Detection of Annular and Solid pellet in PFBR MOX Fuel Element using High energy X-ray Radiography

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ABSTRACT

Advanced fuel fabrication facility (AFFF) has manufactured (U-Pu)O_2 MOX fuel with a wide range of composition for thermal and fast reactors. At present, AFFF is engaged in fabrication of the mixed oxide (MOX) fuel with (U-28%Pu)O_2 for upcoming Prototype Fast Breeder Reactors (PFBR).The fully loaded PFBR fuel element contains a stack of annular (U-Pu) MOX pellets and two stacks one at the top and one at the bottom of solid DDUO_2 pellets and hardware components. As a part of quality control step, X-ray Gamma Autoradiography (X-GAR) is carried out to check cross mixing of DDUO_2 and MOX pellets. As per the quality control philosophy some characteristics of fuel are checked by more than one technique so as to get better confidence in quality of fuel. In view of this the high energy X-ray radiography is used to check the cross mixing of (U-Pu) MOX pellet in stack of DDUO_2 pellets. Many trials were carried out to optimize the X-ray radiography parameters. The technique even detects solid MOX pellet if gets mixed with annular MOX pellets and annular DDUO_2 pellets in the stack of solid DDUO_2 pellets providing full proof system.

Key words: Gamma Autoradiography, X-GAR, X-ray radiography, PFBR.

INTRODUCTION

Advanced fuel fabrication facility (AFFF) has manufactured UO_2 based MOX fuel with a wide range of composition of PuO_2 for thermal and fast reactors. At present, AFFF is manufacturing PuO_2 based MOX fuel with composition of (U-21%Pu) O_2, and (Pu-28%Pu) O_2 for upcoming PFBR at Kalpakkam. The pellets were fabricated by conventional powder metallurgical route involving steps like mixing, milling, pre-compaction, granulation and final compaction followed by sintering.

The stack of correct composition was loaded in bottom end plug welded clad tubes. The tubes were finally sealed by end plugs using GTAW welding procedure. Apart from X-ray radiography and Helium leak testing, the pins were subjected to X-ray Gamma Autoradiography (X-GAR). X-ray radiography was carried out to check the physical integrity of end plug weld. Helium leak testing was carried out to eliminate the possibilities of existence of leak in the fuel pins. X-GAR technique is used for checking of cross mixing of DDUO2 pellets in a stack of annular (U-Pu) MOX pellet and vice versa. The schematic diagram of PFBR fuel element has been shown in Figure 1. As per the quality control philosophy some characteristics of fuel are checked by more than one technique so as to get better confidence in quality of fuel. In view of this the high energy X-ray radiography was used to check the cross mixing of (U-Pu) MOX pellet in stack of $DDUO_2$ pellets. Many trials were carried out to optimize the X-ray radiography parameters. The technique even detects solid MOX pellet if gets mixed with annular MOX pellets and annular $DDUO_2$ pellets in the stack of solid $DDUO_2$ pellets providing full proof system.

