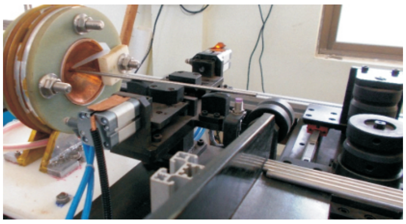
Special Purpose Machine

Automation of Magnetic Pulse Welding of PFBR Fuel and its End-Plug

Renu Rani[1]*, Surender Kumar Sharma[1], Nitin Waghmare[1], Shobhna Mishra[1], JMMVS Aravind[1], Rishi Verma[1] and Archana Sharma[1]
P. V. Suresh Verma[2], Nagendra Kumar[2], D. B. Sathe[2] and R. B. Bhatt[2]

[1]*Pulsed Power & Electromagnetics Division, Bhabha Atomic Research Centre, Visakhapatnam, Andhra Pradesh-531011, INDIA*
[2]*Advanced Fuel Fabrication Facility, Bhabha Atomic Research Centre, Tarapur, Maharashtra, INDIA*



Magnetic Pulse Welding Setup

ABSTRACT

Special Purpose Machine for Automation of Magnetic Pulse Welding (MPW) for top end- plug welding of Prototype Fast Breeder Reactor (PFBR) fuel pin inside glove-box is designed and developed. Simplification of the fuel fabrication operations and reduction of personal radiation exposure to a large amount of plutonium is one of the most important objective in the development pin welding automation system. As PFBR pin contain MOX Fuel (PuO_2 and UO_2), Biological half-life of plutonium is 200 years and specific activity of plutonium is 0.06 Ci/gm. Pin welding is one of the steps in fuel fabrication process which involves high radiation exposure to the setup operator. A remote-controlled automation system has been introduced for pin end plug welding. This system has been commissioned at BARC Tarapur.

KEYWORDS: *PFBR, Fuel Pin, End Plug, Electromagnetic Welding, Automation.*

Introduction

Fully automated and remote pin end plug welding system was conceptualized, designed and developed for magnetic pulse welding of fuel pin inside glove-box chamber to reduce personal radiation exposure during fabrication of mixed oxide (MOX) fuel containing about 20~30% of plutonium on the production scale of 3 tonnes of MOX fuel every year. The driver fuel of Prototype Fast Breeder Reactor (PFBR) is Uranium Plutonium Mixed Oxide ($(U,Pu)O_2$,MOX). MOX fuel pellets are loaded in SS-D9 clad tubes. Schematic diagram of the fuel pin are shown in Fig.1.

Fuel for the future core of Prototype fast breeder reactor will include plutonium re-processed from short cooled high burnup spent fuel. Fabrication of this fuel presently involves various activities resulting in high men-rem consumption by the operator owing to its high specific activity. The challenges are further compounded due to requirement of high production rate.

Fuel Fabrication Processes

The conventional powder metallurgy route, powder to pellet (POP), for fabrication of MOX fuel pellet involves mechanical milling, mixing of suitable binder and lubricant with UO_2 and PuO_2 powder, pre-compaction, granulation, final compaction, sintering and grinding as shown in the flow chart.

After pellet loading, fuel elements are welded. To automate this step, a special purpose machine is designed to weld fuel pin end plugs using magnetic pulse welding process.

Magnetic Pulse Welding

Magnetic Pulsed welding process is a solid-state welding process in which metallurgical bonding is affected by impacting metal or alloy parts against each other at high velocity by use of controlled high frequency and high intensity pulsed magnetic fields. This process is similar to the explosive welding process except that magnetic energy is used for impacting the parts together instead of explosive energy. Magnetic pulsed welding

