In-situ monitoring of metal foam evolution and decay

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Abstract

Metal foams can be produced in different ways but the investigation of the actual evolution process is always difficult owing to the specific properties of metallic melts: they are hot, chemically aggressive and not accessible to visual observation. Therefore, all investigations in the past reconstructed the evolution of metal foams by comparing different solid foam samples in different evolution stages after foaming. We present two types of in-situ observations of expanding and decaying metal foams: firstly measurements of the time-dependent volume as the foam evolves and second, observations of the internal bubble structure by X-ray radiography. For the former experiment a specially constructed dilatometer is used which allows for a controlled expansion of the metallic melt while measuring its volume and temperature. For the latter method a metal foam was created in a furnace while X-ray radiograms were obtained in short intervalls using a high-intensity synchrotron source.

1. Introduction

One way to produce closed-cell metal foams is the powder method [1]. It consists of mixing metal powder with the blowing agent powder. After this the powder mixture is compacted to a dense semi-finished product. Heating this precursor material to its his melting point transfers the metal into a semi-liquid, viscous state. At the same time the blowing agent releases its gas, thus creating a highly-porous structure [2].

2. Sample preparation

For the foaming tests in the dilatometer we used the casting alloy AlSi7. First the metal powders Al and Si were mixed with the blowing agent titanium hydride in a tumbling mixer. After hot pressing (pre-pressing at 450° C with a force of 60 kN for 20 min, final-pressing with a force of 90 kN for 20 min) we obtain a foamable alloy tablet; the tablets are 10 mm thick and 32 in diameter. We machined these tablets to the dimensions needed for the "Laser-Expandometer" (h=9mm, d=31mm) (Fig. 1).

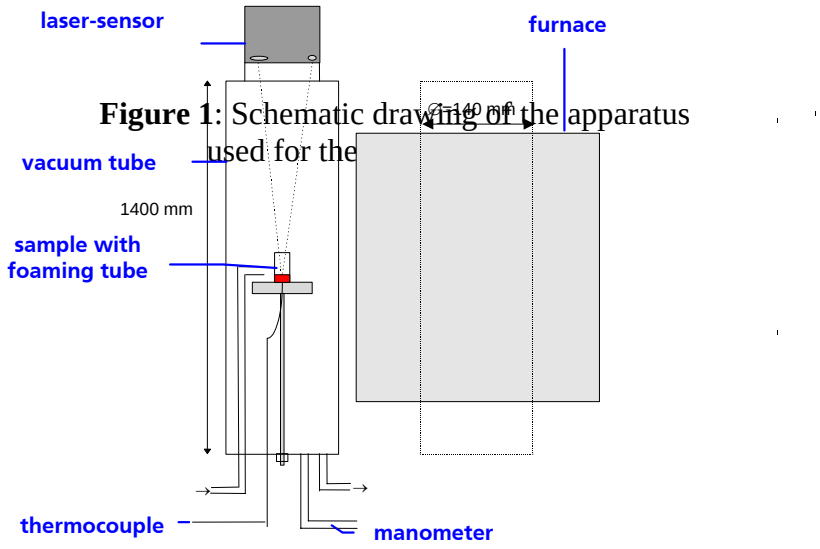

Figure 1: Schematic drawing of the apparatus used for the

3. Dilatometer tests

The tests were performed by foaming the precursor tablets inside the so-called "Laser-Expandometer" (Fig.1). The metal foam is created inside a small cylindrical steel mould (diameter: 32 mm, hight: 70 mm) which is open at the top. The mould is located in the centre of a quartz glass tube (1400 mm long, 140 mm diameter) where it is held by a sample support made of stainless steel. The heat source is a folding furnace with can be slid around the foaming tube within a few seconds. The furnace was pre-heated to the desired temperature without the foaming tube being in it. After this, the hot furnace was closed around the glass tube of the expandometer causing an immediate rise in the temperature at the sample

site. During the heating of the foamable precursor -and therefore the foaming of the alloy- a laser sensor (attached to the top of the quartz tube) constantly measured the position of the upper side of the sample through the open top side of the mould. Moreover, the temperature of the expanding sample and of the sample surronding steel mould were constantly measured with thermocouples. In the present study we measured V(t) while varying of the blowing agent content.

