ELECTROMAGNETIC JOINING

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Industry Meet
At
NAL Bengaluru

18 Oct 2019

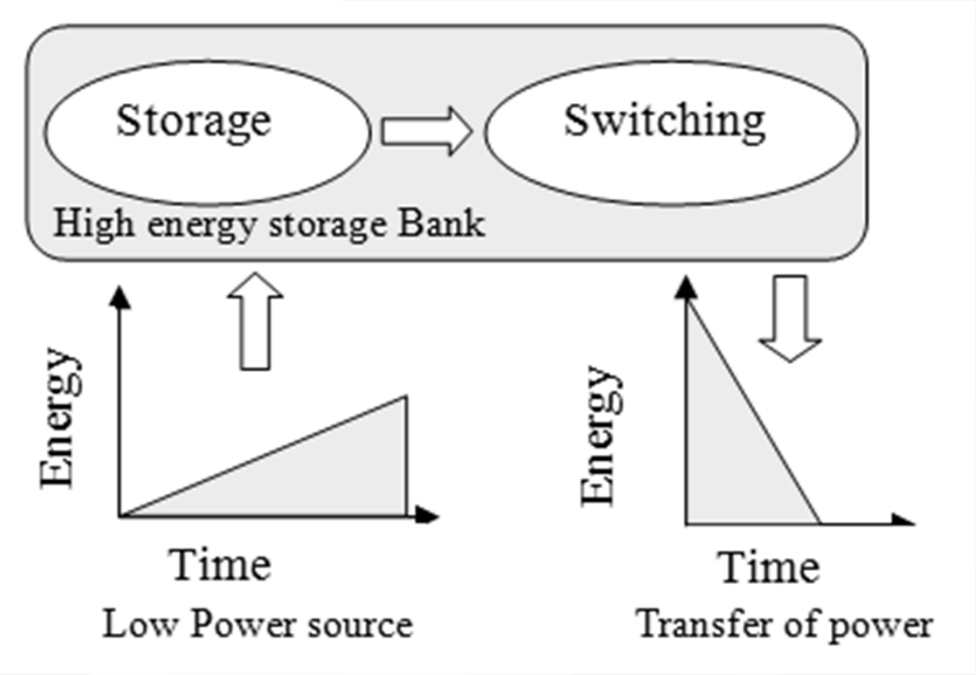
CSIR-Advanced Materials and Processes Research Institute (AMPRI) Bhopal

Overview

- Introduction
- Process/Physics
- Application
- EMF/EMJ@AMPRI
- Futuristic product development @ AMPRI

Introduction: Pulsed Power

Pulsed power: Concentration of energy in very small space and time and its sudden release