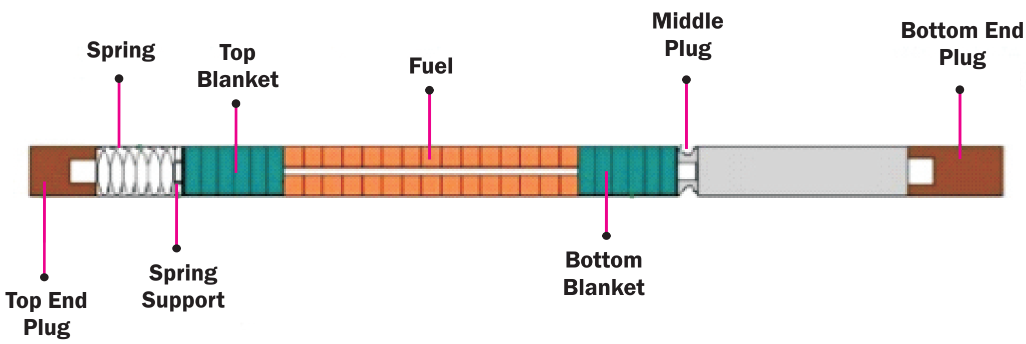


Fig.1: Schematic of PFBR fuel pin.

*Author for Correspondence: Renu Rani
E-mail: renusharma@barc.gov.in

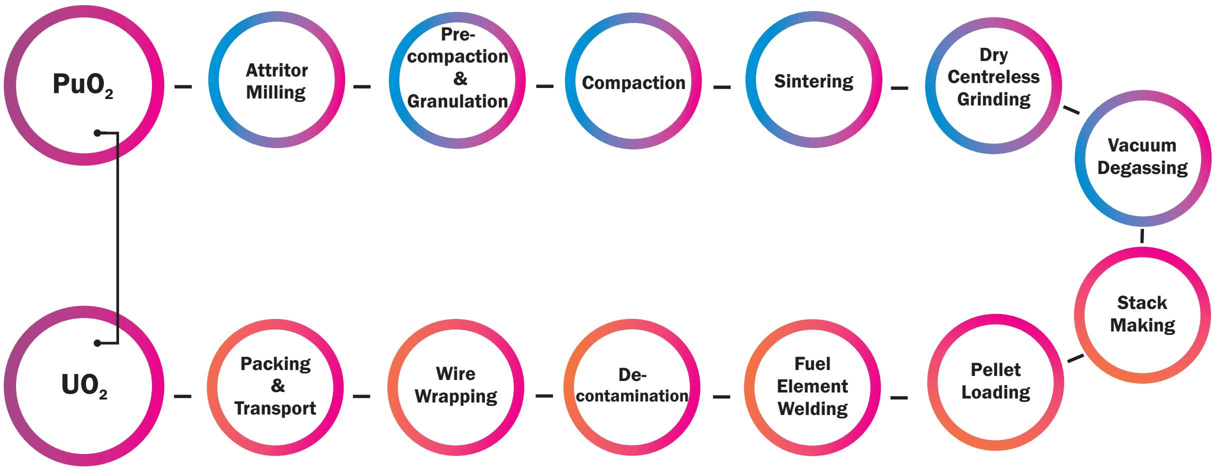


Fig.2: Flow chart of PFBR fuel pin fabrication.

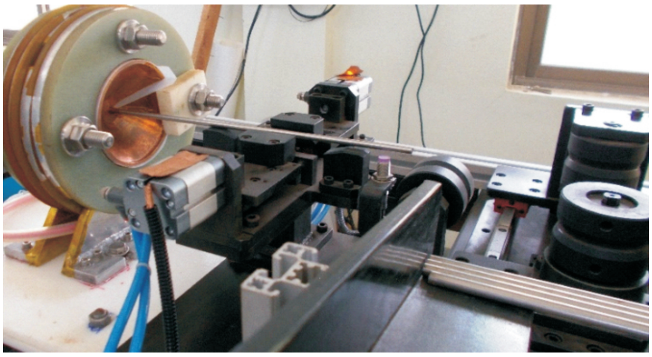


Fig.3: Magnetic pulse welding setup.

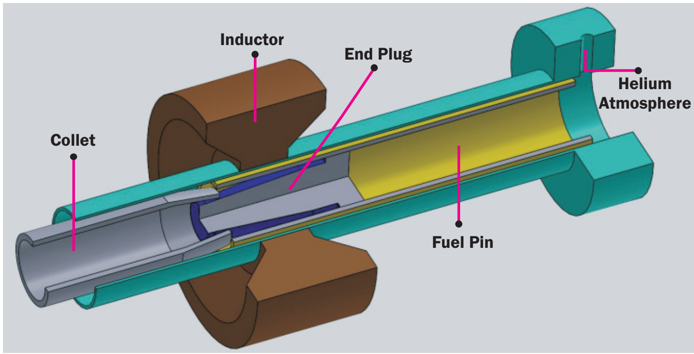


Fig.4: Section view of PFBR pin inside EM coil in helium atmosphere.

