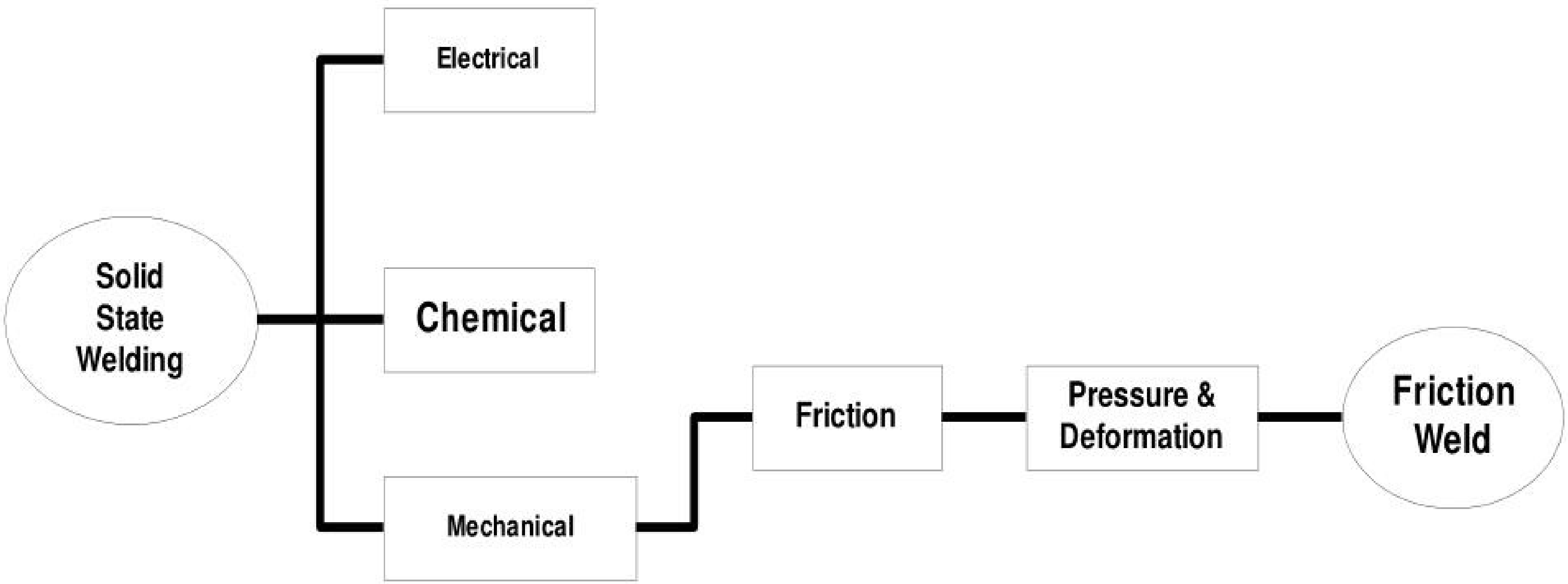
FRICTION WELDING

Friction Welding

Lesson Objectives
When you finish this lesson you will understand:
• Continuous Drive Friction Welding & Applications
• Variables Effecting Friction Welding
• Variations of friction Welding Process
• Dissimilar Materials Welded
• Inertia Welding Process & Applications

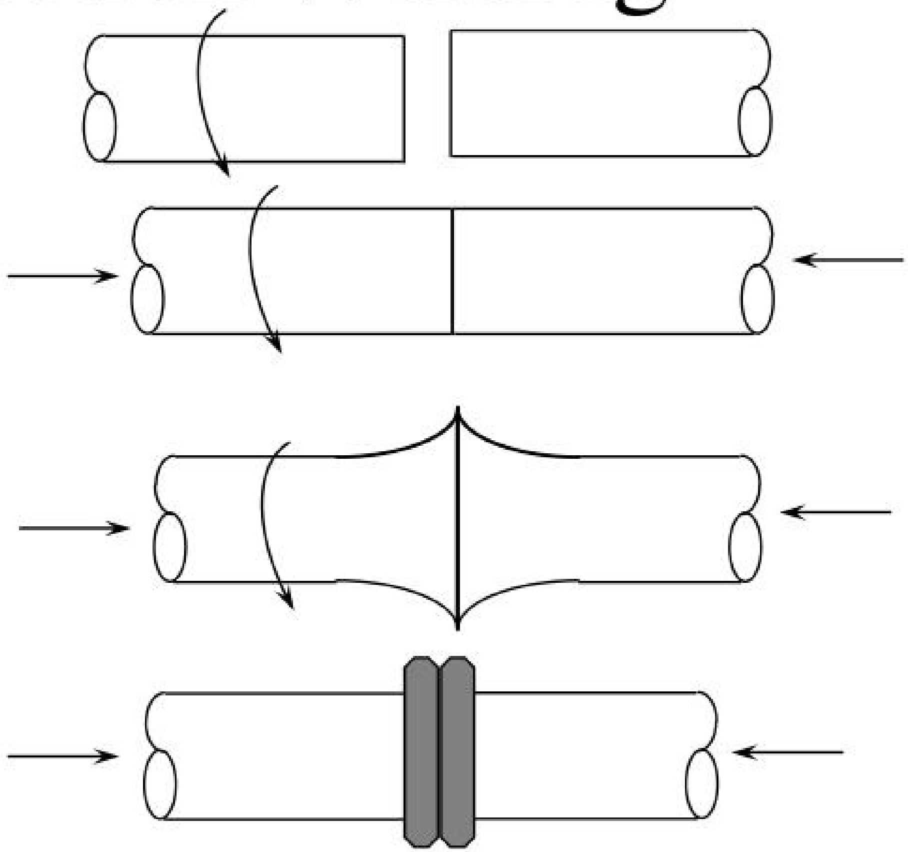
Learning Activities
1. View Slides;
2. Read Notes,
3. Listen to lecture
4. Do on-line workbook
5. View Video

Keywords: Friction Welding, Inertia Welding, Forging Pressure, Orbital Friction Welding, Linear Friction Welding, Angular Reciprocating Friction Welding, Radial Friction Welding, Friction Stir Welding


Solid State Welding
Electrical
Chemical
Mechanical
Friction
Pressure & Deformation
Friction Weld

Definition of Friction Welding

- Friction welding is a solid state joining process that produces coalescence by the heat developed between two surfaces by mechanically induced surface motion.



Examine the Friction Weld Video on the Web Page

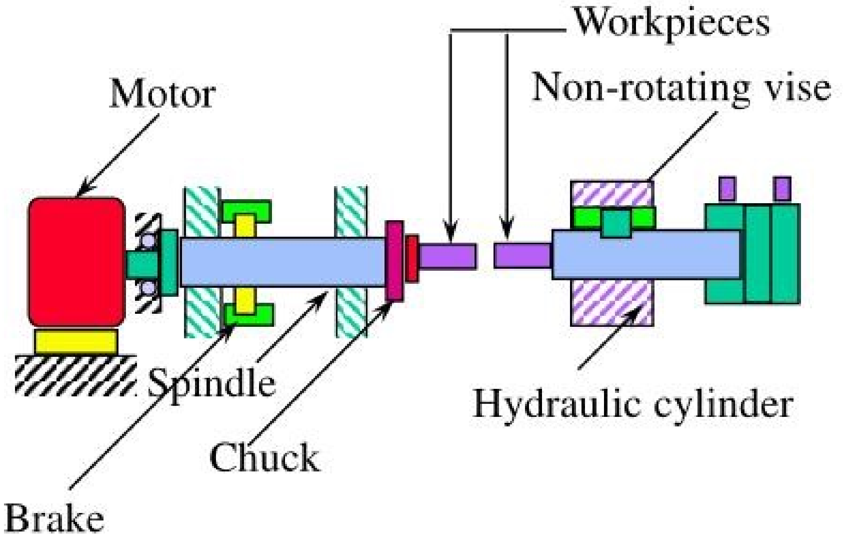
Link to Friction Welding Video

Categories of Friction Welding

- Continuous drive
- Inertia

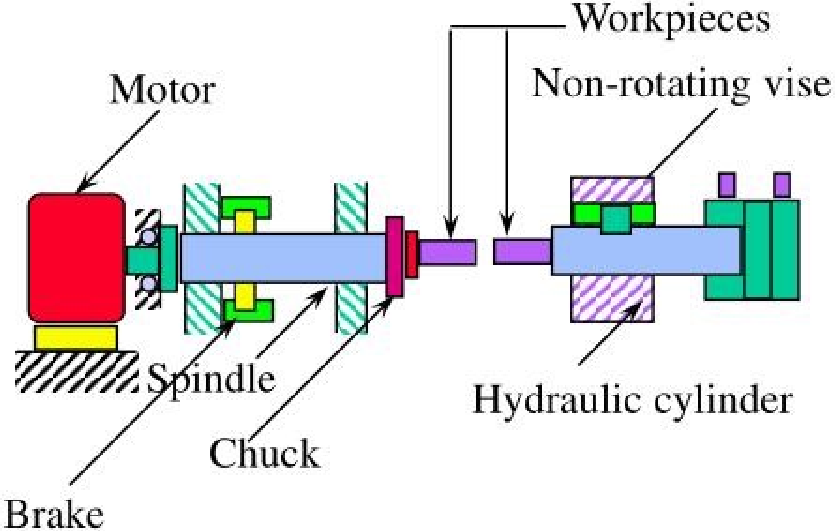
Continuous Drive Friction Welding

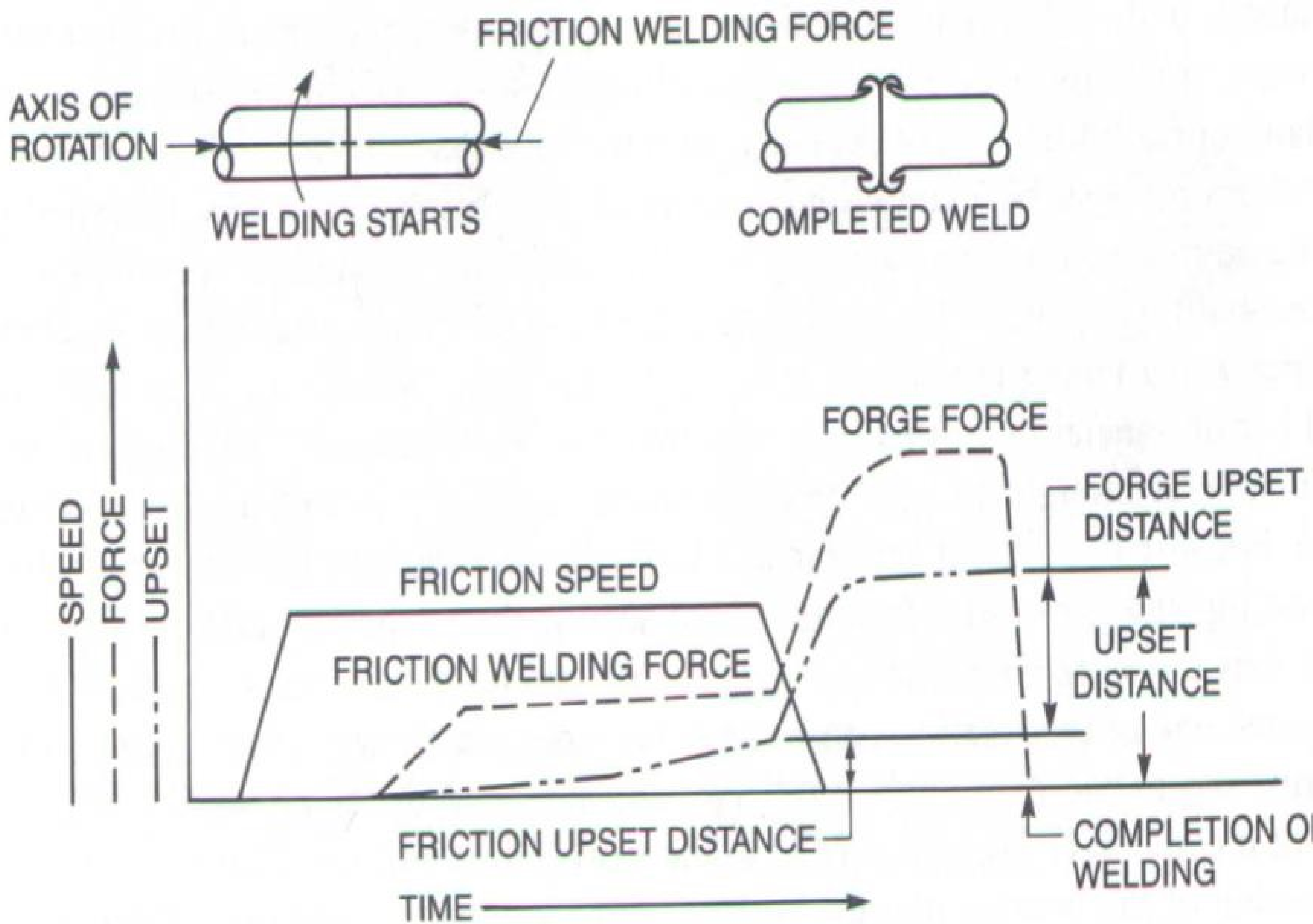
- One of the workpieces is attached to a rotating motor drive, the other is fixed in an axial motion system.
- One workpiece is rotated at constant speed by the motor.
- An axial or radial force is applied.



Continuous Drive Friction Welding

- The work pieces are brought together under pressure for a predeter-mined time, or until a preset upset is reached.
- Then the drive is disengaged and a break is applied to the rotating work piece.



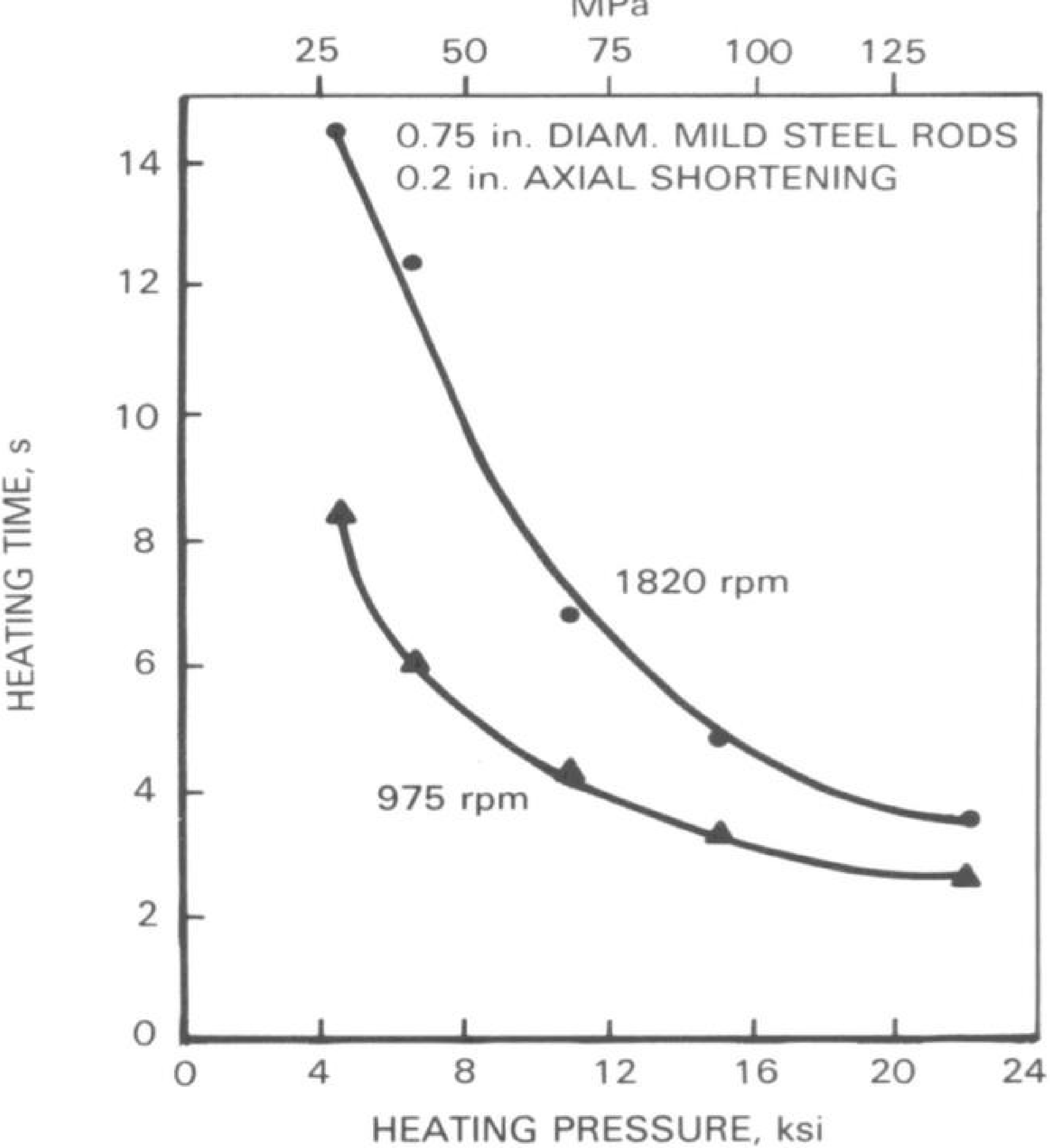


(B) GENERALIZED DIAGRAM OF DIRECT DRIVE FRICTION WELDING.