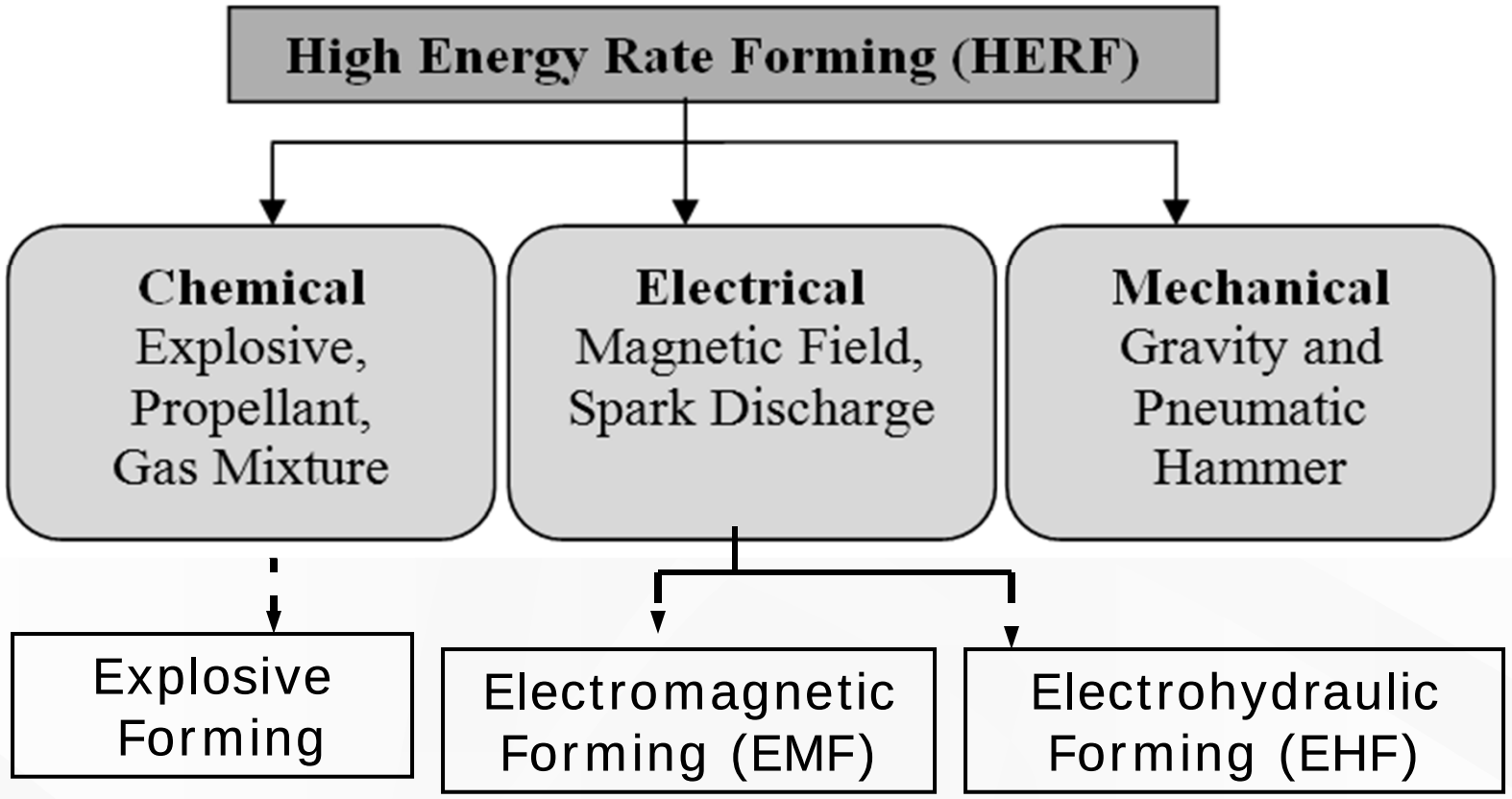


Best analogy: Reverse process of a droplet of water falling on still liquid

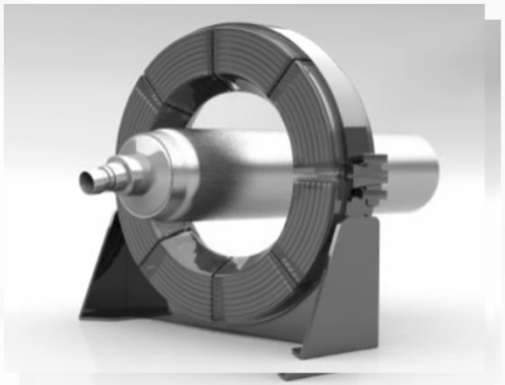
Pic from; http://wordsofjoy75.blogspot.in/2013/06/breaking-silence.html, Nov 2015

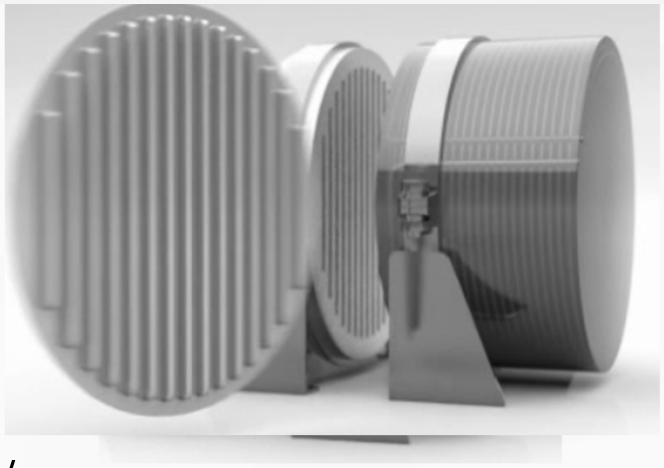
High Velocity Forming

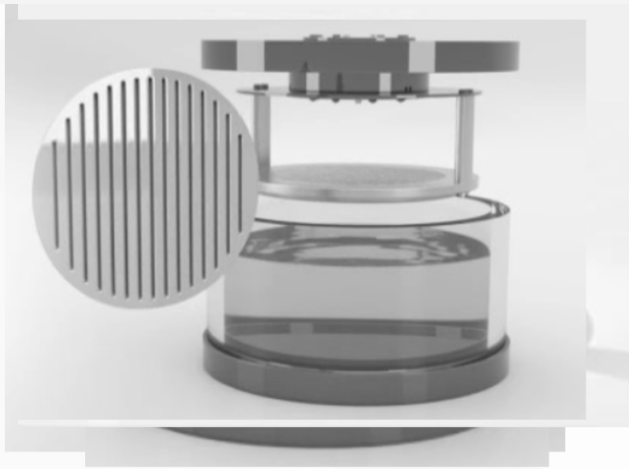
High Velocity Forming/HERF: Forming process at high strain rate of 10^2/s (Velocity > 10 m/s) and above