process is readily applied to the welding of cylindrical plugs to small diameter tubes. Although breeder reactor fuel pin design may vary in size, the application described here consisted of cladding tubes approximately 6.6 mm in diameter and 2580 mm in length with a wall thickness of 0.45 mm. After the cladding tubes are filled with fuel pellets and associated metal hardware, tapered end plugs are inserted at the end of the tubes and welded. A typical setup for MPW is illustrated in Fig. 3 & Fig. 4.

The axial length of the welds depends upon the welding parameters selected. Usually, the parameters are adjusted to provide welds of 1.5 mm to 2.3 mm long. Since the welds are made at relatively low temperatures, there is no melting or heat affected zones.

Studies show an approximate 25% increase in the hardness of the weld zone over the original base material. Microscopic image of the weld interface between SS clad tube and end plug is shown in Fig. 5.

The advantages of the MPW process over conventional fusion welding process for end closure welds are listed below

- More bond length
- No melting or heat affected regions
- No subsequent heat treatments required
- Not sensitive to material history
- Easier to weld dissimilar metals/alloys
- Easier to weld crack susceptible metals/alloys
- High production rate capability
- Simple fixtures - no moving parts
- Specialized operators not required

Automation System for Magnetic Pulse Welding Inside Glove-Box

The Automation System segregates of pins (press-fitted with end plug) from inclined tray, transfers them in the weld chamber, removes welded pins from the weld chamber and collects them in another glove-box.

During fuel fabrication process specified number of pins will be transferred by conveyor to inclined tray of automation system from pin loading glove-box. Pins will roll down by gravity on inclined tray. The automation system separates single pin from bunch of pins stacked on inclined tray, transfers pin to weld chamber, precisely holds the pin concentrically inside EM coil from both ends during the welding process, removes the welded pins from the chamber and finally collects them in collection tray of another Glove-Box for further processing.

Methodology

The developed automated end plug welding system can be divided in two parts, namely, the Mechanical part and Control part. The dimension of Mechanical system are fixed considering Glove-Box adaptability and application feasibility. Length of full automation system is 3500 mm to accommodate both PFBR pin (2580 mm long) and MPW coil. The width of the system is 1200 mm for enabling manual approach to system during maintenance as per Glove-Box design standards.

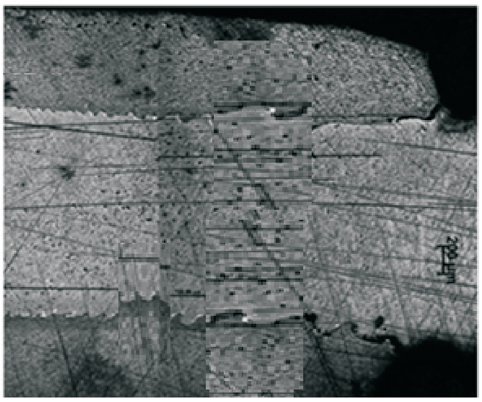


Fig.5: Welded fuel pin and microscopic image of weld interface.