Results

The influence of the blowing agent amount on the foaming process was investigated in this study. The results are shown in Fig. 2(a) and (b). In the case of pure alloy sample (without blowing agent) we can see the well-known solid-state expansion due to an expansion of entrapped impurities. At a titanium hydride content of 0.1 wt.-% the gas release of blowing agent leads to a sample expansion of 300 percent. With increasing titanium hydride content the expansion increases (Fig 2(a)). Foams from samples with a titanium hydride content less or equal 0.5 wt.-% reach their expansion maximum directly; the foam is nearly stable after this point. Precursors with a higher amount of blowing agent have a different foaming behaviour: during foaming one observes an expansion peak, after which the foam partially collapses (Fig. 2(b)).

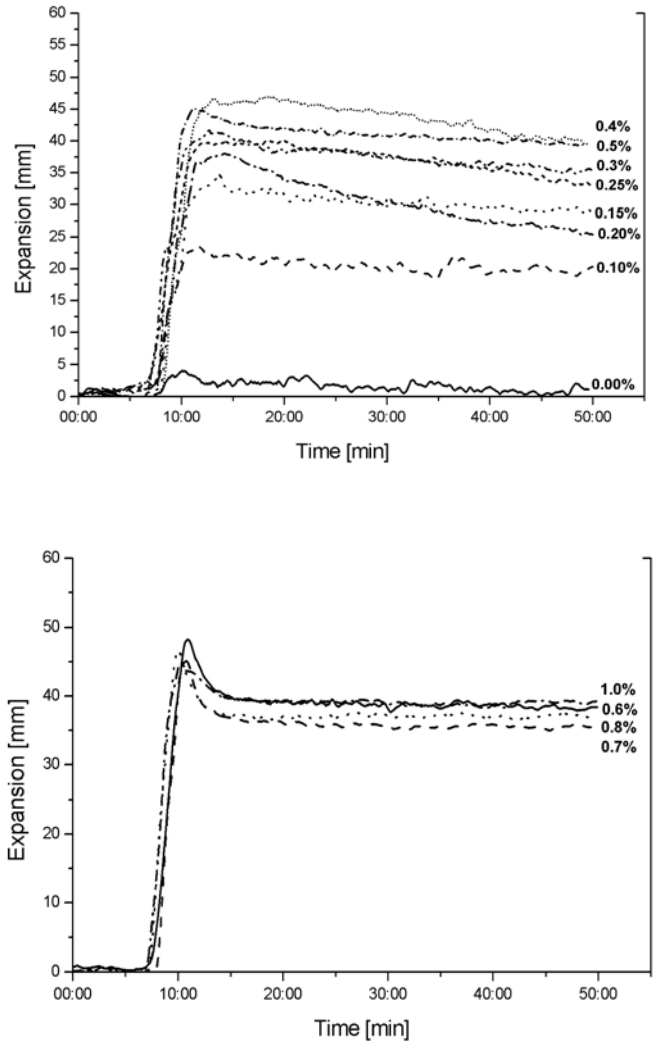

Figure 2
Expandograms fo AlSi7 foams with varying blowing agent contents
(a) 0 - 0.5 Gew.-% TiH_2,
(b) 0.6 - 1.0 Gew.-% TiH_2

4. X-ray imaging

Monitoring the foaming process of liquid metals is much more difficult than doing the same e.g. with aqueous foams. Many of the monitoring techniques used for such foams cannot be used owing to the specific properties of liquid metals. To see details during the foaming process we have chosen X-Ray radiography. Since one wants to take pictures of the foam in relatively short sequence, one needs a strong X-ray source, e.g. a synchrotron source.