Process







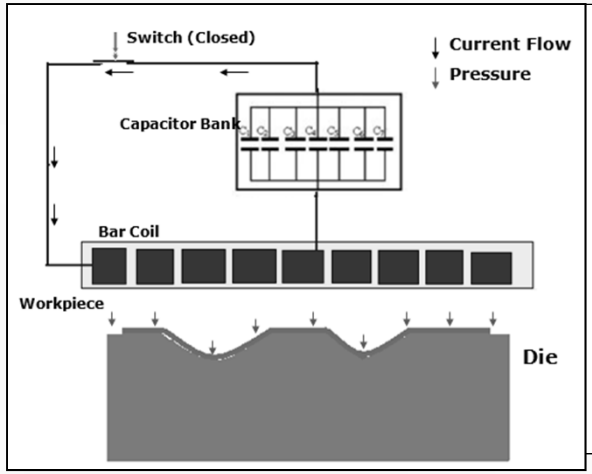
Pictures from BMAX (www.bmax.com)

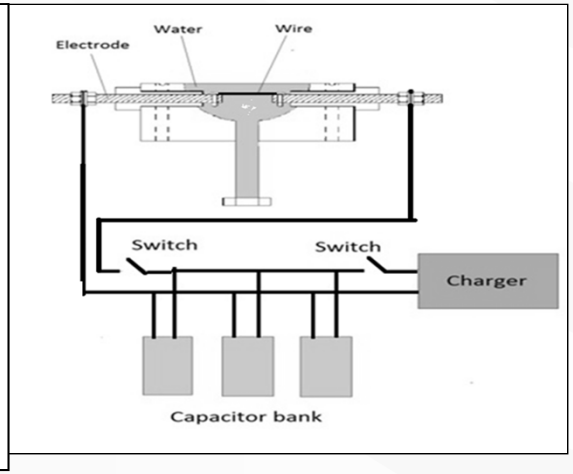
Electromagnetic Joining/ Crimping

Electromagnetic Forming

Electrohydraulic Forming

❖**Capacitor is discharged causing a time varying current to flow through a coil (EMF)/vaporizing wire (EHF).**





❖**Current in the coil produces a transient magnetic field that induces eddy currents in the workpiece (EMF). Eddy currents generate an opposing magnetic field- causes the coil to repel the workpiece into the die.**

❖ **Current passed through an electrode pair placed in die cavity (filled with fluid) with or without bridgewire. Shockwave generated and same is applied to the workpiece (EHF)**

ADVANTAGES OF HERF PROCESSES

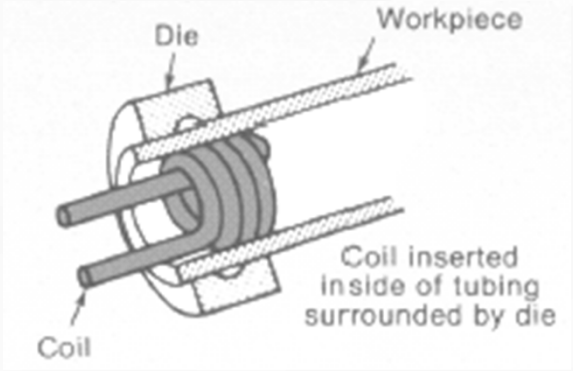
- High Productivity, Simple tooling (one-sided die and no punch), same tools can be used for various thickness and materials
- Non contact method, high surface finish and less tool wear
- No lubrication, post cleaning rarely necessary
- Automation friendly and reduces springback and prevents wrinkles, Uniform strain distribution
- Pressure transmitted through a fluid medium- advantages of hydroforming are partially incorporated (EHF)

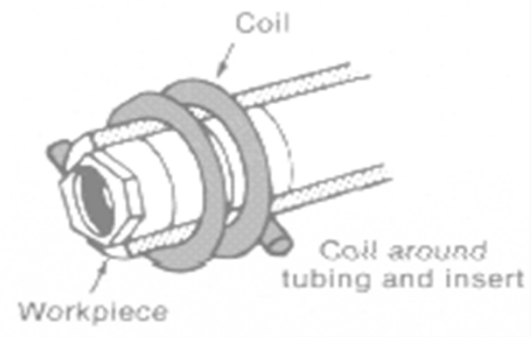
Challenges in using HERF Process

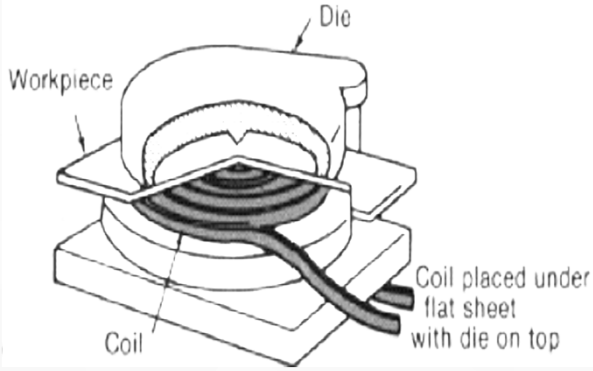
- HERF processes are not suitable for large components and thick sheets
- Working with High Voltage – safety concern
- Higher capital investment for the equipment, Limited equipment suppliers
- Deformation behaviour and formability at very high strain rates is not well understood in case of all the materials. Modelling of the processes is difficult.

