TALAT Lecture 3803

Process Technologies

15 pages, 21 figures

Advanced Level

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Objectives:

- to describe fabrication processes for superplastic forming, i.e. female and male die forming, and the criteria for selecting the correct process

Prerequisites:

- General background in production engineering and material science

Date of Issue: 1994

3803 Process Technologies

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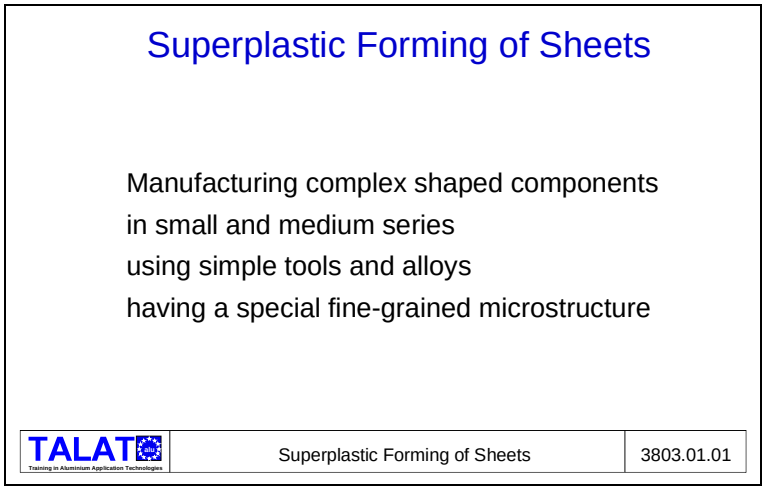
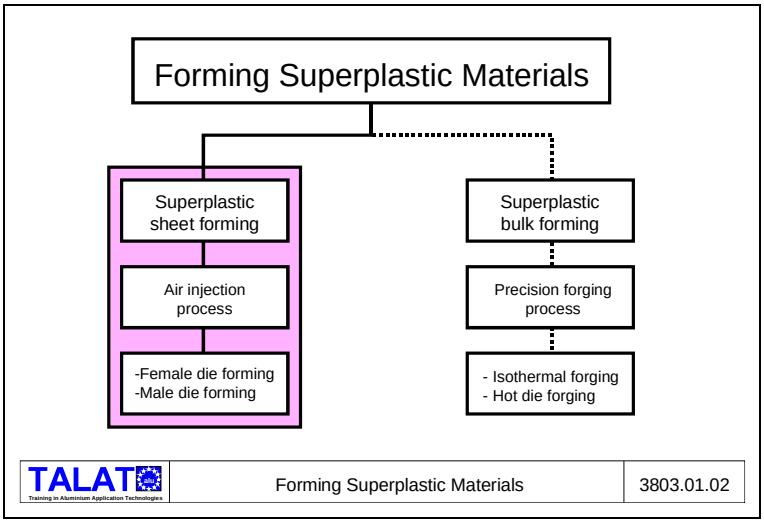
3803.01 Superplastic Fabrication Methods

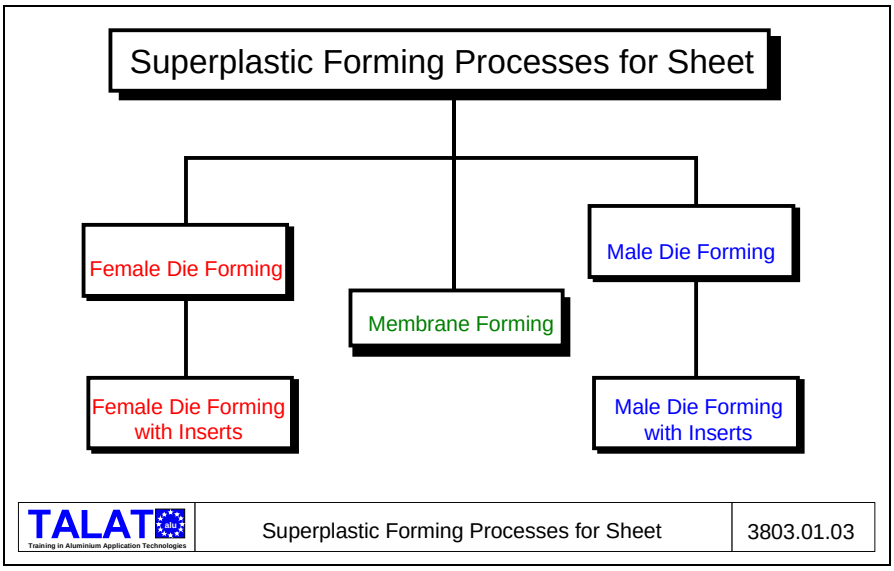
Figure 3803.01.01 defines in general terms the application of superplastic forming of sheets metals.



