Cost modelling for the fabrication of aluminium foam via powder metallurgical route

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Abstract

For a given aluminium foam component a theoretically ideal production plant is designed and used for calculation of the manufacturing cost for this part in series production. A sensitivity analysis is used to determine the effect of changes in the production process or the precursor cost on the manufacturing cost of the component. Target costing studies show the required cost reduction when aluminium foam competes with magnesium die castings.

1. Introduction

Light materials with high elastic modulus and the ability to absorb deformation energy are of high interest to automotive designers. Porous metal foams fulfill these requirements [1]. Lost foam cores in light metal castings are new possible applications. The cost considerations presented in this paper are based on such a core.

After successful fabrication of aluminium foam prototype components, LKR is now looking into the development of series production routes.

The production facility, which is shown here in more detail is only focussed on the actual foaming process, while the production of precursor material is not considered. LKR uses Alulight® precursor material, which is manufactured by Mepura [2], via powder metallurgical route: Aluminium powder is mixed with titanium hydride powder, compacted and extruded to form precursor rods [3].

Preliminary tests were performed with lost cores in gravity or low pressure casting with aluminium [4], LKR is concentrating on applying the foam cores in Indirect Vertical Squeeze Casting with aluminium and magnesium alloys [5]. The slow bottom-up die filling of the UBE – process is advantegeous for this kind of product [6]. Product targets are quasi-hollow components in the suspension or body area of cars.

2. Production Plant

Based on the experience gained in prototype production LKR and its project partner HPI (High Performance Industries) from Ranshofen, Austria, designed a potential plant for large volume production. It was designed for a lost core product with a volume of 750 cm³ and a weight of roughly 380 g (see Figure 1). The plant should achieve a daily production of 5000 pieces, in order to supply the high volume needed for production of a commercial vehicle.

As mentioned above the precursor material will supplied by Mepura in the shape of extruded profiles. Therefore, the plant must perform the following steps: cutting and inserting of the precursor material into the dies, closing of the dies, heating them up to foaming temperature, cooling, opening of the dies, part extracting and finally coating of the dies. These steps shall be performed along a closed loop production line.

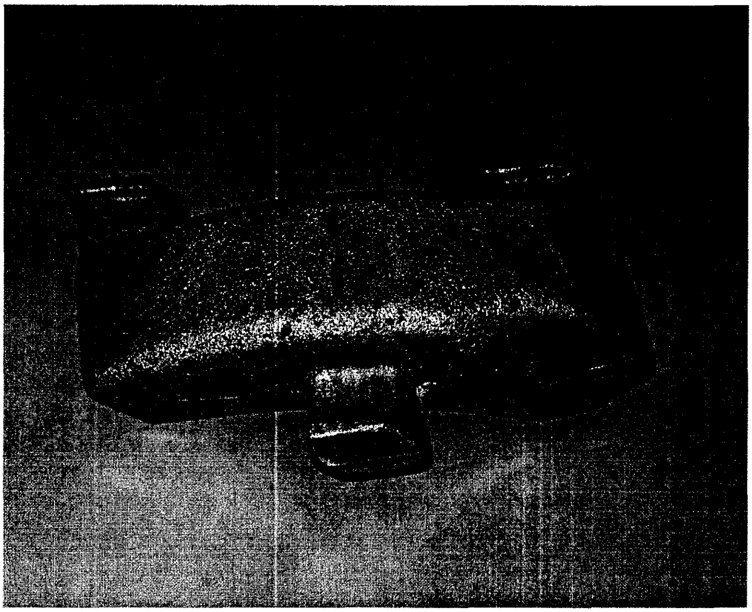

Figure 1: Aluminium foam core

After extraction from the die the foam parts shall be placed into a trimming press and then put on a balance to check the overall density. Then the parts shall be placed into boxes.

Figure 2 shows the layout of this plant. Most of the handling jobs are performed by automatic manipulators. (1) is the precursor supply unit, (2) is a saw and a maipulator for inserting the precursor into the dies, (3) the continuous foaming furnace, (4) the cooling line, (5) the trimming press, (6) a manipulator for inserting the foam parts into the part boxes (7).Two workers are needed for operating this plant. These workers must handle the supply of precursor material into the plant, transportation of the part boxes, visual check of the parts, and the exchange of dies.

