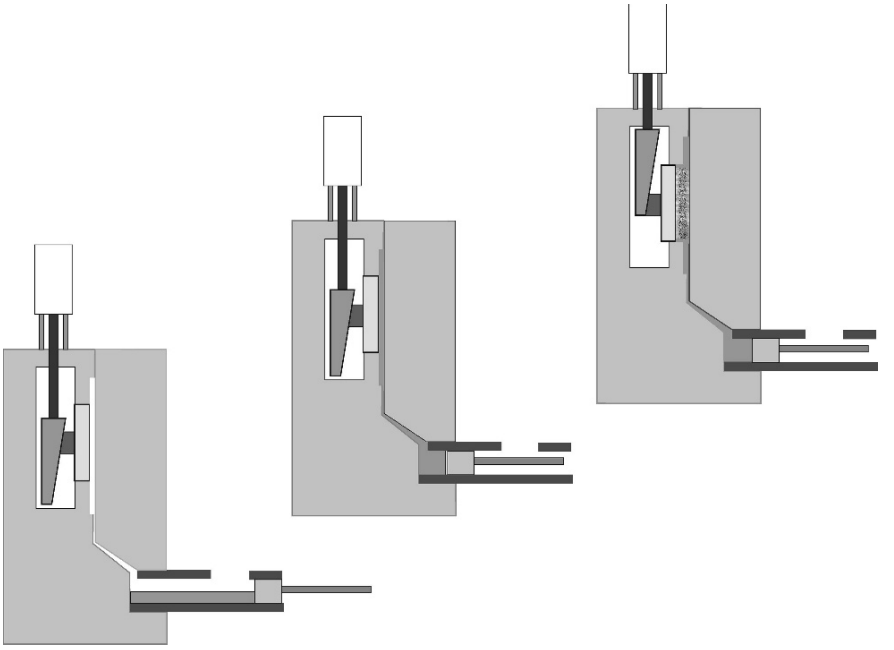
Part I

# TECHNOLOGY



*Es ist nicht genug, zu wissen, man muss auch anwenden; es ist nicht genug, zu wollen, man muss auch tun.*

**Johann Wolfgang von Goethe**

Integral foam molding of light metals is based on very similar technologies developed and used in industry to produce polymer integral foams. We apply molding techniques – die casting and thixomolding – where liquid metals mixed with a blowing agent are injected with high velocities into permanent steel molds. The basic idea is that a compact layer develops at the mold surface due to the chilling effect of the cold mold wall. The solidification time of the kernel of the casting is much longer and the decomposition of the blowing agent leads to a foamed core.

When we started this development, there were some serious arguments why this general approach would be prone to fail. Firstly, the viscosity of metal melts is very low compared to polymers. Normally, a high viscosity is said to improve the stability of foams. Thus, the very low viscosity is expected not to allow the formation of a foamed core. Secondly, the solidification of metals proceeds much faster than that of polymers. Whether this extreme short time scale allows the decomposition of the blowing agent and the development of a cellular structure was questionable.

During process development it became more and more evident that the low viscosity is not a disadvantage of metals but might be turned into an advantage. There are two aspects why the low viscosity is a benefit. On the one hand, the low viscosity combined with the high mold filling velocities leads to turbulent melt flows which helps to admix the blowing agent into the melt in a homogeneous way. On the other hand, the mold filling behavior is completely different from that of polymers and supports the development of the solid surface layer. Also the very short solidification times have shown to be not only critical but also to be the reason why the solid skin is in fact compact and not the result of the compression of the surface bubbles of a former foam.

The blowing agent and its decomposition dynamics is the key for the success of the whole process. On the one hand, the decomposition kinetics has to be slow enough to prevent premature gas release. On the other hand, the decomposition has to be fast enough in order to guarantee that most of the blowing gas is released until solidification puts an end to the whole foaming process. Magnesium hydride meets these demands for light metals in a nearly perfect way and the resulting density profiles are the product of an interplay between gas release and solidification.

A very astonishing outcome of integral foam molding of light metals is that standard die casting alloys may be applied. The use of conditioned melts is not necessary in order to achieve a cellular foam core. This finding is quite surprising since it is well known that non-conditioned metal melts do not foam. Usually, particles have to be added to the melt to make metals foamable. The reason for this result is that foam formation takes place in the semi-solid state during integral foam

molding. The solid phase particles show a barrier effect analogous to deliberately added ceramic particles. Thus, recycling of integral foam parts is also not an issue.

It is important to emphasize that integral foam molding is not thought to substitute standard die casting parts by foamed parts without changing the design. The appearance of integral foam parts is quite different from compact castings. Besides a strong weight reduction, they show interesting properties such as a high stiffness, high energy absorption capacity and strongly increased damping. Thus, integral foam parts open completely new applications and require a design adapted to process and application.

In summary, there are many similarities but also important differences between the processing of metals and polymers. The development of foam molding processes for metals, which is just at the beginning, may profit from the long experience available for polymers. Nevertheless, the specific properties of metal melts also open totally different process strategies.