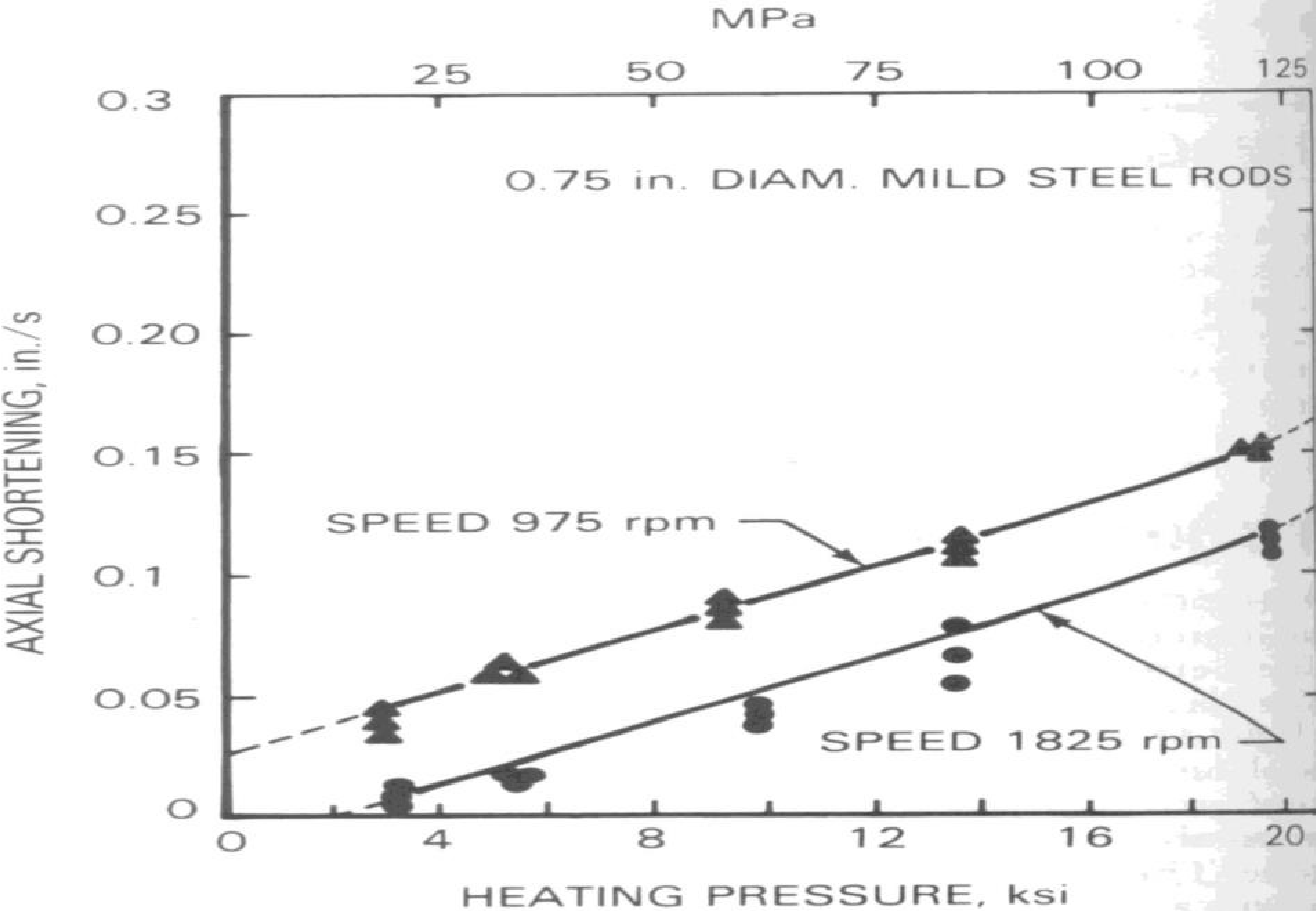
Linnert, Welding Metallurgy, AWS, 1994

Friction Welding Variables
(Continuous Drive)

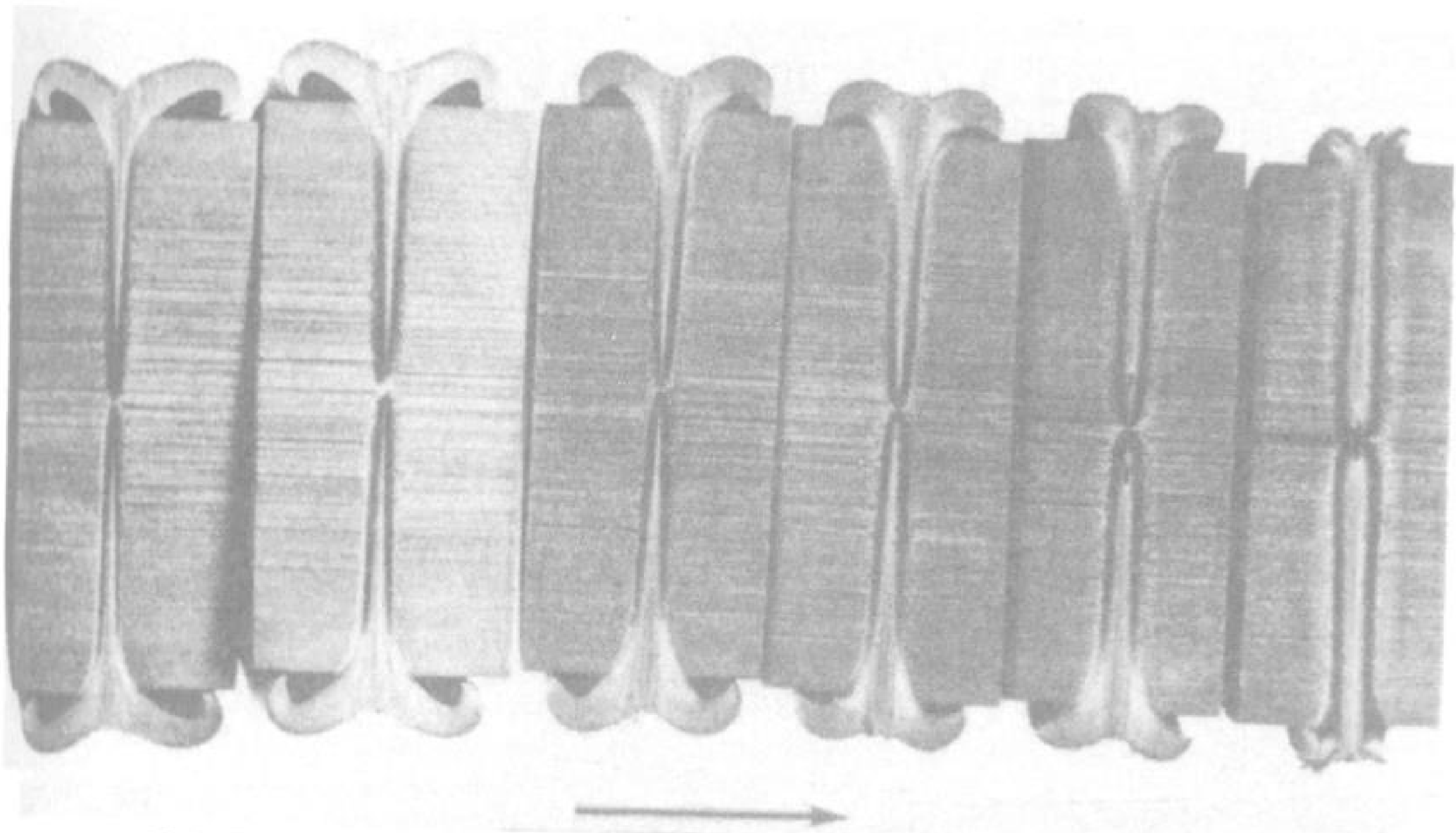
- Rotational speed
- Heating pressure
- Forging pressure
- Heating time
- Braking time
- Forging time



AWS Welding Handbook



AWS Welding Handbook



(A) (B)
EXCESSIVE

(C) (D)
DECREASING AXIAL
SHORTENING

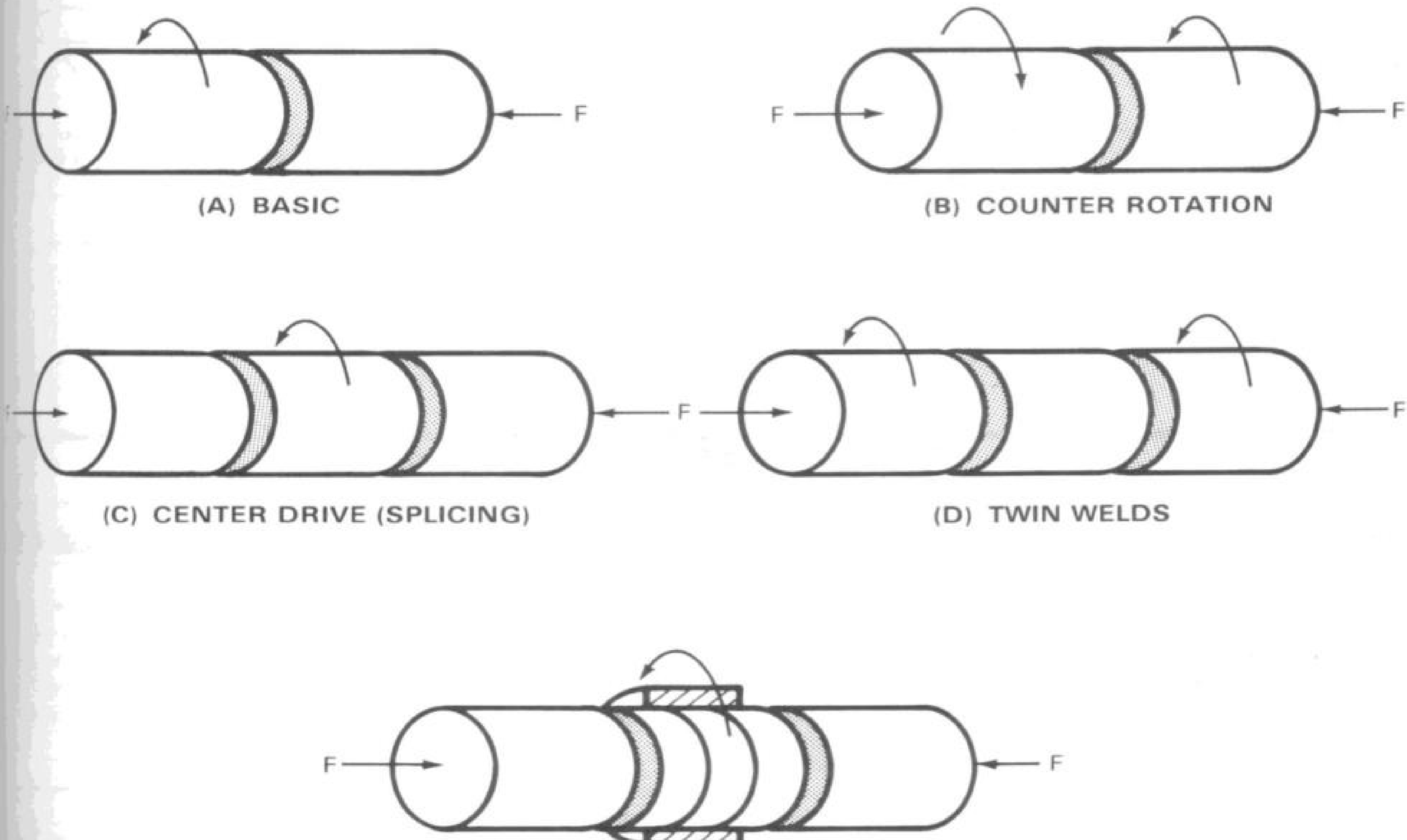
(E) (F)
INSUFFICIENT

Direct Drive Machine

Courtesy AWS handbook

Questions

Friction Welding Process Variations



(A) BASIC

(B) COUNTER ROTATION

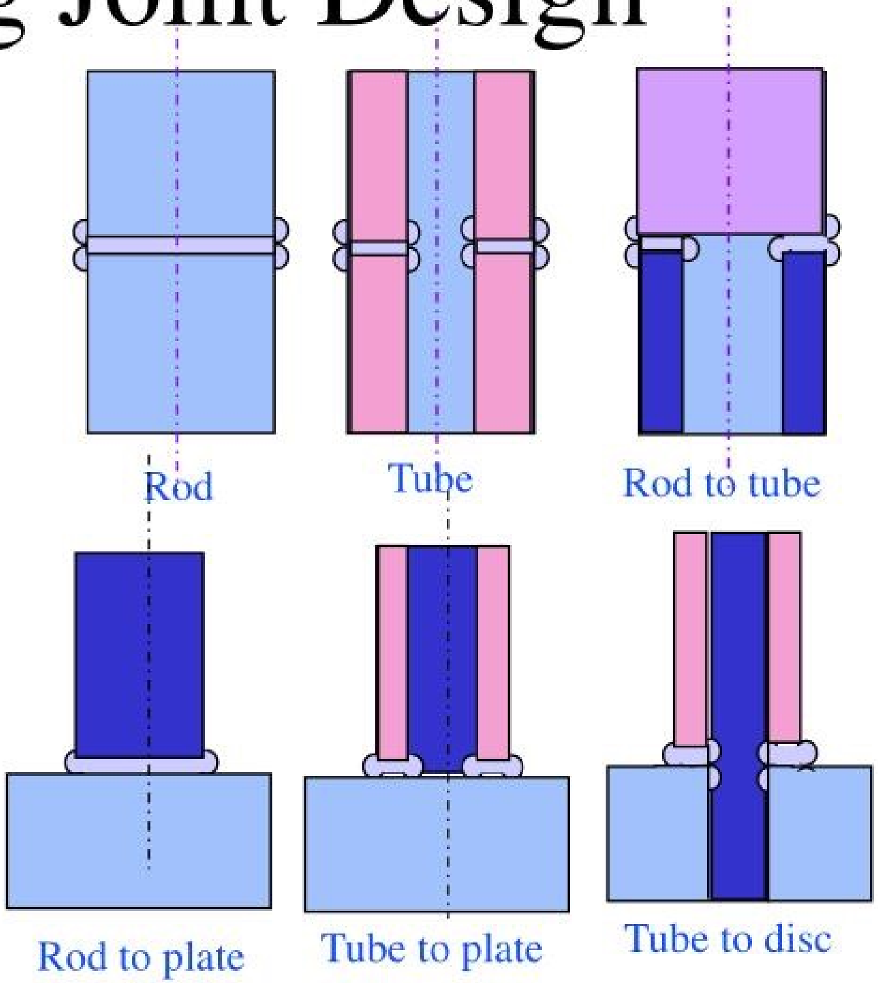
(C) CENTER DRIVE (SPLICING)

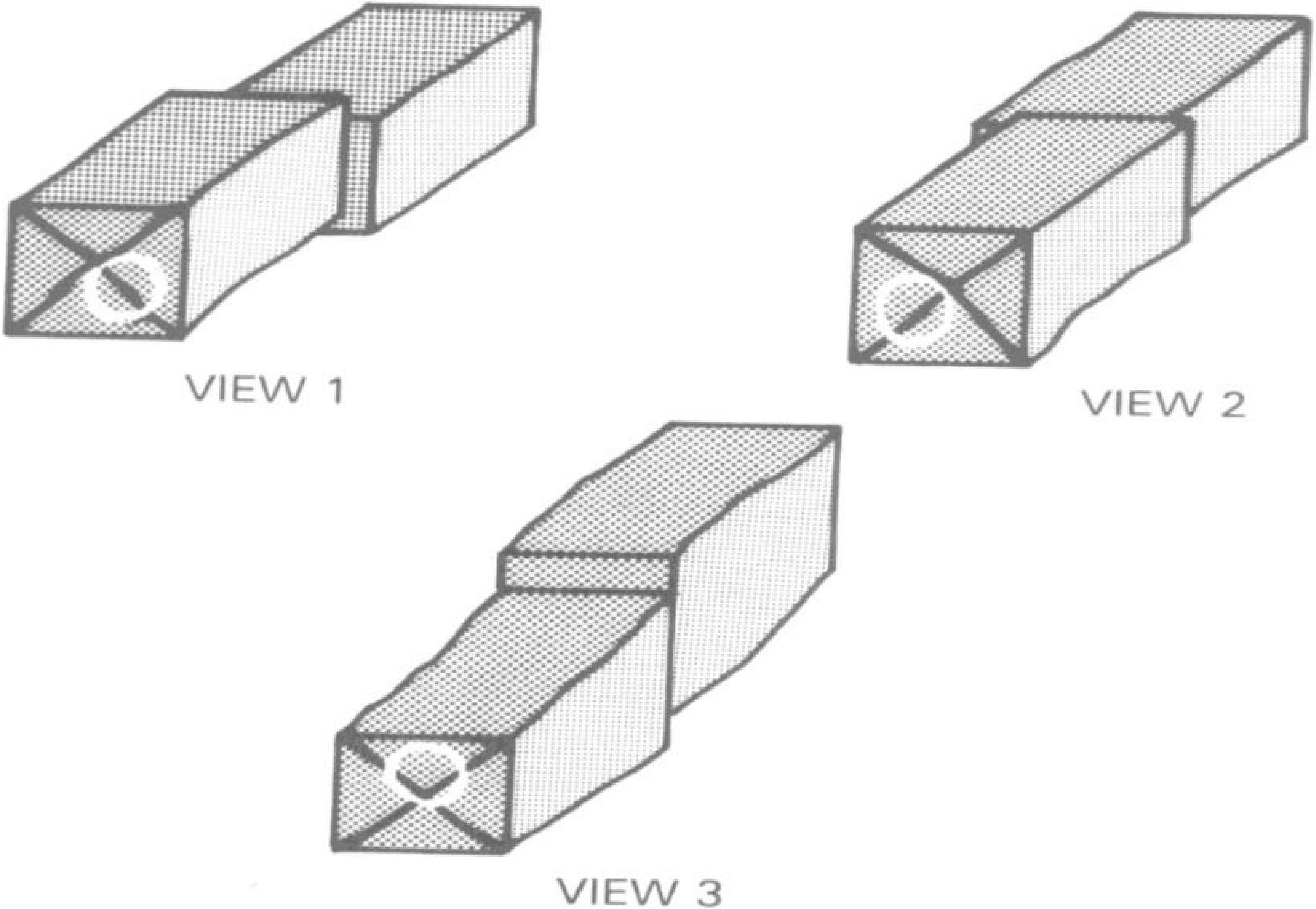
(D) TWIN WELDS

(E) CENTER DRIVE (DUAL PRODUCTION)