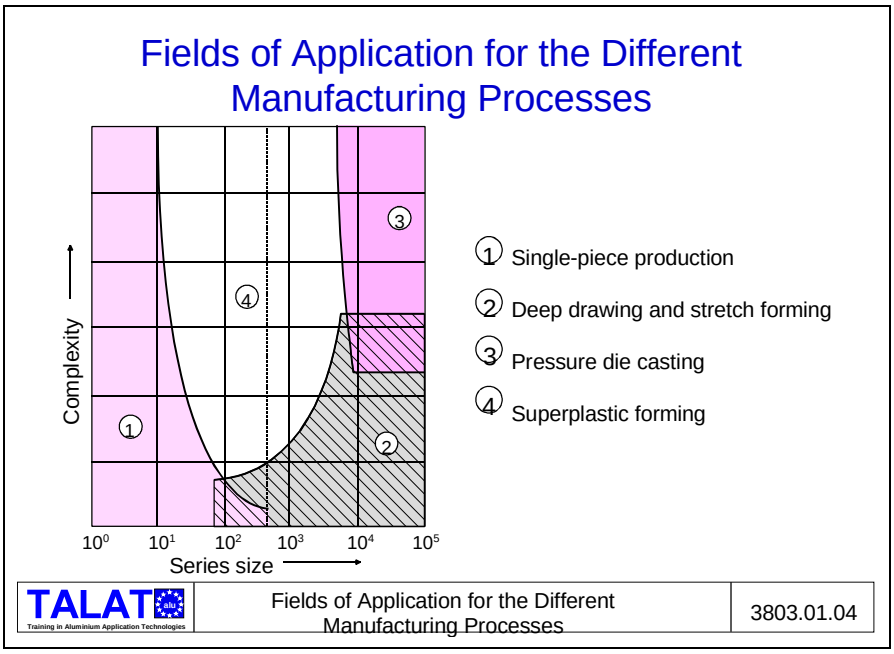
In principle, superplastic forming of metals can be subdivided into bulk metal and sheet metal forming, see **Figure 3803.02.02**. Hot die forging, precision forging and isothermal forging are examples for bulk superplastic forming. Bulk forming, however, shall not be treated in this lecture.



Processes for superplastic forming of sheet metals are subdivided further into three main pneumatic forming processes: die forming, patrizen forming and membrane forming, see **Figure 3803.01.03.** The economy of female die forming and male die forming can be increased by using a number of tool inserts assembled in one tool so as to produce a number of parts simultaneously.



Fields of application for the different manufacturing processes are shown in **Figure 3803.01.04.** Superplastic forming can best be applied for producing medium series of parts and for complicated shaped components. The field of application of superplastic forming is limited by conventional process technologies. Small series of complicated parts generally have to be produced as single-parts. Classical sheet forming technologies are suitable for parts which are not so complicated. The relatively expensive pressure die casting is most suitable for producing large series of complicated parts.



3803.02 Female Die Superplastic Forming

Female die forming utilises a concave form, see **Figure 3803.02.01**. During the whole forming process, the flange of the sheet blank is clamped tight between the top and lower pressure chambers. A flow-in of the material into the tool interior is thus not possible. The forming zone, therefore, consists of the blank membrane area within the tool. The pressure difference applied in the first phase, causes free forming (pneumatic sinking) of the blank membrane in the direction of the lower pressure. In the second phase, the gradually increasing doming leads to contact between tool and blank. The gas membrane then divides into sub membranes, leading to varying flow rate conditions and consequently to non-homogeneous material flow. Furthermore, the locally varying frictional conditions result in an unfavourable wall thickness distribution.

