



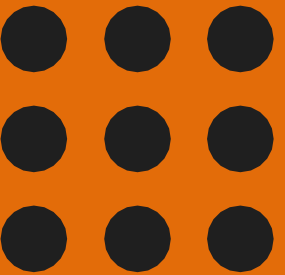
SNS COLLEGE OF TECHNOLOGY

Coimbatore-35

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sns
INSTITUTIONS



DEPARTMENT OF AEROSPACE ENGINEERING

19AST202 Aircraft Production Technology

II Year III Sem

Unit 2

METAL FORMING

Super plastic forming and diffusion bonding



SNS *Design Thinkers*

Dr. M. SUBRAMANIAN, Professor & Head/Aero





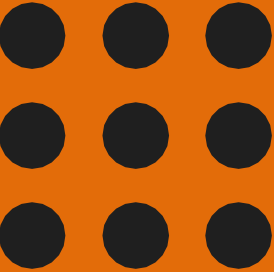
Introduction

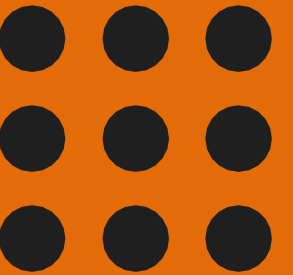
- The first recorded laboratory observation of what was almost certainly SP deformation was published in 1912 by Bengough.
- The first really implementation of SPF/DB was Boeing F15 Eagle, Eurofighter afterwards and Sanders and Ramulu (2004).
- SPF/DB form more complex parts than possible with hot forming.
- Designers and researchers have exploited titanium's natural ability to be superplastically formed and diffusion bonded at elevated temperatures and low strain rates to produce components
- The addition of Mg and Al-6%Cu alloy proved to be the inventive step that made commercially useful superplastic components a reality.



Superplasticity

- Superplasticity is the ability of specific polycrystalline materials to endure extensive tensile plastic deformation.
- Superplastically deformed material gets thinner in a very uniform manner, rather than forming a “neck” which leads to fracture.
- Numerous metallic materials can show elongations of 500–1000% or more.
- A material is normally considered to be SP when it has an m value ≥ 0.3 (where m is strain rate sensitivity of flow stress).