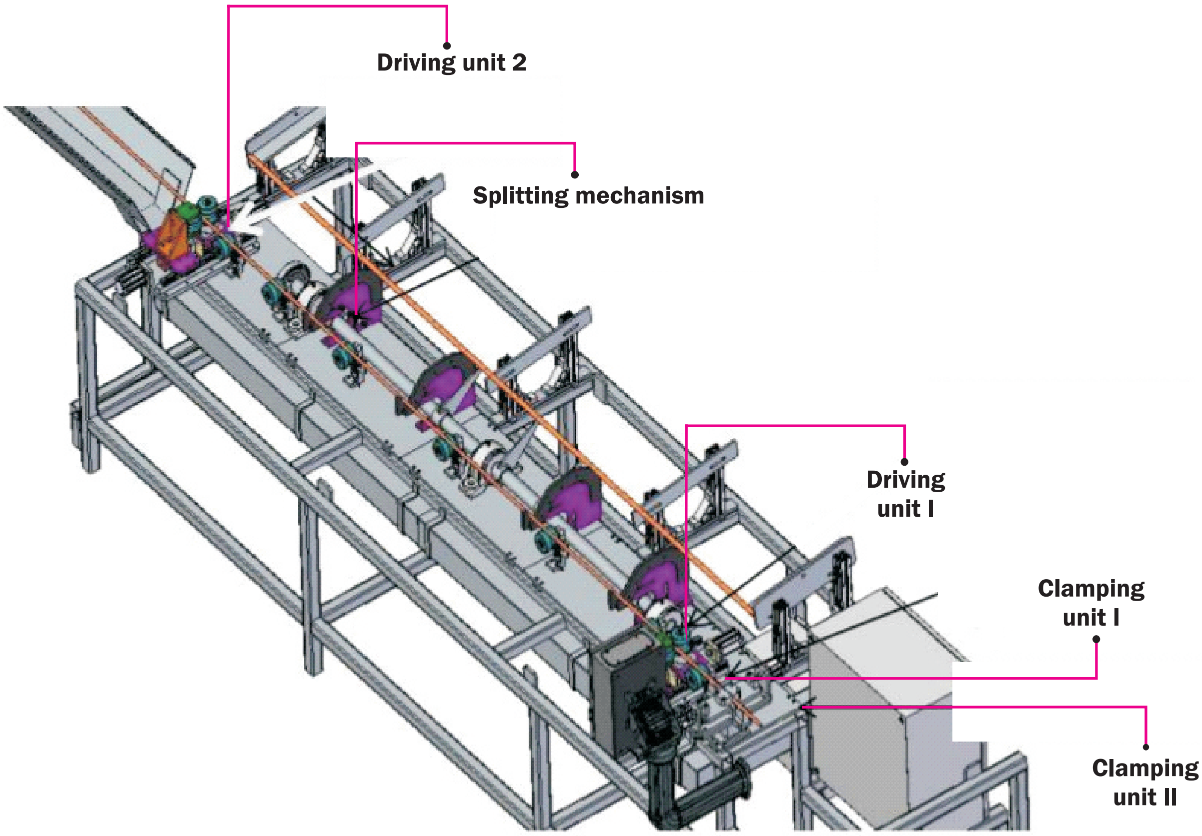


Fig.6: Pin welding automation system inside glove-box.

The mechanical part consists of six sub-assemblies

- Roller sub assembly
- Gripper sub assembly
- Splitting subassembly
- Pneumatic cylinders
- Servo system
- Guided ways and guided blocks

The control part consists of a motion controller, PC for operation control & monitoring, servo motors and sensor circuit. The end Plug welding system also has UPS system with battery backup for 30 minutes. The schematic of the system design is shown in the Fig.6

Sequence of Operation

The sequence of operation which gets repeated 50-60 times to weld one tray of pins, as tray contains 50-60 nos. of pins. Component runs over the sliding support plates by gravity.

Splitting mechanism separates the single pin from array of pins collecting on inclined tray. It carries one pin and place it over supporting rollers. Servo motor (RPM 20) provides the rotary motion to the shaft at which splitters are connected. Proximity sensors below Supporting rollers sense the position of pin.

When pin positioning is detected by proximity sensors, driving rollers grips the pin with pneumatic cylinders and starts carrying it towards the MP welding coil with servo motor. Proximity sensor is fitted next to driving rollers. This is referred as zero and based on the distance given in the pre-program driving roller rotates continuously and pushes further forward towards the welding coil.

Gripper assembly before and after electromagnetic coil will hold the pin and end-plug during welding when pin is positioned inside the coil to ensure concentricity of pin and restrict movement during welding after taking shot on welding coil gripper assembly will open as time set in control unit.

Driving roller second assembly will rotate in reverse direction to remove pin from coil and carry it to exit bin that is in next in-line glove-box.

Conclusion

A fully automated fuel pin end-plug welding system with magnetic pulse welding has been developed for PFBR fuel pin. Developed system will significantly contribute to reduction in operator man-rem while harmonizing with high throughput rate and product quality required for PFBR fuel fabrication.

