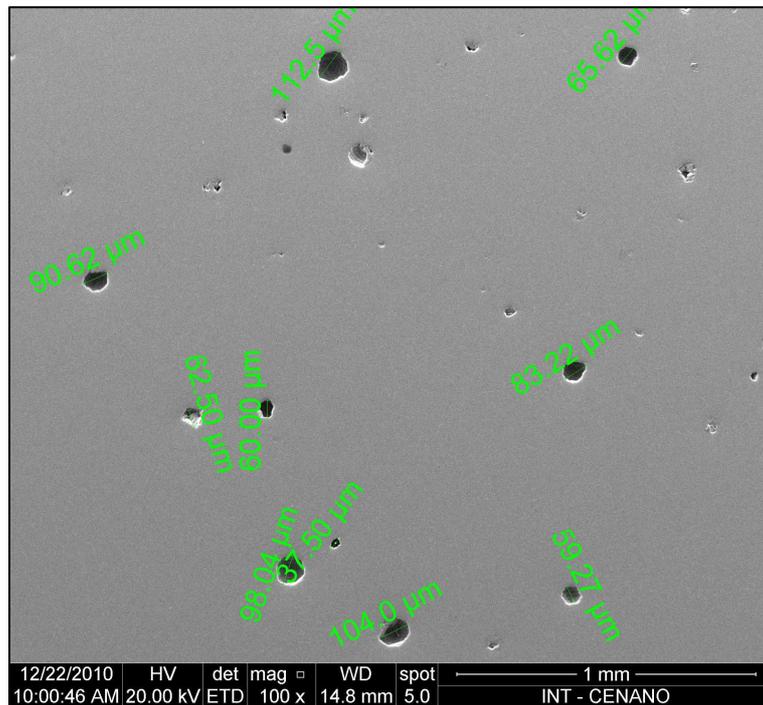


Fig.5. Pores size quantification, SEM aspect: sample 2.

The pores size variation of sample 2 is displayed in the plot of figure 6. Table 2 (sample 2) shows the values of pores size variation which was plotted in figure 6.

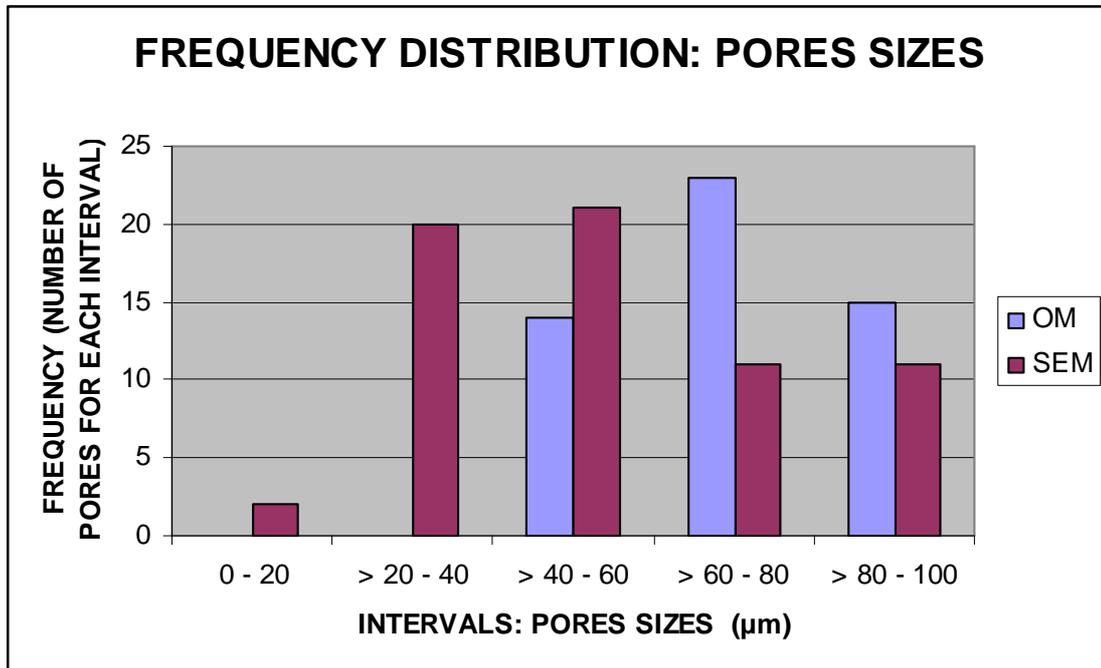


Fig. 6. Optical microscope and SEM: pores size variation plot: sample 2.

Table 2. Sizes of pores variation: optical microscope (OM) and SEM, sample 2.

Size ( $\mu\text{m}$ )	OM	SEM
0 - 20	0	2
> 20 - 40	0	20
> 40 - 60	14	21
> 60 - 80	23	11
> 80 - 100	15	11

#### 4. DISCUSSION

Based on the results shown in figures 3 and 6 it can be observed that the scanning electron microscope can measure a wider range of pores sizes. This fact happens because this equipment allows a larger focus depth. Therefore, the observation of pores by this equipment is easier and more accurate, since the images thus obtained are more planar, as can be checked by comparison between images generated in the optical microscope (figures 1 and 4) and the ones achieved in a scanning electron microscope (figures 2 and 5). In this work it is clear that measuring pores with diameters below  $40 \mu\text{m}$  is difficult. Even if the objective lens is change by another which can provide higher magnification, the problem remains, since the difficulty to get surface focus is the same, i.e., apparently the pores are observed in a different plane. However, the process of measurement by optical microscope coupled with automatic image analysis system is much faster and allows computer aided counting.

#### 5. CONCLUSION

Scanning electron microscope is able to measure a much wider range of pores sizes, with more accuracy and clear image.

However, the optical microscope coupled with automatic image analysis system is faster and allows computer aided counting.

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