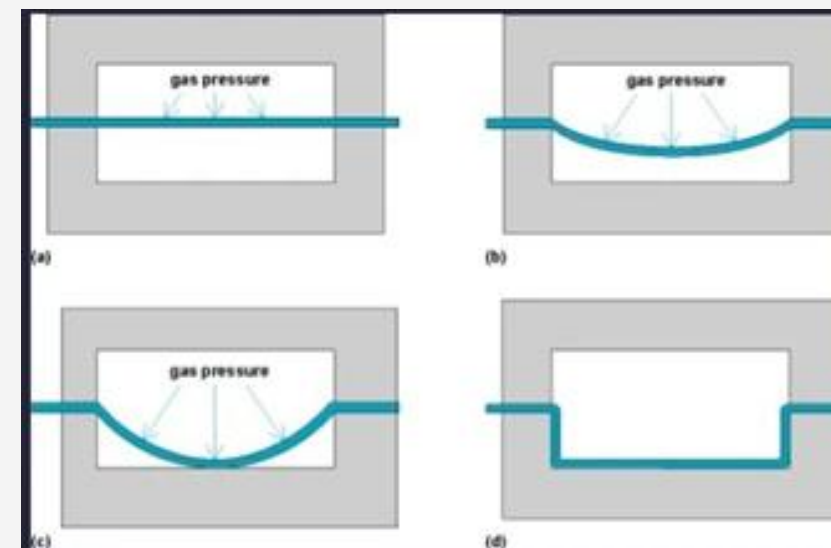


Superplastic Forming

Placing the starting sheet Between upper and lower dies

Heating the sheet until it starts behave superplastically

Applying pressure to form the sheet

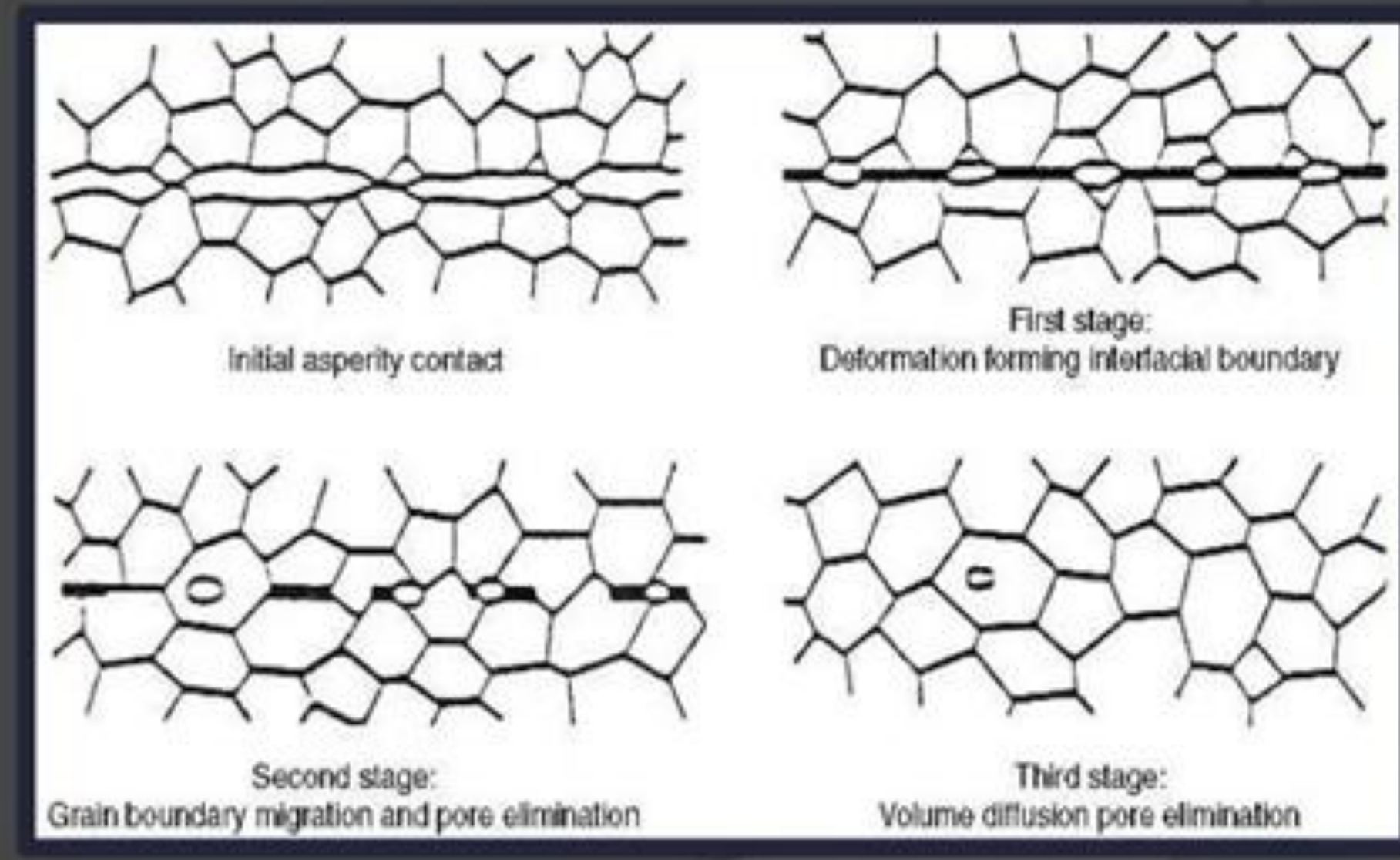




Diffusion Bonding Process

Diffusion Bonding is a solid-state joining process between two metals in the way that the microstructure and mechanical behavior of the bond becomes identical to the parent material.

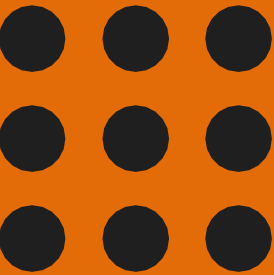
- Elevated Temperature
- Applying pressure for intimate contact
- Deforming and plastic flow of microstructural particles
- Grain formation in the bond-line





Superplastic materials and alloys

- Titanium alloys:
 - Ti-6Al-4V - AISI 304 stainless steel
 - Ti SP-700 alpha-beta alloys
- Aluminum alloys:
 - AA5083 ALNOVI-1 (s Al-4.5 Mg, 0.7 Mn, 0.12 Cr)
 - 6-Al-4V alloy
- Magnesium alloys
 - AZ31 magnesium alloy



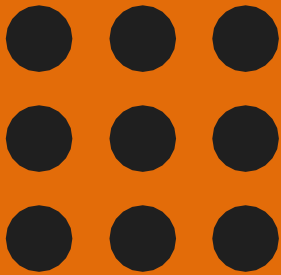


Combination of SPF and DB

- Pressure is applied on opposite faces.
- The applying pressure with respect to temperature should be in a range of which metals still act as a superplastic material.
- After that, diffusion bonding due to high pressure and temperature will occur in sections that need to be adhered
- According to complexity various methods are going to use for SPF/DB processing of metals.