Application of EMF/EMJ in Industries

- Research institute
- Nuclear
- Home Appliances
- Power

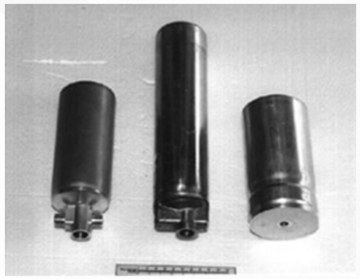




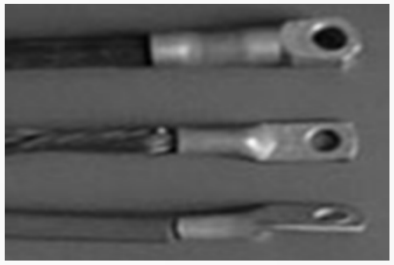


- Medical (wheelchairs, walkers, canes etc.)
- Aerospace (flight contro rods and torque tubes)
- Air conditioning (valve components)
- Automobile (dissimilar metal- torque tubes and shock absorbers etc.)

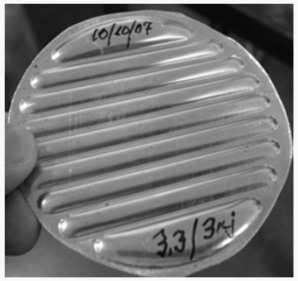
Welding



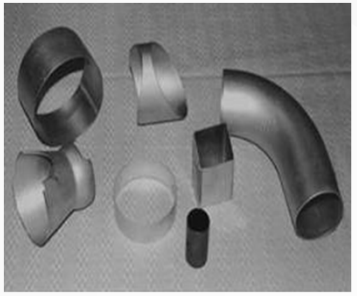
Crimping



Forming



Cutting Piercing



Source: www.magneform.com; www.pulsar.co.il, www.iap.com, https://www.pstproducts.com)

@AMPRI

Electromagnetic joining & Forming:

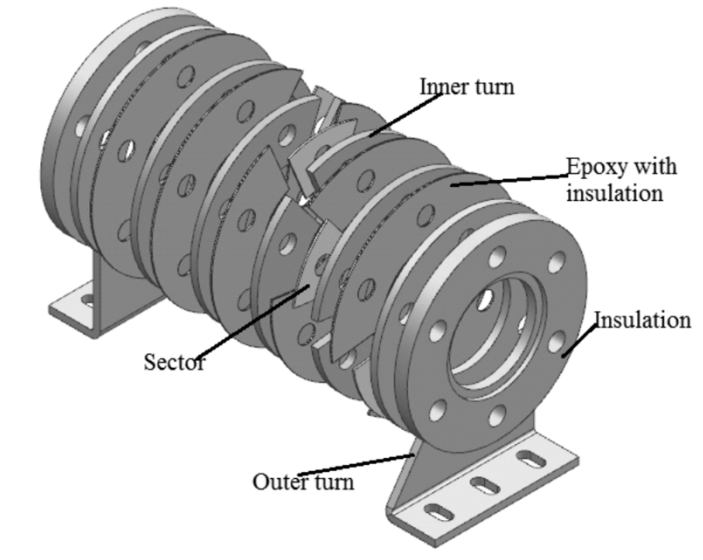
- **Expertise on design of Coil and Field shaper (FS) for joining of symmetric and non-symmetric geometry**
- **Electromagnetic Joining of Cu-SS, SS-Nb, SS-Ti, Al-Al, Al-SS, Al-MS, Al-Cu, Cu-Cu, Al-Al**

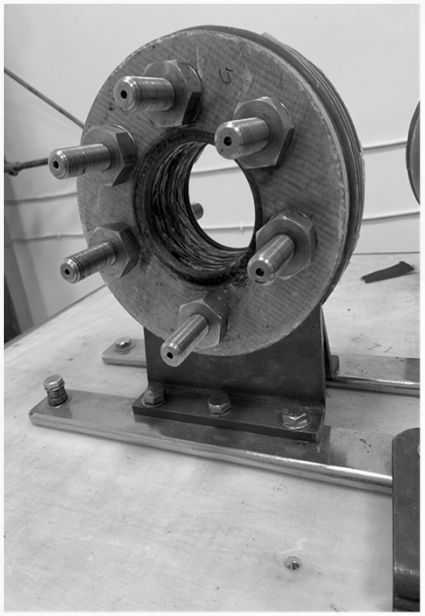
Cu-Cu, Al-SS, Al-Cu, Cu-MS, Cu-Al, Al-MS, Cu-SS, SS-Cu
(circular profile joining)

Rect. Profile

Study on design of Coil

- **Effect of no. turns of coil, ID, OD, turn thickness on output (Inductance- current..)**
- **Effect of web width and material/slit geometry of FS on process parameters**
- **Effect of coil configuration/design on force/deformation (using FEA)**