Salient Features of Operation

- Pin will be rigidly fixed from both sides near welding Point because vibration can be generated during EMP welding as magnetic pulse welding is solid state impact welding.
- Pin holder and its support is made up of completely insulated material as working is in high voltage environment.
- Placement of job piece is carried out with high precision with tolerance of 0.1-0.2 mm in x-y-z direction inside the coil by servo motor and proximity centre.
- Operational safety features incorporate for fail safe operation are UPS system with battery backup 20 min to ensure the safe completion of ongoing process in case of power failure.

In case of system idle condition sufficient space is provided near welding system for manual operation.

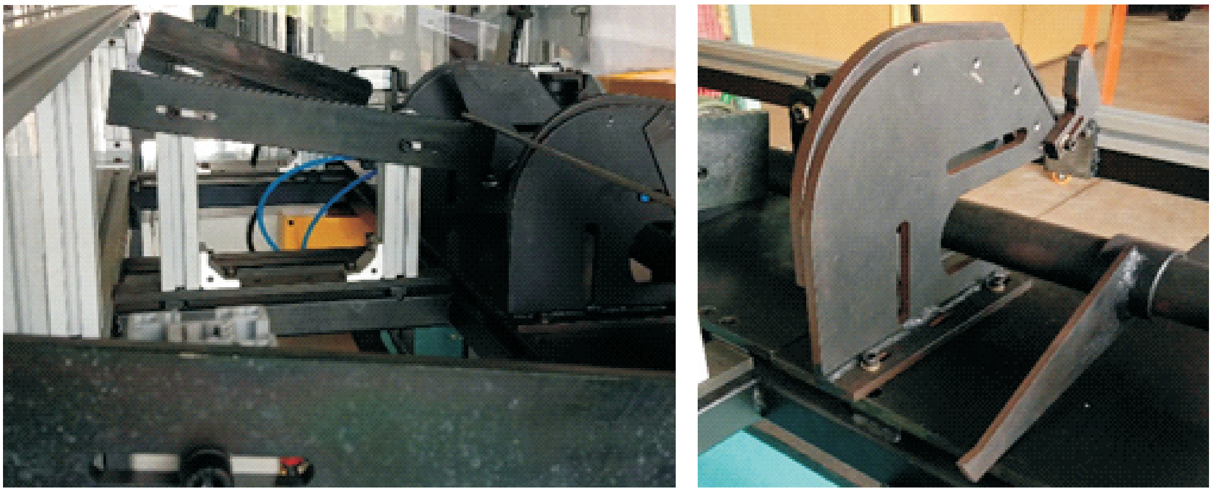


Fig.7: Inclined pin storage tray and pin splitting mechanism.