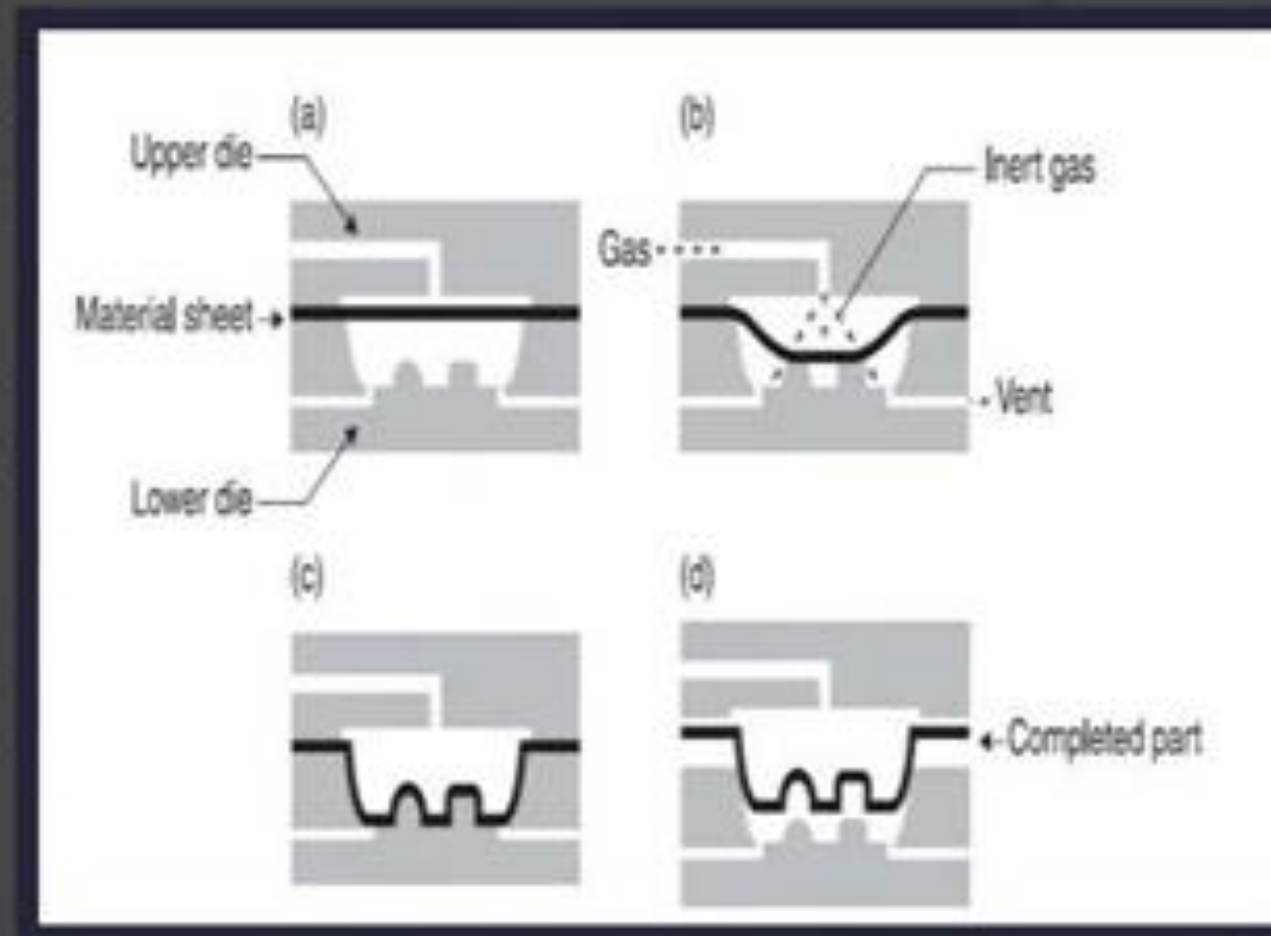
Types of SPF/DB Process:

- Single-Sheet
- Multi-Sheet
 - Two Sheet
 - Three-Sheet
 - Four Sheet

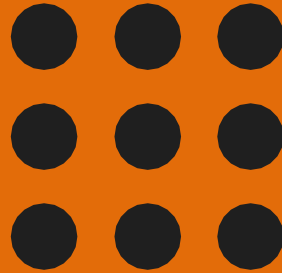


Single-Sheet (SPF/DB Process)

- Die and sheet are maintained at the same temperature within a heating press.
- The gas pressure is imposed over the sheet causing the sheet to form into the lower part of the die.
- The process progresses further until the deformed sheet makes contact with the lower die cavity.
- A diffusion barrier such as boron nitride is used on the surface to avoid sticking.



Demonstration of single-sheet forming using Superplastic forming





Multi-sheet: (SPF/DB Process)

Figure (a)

