How metal foams behave if the temperature rises

Metal foams have been attracting industrial attention and research dollars as their properties have come to be appreciated...

The outstanding properties of metal foams have attracted a great deal of interest from industry and the re-search community in recent years. Industries as diverse as bio-engineering, aerospace, automotive design and manufacture, and jewellery have been attracted by metal foams' impact energy absorption, air and water permeability and unusual acoustic and insulating properties.

Depending on their porosity, metallic foams are classified as closed-cell or open-cell. Closed-cell foams are in contention for light-weight construction due to their high stiffness and low density, packaging, electrical insulation and acoustic damping applications. Open-cell foams find uses in heat exchangers and filters and titanium, gold and silver foams have been used in a variety of fields that embrace bio-medicine, art and jewellery. While much of the interest has centred on aluminium foams because of their light weight (*Metal Powder Report*, January 2005) steel foams are attracting interest too.

Most metallic foam applications are seen at normal ambient temperatures, but there many potential applications where higher temperatures are involved aerospace, automotive and cryogenics to name but three. The successful application of foams at higher temperatures requires a good understanding of their high-temperature mechanical properties.

A research group working in the Department of Ferrous Metallurgy IEHK at RWTH Aachen University set out to study the behaviour of two different types of foams based on low-alloy steel powders manufactured by Höganäs. They used high-temperature compressive tests to investigate the effect of the foams' density as well as the effect of the test temperature on their mechanical properties. For comparison, samples of com-mercially available AlCaTi foams (sometimes known as Alporas) were compressed over a range of temperatures from room temperature up to 620°C. Aluminium foams have received a substantial slice of the attention recently generated in the world outside research.

Two different types of steel foams based on the low-alloy steel powders Distaloy SA and Astaloy Mo were made in the laboratory using what the team say is a newly developed method - Slip Reaction Foam Sintering (SRFS).

Different methods were used to manufacture the steel powder. Distaloy powder is a diffusion-alloyed sponge iron, whereas the Astaloy powder is pre-alloyed and water-atomised. They have different particle morphologies: Distaloy powder is rounded in shape with a craggy surface while Astaloy powder is characterised by its irregular shape, as shown in Figure 1. The chemical composition of both steel powders is given in Table 1.

Figure 2 shows a schematic of the basic processing steps of the SRFS process. The fine powders are blended with a laminate silicate dispersant Dehydril HT® from

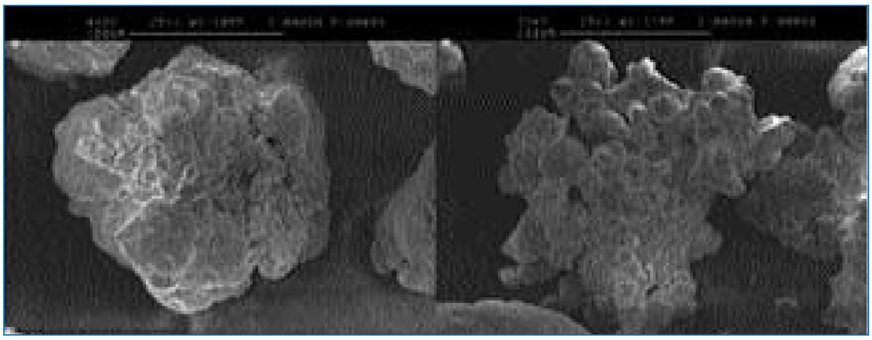

Figure1. SEM micrographs showing the different morphologies of a) Distaloy and b) Astaloy powders, respectively.

Table 1. Chemical composition of the Distaloy and the Astaloy powders, mass contents in %.

	C	H_2-loss	Cu	Ni	Mo	O_{tot}
Distaloy	<0.01	0.1	1.50	1.75	0.50	
Astaloy	<0.01	-	-	-	1.5	0.1

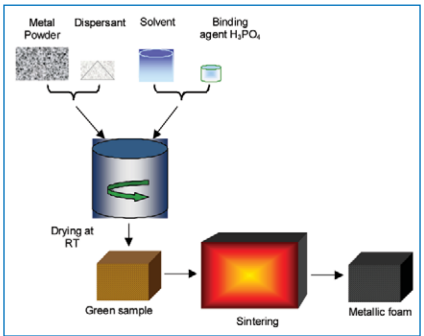

Figure 2. Slip Reaction Foam Sintering (SRFS)- process.

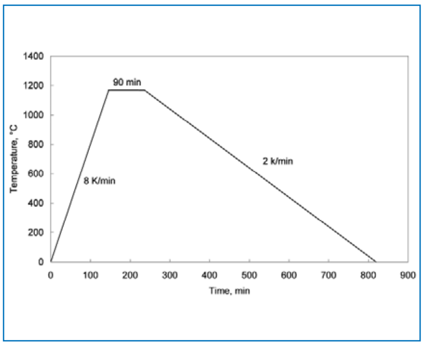

Figure 3. Time-temperature diagram of the sintering process of SFRS-foams.

Cognis with the chemical formula $Mg_3(OH)_4[Si_2O_5]$. At the same time, concentrated ortho-phosphoric acid is added to a solvent, e.g. water. Stirred together with the fluid mixture, the powder forms a slip. A chemical reaction takes place between the iron particles and the acid resulting in the production of gaseous hydrogen which forms the pores in the slip, equation (1):

$$Fe + 2H_3PO_4 = Fe(H_2PO_4)_2 + H_2 \qquad (1)$$

So far, these are closed pores and a metal phosphate also forms. This metal phosphate is known as a strong binder from the refractory industry. It acts as a binding agent and solidifies the slip. Equations (2) and (3) show the chemical reactions taking place in case of pure iron powders (free from oxides):

$$Fe(H_2PO_4)_2 + Fe + O_2 = 2FePO_4 + 2H_2O \qquad (2)$$

$$Fe(H_2PO_4)_2 + Fe + ½O_2 = Fe_2P_2O_7 + 2H_2O \qquad (3)$$

This binder freezes the porous structure of the slip. The structure hardens and a green sample is obtained which is stiff enough to be handled. This green body gets its strength only by the retentive force of the metal phosphate. After drying, the green samples are then sintered under a hydrogen reductive atmosphere at a temperature of 1170°C according to the time/temperature diagram shown in Figure 3. During sintering, the solvent evaporates, turning the closed pores into open ones, and the ferric oxide, which formed by the reac-tion between iron powder and solvent, is reduced. The interconnections between the primary pores caused by the evaporation of the water are called secondary pores. The ferric phosphate condenses during sintering setting free water and forming a glass phase with laminate silicate, as shown in equation (4).

$$P - OH + HO - P = P - O - P + H_2O \qquad (4)$$

Closed-cell aluminium foam, known under the trade name Alporas, was used to compare the behaviour of such foams with that of low-alloy steel foams. Alporas foam, with the chemical composition shown in Table 2, was produced via a batch casting process, illustrated in Figure 4. The foamed metals are produced