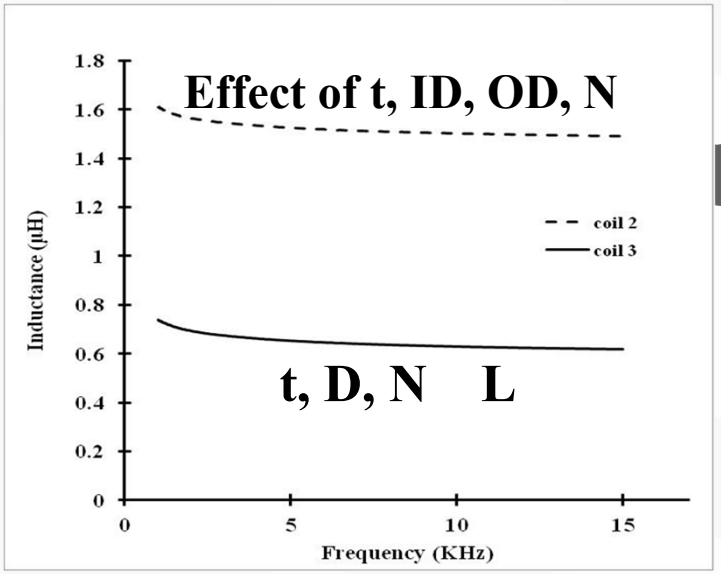




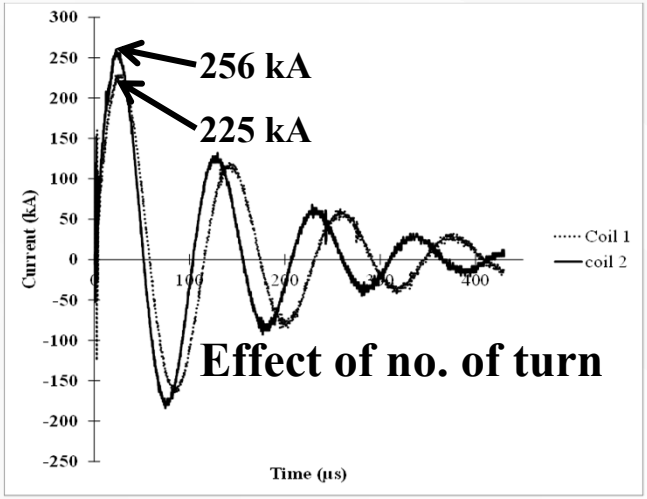
Effect of coil Design on the discharge current

Table- Different dimension of coil

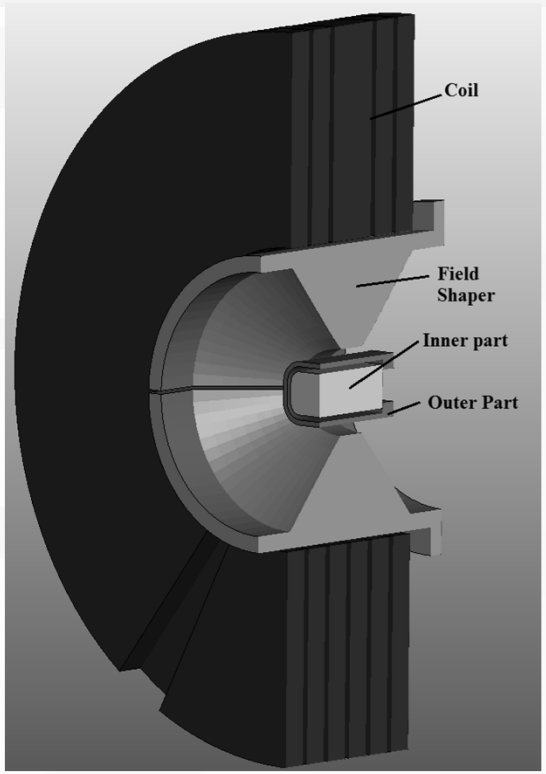
Coil	ID/OD (mm)	N	Turn Thickness
C1	91/220	4.40	8
C2	91/220	4.33	8
C3	55/200	2.4	3
C4	91/210	4.33	8
C5	101/210	4.33	8

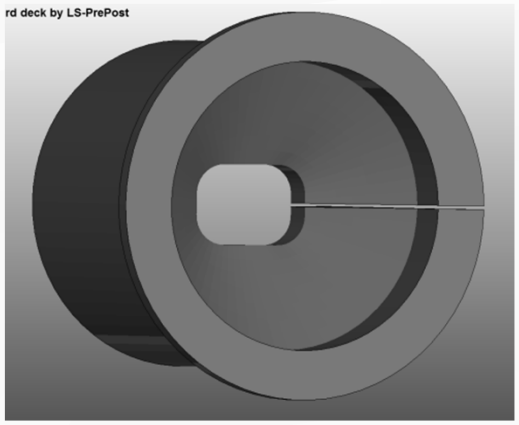


Variation in parameters	Change in current ΔI (kA)	Change in frequency Δf (kHz)
Coil ID(91-101)	-9	-0.3
Coil OD(210-220)	32	1.7
N (4.40- 4.33)	-31	0.9