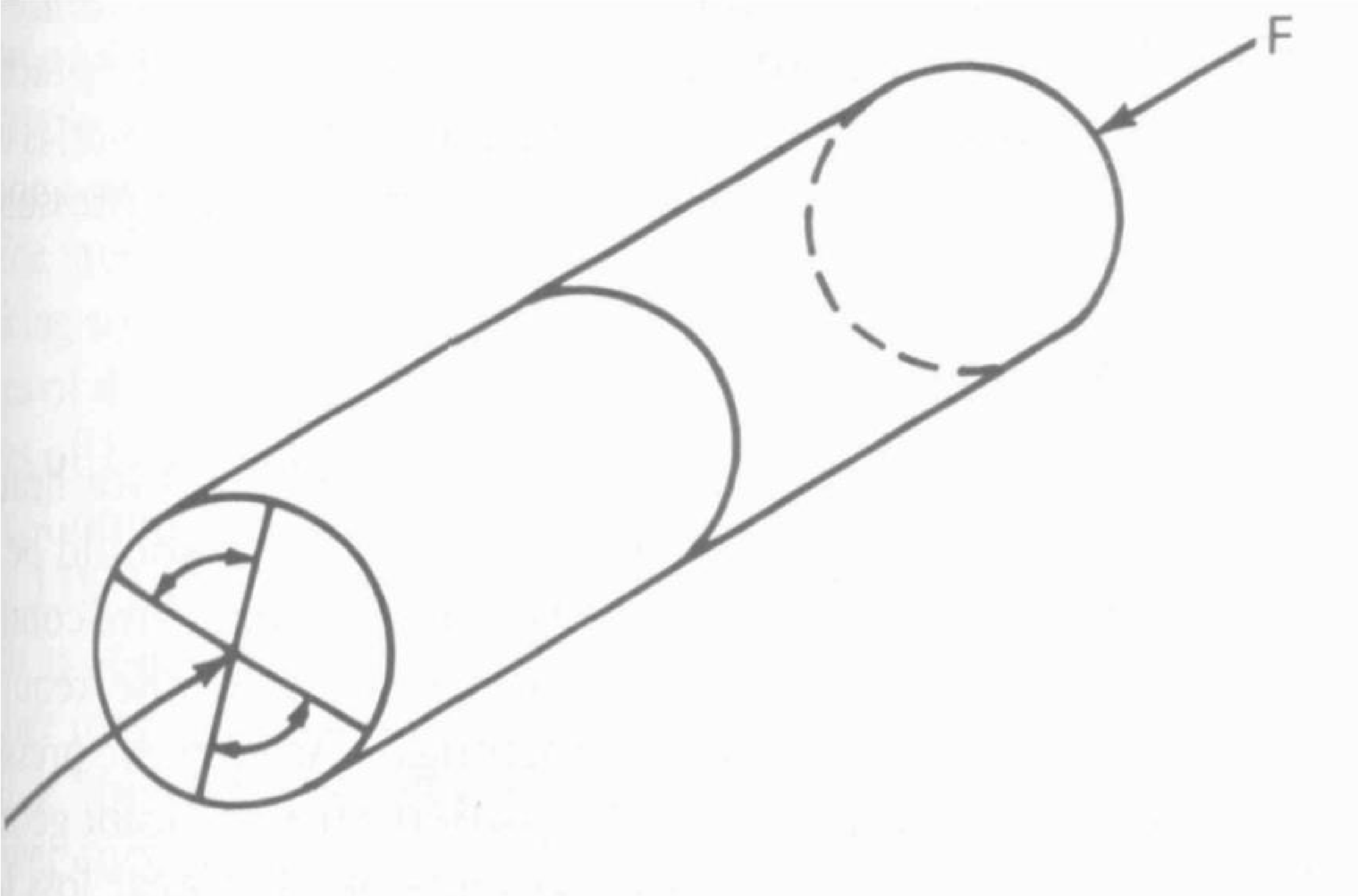
Friction Welding Joint Design

- The joint face of at least one of the work piece must have circular symmetry (usually the rotating part).
- Typical joint configurations shown at right.

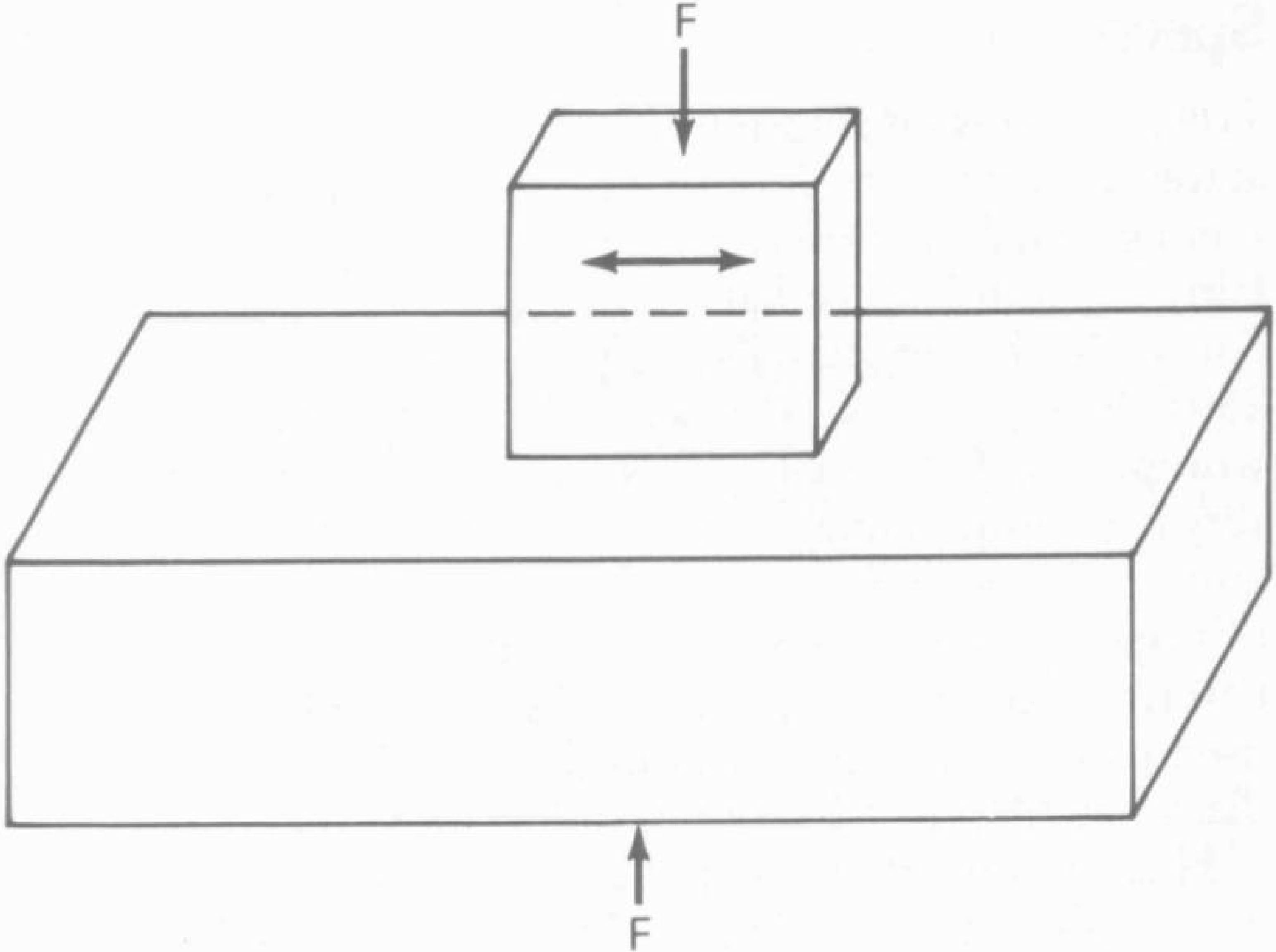




Orbital Friction Welding



Angular Reciprocating Friction Welding



Linear Reciprocating Friction Welding

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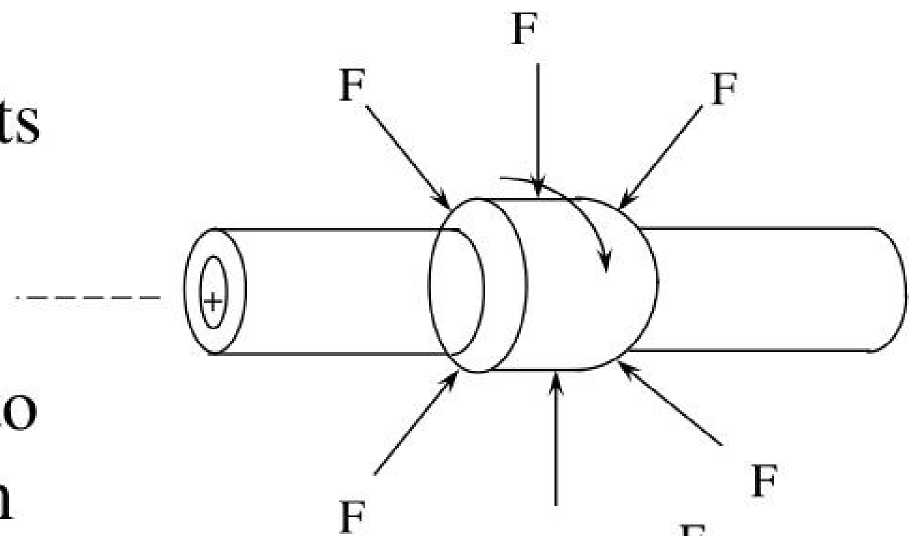
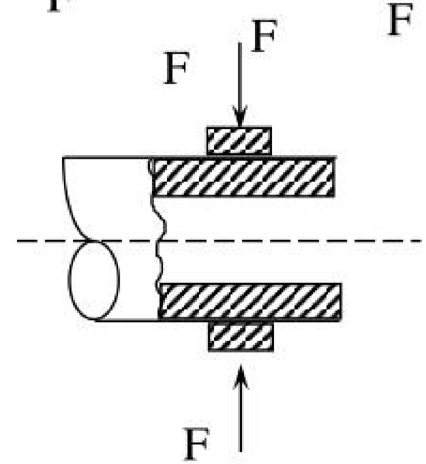
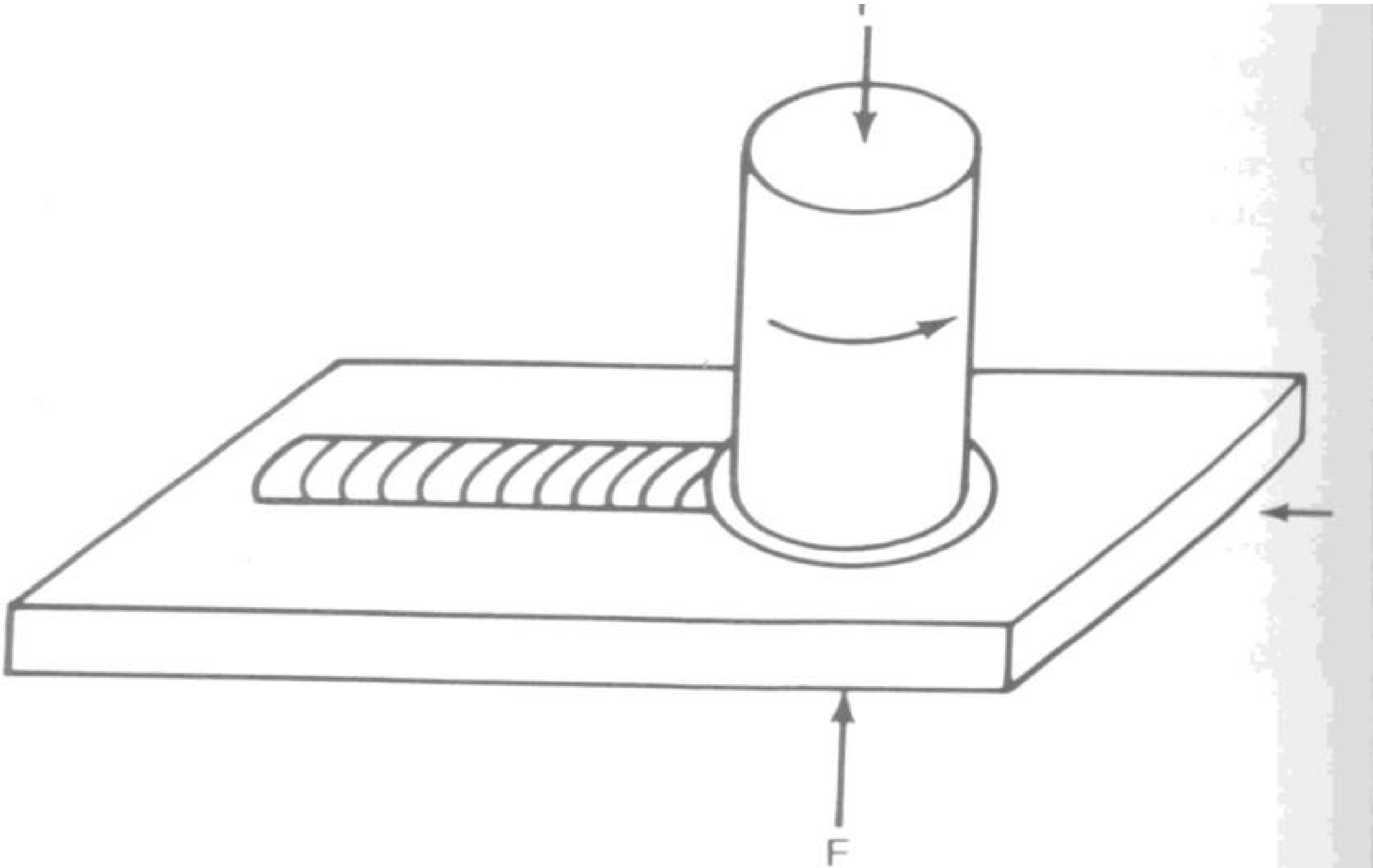
Radial Friction Welding

- Used to join collars to shafts and tubes.
- Two tubes are clamped in fixed position. The collar to be joined is placed between the tubes.
- The collar is rotated producing frictional heat.
- Radial forces are applied to compress the collar to complete welding.



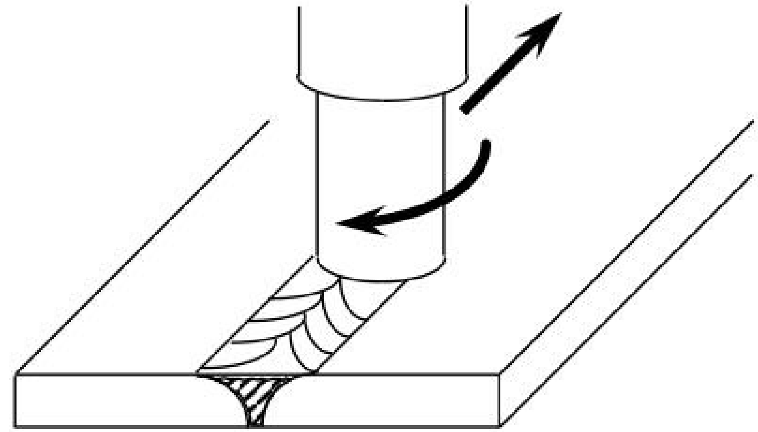




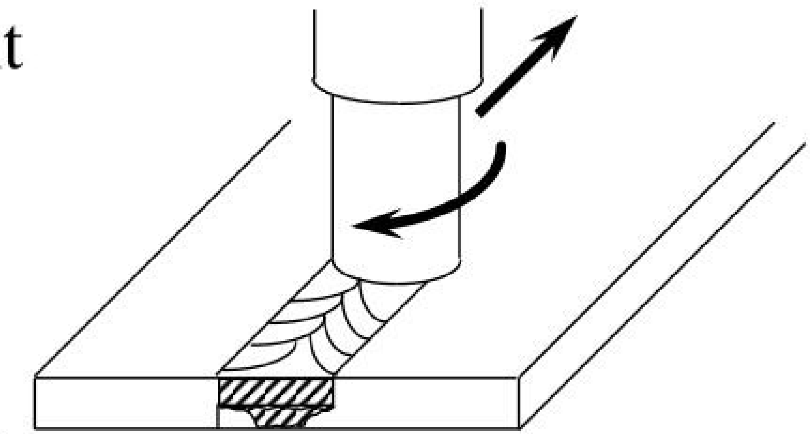
Friction Surfacing

Friction Stir Welding

- Parts to be joined are clamped firmly.
- A rotating hardened steel tool is driven into the joint and traversed along the joint line between the parts.
- The rotating tool produces friction with the parts, generating enough heat and deformation to weld the parts together.