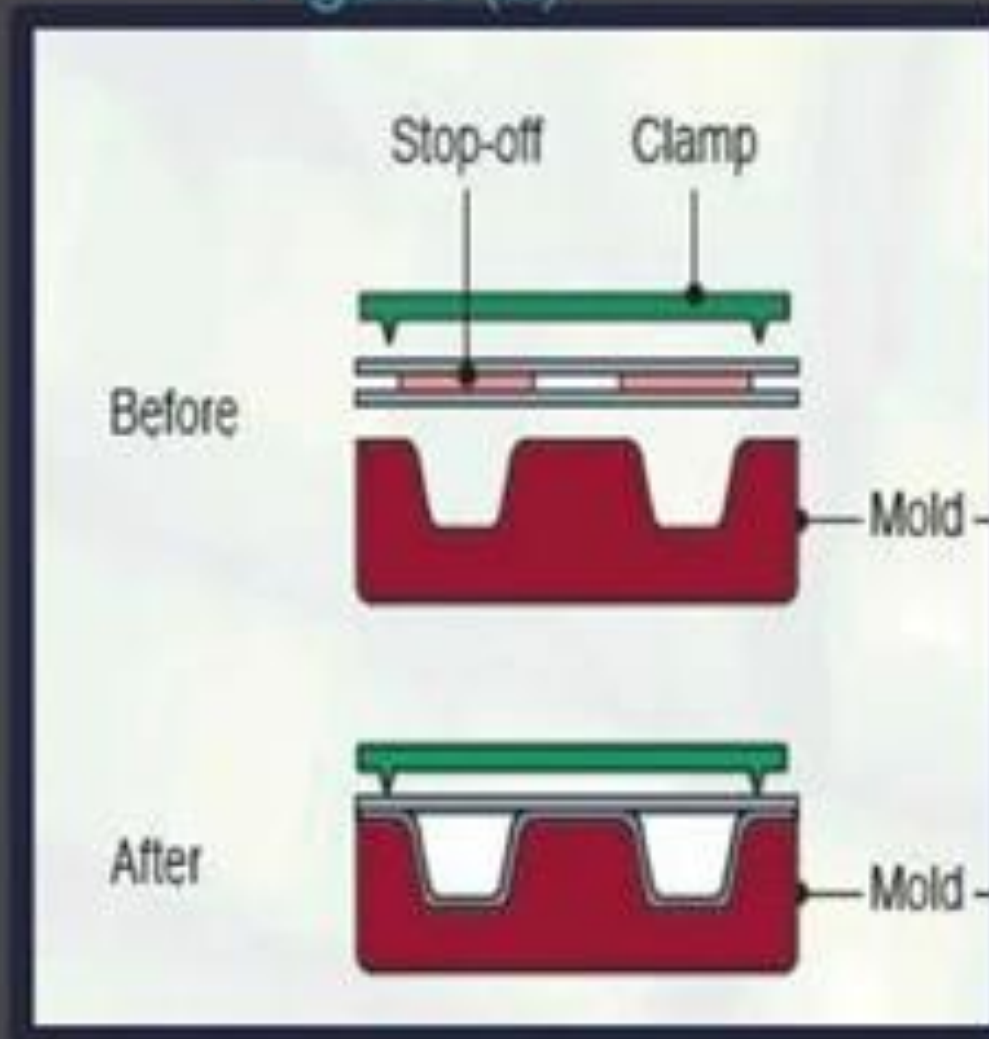
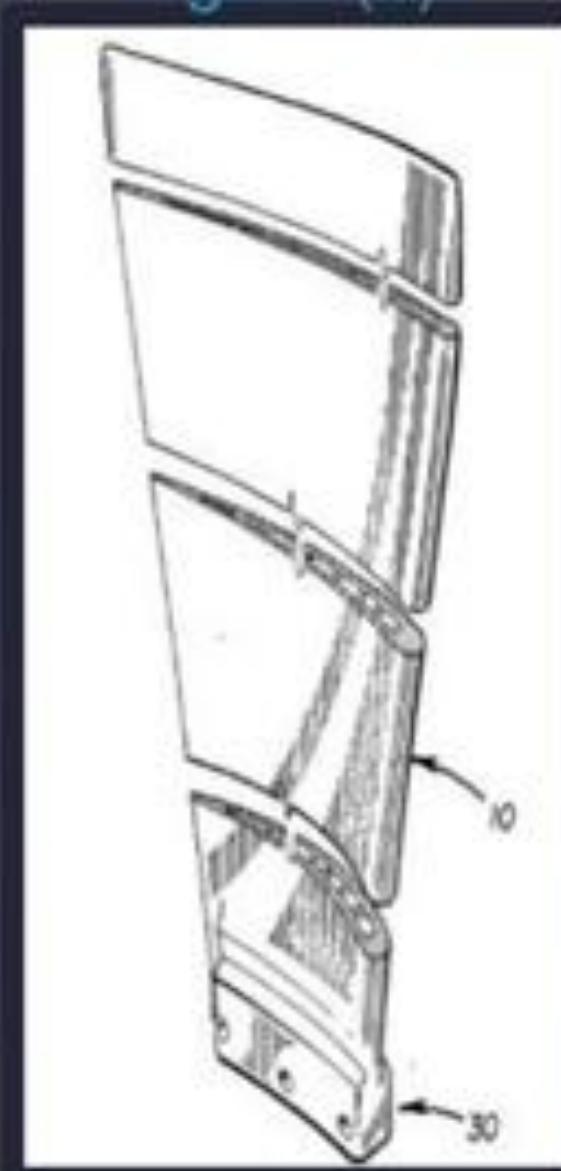


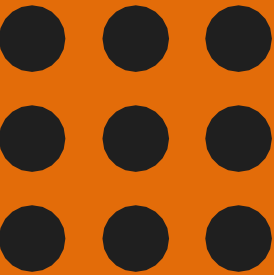
Figure (b)