4.1 Method

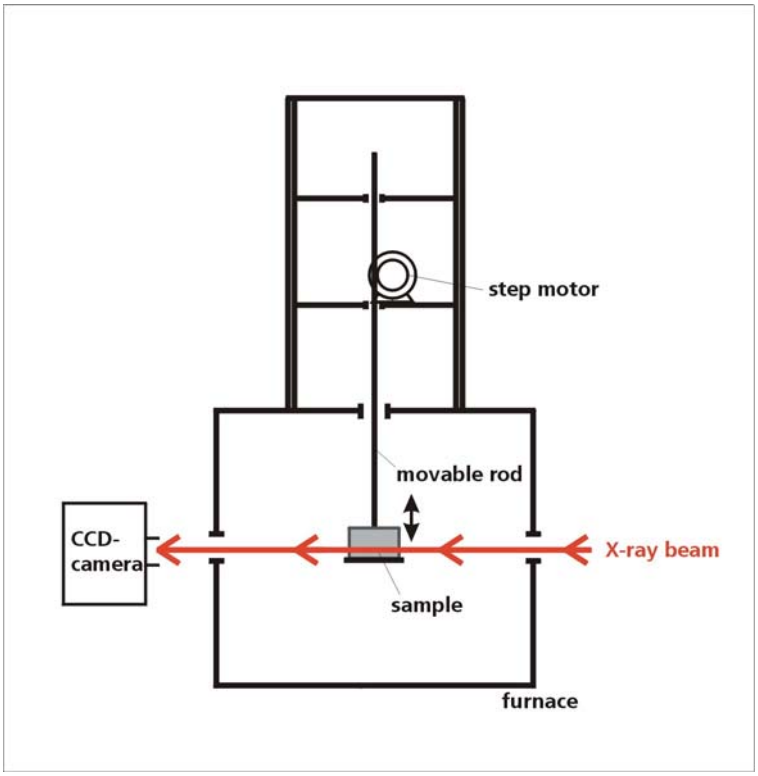

Figure 3: Furnace and experimental set-up for
in-situ investigations of drainage and cell evolution

For the in-situ foam investigation of drainage and foam evolution with synchrotron X-ray-radiography we developed a special furnace. This furnace enables it to foam at the same time the sample and to let the X-ray pass through the sample. A sketch of the furnace is shown in fig. 3. The two cooled aluminium windows on the two opposite sides of the furnace

allow the transmission of the X-ray beam through the furnace. Furthermore, the X-ray beam passes the furnace in its centre. The sample transfer is arranged by a sample holder fixed on a rod. The movement (sample in measurement position, calibration etc.) of the sample holder is given by a computer-controlled stepping motor. After pre-heating the furnace and making a calibration measurement we moved the sample into the X-ray-beam. The measured transmission signal is detected by a *Fast Readout Low Noise* (FreLoN)-CCD-camera. Photos are taken each 333 or 500 ms. Therefore, the entire foaming process from the melting of the precursor to expansion and collapse can be monitored.

4.2 Observation of cell rupture

An example for observable features is given in figure 4. The used sample for this experiment was a sandwich with the dimensions 4,5 x 10 x 30 mm (height x width x depth). One clearly sees the rupture of a metal foam cell. For the first time it is possible to observe details of the foam

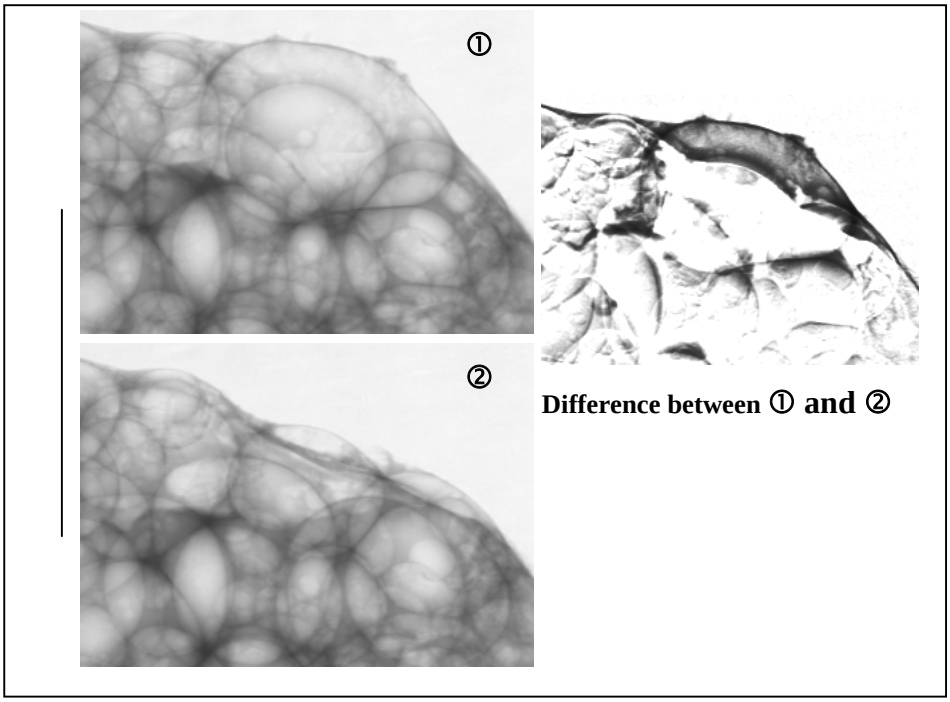

Figure 4: An example for cell rupture monitored with X-ray-beam
X-ray energy: 30 keV

evolution in metals. Coming from aqueous foams we can now generalize theories to metal foams. In the column on the right side we see the calculated difference between picture 4.1 and 4.2. With this difference picture the movement of the liquid can be detected.