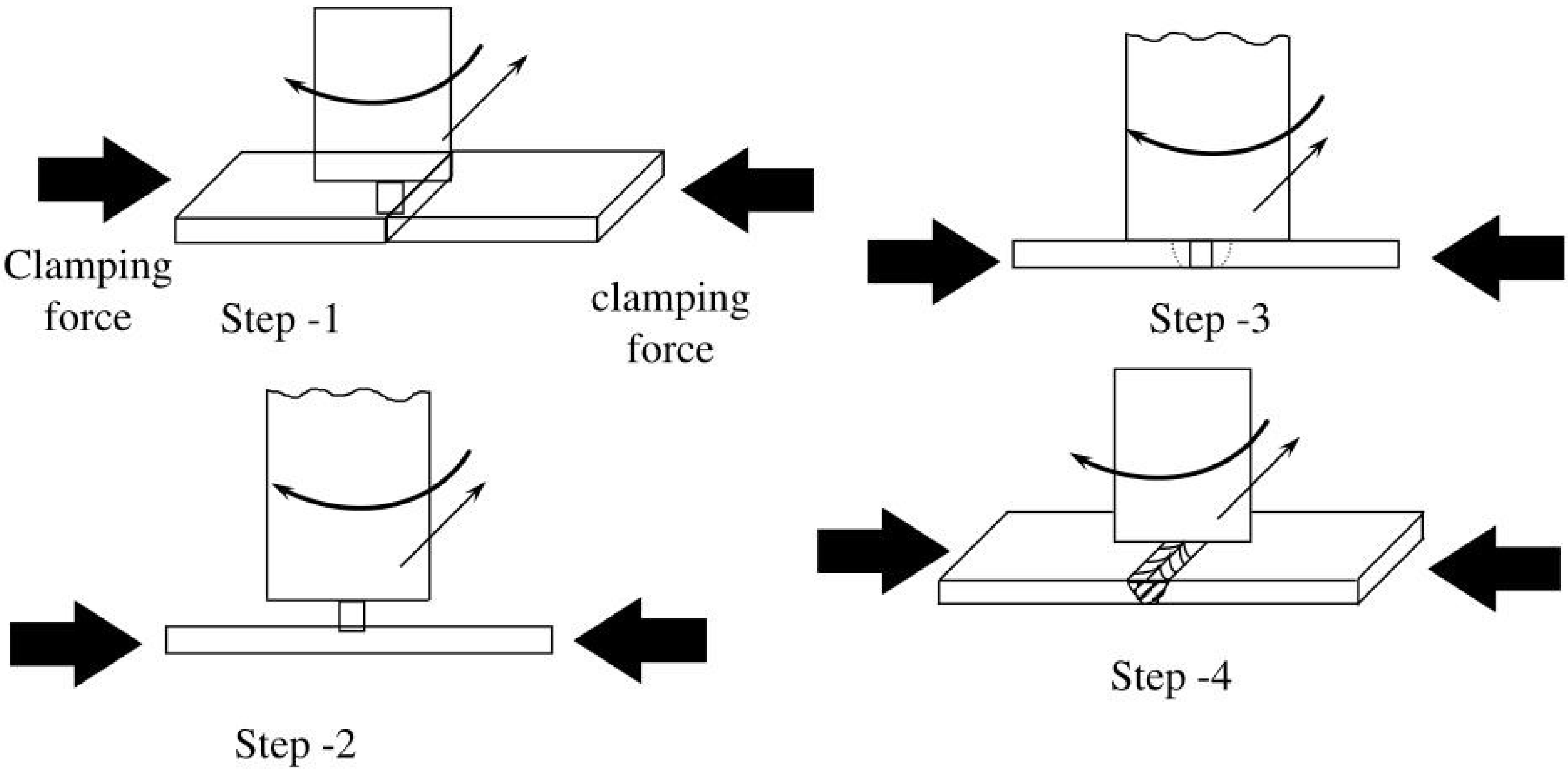


Butt welds

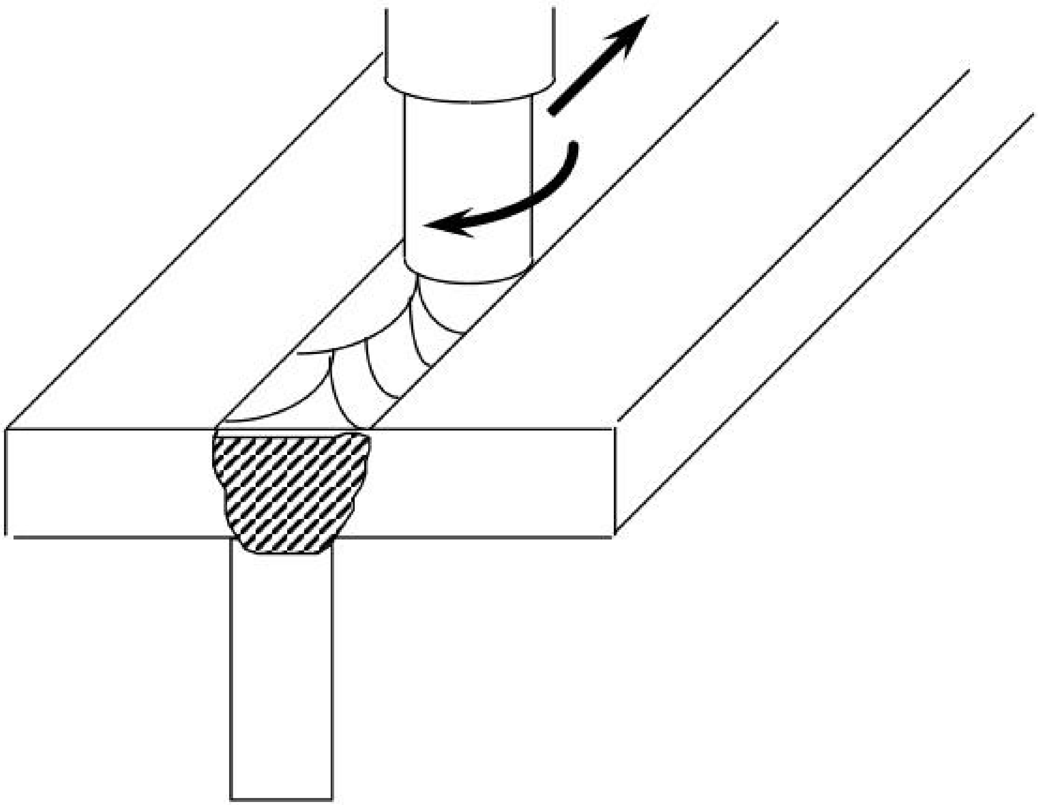


Overlap welds

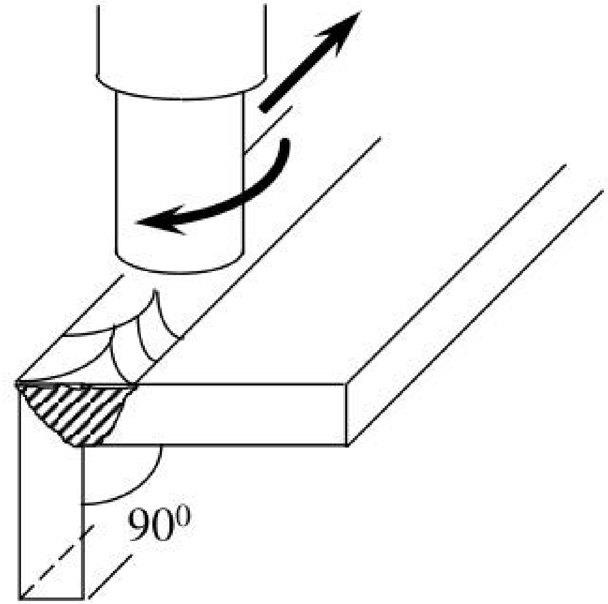
Friction Stir Welding



Friction Stir Welding

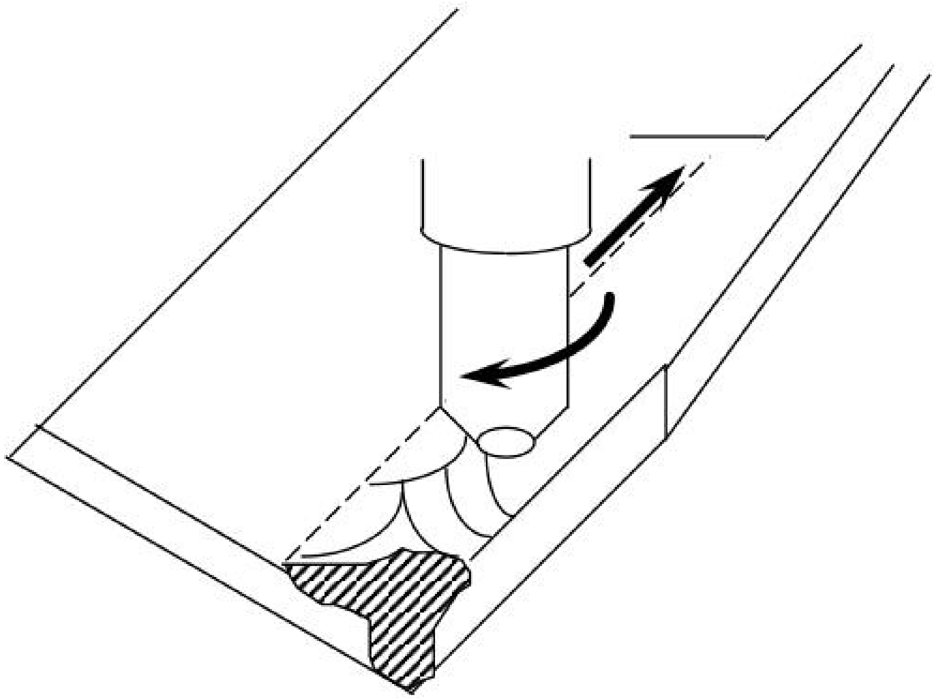


T-section (2- component top butt)



Corner welds

Friction Stir Welding



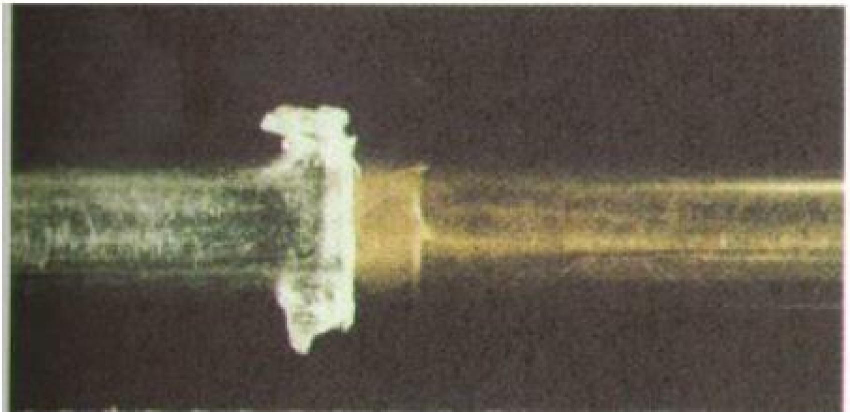
Fillet butt welds

Questions

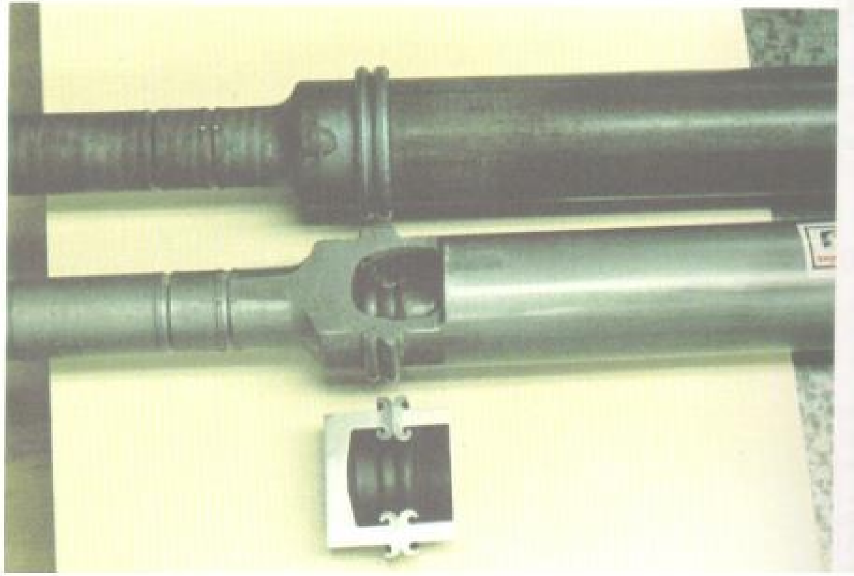
Friction Welding Applications

- Frequently competes with flash or upset welding when one of the work pieces to be joined has axial symmetry.
- Used in automotive industry to manufacture gears, engine valves, and shock absorbers.
- Used to join jet engine compressor parts.

Friction Welded Joints



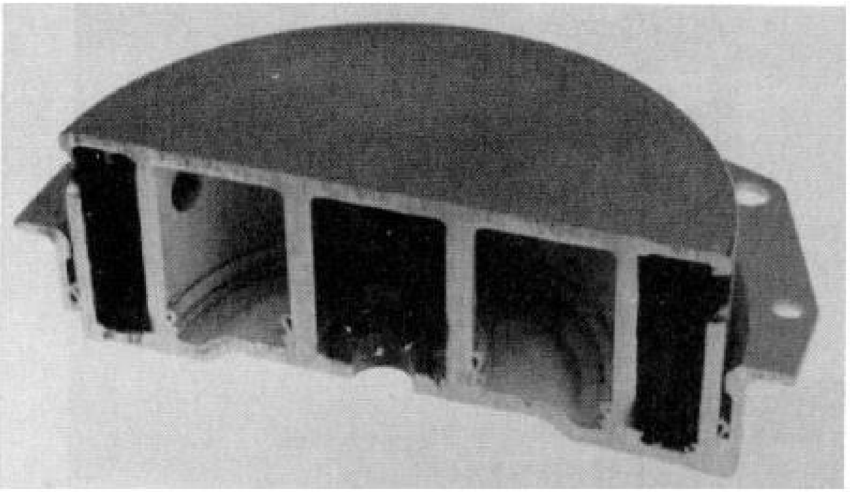
Friction Welded Joint



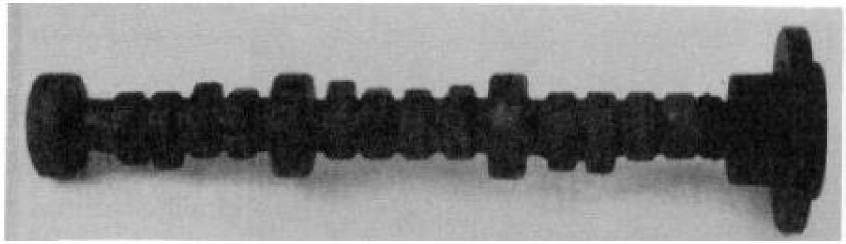
Friction Welded Automotive Halfshaft

Courtesy AWS handbook

Friction Welded Joints



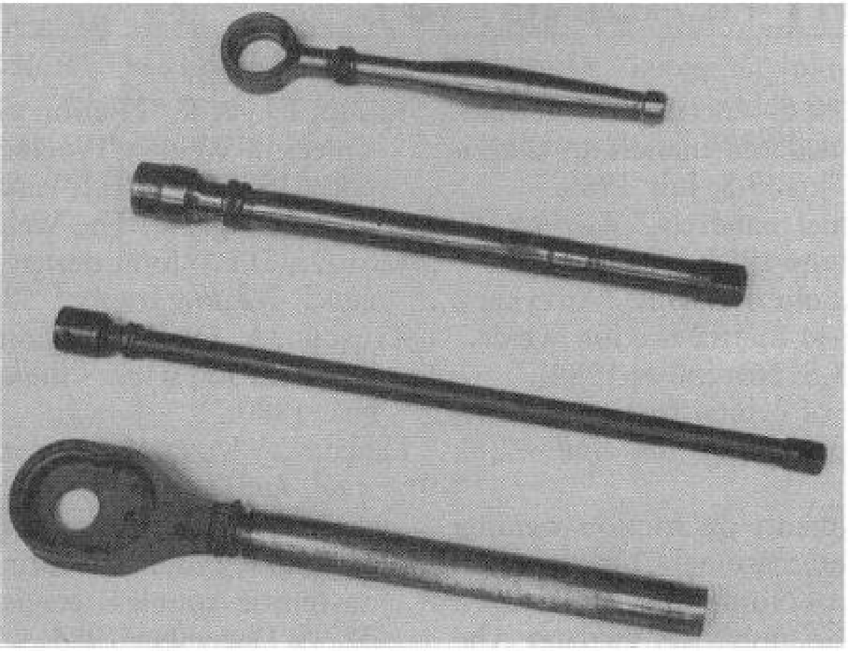
Cross Section of Aluminum Automotive Airbag Inflator. Three Welds Are Made Simultaneously



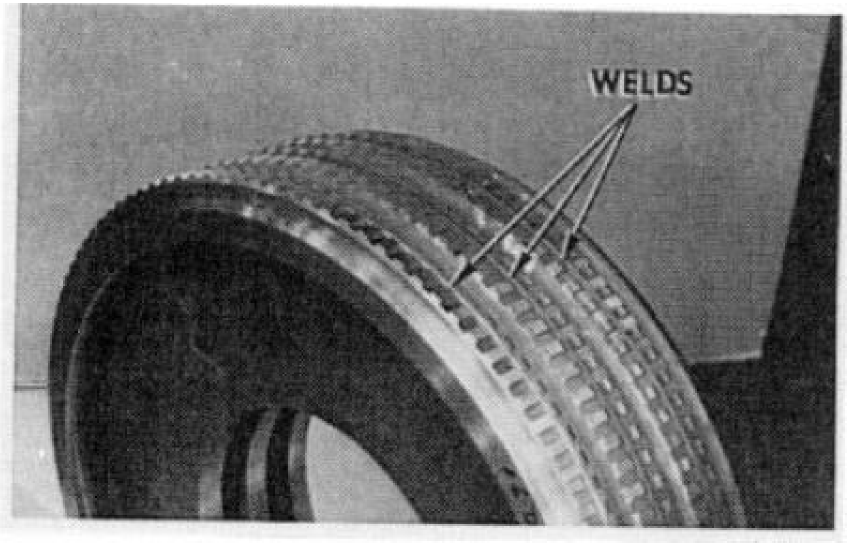
Camshaft Forging Friction Welded To Timing Gear.