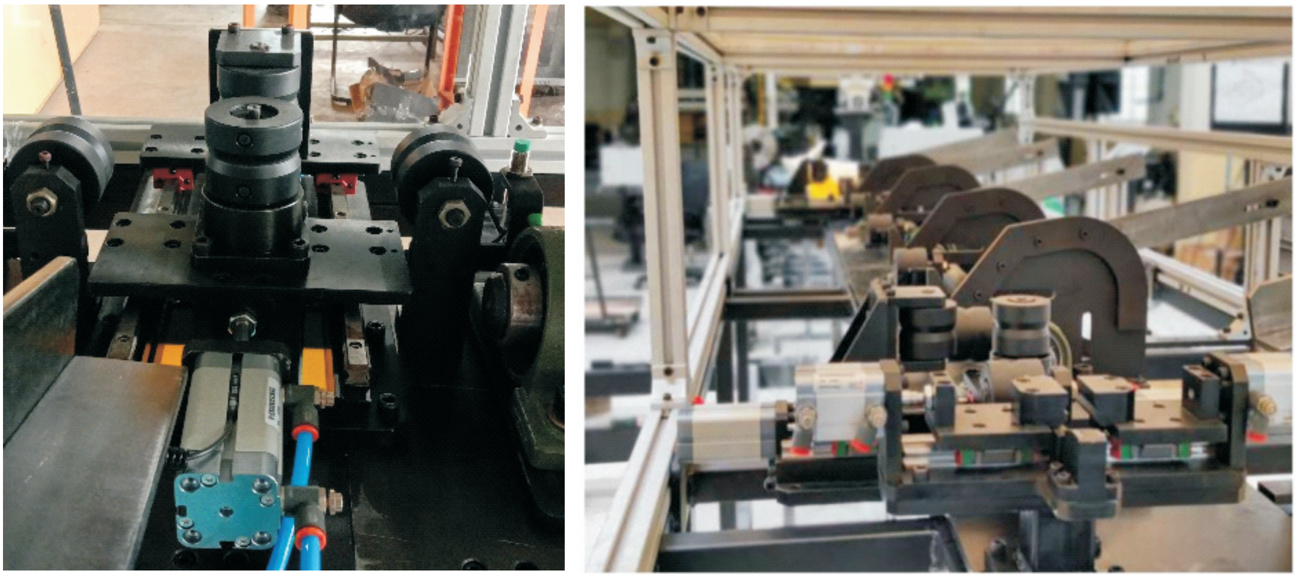
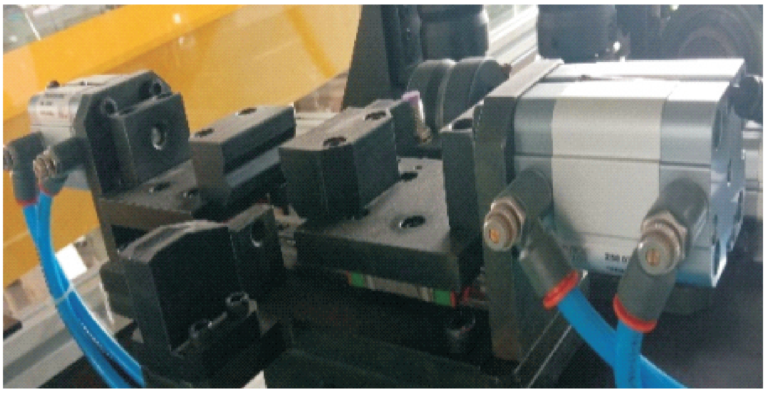


Fig.8: Driving rollers and supporting rollers.



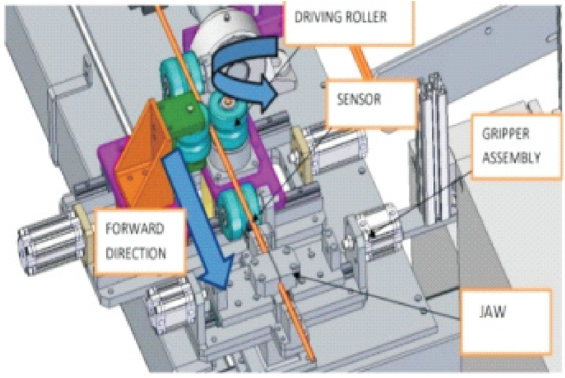


Fig.9: Gripper assembly and pin position during welding.

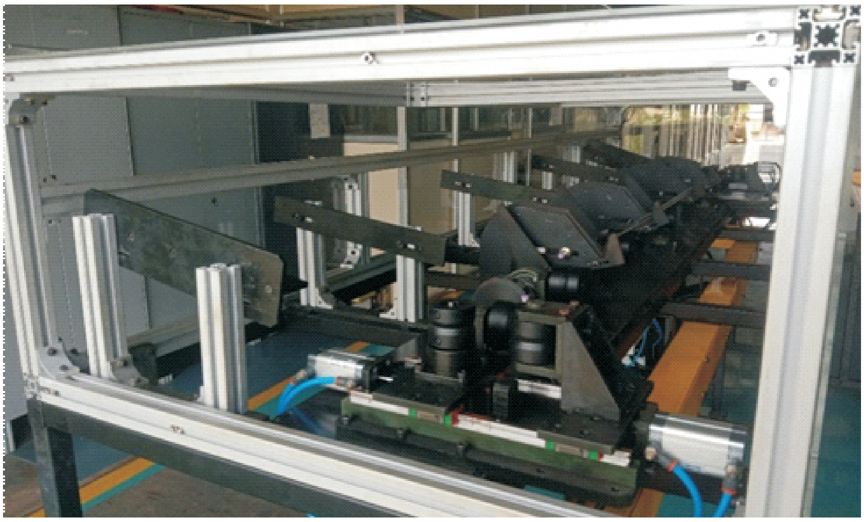


Fig.10: Driving roller second assembly and system with glove-box with exit bin.

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