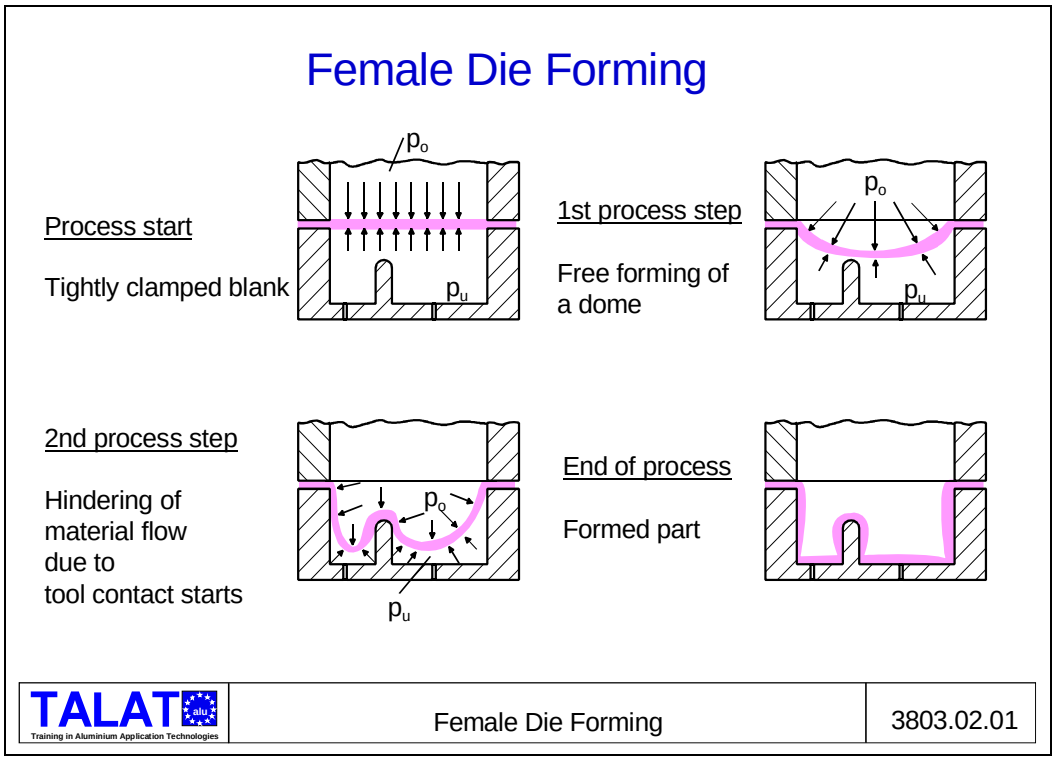


Figure 3803.02.02 illustrates the forming steps during female die forming, described in **Figure 3803.02.01**, using a photographic technique. The first phase of undisturbed free forming can be seen clearly. In the second phase, two sub membranes exist.

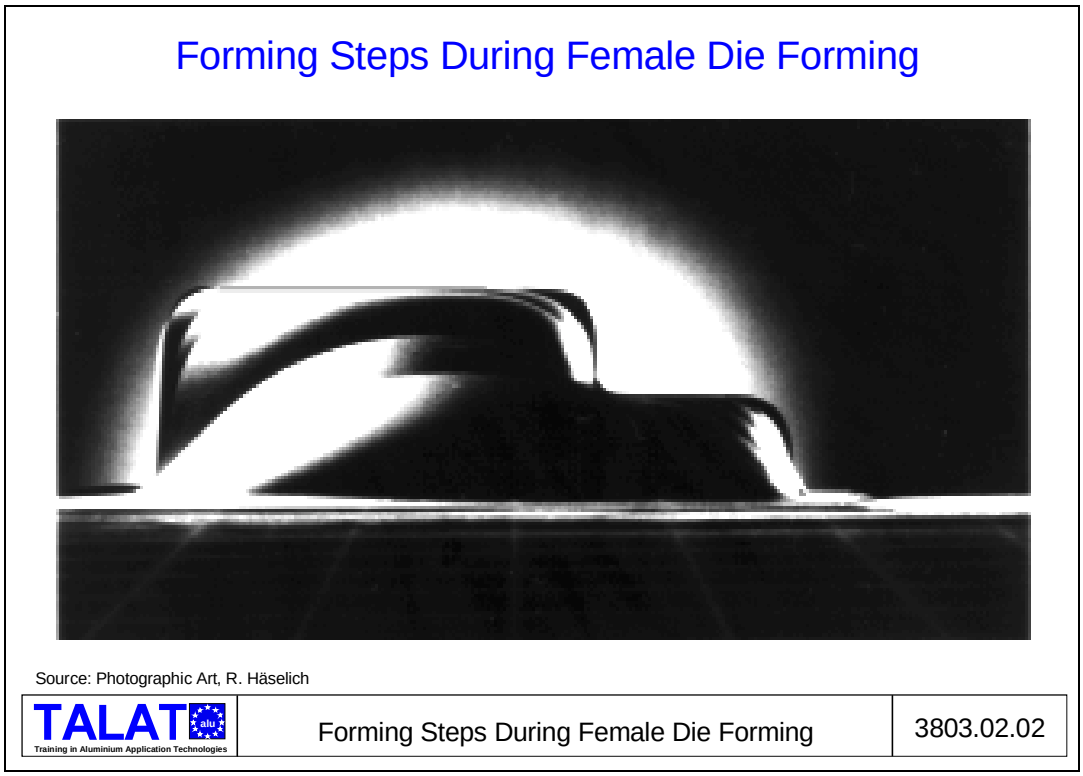


Figure 3803.02.07 shows a tool insert for a Landrover front part. The complicated internal design with very narrow webs is clearly visible. The use of die inserts reduces the cost significantly.