Courtesy AWS handbook

Friction Welds



Inertia Welded Hand Tools

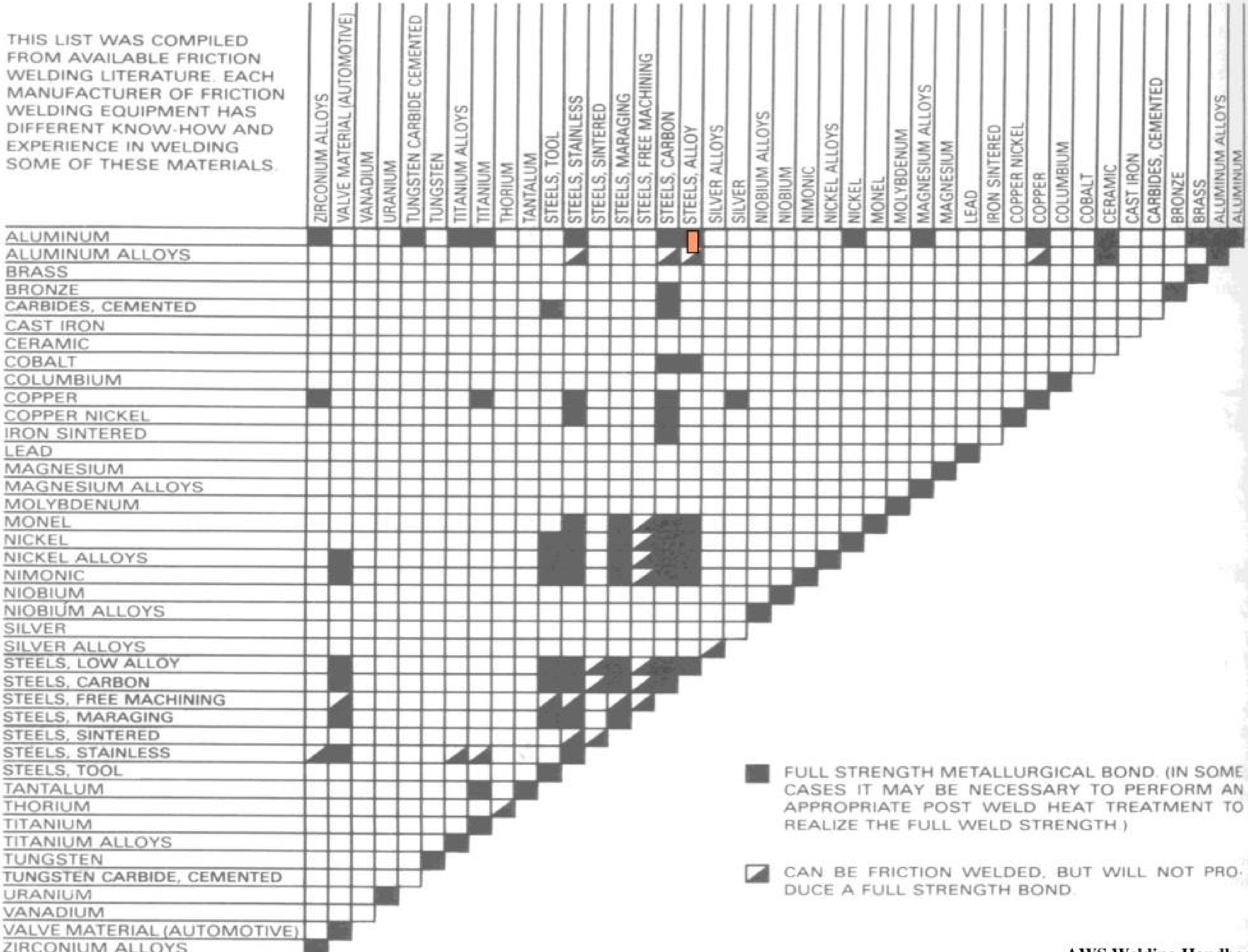


A Jet Engine Compressor Wheel
Fabricated by Friction Welding

Courtesy AWS handbook

Dissimilar Metals – Friction Welded

Aluminum to Steel Friction Weld



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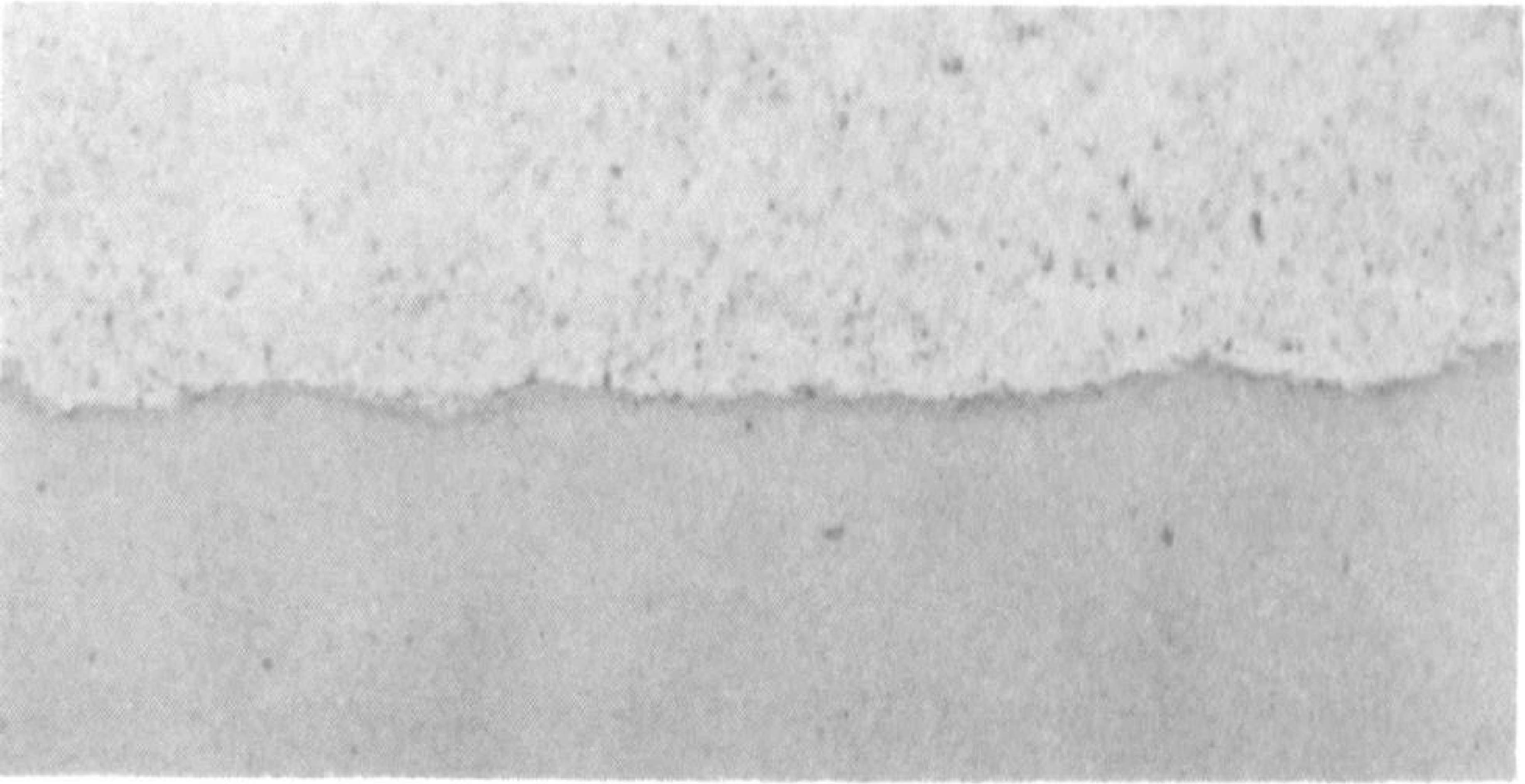
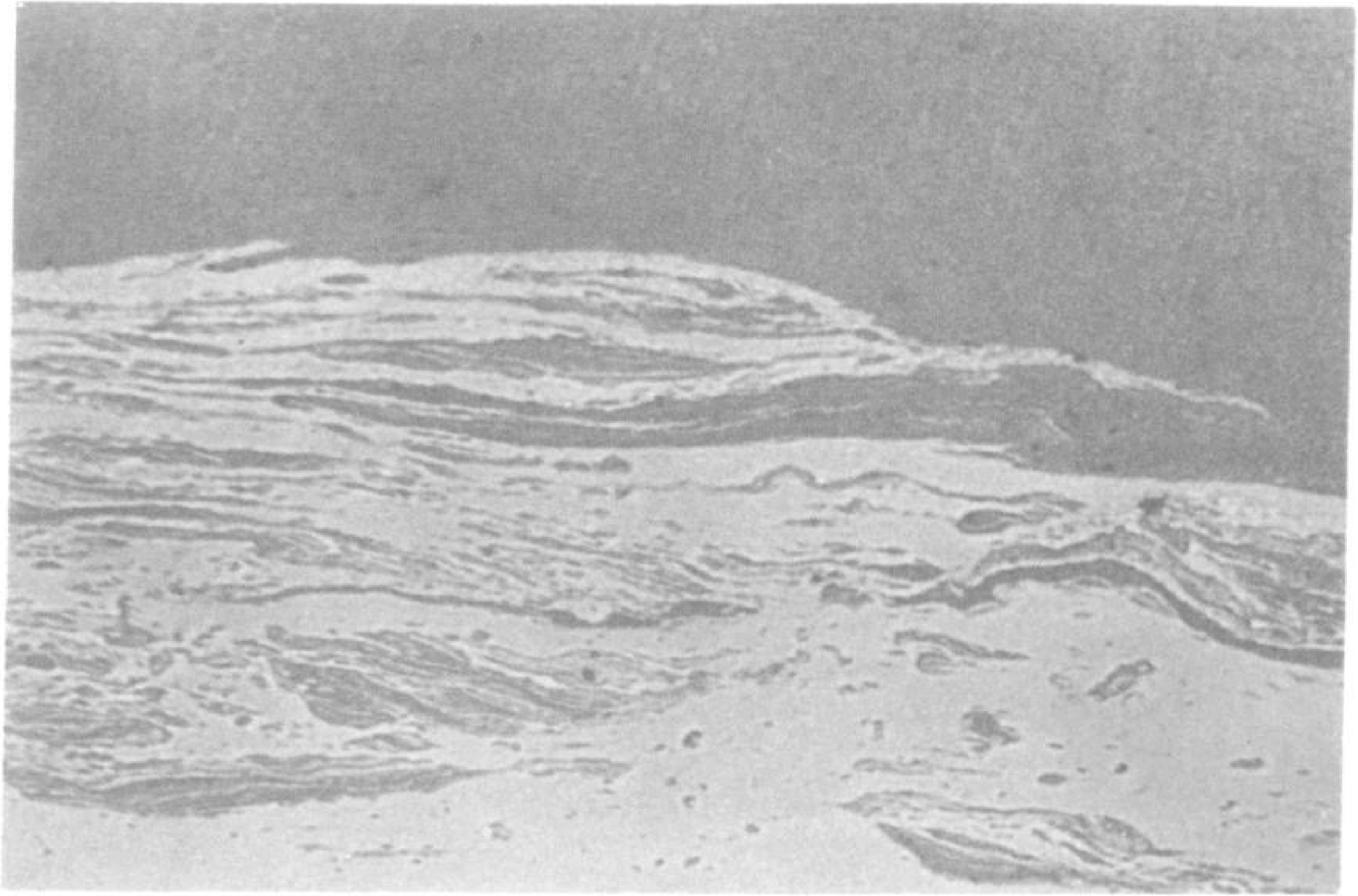


Photomicrograph of Aluminum (top) to Steel (bottom)



Friction Weld Tantalum to Stainless Steel
Note: mechanical mixing

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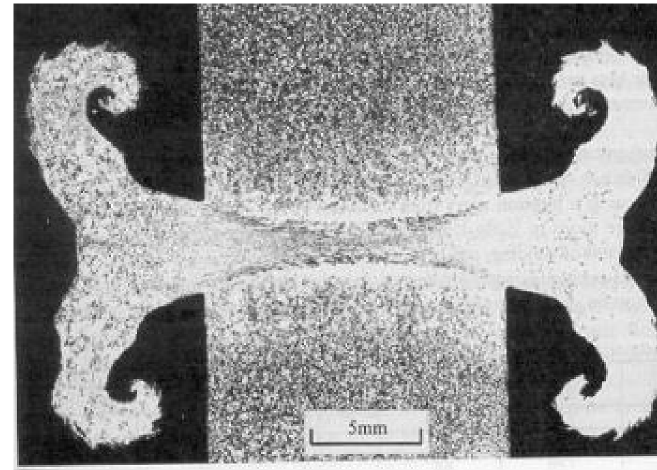
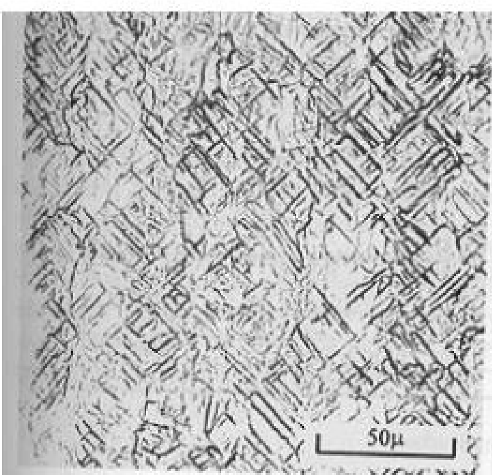
Continuous Drive Friction Weld of Titanium Pipe