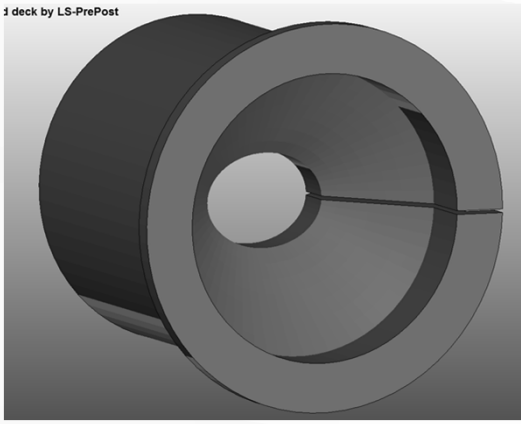


Design of Coil and FS

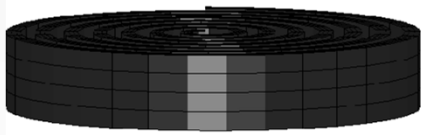




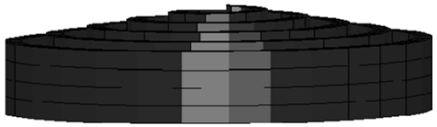
Rectangular FS



Elliptical FS

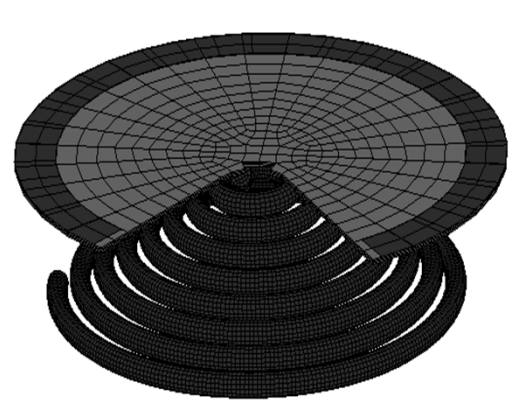


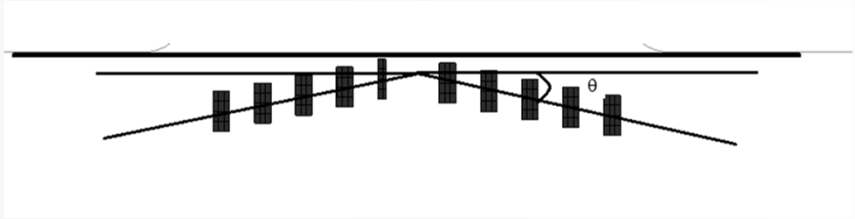
a) 0 Degree- Flat spiral coil



b) 6 Degree- Tapered coil

c) 12 Degree- Tapered Coil



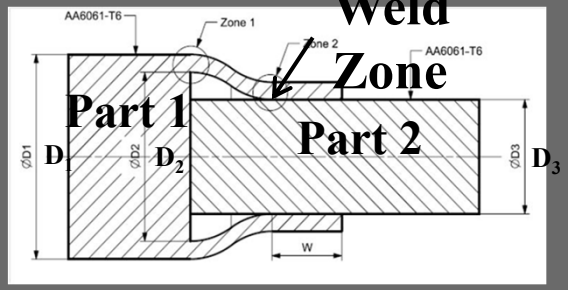


Flat forming coil

Electromagnetic Joining

Sample Design:

Al-Al Joining joint design



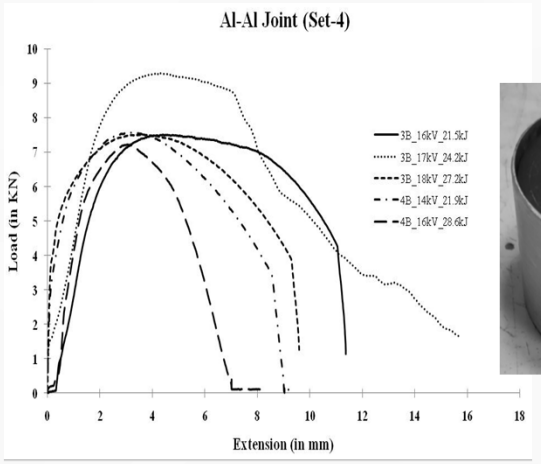
Failure criteria between part 1 and weld