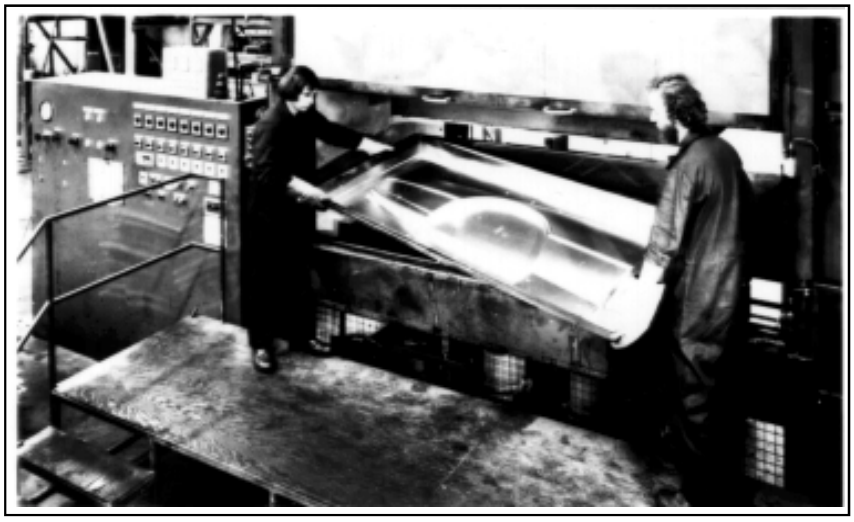
Tool for a Landrover Front Part

Source: Superform Metal Ltd.

TALAT Training in Aluminium Application Technologies	Tool for a Landrover Front Part	3803.02.03

Figure 3803.02.04 shows a complete equipment for female die forming. One sees a rather simple machine construction which is, however, equipped with a complicated control and regulation system for gas and heat flow.

Equipment for Female Die Forming



Source: Superform Metal Ltd.

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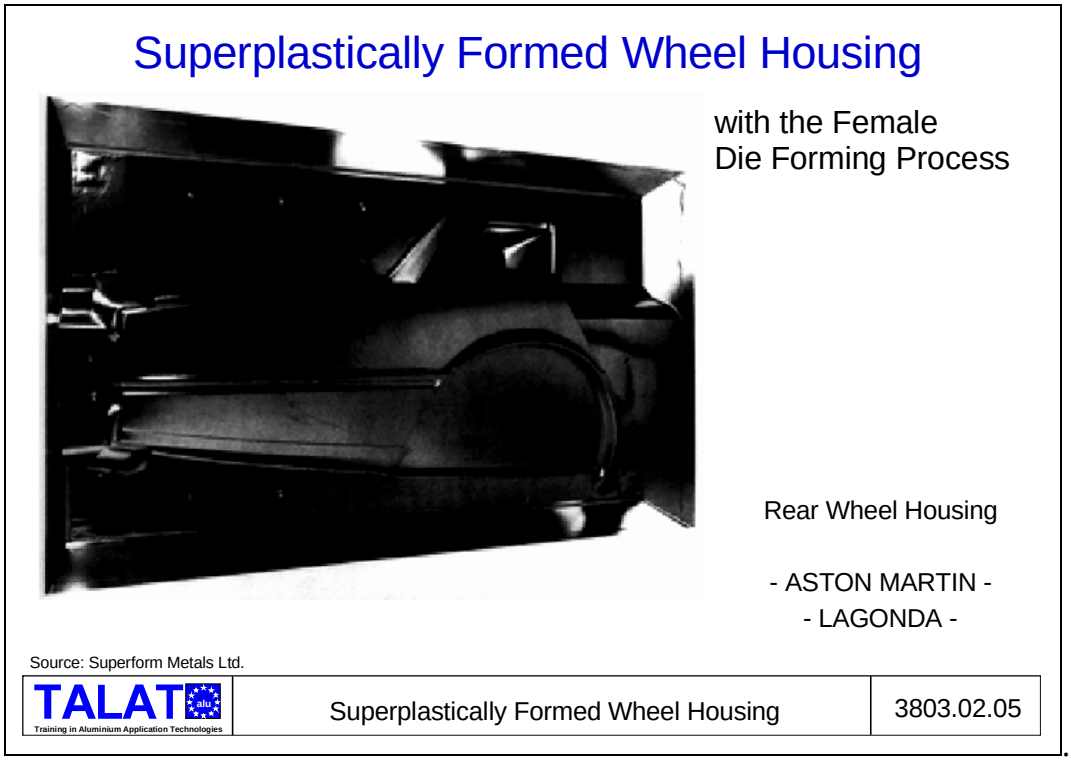
The rear wheel housing of an ASTON MARTIN LAGONDA is a typical component produced with female die forming, see **Figure 3803.02.05**



3803.03 Superplastic Forming with Male Dies

The male forming process works with a convex form, see **Figure 3803.03.01**. During the whole forming process, the flange of the sheet blank is clamped tight between the top and lower pressure chambers. A flow-in of the material into the tool interior is thus not possible. The forming zone, therefore, consists of the blank membrane area within the tool. The pressure difference applied in the first phase, causes free forming (pneumatic sinking) of the blank membrane in the direction of the lower pressure. In the second phase, when the doming is large enough, the punch with the positive form is moved in and the material pressed on to the form by changing the pressure direction. Frictional contact and local thinning of the membrane occurs much later than in female die forming. As a result, the wall thickness distribution is more favourable than in female die forming.