Ti-6Al-4V-0.5Pd
246 mm diameter

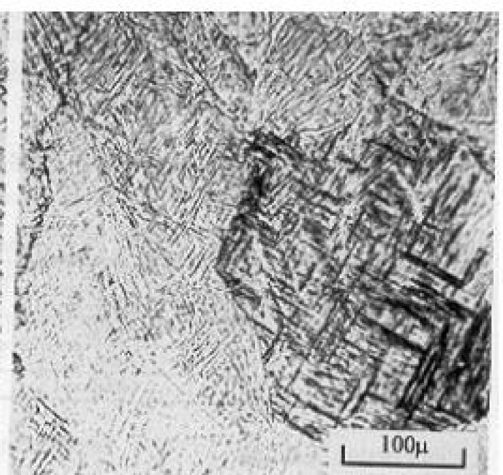
14mm wall thickness

No shielding used

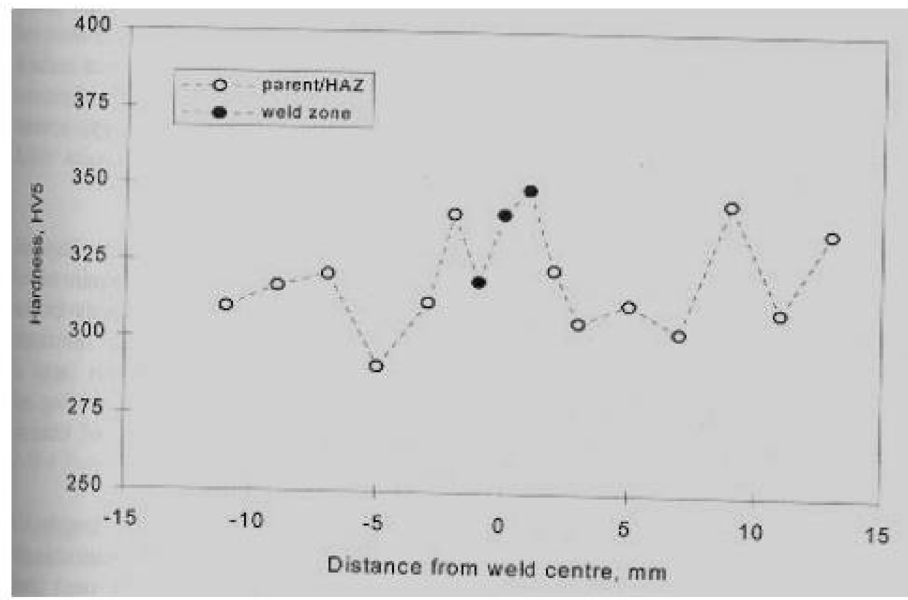




Center



HAZ



Froes, FH, et al, "Non-Aerospace Applications of Titanium" Feb 1998, TMS

Radial friction weld of Ti-6Al-4V-0.1Ru

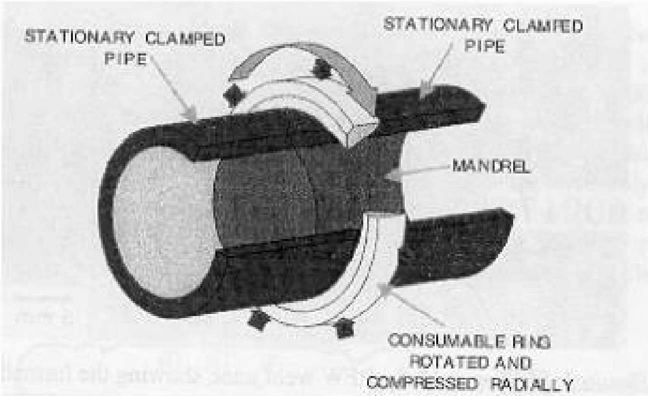
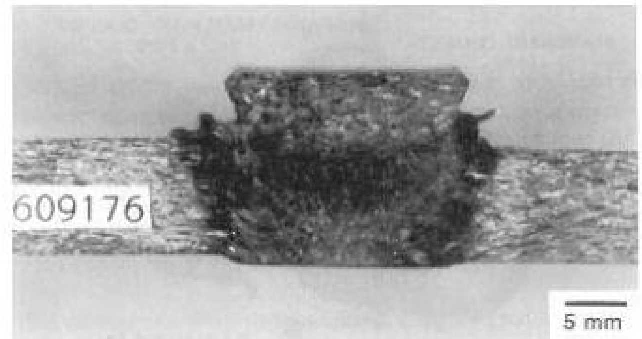
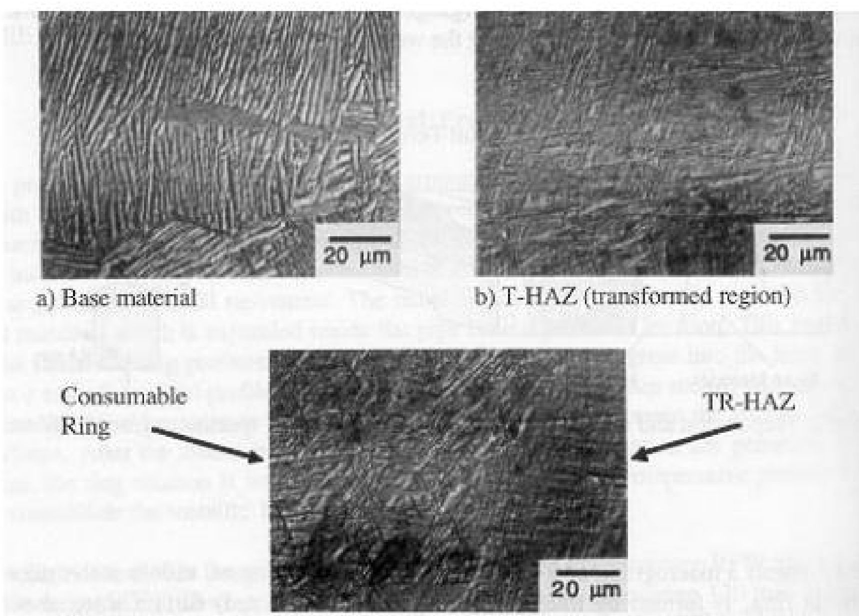


Figure 1: Principle of RFW process.

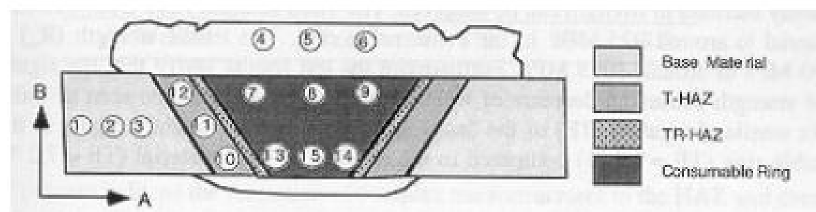


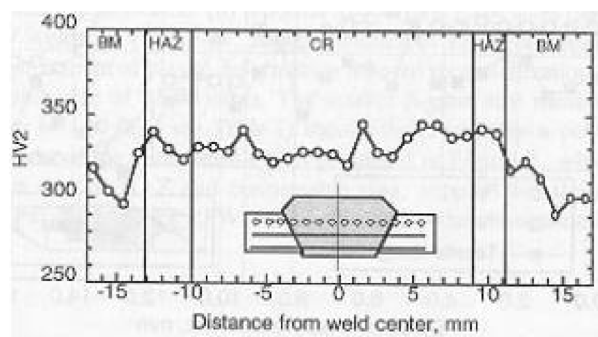


a) Base material

b) T-HAZ (transformed region)

c) TR-HAZ (transformed & recrystallized region) and CR (consumable ring).

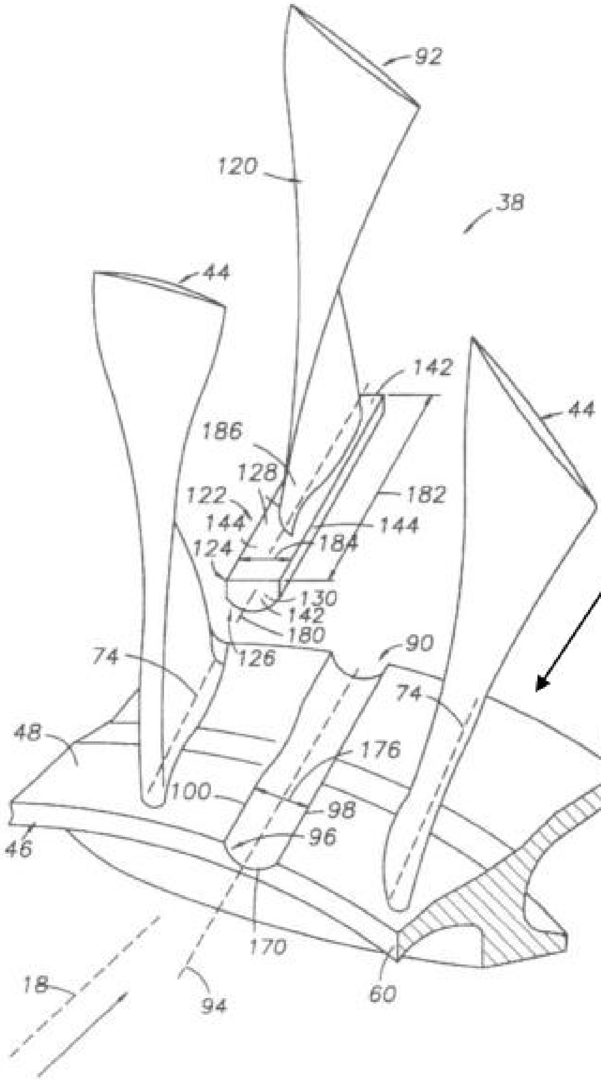


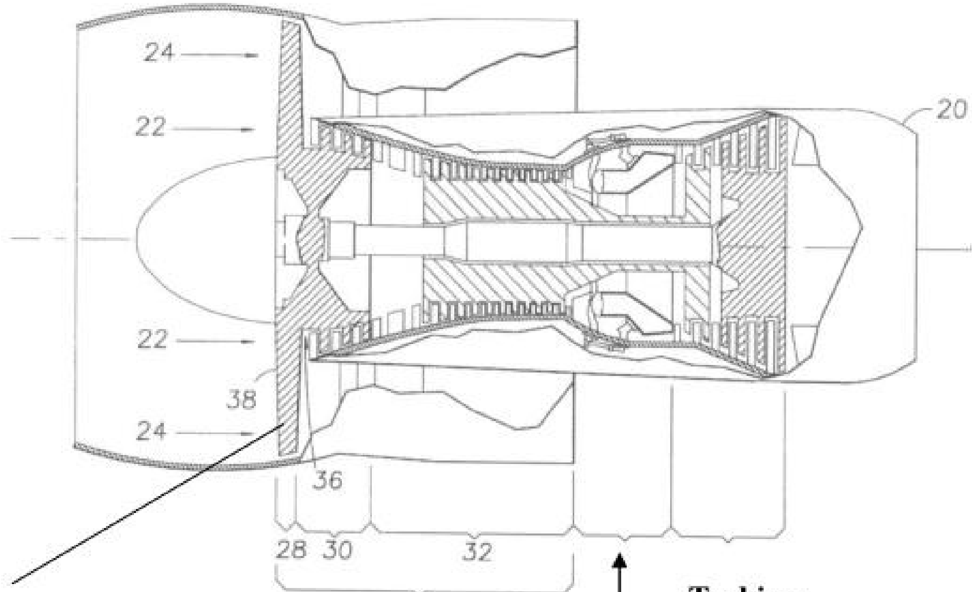


Properties in Weld Better than Base Metal

Froes, FH, et al, "Non-Aerospace Applications of Titanium" Feb 1998, TMS

Linear Friction Weld Repair of Fan Blades





Fan

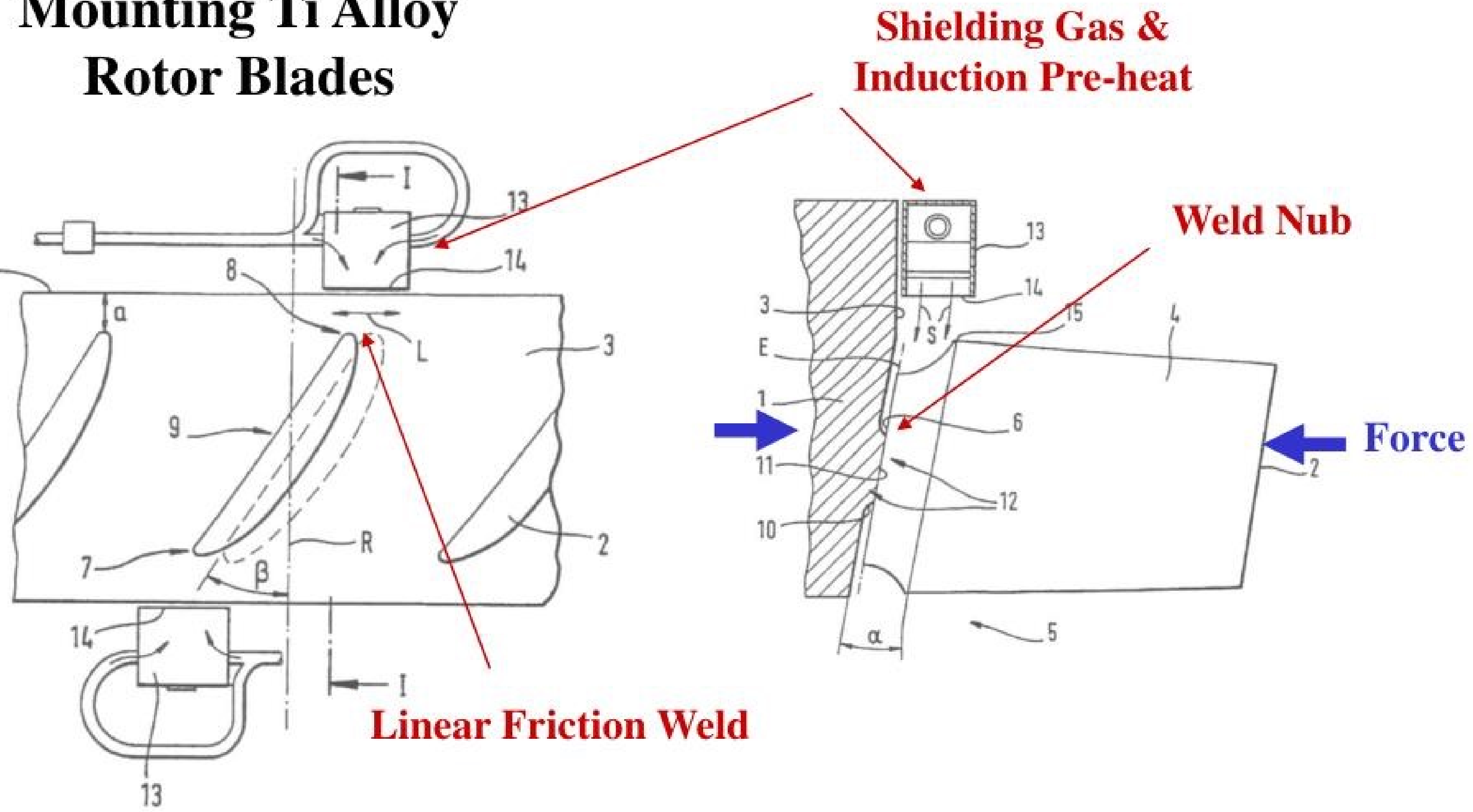
Compressor

Combustor

Turbine

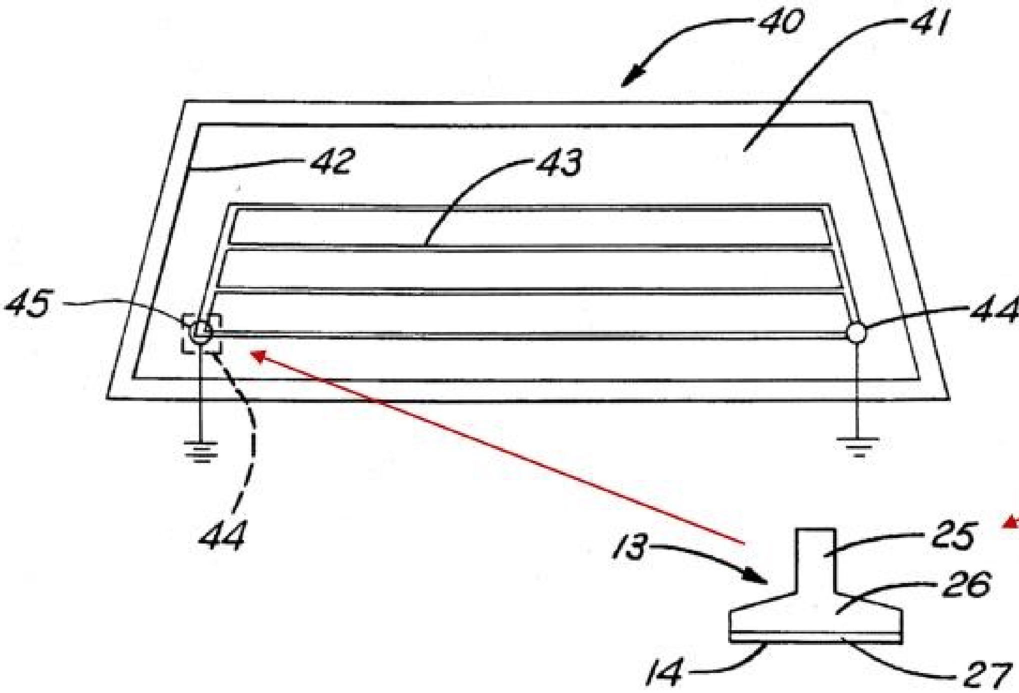
Walker, H, et al, "Method for Linear Friction Welding and Products made by such Method" US Patent 6,106,233 Aug 22, 2000