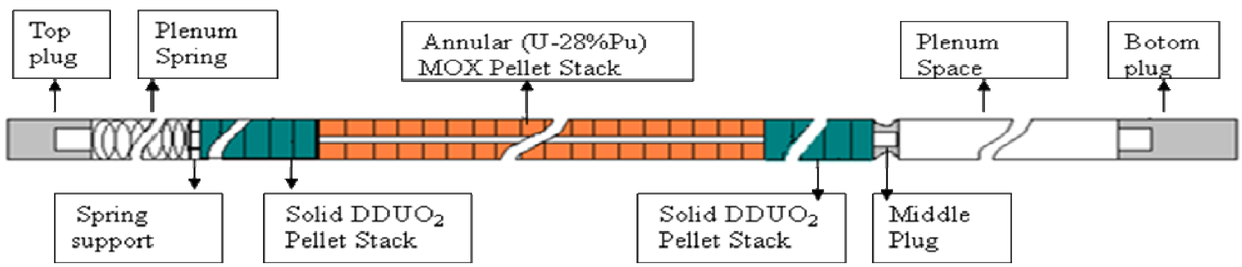

Figure 1 Schematic diagram of PFBR Fuel Element

EXPERIMENTAL

The X-GAR was used to detect cross mixing of pellets of different composition/ enrichments, composition fluctuation in fuel column, presence and correct sequence of hardware components (spring, spring support etc.). The X-GAR system consists of 3.5 meter long tray which moves on the base by chain and sprocket arrangement. The X-ray films loaded in flexible cassette were kept on the tray below the PFBR fuel element as shown in Fig.2. The tray was moved in front of X-ray machine. X-ray coming from machine registered the image of internal hardware components. The fuel elements along with film cassette were left undisturbed for predetermined period so that gamma coming out of fuel pellets will be registered on the film. As mentioned earlier, the difference in optical density obtained due to different gamma intensity of $DDUO_2$ pellets and MOX pellets distinguishes MOX pellet from $DDUO_2$ pellets.

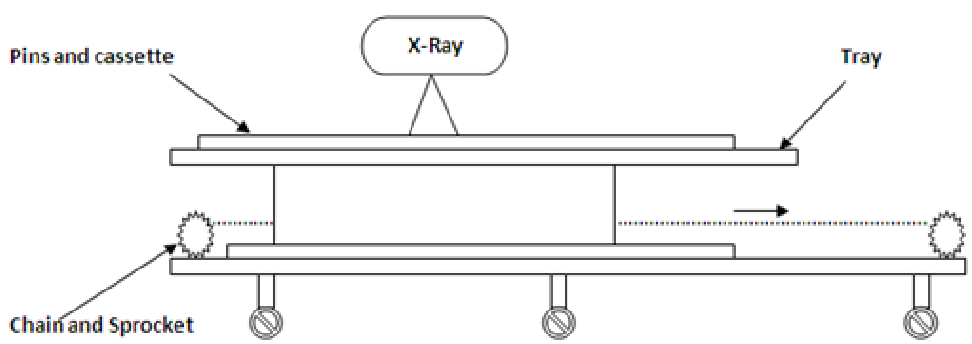

Figure 2 Schematic diagram of radiography system of PFBR Fuel element

RESULTS AND DISCUSSIONS

Figure. 3, shows the typical X-GAR image of a PFBR fuel element containing all internals: Plenum spring, spring support, solid $DDUO_2$ pellet stack, annular (U-28%Pu) MOX pellet stack, middle plug and plenum space. Apart from this the XGAR technique can also be used for measurements of length of hardware components and stack lengths of $DDUO_2$ pellet and MOX pellets in fuel elements using standard pin.

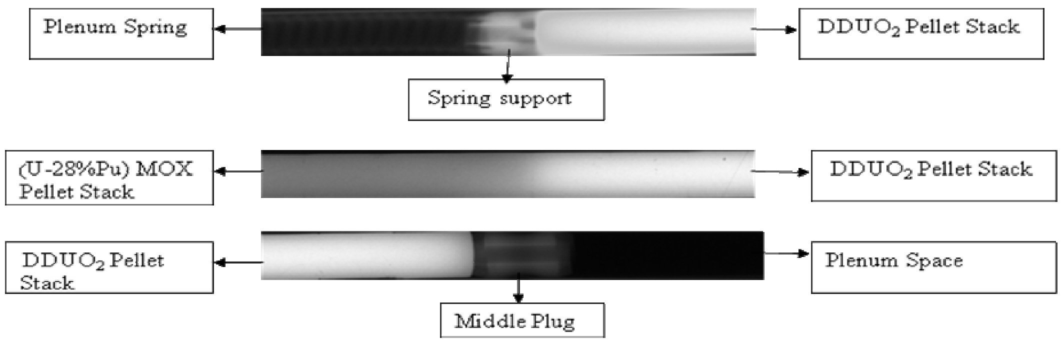

Figure 3 X-GAR image of PFBR Fuel element.

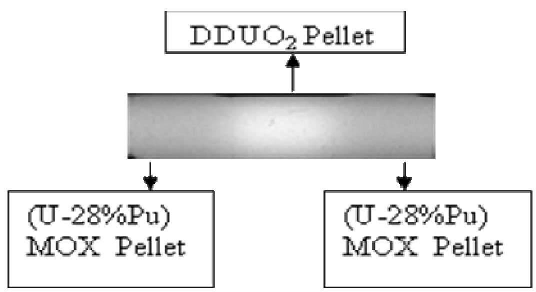

Figure 4. Image of X-GAR showing the presence of $DDUO_2$ pellet in stack of (U-28%Pu) MOX

It is clear from Figure. 4, that the X-GAR image does not distinguish between solid and annular pellets. To see inside diameter of the pellet it is required that X-ray should penetrate the pellets fully. In view of this, following set of different exposure parameters in terms of kVand mA- minutes were tried on D-2 X-ray film, to obtain the best image. The exposure parameters experimented is given in the Table 1.