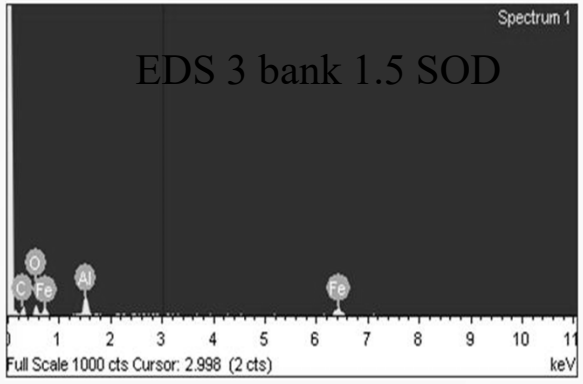
(i) $D_1^2 - D_2^2 > 10D_3$:– Zone 1

(ii) $D_1^2 > D_2^2 + 10D_2 - 30$:- Zone 2

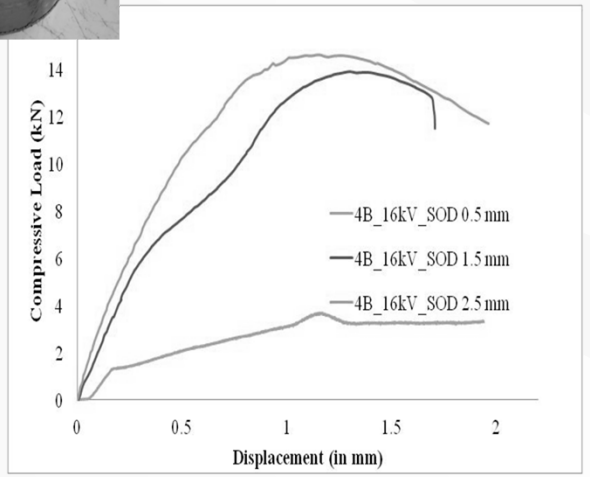
(iii) $t_f = [\{\sqrt{(D_3^2 + 10D_3)}\} - D_3] / 2$

		D_1	D_3	Thickness	SOD
Set 1	Al-Al	16 mm	8 mm	2.5 mm	1.5 mm
Set 2	SS-Al	14.2	8	1.6	1.5 mm
Set 3	Al-Al	14.2	8	1.6	1.5 mm