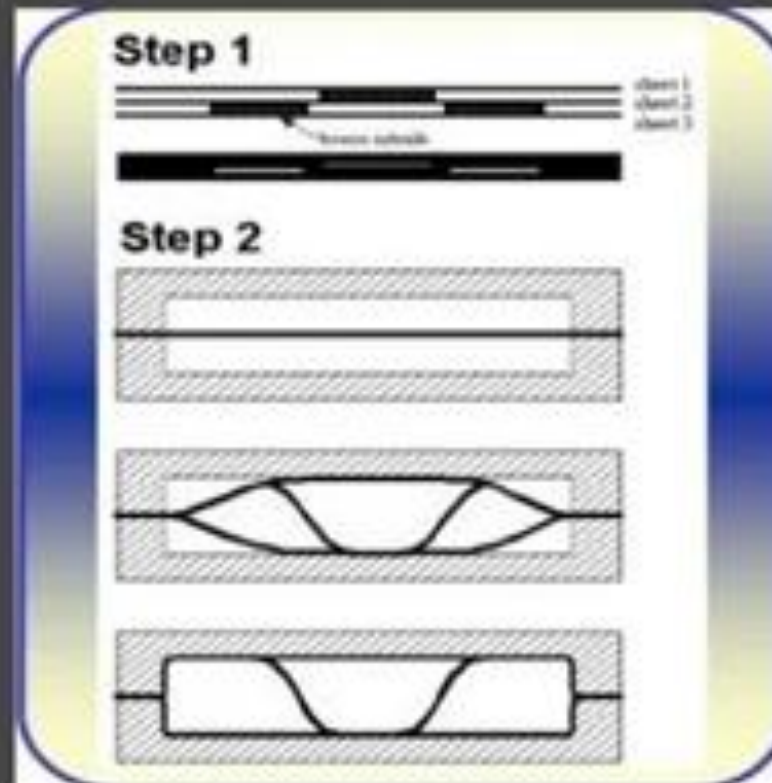
Two sheet

- Two-sheet diffusion bonding is to apply “stop-off” between the sheets in the areas where stiffeners are required in the final product.

- a) Two sheet and blow forming and Diffusion Bonding
- b) Manufactured Aircraft component of two-sheet SPF/DB



Three-Sheet (SPF/DB Process)



Example of the 3-sheet structure

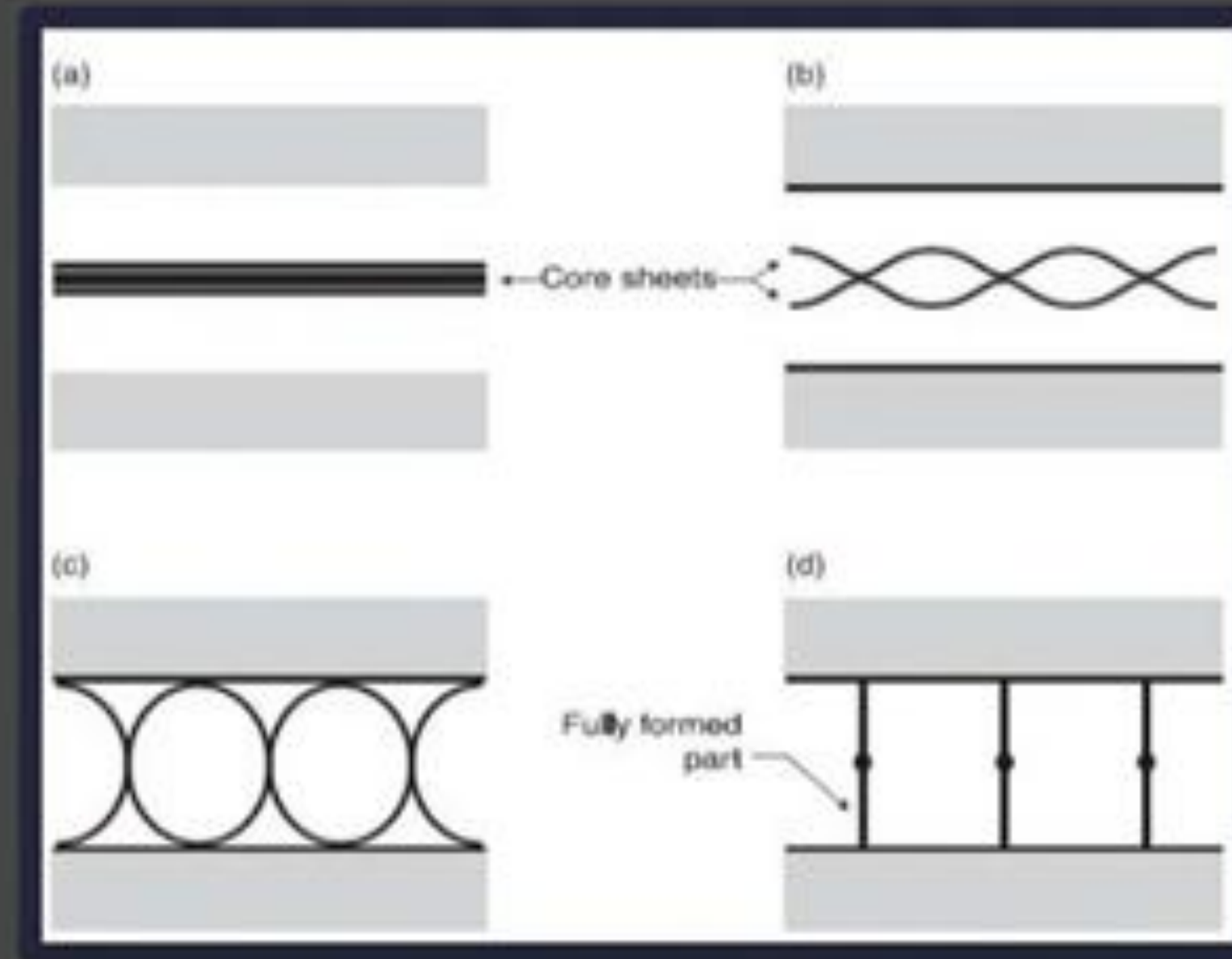
(a). Steps For Three sheet process

- For three (or more) sheet structures, gas pressure forms the outer sheets (the skin) and the center sheet(s) are stretched into a core configuration.
- Stop-off acting as a diffusion barrier is deposited onto areas where no bonding is required

