Superplastic Forming (SPF) 101

Introduction

400 Ton Superplastic Forming Press

Superplasticity is a characteristic of metals or metal alloys, which become more malleable at high temperatures. Because of this characteristic, alloys can be stretched into much larger sizes, producing high-strength, lightweight components with complex geometries.

In the Superplastic Forming (SPF) process, metal sheets are exposed to inert gases like argon (extremely pure) within a vacuum system. The gas is applied uniformly to the sheet over the cavity of the die. The material is shaped over molds to produce the required parts, including three-dimensional structures like hollow or honeycomb structures. Variable gas pressures are used to ensure the desired thickness is achieved.

Materials and applications

Superplasticity is found in various materials, including metals and alloys, ceramics, bulk metallic glasses, and geological materials. Aluminum becomes superplastic at temperatures greater than 500 degrees Celsius and titanium at temperatures exceeding 900 degrees Celsius. New alloys are also emerging in the market, which exhibits superplasticity even at lower temperatures.

Materials like these allow for thinner sheets, improving both the molds' life and the parts and reducing component weight and cost. When compared to traditional forming methods, SPF offers material savings (>10%), reduced tooling costs (>20%), shorter lead times, and improved part strength.

One of SPF's most significant advantages is the capacity to produce larger, stronger, and lighter parts than a traditional press, with fewer joints and welds. This is due, in part, to a particular (and secret) laminate material that is used in the process, like that used in the manufacture of jet engines, for example.

The high strength-to-weight ratio and corrosion resistance of SPF components make them ideal for aerospace industry applications. SPF presses are used for some of the world's most extensive commercial aircraft programs to produce wing parts, engine casings, blades, and rudders. SPF is also used for automotive components, medical devices, architectural panels, and even golf club heads.

An example of SPF in action in the aerospace industry is in use by leading manufacturing for the aircraft, space, and defense, where Ti-6AI-4V alloy was used to manufacture a nacelle center-beam frame in a single component, as an alternative to the eight elements and 96 fasteners previously required—using both SPF and diffusion bonding, resulted in a cost savings of 55 percent and a weight savings of 33 percent.

White Paper originally published at
https://www.macrodynepress.com/super-plastic-forming-spf-hydraulic-presses/

Diffusion bonding is another process, more environmentally friendly, used in the nuclear and aerospace industries to bond multiple sheets together in a vacuum or an inert gas environment. The solid-state diffusion process allows the sheets' molecules to integrate at high temperatures and pressure while retaining most of the individual metals or alloys' inherent properties.

Establishing Process Parameters

The SPF process is very distinct and requires long cycle times at extremely high temperatures. The average time it takes to make one part at temperatures ranging between 930 and 970 degrees Celsius is about 7 hours.

A slow forming rate makes the process ideal for low volume production applications, though it is one of the disadvantages of SPF. Luckily, advances in process technology have made way for faster throughput and improved cycle times making SPF more competitive for high volume applications, like those used in automotive applications.

The chart below generalizes some of the process parameters of SPF:

Parameter	Range
Typical tonnage	50 – 800 tons
Typical bed size	60" x 40" to 120" to 80"
Typical pressing pressure	500 – 1000 psi

Example:

The tonnage specifications of SPF presses depend upon the size of the die and the component. The presses are practically clamping mechanisms, and the speeds are not the same as in a regular press operation. Apart from 500 psi pressure required to open the press, the tonnage must be higher to provide the proper clamping effect.

600 Ton Superplastic Forming Press

If the part is 50 inches by 30 inches in size, the part area will be 1,500 square inches. Take that 1500 square inches and multiply it by the pressure: 500 psi would equate to 750,000 pounds of force (or 375 tons). Ideally, the press tonnage should be 450 to 500 tons, with a fast closing speed of around 50 inches per minute, a quick return of 50 inches per minute, and pressing 1 to 5 inches per minute.

It is essential to ensure that the materials are of uniform thickness across the entire sheet area to ensure a uniform tensile strength is retained. The process must also accommodate the effects of spring back, which tends to occur once the pressure is released during the production process.

Likewise, galling can occur when friction and adhesion are present, which causes localized roughness and other surface defects. It is particularly true of aluminum when it is heated to a superplastic state and is subject to compressive forces. To prevent the intermediate material from adhering to the mold, which causes variations in the material flow as it is stretched, use high-temperature lubrication to limit the friction and mitigate the risk of galling.

Hydraulic SPF Press Design

A hydraulic press specifically designed for an SPF application is at the core of any SPF operation. Several key SPF press features will have implications on the process outcomes:

- Accurate and repeatable argon gas pressures and multi-zone temperature control. These are critical elements of a successful SPF operation. To maximize the effectiveness of these systems, flexible and repeatable press control is required. Precision gas management systems include heat exchangers for hot gas cooling during exhaust and provide accurate and repeatable argon gas pressures.

175 Ton Superplastic Forming Press

- Innovative hydraulic and control features allow press tonnage to be increased proportionally to the argon pressure rise and vice versa to minimize loading of the die seals.
- Highly efficient heat shields and ceramic insulation are standard on Macrodyne SPF presses and provide optimal insulation of high temperatures resulting from the process while ensuring long component life and operator safety.
- Specialized plunger guide arrangements comprised of central plunger-type guide assembly and temperature compensated guide bar/anti-rotate arrangement located in the crosshead provide enhanced guiding of the moving platen.
- Advanced control systems to manage process variables, including multi-zone temperature control, ensure successful superplastic forming operations.
- High-speed data acquisition systems provide increased access to process variable information and optimize data integration between the press and the internal networks.
- Rolling bolsters for rapid and safe changing of dies. They are customizable and are available in single- and double-die configurations for single direction or T-type travel.

Why Macrodyne?

Whether you are new to the SPF process or represent a company with extensive experience with the application, we encourage you to contact us today. We can work with you to optimize your production environment and help you achieve best-in-class part quality at higher volumes and lower costs.

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Our presses are available in standard configurations or customized to suit the Buyer's specific requirements, regardless of the size or complexity.

Visit Macrodyne Superplastic Forming page to learn more about custom Superplastic Forming Presses.

Contact us about your hydraulic press needs.

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