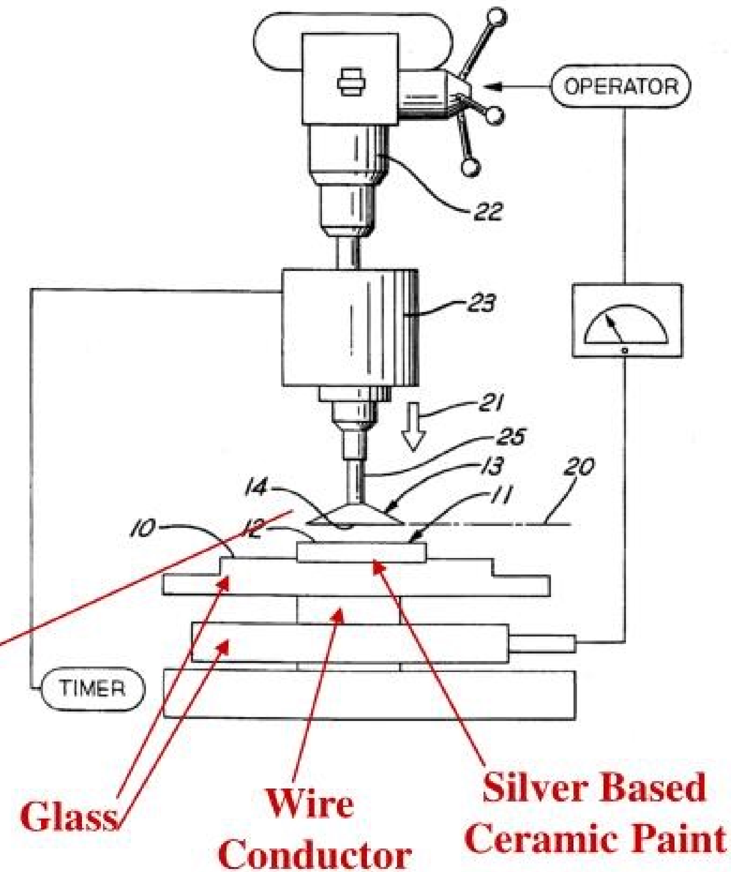
Friction Welding for Mounting Ti Alloy Rotor Blades



Schneefeld, D,et al. “Friction Welding Process for Mounting Blades of a Rotor for a Flow Machine”, US Patent 6,160,237 Dec 12, 2000

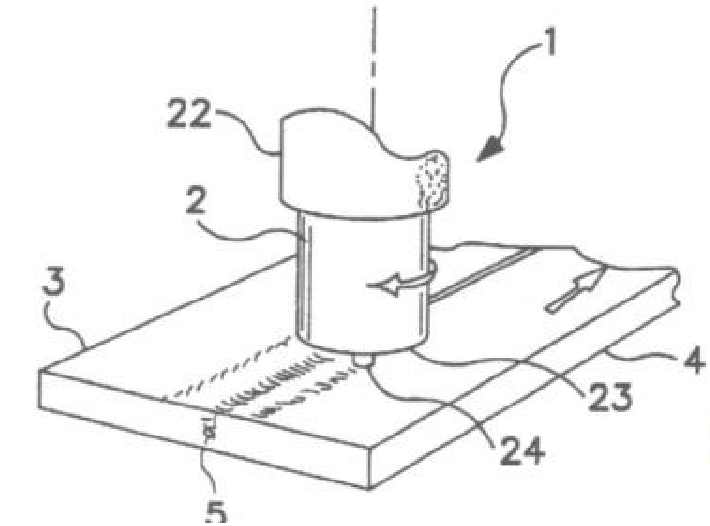
Friction Welding Connector to Imbedded Window Wires

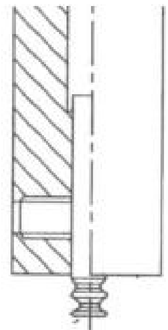




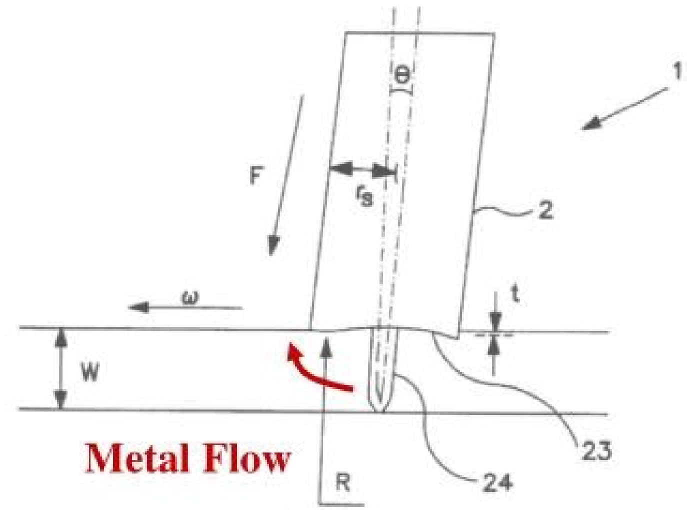
White, D et al, "Friction Welding Non-Metallics to Metallics", US Patent 5,897,964 Apr. 27, 1999

Friction Stir Welding – Tool Design Modification

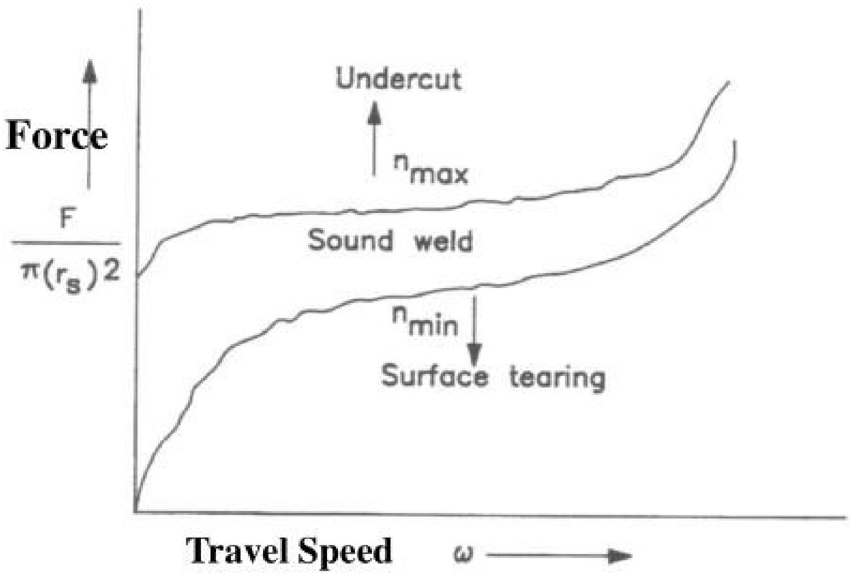


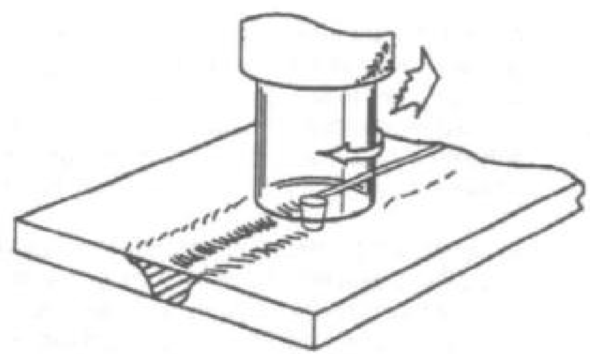


Hard Tool Tip Buried in Work Piece



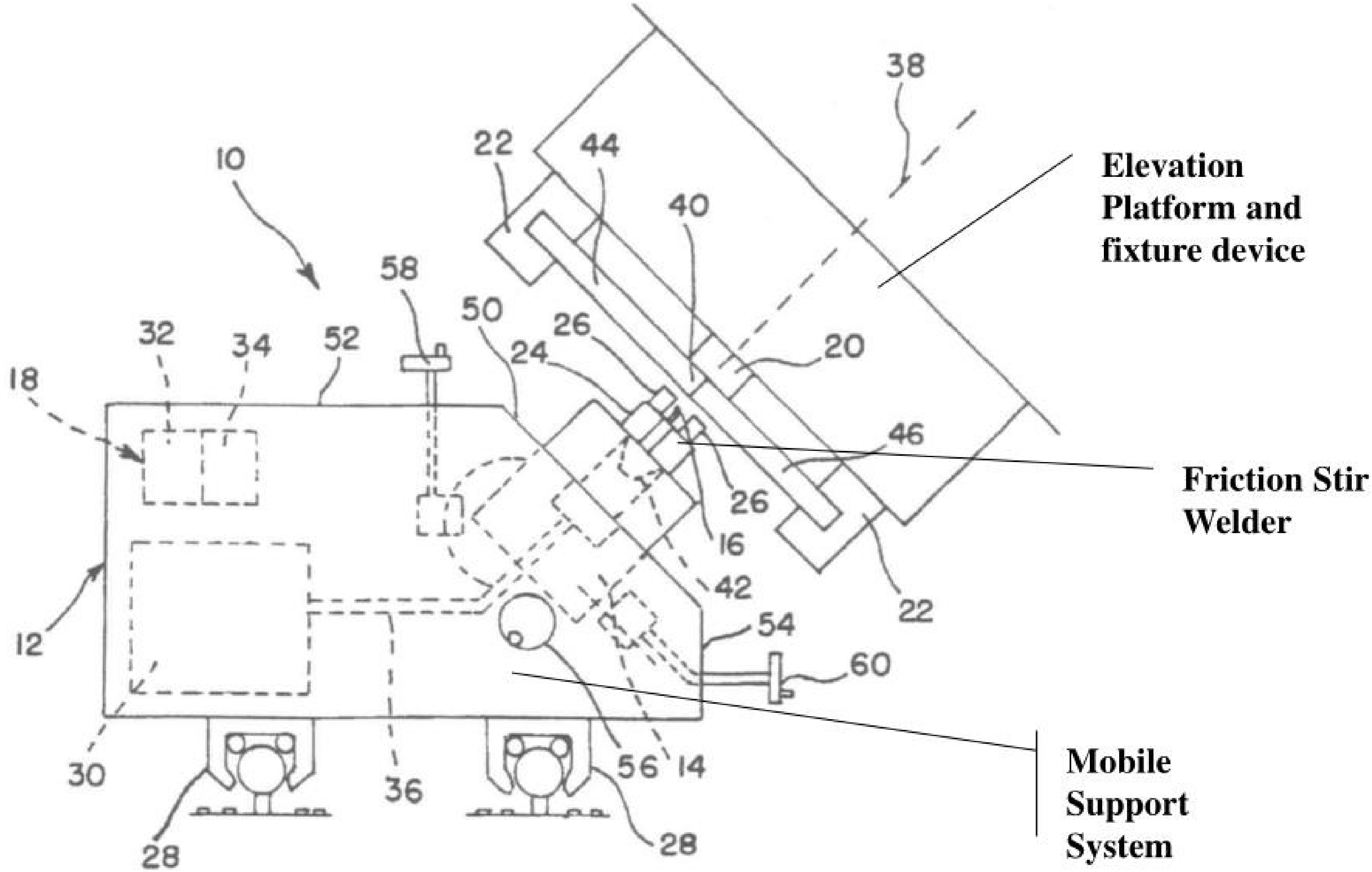
Metal Flow





Midling, O, et al, "Friction Stir Welding" US Patent 5,813,592 Sep. 29, 1998

Friction Stir Welding – Automation Moving Device



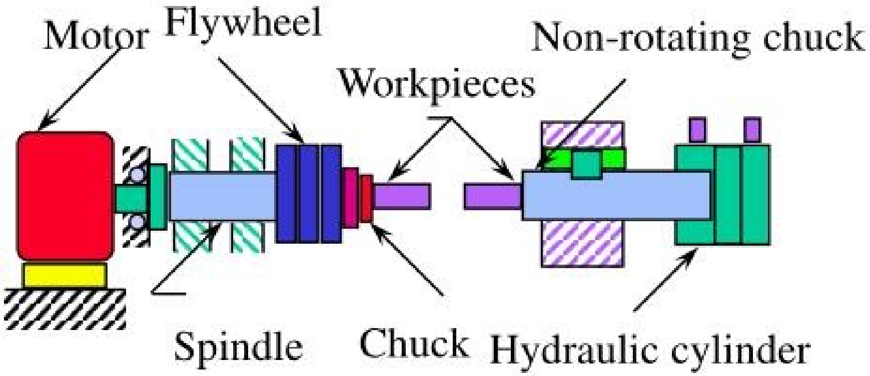
Ding, R. et al, "Friction Stir Weld System for Welding and Weld Repair", US Patent 6,173,880 Jan 16, 2001

Questions

Inertia Welding

Inertia Welding Process Description

- **One of the work pieces is connected to a flywheel; the other is clamped in a non-rotating axial drive**
- **The flywheel is accelerated to the welding angular velocity.**
- **The drive is disengaged and the work pieces are brought together.**
- **Frictional heat is produced at the interface. An axial force is applied to complete welding.**



Inertia Welding

$$E = \frac{IS^2}{C}$$

$$E_u = \frac{E}{A}$$

Where

E = Energy, ft-lb (J)

I = Moment of Inertia, lb-ft^2 (kg-m^2)

S = Speed, rpm

C = 5873 when the moment of inertia is in lb-ft^2

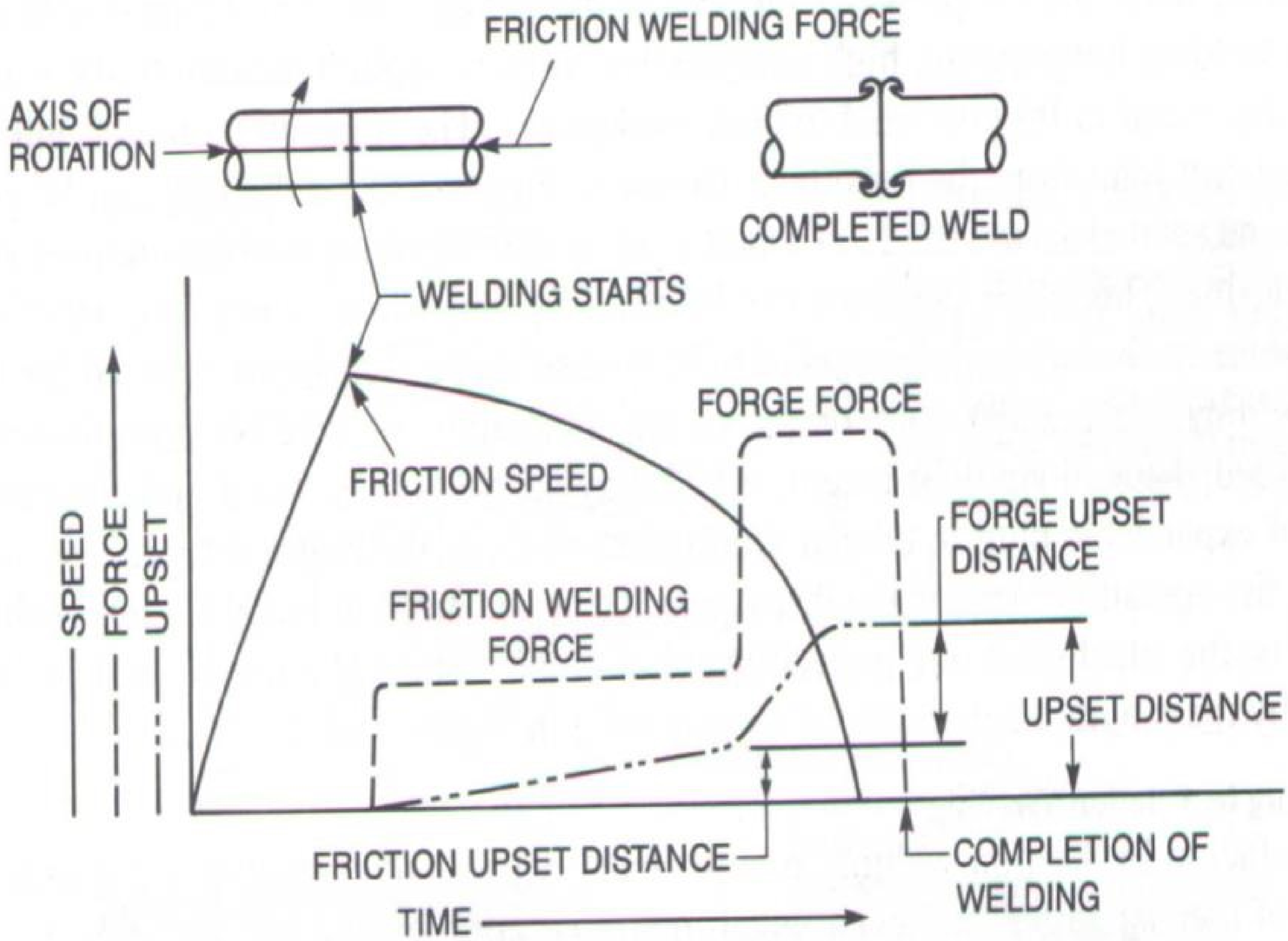
C = 182.4 when the moment of inertia is in kg-m^2

E_u = Unit Energy, ft-lb/in^2 (J/mm^2)

A = Faying Surface Area

Inertia Welding Variables

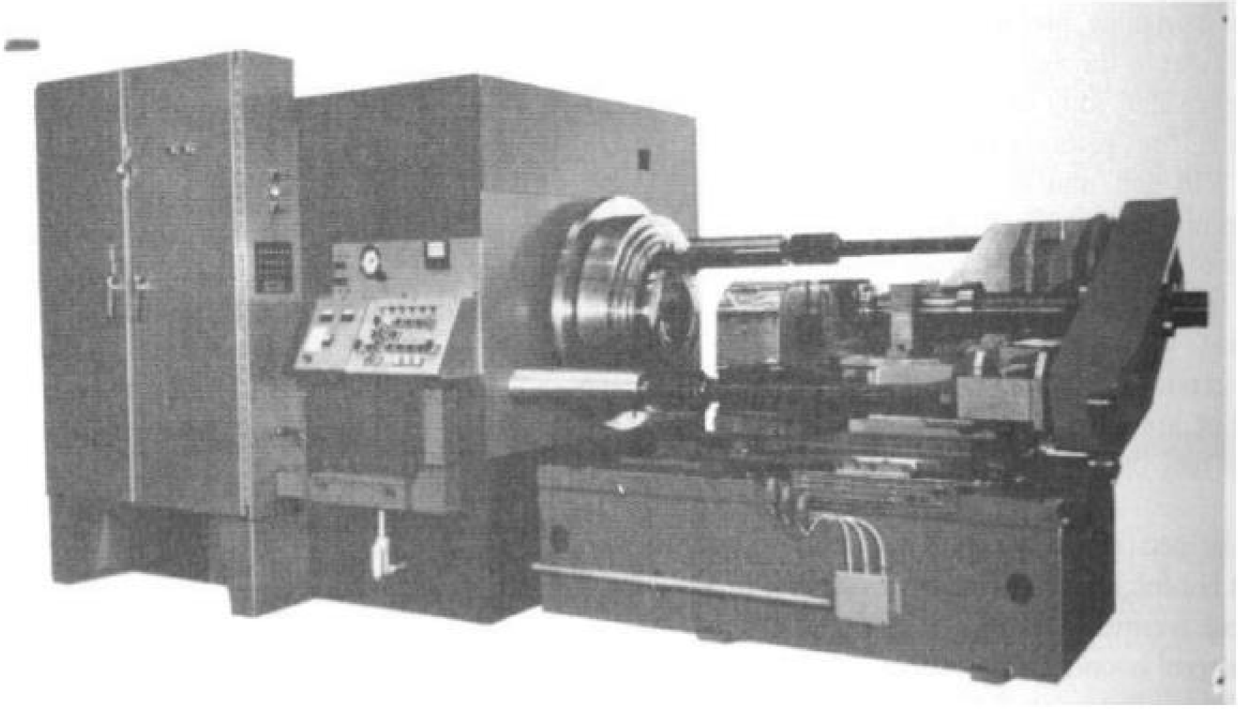
- Moment of inertia of the flywheel.
- Initial flywheel speed.
- Axial pressure.
- Forging pressure.