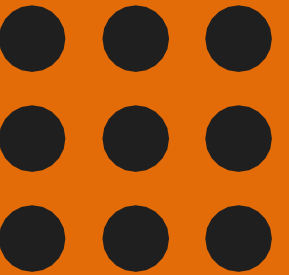


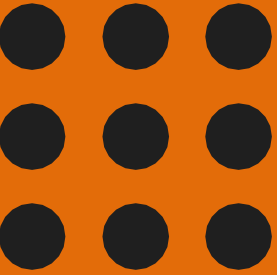


Four Sheets (SPF/DB Process)

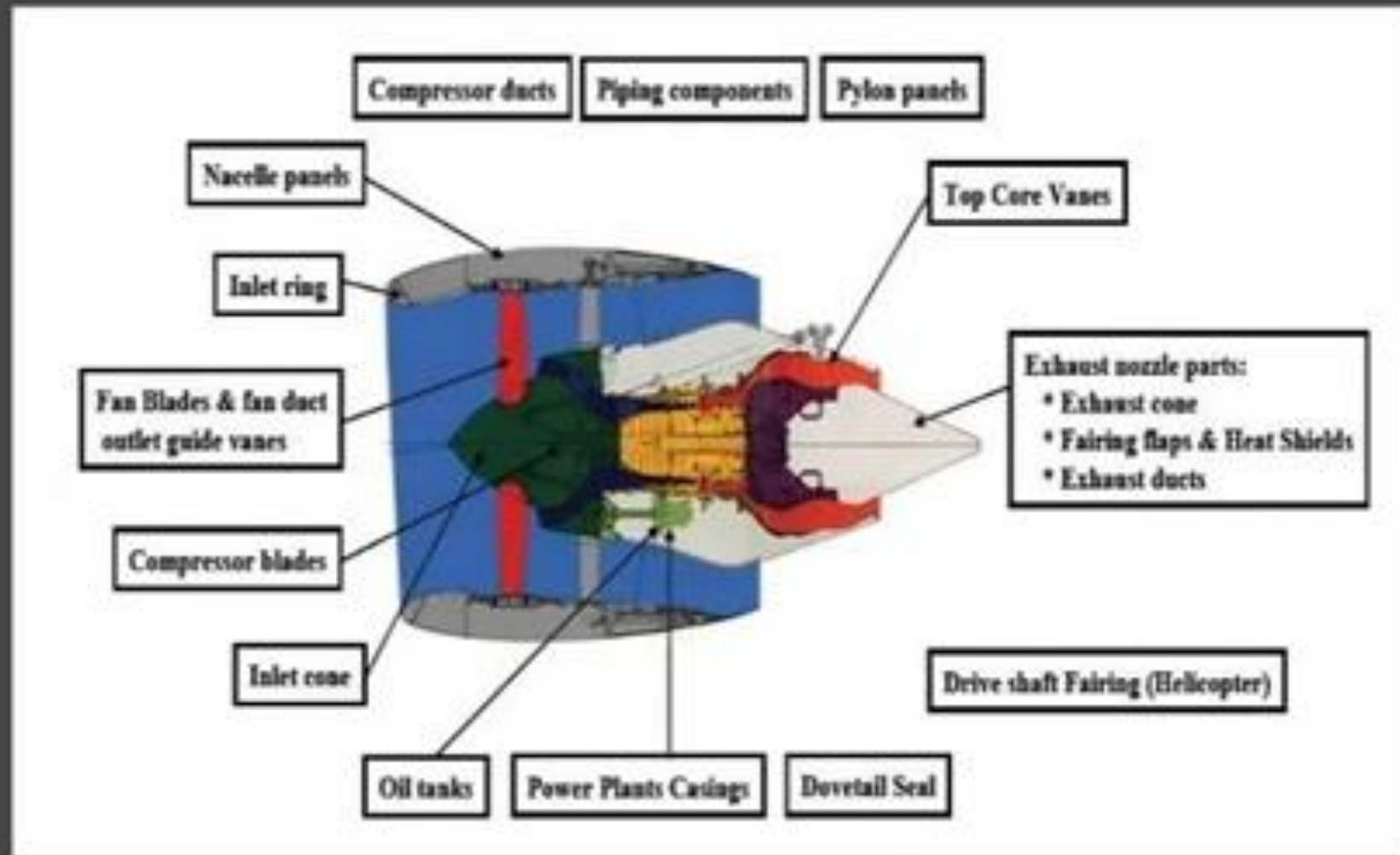


(b). Example of Multisheet





Applications of SPF/DB in Aerospace Industry



(A) Aeroengine



(B) Northrop B 2 Spirit Bombarder



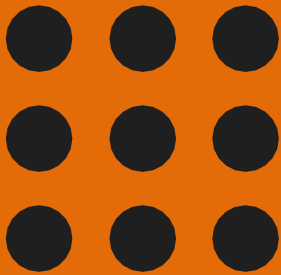


Applications of SPF/DB in Aerospace Industry



- Major SPF/DB development initiated 30 years ago was the Rolls-Royce hollow, wide-chord fan blade.
- Trent series turbofans and provides almost 50% weight saving.
- The use of titanium provided the final product with excellent fatigue resistance, low weight and corrosion resistance.
- The blades are manufactured from external Ti panels with a central Ti-membrane sheet with use of stop off.
- Precision dies are used for to develop internal corrugations and external aerodynamic shape