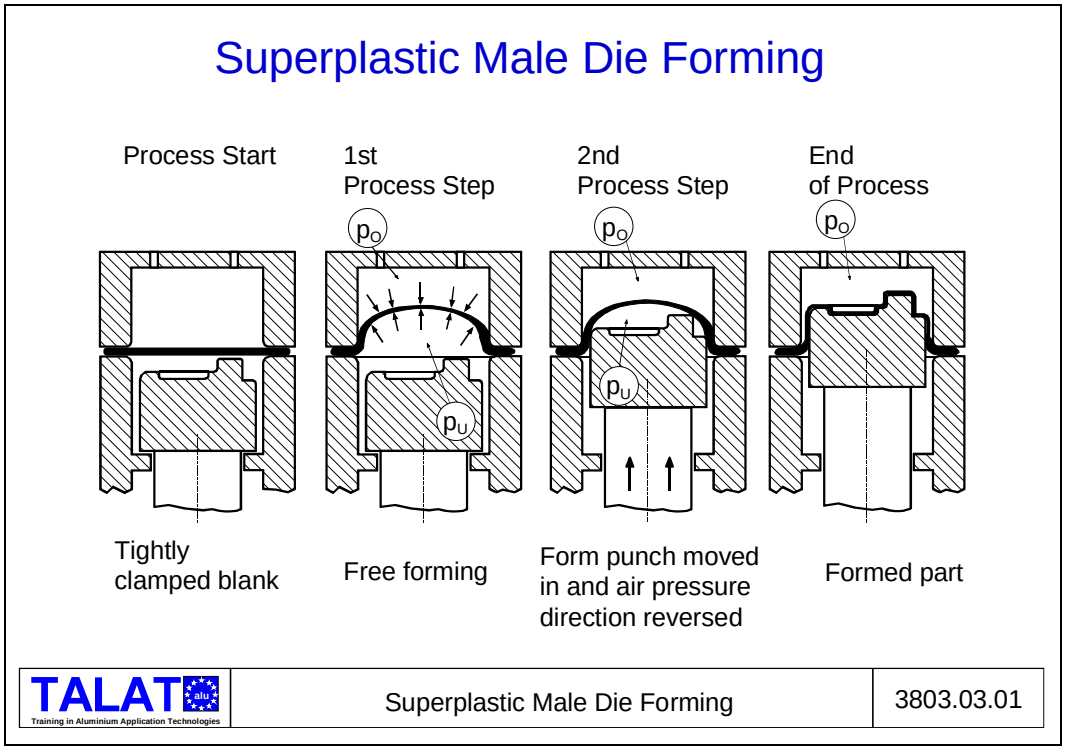


Figure 3803.02.11 shows the complete equipment used for superplastic male die forming: preheating furnace, machine and regulation and control systems for gas and heat flow.

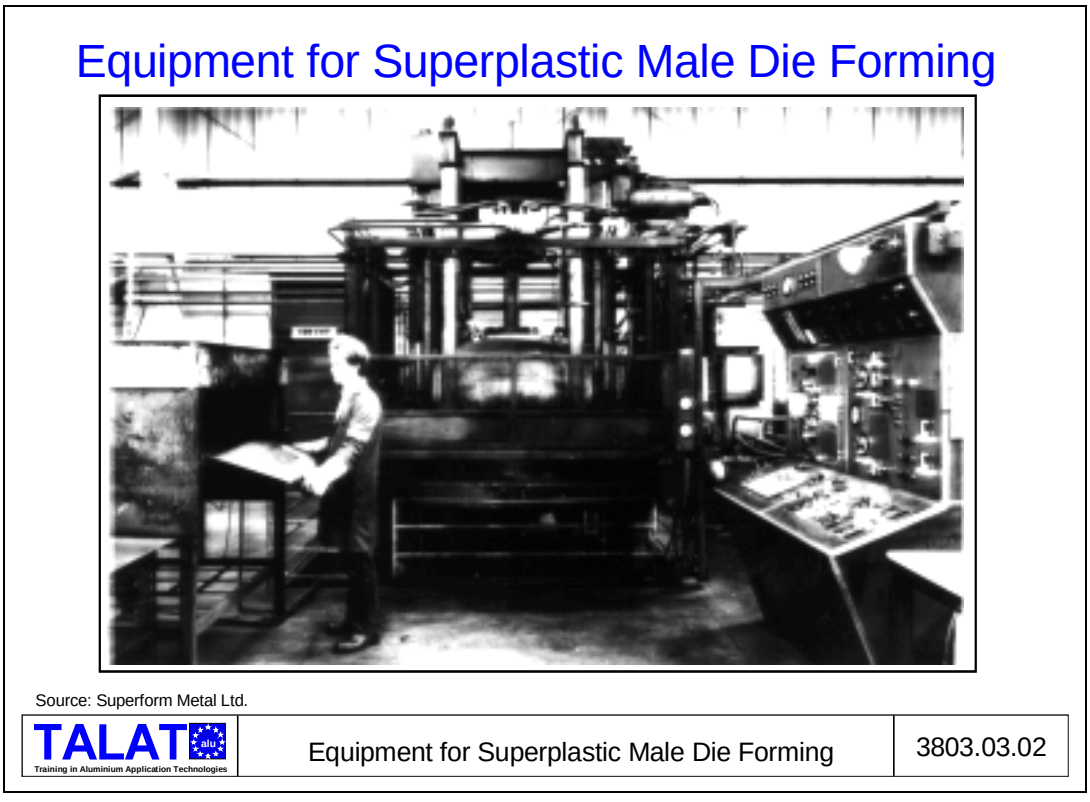


Figure 3803.03.03 shows an opened malew die forming machine where the material flanges are visible. The punch is at the top-end of the stroke.