(A) GENERALIZED DIAGRAM OF INERTIA FRICTION WELDING.

Linnert, Welding Metallurgy, AWS, 1994

Inertia Welding Machine



Courtesy AWS handbook

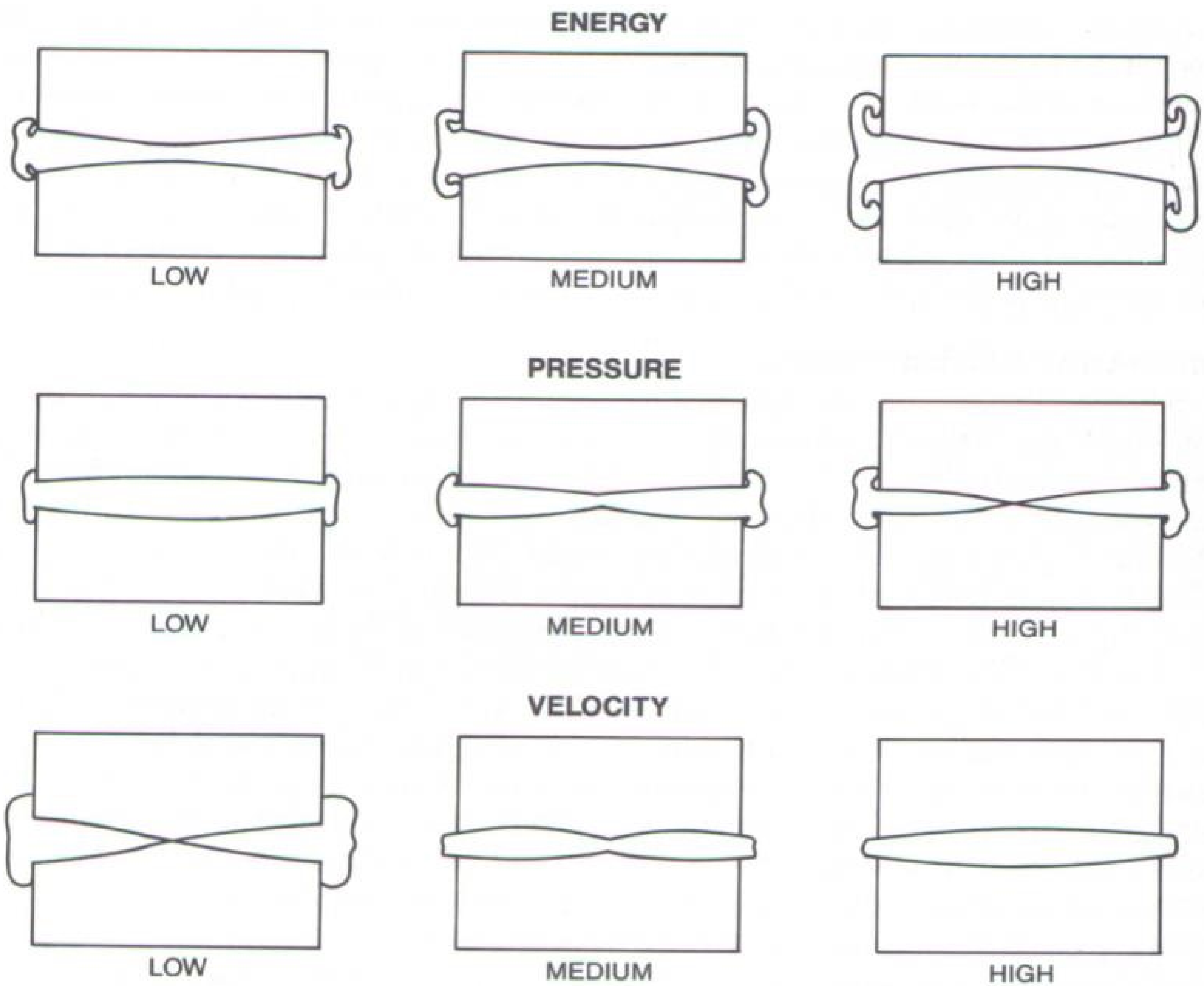


Figure 6.59 — Inertia friction welding patterns of heat and upset or flash at the weld produced by variations in energy, pressure and velocity

Linnert, Welding Metallurgy, AWS, 1994

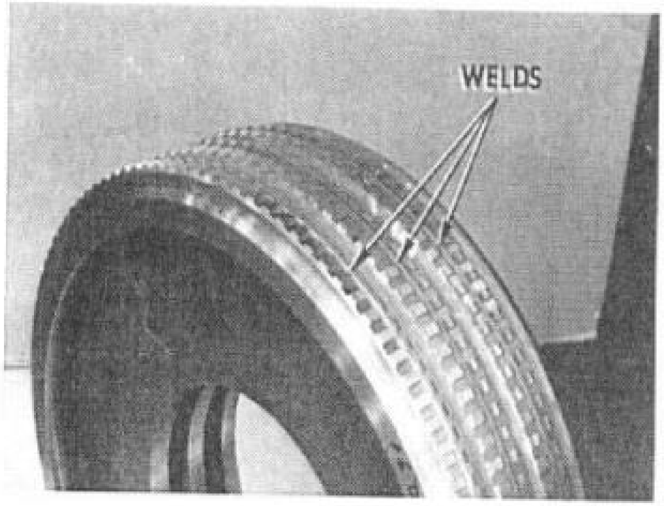
Questions

Homework

A Few Specific Examples

Super-speed (750 SFM) Inertia Welding of Jet Turbine Components

Part	Ave. Diameter Range (in.)	
Stator components	10-80	
Combustor Casing	42	Waspaloy
Low pressure turbine casing	72	Waspaloy
Other Parts	various	Inconel Waspaloy Hastelloy Rene



Problems

- Melting Destroys Properties
- Low (200F) Forging Temp Range – Need Precise Control

Ablett, AM et al, "Superspeed Inertia Welding", US Patenmt 6,138,896, Oct. 31, 2000

Super-speed (750 SFM) Inertia Welding of Jet Turbine Components

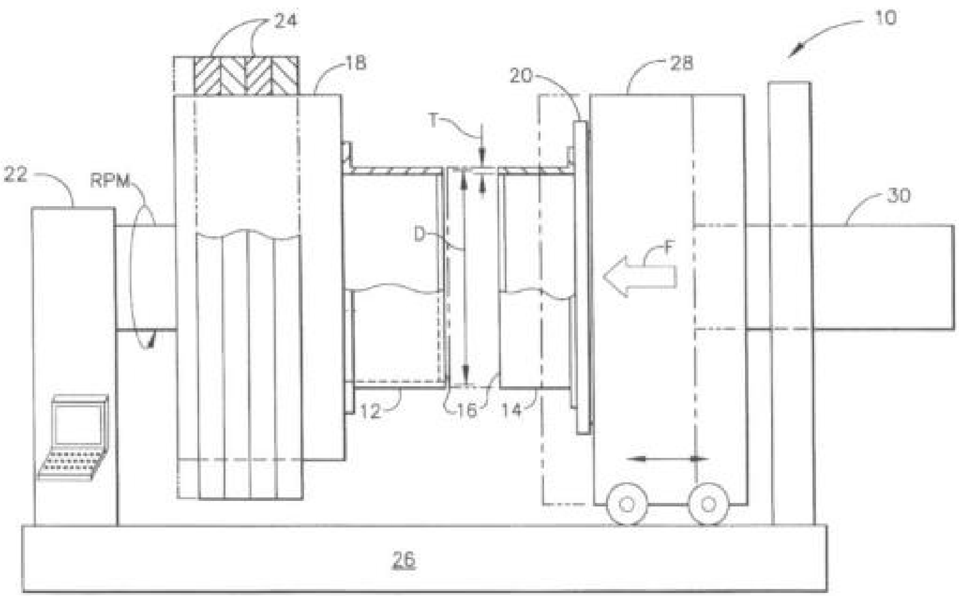
Control Parameters

- Workpiece Geometry (size)
- Applied Weld Load Contact Stress)
- Initial Contact Speed (surface velocity
- Unit Energy Input (moment of inertia, radius of gyration)

$$E = WK^2(RPM)^2 / 5873\,A$$

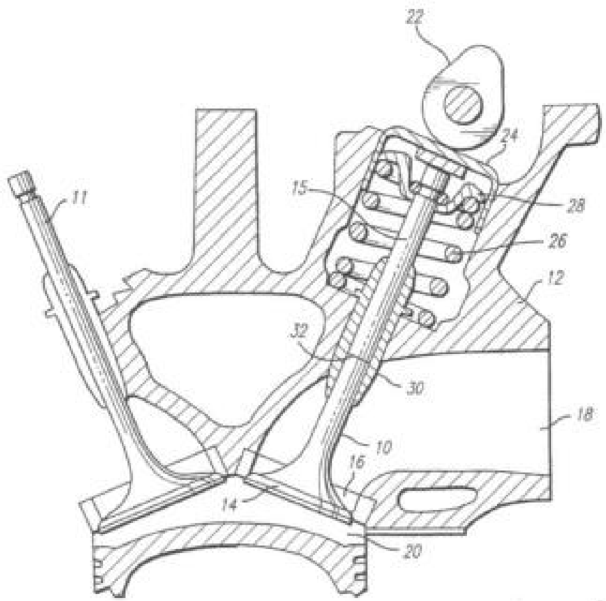
$$(RPM) = 12(SFM)/\pi D$$

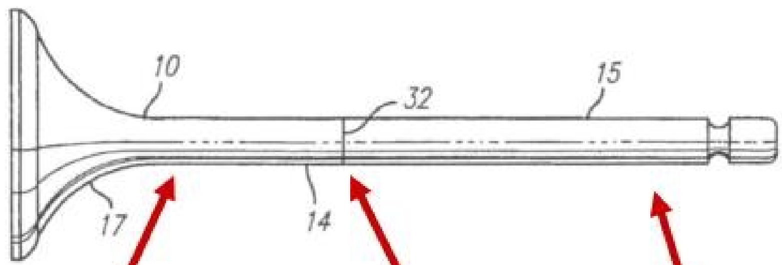
Where
E = unit energy input
W = flywhel weight
K = radius of gyration
RPM = initial rotation
SFM = contact speed
D = diameter
A = contact area



Ablett, AM et al, "Superspeed Inertia Welding", US Patenmt 6,138,896, Oct. 31, 2000

Titanium Engine Valve





Inertia Weld

Titanium Aluminides
or
Titanium Borides
(Brittle at RT)

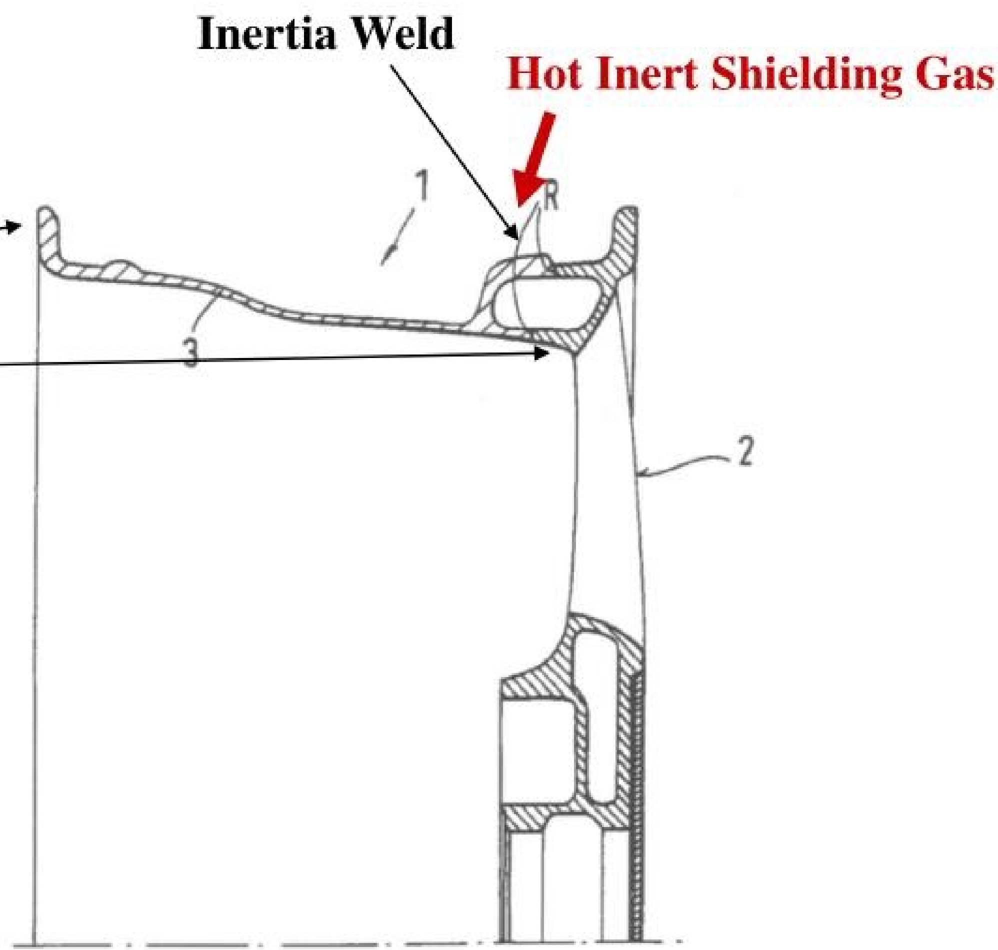
Titanium Alloy
(Ductile)

Jette, P , Sommer, A., "Titanium Engine Valve", US Patent 5,517,956 May 21, 1996

Inertia Welding of Magnesium and Aluminum Wheels for Motor Vehicles

<u>Wheel</u>	<u>Spider</u>
Aluminum	Magnesium
Mg AM60	Mg AE42
Mg AM60	Mg AZ91
Mg AE42	Mg AZ91

Welding parameters determined by the lower-deforming alloy or the alloy with higher melting point



Separautzki, R,et al, “Process for Manufacturing a Wheel for a Motor Vehicle”
US Patent 6,152,351 Nov 28, 2000

Similarities between Continuous Drive and Inertia Drive

- In both methods, welding heat is developed by frictional heat and plastic deformation.
- Both methods use axial force for upsetting purpose.
- In both methods the axial pressure may be changed (usually raised) at the end of rotation.

Differences between Continuous Drive and Inertia Drive

Continuous drive	Inertia drive
• One of the workpieces directly connected to a rotating motor drive.	• One of the workpieces is connected to the flywheel.
• Rotational speed remains constant until the brake is applied.	• Rotational speed decreases continuously to zero during the process.
• Rotational energy of the workpiece dissipates through friction and plastic deformation, producing welding heat.	• Kinetic energy of the flywheel dissipates through friction and plastic deformation producing heat.