Figure(a) Wide –
Chord fan blade





Applications of SPF/DB in Aerospace Industry

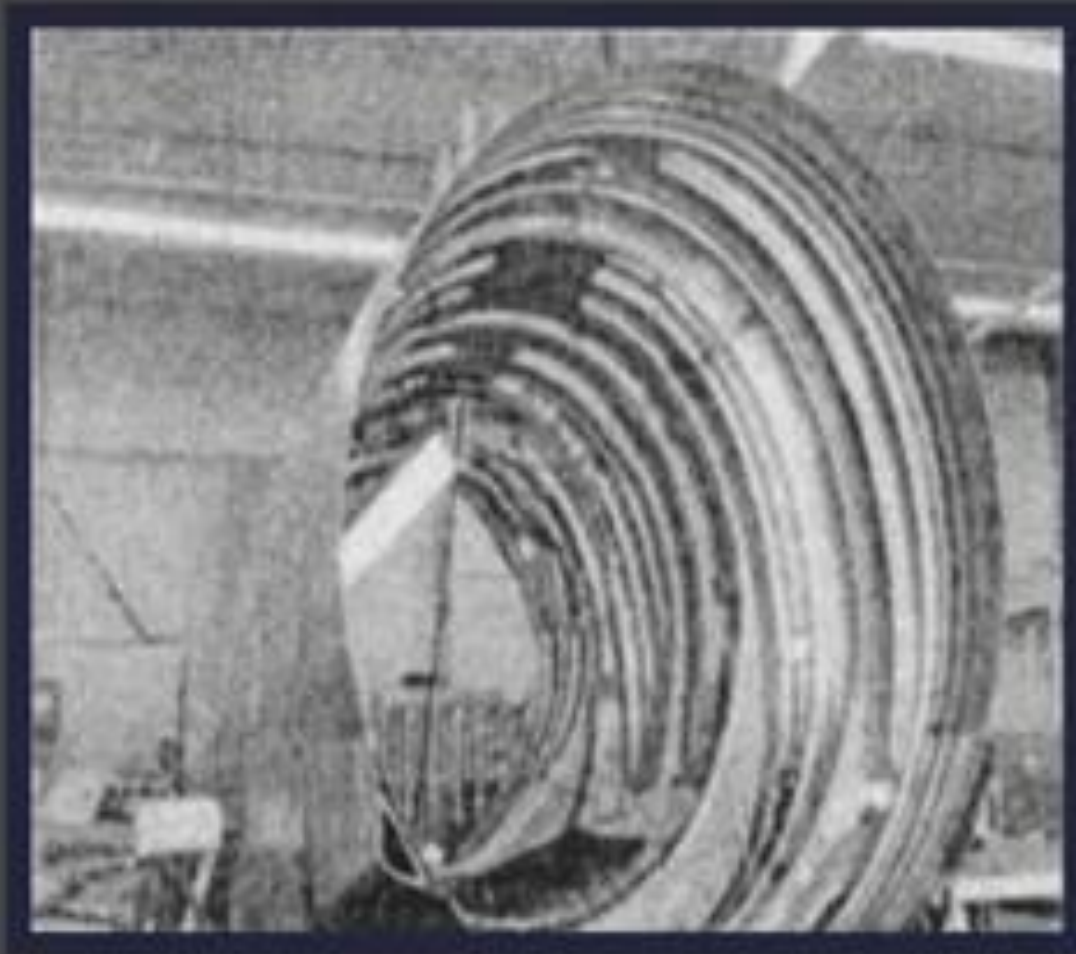
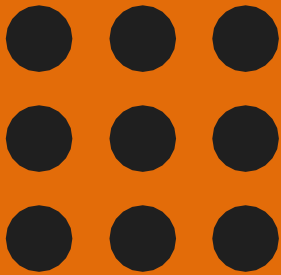
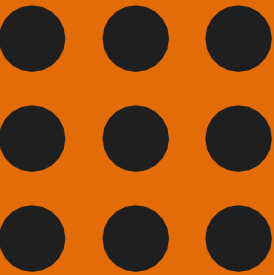


Figure (b)
Titanium Fuselage
part in Aviation

- The use of SPF/DB titanium for the aft fuselage resulted in 726 fewer components
- 10,000 fewer fasteners
- Achieved 15% weight savings over the previous process.