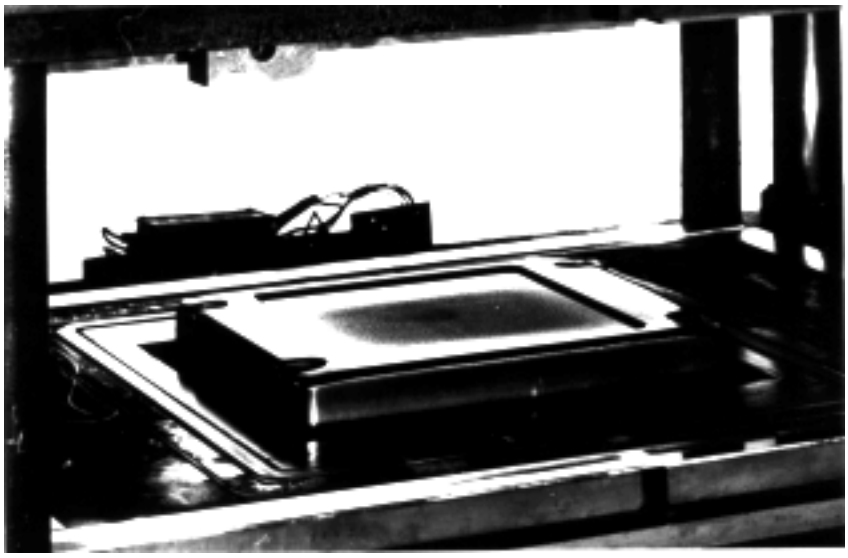
Machine for Male Die Forming

Source: Superform Metal Ltd.

TALAT Training in Aluminium Application Technologies	Machine for Male Die Forming	3803.03.03

Figure 3803.03.04 shows the tool for male die forming. One can clearly see the crimped seam, running around the periphery, used to seal the gas pressure cavities as well as the connections for heating the tool. The punch has moved to the top-end of the stroke.

Tool for Male Die Forming



Source: Superform Metal Ltd.

TALAT Training in Aluminium Application Technologies	Tool for Male Die Forming	3803.03.04

Figure 3803.03.05 illustrates the different stages in the manufacturing of a component using the male die forming process. The three intermediate stages of the left show the

initial phase of free forming. The last three stages show the steps of forming after pressure reversal.