4.3 Measurement of drainage

With the X-ray transmission signal it is possible to measure the drainage effect. In the early stage of sandwich heating one sees on the CCD photos a low transmission signal in the region of the sandwich (Fig. 5(a)). During the foaming process and because of the different density the CCD-camera measured a higher signal when the beam passed through the foam than crossing top sheets. After full foam expansion between the top sheets, they start to melt. At the end of the sheet melting a high amount of liquid metal flows from the top of the sample to the bottom. The drainage of liquid metal should be observed as a lower transmission signal in the foam region because of the higher density of the high liquid metal part. Therefore we expect in the diagramm some notchs. This can be observed in Fig. 5(b).

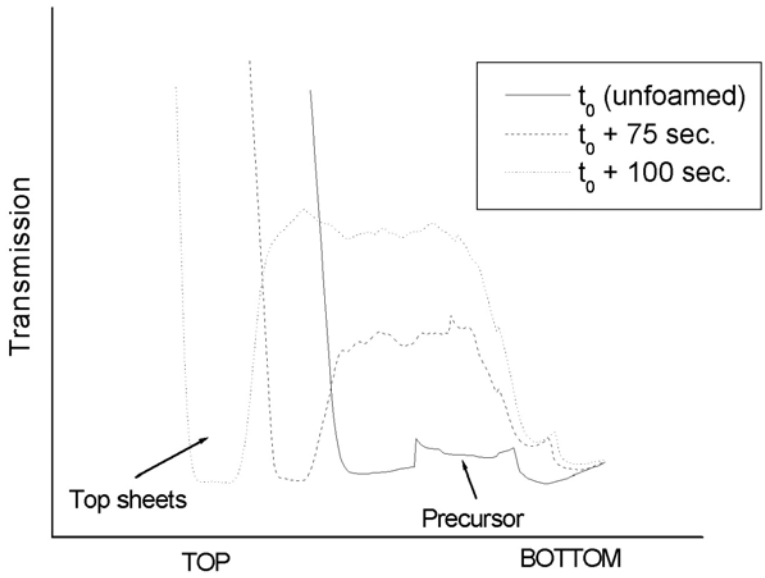

Figure 5(a): Transmission X-ray signal – Beginning of foaming

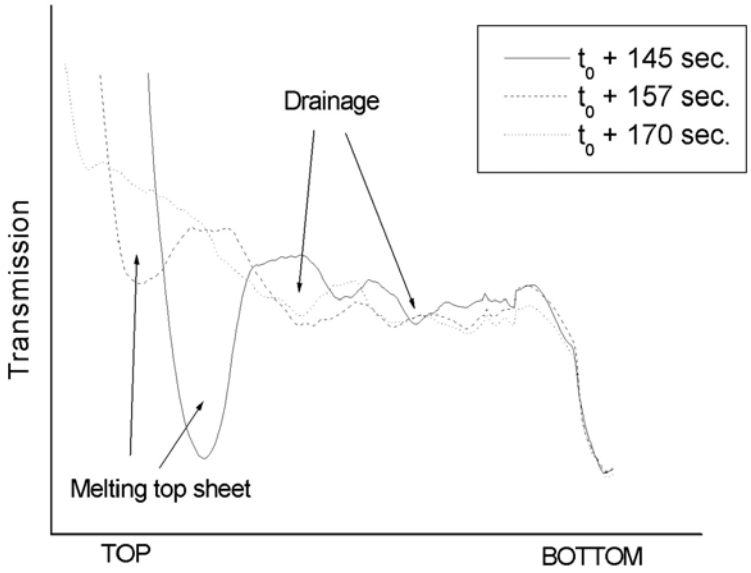

Figure 5(b): Transmission X-ray signal - Drainage

References

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