Applications of SPF/DB in Aerospace Industry

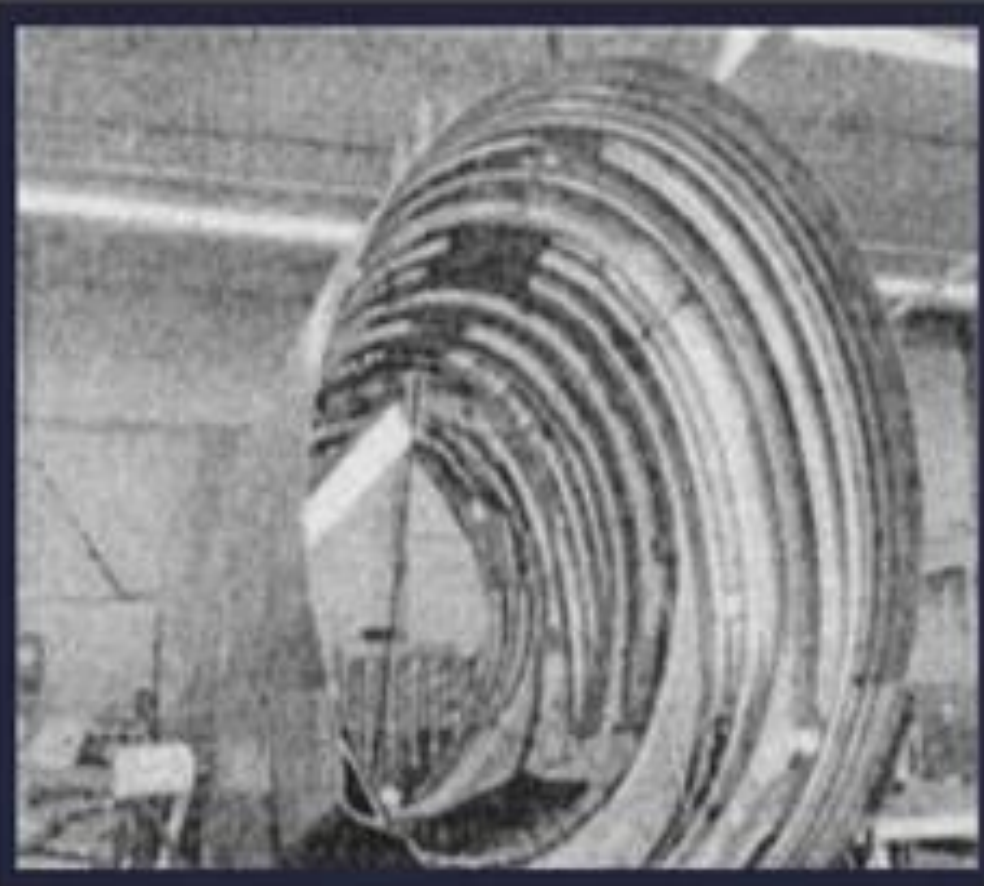


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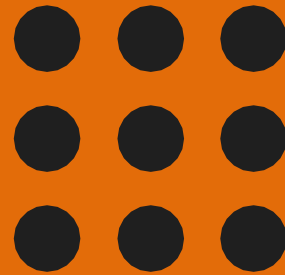


Applications of SPF/DB in Aerospace Industry



Figure (b) Military Aircraft Structure door

- The Al-Li based alloy used in several applications on military aircraft was probably the first to be used in component manufacture.
- But this alloy was found to have rather low impact resistance.
- Third generation' Al-Li based alloys are now under development.





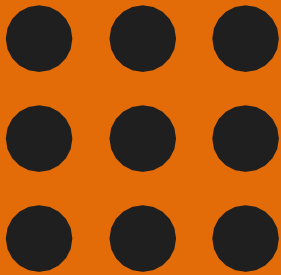
Inspection and Testing Methods of SPF/DB Parts

- The quality of a diffusion bond joint can be evaluated using NDT and/or metallographic examination.
- Ultrasonic testing is able to detect quite large voids.
- X-ray radiography can be used on relatively thin sections.
- The most discriminating test of the quality of bonds produced in thick sections is impact testing
- For bonds formed in sheet materials where impact testing is not applicable, constrained tensile and compressive lap shear tests are used.
- Resistance to “hot peel” is an important practical test for evaluating the quality of DB between thin sheets.



Methods for improving quality of SPF/DB (Reducing defects)

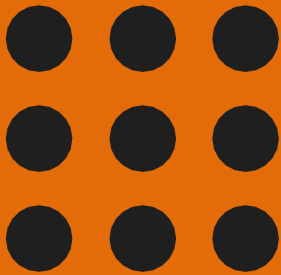
- Clean sheet surface pure of abrasive particles.
- Providing inert atmosphere and vacuuming air between sheets
- Sufficient pressure
- Sufficient time
- Proper temperature
- Using small grain size materials

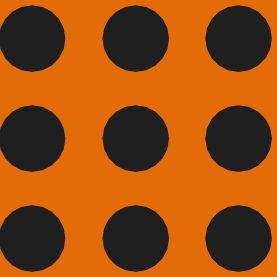




Advantages of SPF/DB process

- Ability to produce complex monolithic components in one process
- Eliminating the number of fasteners and assembly
- Reducing weight
- Eliminating limitation in geometry
- Forming brittle alloys or alloys which are difficult to form with other methods
- Accurate dimensions and excellent mechanical properties
- No residual stresses or spring-back
- Low stress acting on tooling and increasing tool's life
- Repeatability of the process





Disadvantages of SPF/DB process

- Various parameter should be considered like temperature, pressure, time , etc.
- High energy consumption
- Thermal damage of tooling
- Expensive dies and equipment





Thank you