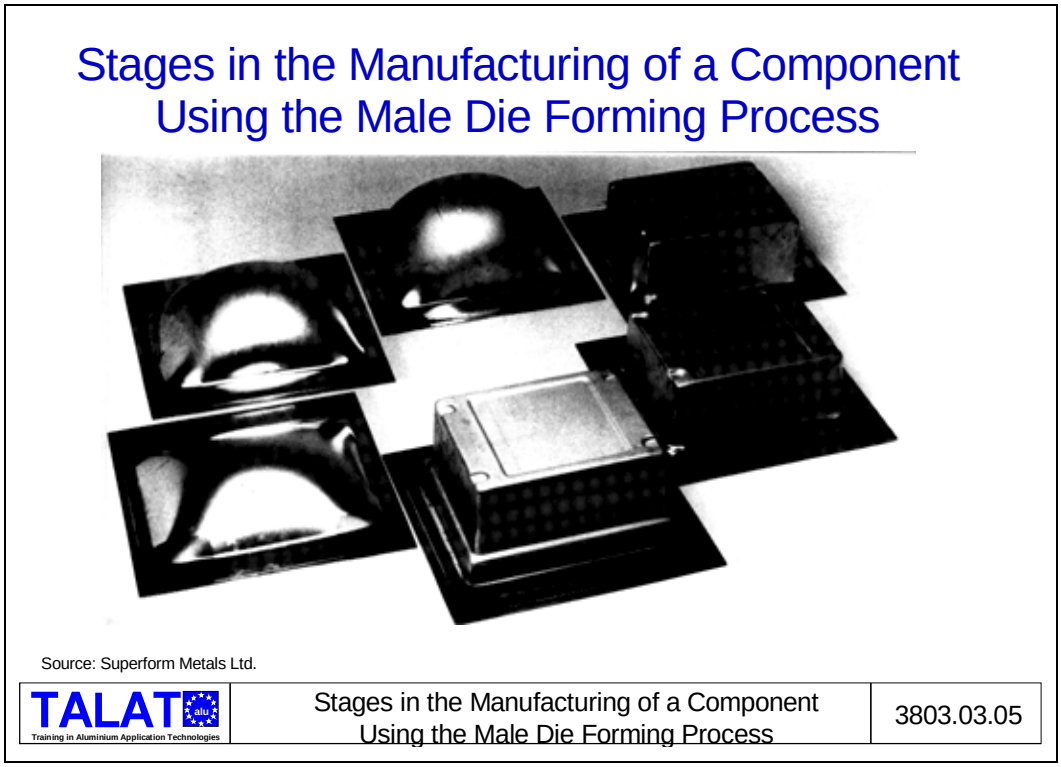
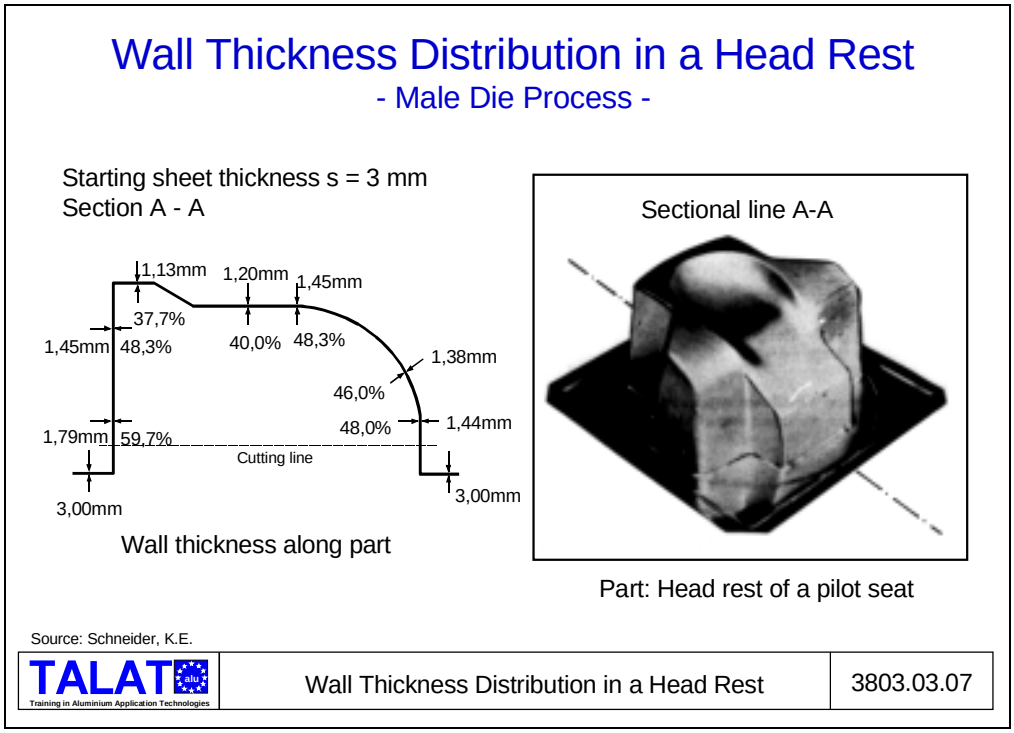


Figure 3803.03.06 shows a tool set, consisting of a punch, punch holder plate and blank holder, for male die forming of an external rear view mirror housing for a car together with an untrimmed and a trimmed component.

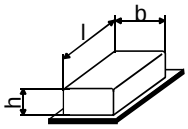
Figure 3803.03.07 shows a head rest for a pilot seat. The characteristically high form of the part makes it most suitable for male die forming. A sectional view is shown on the left. A good wall thickness distribution exists above the trimming line.



3803.04 Criteria for the Choice between Male Die and Female Die Forming

Figure 3803.04.01 shows the criteria required in principle for choosing the male die forming process. The male die forming process allows an accurate replication of the interior contours. Due to local differences in material flow, the external contour do not exactly conform to the required geometry. Since the male die forming process exploits the material volume better than die forming, it is possible to work with thinner starting sheets in the former case. Secondary form elements protruding out of the basic form in the blowing direction have a positive effect on the male die forming. The maximum ratio for the surface increase is 0.6.

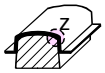
Criteria for Choosing Male Die Forming



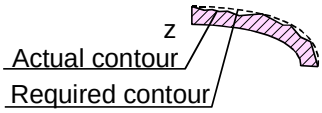
The ratio of surface area increase A_0/A_1 is greater than 0.4.

$$A_0 = l \cdot b$$

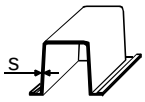
$$A_0 = l \cdot b + 2 \cdot h(b + l)$$



Exact replication of contours on inside of part.



External surface of part free from manufacturing blemishes (scratches etc.). Wavy external surface of part due to wall thickness variations.