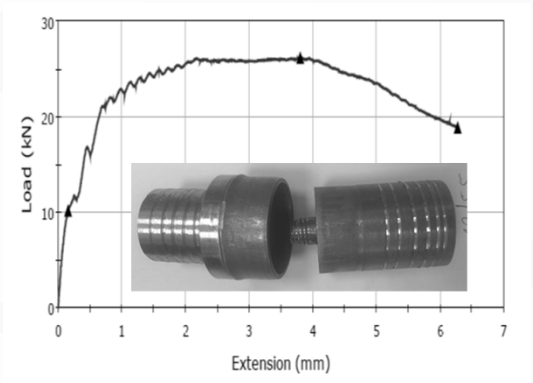


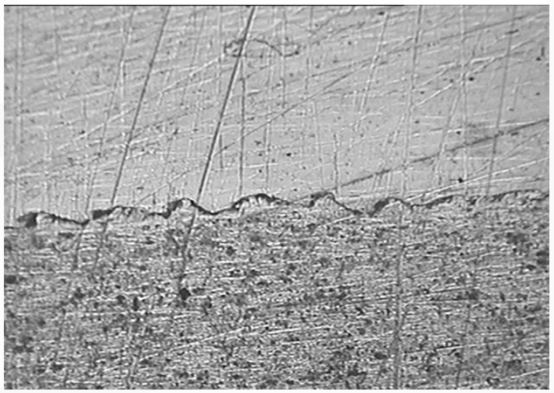


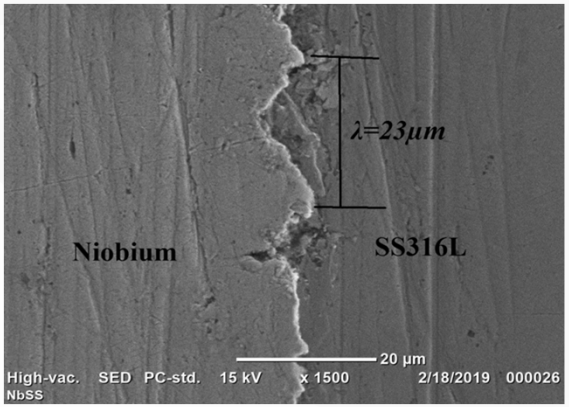
Al-MS electromagnetic joining



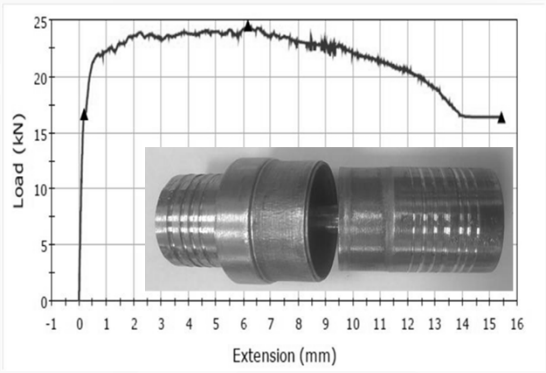
SS-Nb Joint

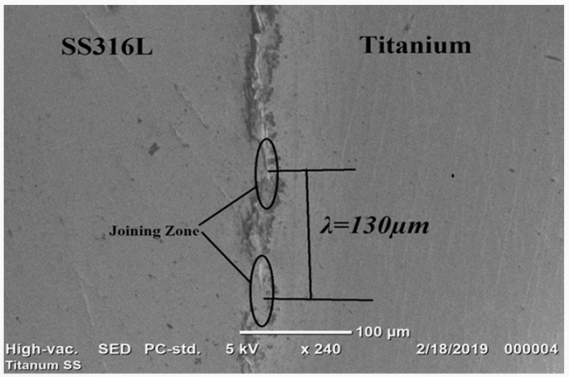






SS-Ti Joint

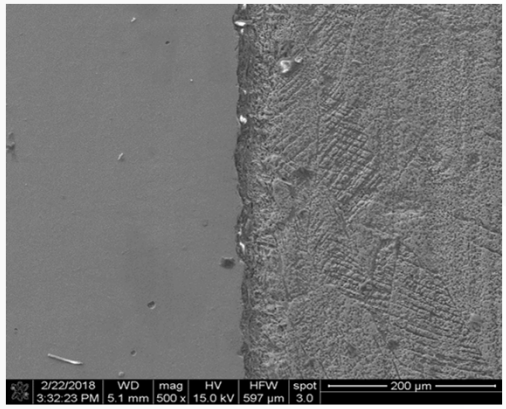




Helium Leak proof test

	Job description	Leak Tightness (mbar-l/s)
1.	SS to Nb	**< 1E-10**
2.	SS to Nb	**< 1.2E-10**
3.	SS to Ti	**1E-5**
4.	SS to Ti	**1E-5**

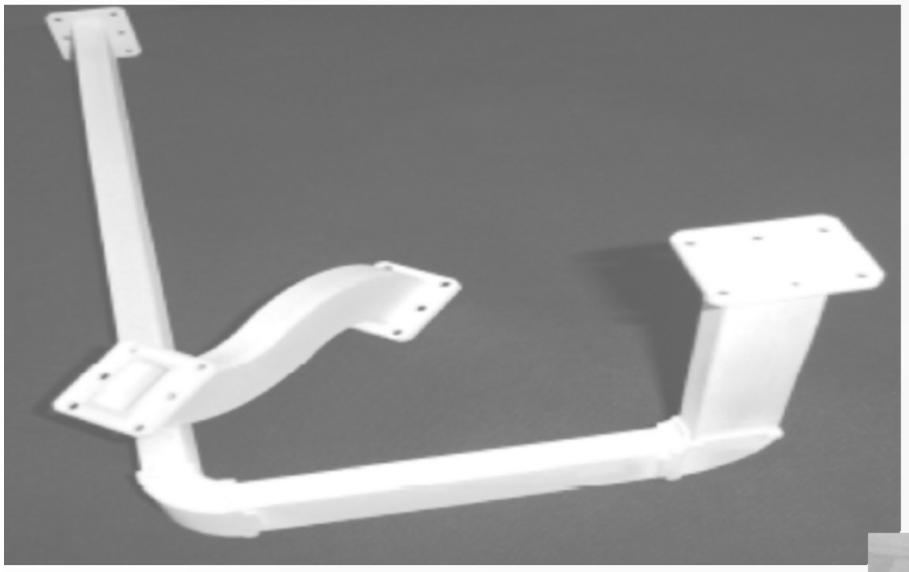
Cu-SS joining

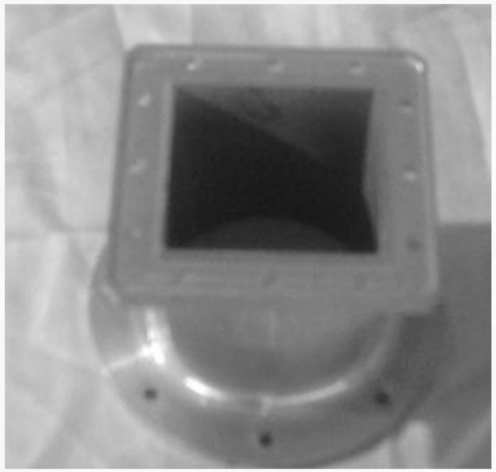


Leak proof test carried out at RRCAT

DEVELOPMENT OF AL WAVEGUIDE AND SIMILAR PROFILE COMPONENTS

- **Reduction of weight**
- **Better performance**





Source: ISRO exhb. BVM


Electromagnetically Formed
Joints
RIM
WHEEL DISC
RIM AND WHEEL DISC MANUFACTURED SEPARETELY ASSEMBLED TOGETHER BY WELDING
Lug-cable crimping
Lugs
Cable
Thank you
http://ec.europa.eu/research/transport/pdf/turin1010_0950_en.p
www.magnepress.com
www.iap.com
Courtesy: BARC, OSU, Pulsar

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