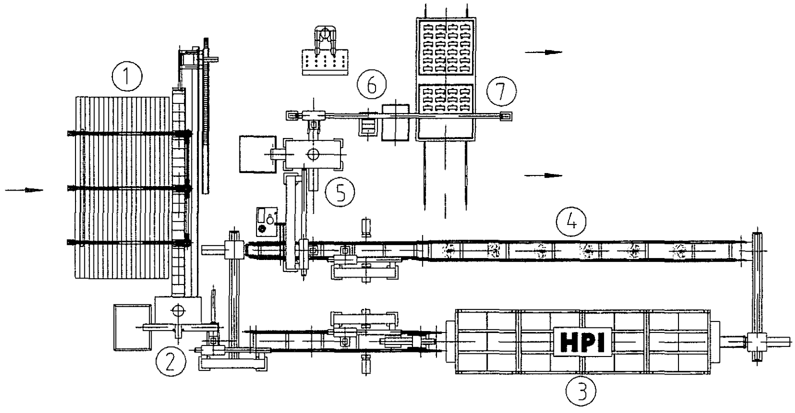

Figure 2: Schematic drawing of a continuous foaming plant

The parts are foamed in a continuous heating furnace in four-cavity dies. The same furnace can be used for different components and dies, as long as the dies fit on the conveyors and into the furnace. The length of the furnace is roughly 3.5m. Thirty dies will be in the process chain at one time.

The productivity of the plant may of course change even if four-cavity dies are always used. Foaming studies at LKR show a linear relationship between modulus and the required foaming time (Figure 3). The foaming time is the total time of the die in the furnace. The modulus is the ratio between volume and surface area of a component.

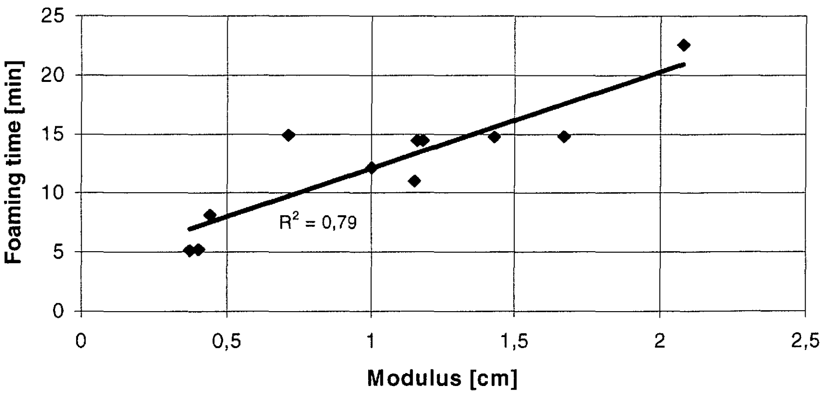

Figure 3: Relationship between modulus and foaming time

3. Cost Considerations

In a first step a standard cost calculation for the given part was performed. Roughly 60% of the part cost are determined by the precursor material, 20% are needed for the dies, 15% for actual manufacturing and 5 % for overhead. Based on this result a cost sensitivity analysis was made in order to check the potential for cost reduction. In this analysis only one parameter was varied, while the others were kept unchanged. The sensitivity analysis showed the following: A reduction of the precursor cost by 20% leads to a reduction of the part cost by 12%. A reduced die cost of 30% lowers the part cost by 6%. If the life time of the dies can be doubled, the part cost will be lowered 15%. Another critical parameter is the number of working shifts per day. If the plant is used only for a one-shift production, only 1500 parts can be made per day, and a single part becomes 35% more expensive than in the assumed three-shift production schedule. If the part shape changes such that the foaming time increases from 10 to 20 minutes, the part cost increases by 10%. If the plant availability sinks from 85% to 75% the part cost increases by 3%.

4. Target Costing Approach

The concept of target costing is based on the fact that 80-90% of the manufacturing cost of a product are determined before the start of production. The allowable costs should be known already in the design and development stage of the product. In some applications such as dashboards, hoods and doors, aluminium foam parts compete with structural components made of aluminium or steel as well as high pressure die castings of magnesium alloys. The magnesium part cost was used as a proxy for what would be an allowable cost for a similar aluminium foam part.The target costing analysis of Konrad [7] showed that a cost reduction in the fabrication of aluminium foam of approximately 20% is required, to gain acceptance of commercial car companies to consider switching from magnesium high pressure castings to foam. This cost reduction seems possible because of technical progress, rationalization and learning curve effects. Figure 4 shows a scenario, which yields roughly half of the part cost in comparison with todays standard cost considered at LKR.

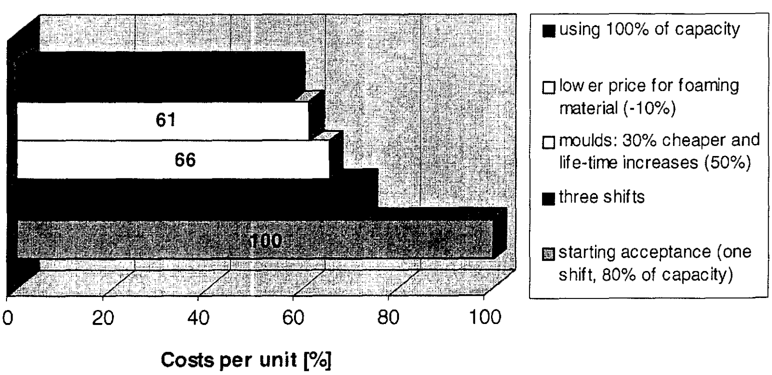

Figure 4: Potential for cost reduction, one possible scenario

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