Weight of part and sheet thickness required to be as low as possible.

Secondary form elements make female die forming very difficult.

TALAT Training in Aluminium Application Technologies	Criteria for Choosing Male Die Forming	3803.04.01

Principle criteria for choosing the female die forming process are discussed in **Figure 3803.04.02.** The maximum ratio for the surface increase is 0.4.

Criteria for Choosing Female Die Forming

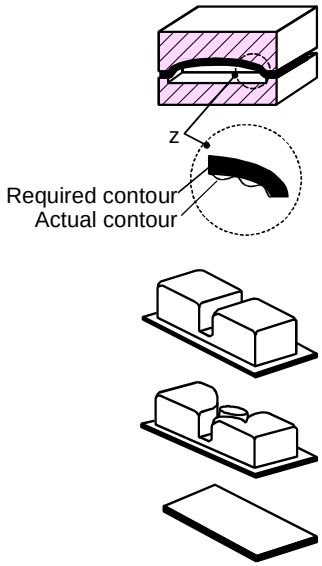
An exact form replication on the outside surface of the part is essential.

Part interior surface free from manufacturing blemishes (scratches etc.). Wavy interior surface of part due to variations in wall thickness.

Ribs divide the part.

Secondary form elements make male die forming difficult.

The blank size necessary is not conducive to male die forming.



TALAT Training in Aluminium Application Technologies	Criteria for Choosing Female Die Forming	3803.04.02

Figure 3803.04.03 compares the component requirements, blank dimensions, geometrical and dimensional requirements, economy and the controlling parameters as a help for selecting the right process for superplastic forming processes.

Choosing a Process for Superplastic Forming

→ Part requirements → Dimensional and geometrical requirements → Economy → Control possibilities

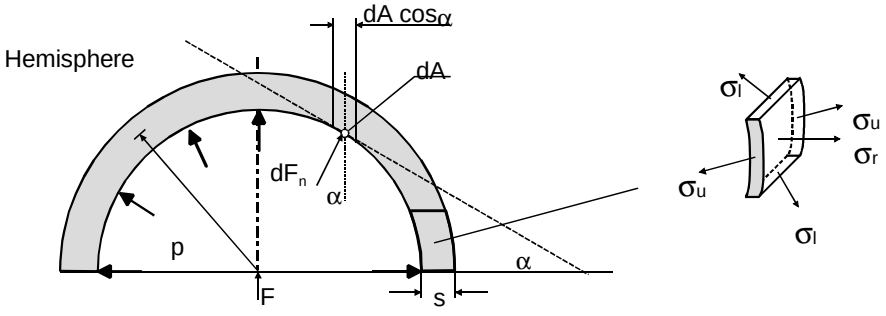
Process \ Criterion	Part size (possible)			Defect-free surface		Dimensional accuracy		Part wall thickness	Economic aspects		Forming ratio		Control of log. strain rate
	< 900 x 1300	< 2300 x 1300	> 900	External surface	Internal surfacce	External surface	Internal surfacce	Constant	Multiple forming	Tool costs	$f_k < 0,4$	$f_k < 0,6$	$\dot{\varphi}$
Female die process		●	●	- -	+	+	- -	- - -		+ + +	●		- -
Female die process with insets			●	- -	+	+	- -	- - -	●	+ +	●		- -
Male die process	●			+	-	-	+	+		+		●	+
Male die process with insets	●			+	-	-	+	+	●	+		●	+

Source: Superform Metals Ltd.

TALAT Training in Aluminium Application Technologies | Choosing a Process for Superplastic Forming | 3803.04.03

Figure 3803.04.04 gives a method for estimating the required gas pressure for forming which can be calculated using the formula $p = 2 \cdot k_f \cdot s/r$. This formula is based on the equilibrium principle of the strength theory: $p \cdot A_{proj.} = k_f \cdot A_{stressed}$

Estimating the Required Gas Pressure



r = average sphere radius

p = internal pressure

k_f = flow stress

s = sheet thickness

Equilibrium conditions $p\ A_{proj.} = k_f\ A_{stressed}$

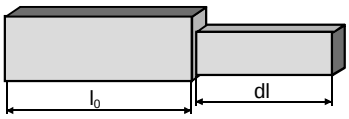
$$p = k_f \frac{2s}{r}$$

TALAT Training in Aluminium Application Technologies | Estimating the Required Gas Pressure | 3803.04.04

In order to obtain k_f from the flow curves it is necessary to estimate the logarithmic strain rate, $\dot{\varphi}$, as outlined in **Figure 3803.04.05**, where v_{wzg} is the tool velocity (see also TALAT 3300, Figure 3303.02.04).

Estimating the Log. Strain Rate (or True Strain Rate)

Elongation of a tensile specimen element



$$\varphi = \ln \frac{l}{l_0}$$

$$\dot{\varphi} = \frac{d\varphi}{dt} = \frac{dl}{ldt} = \frac{v_{wzg}}{l}$$

3803.05 List of Figures