Table 1

Sr. No.	Voltage (kV)	Exposure (mA- minutes)
1.	280	10
2.	290	10
3.	300	10
4.	310	10
5.	320	10

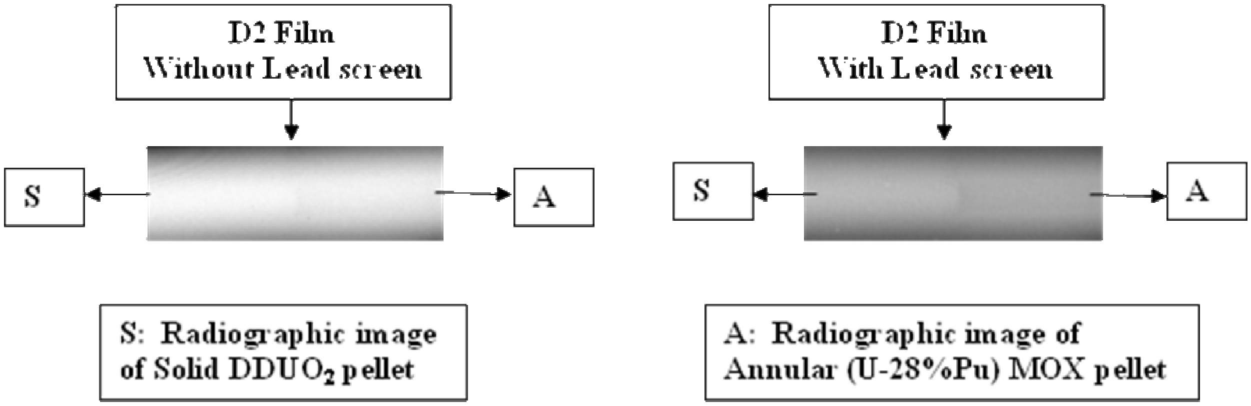

Figure 5 Radiographic image of Solid and annular pellet at 320kV on D2 - film without intensifier screen and with intensifier screen

It is observed that the visibility of the image at 320 kV with intensifier screen is better than the image at other kV. To ascertain above facts a grey value intensity profile was drawn across diameter of pellet for both annular and solid pellet. The figure.6, shows the smooth peak and fig7 shows slight deep indicating the presence of annular pellet

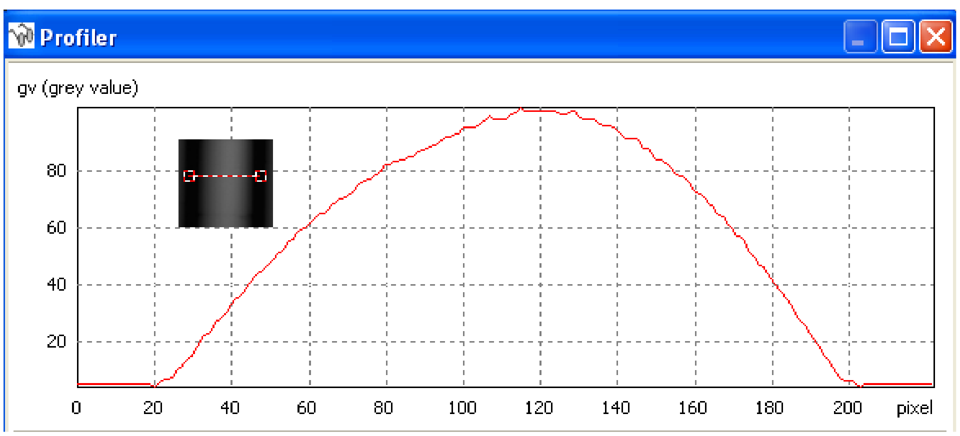

Figure 6 Grey value profile of Radiographic image at 320kV of $DDUO_2$ Pellet along diameter of pellet indicating the solid pellet

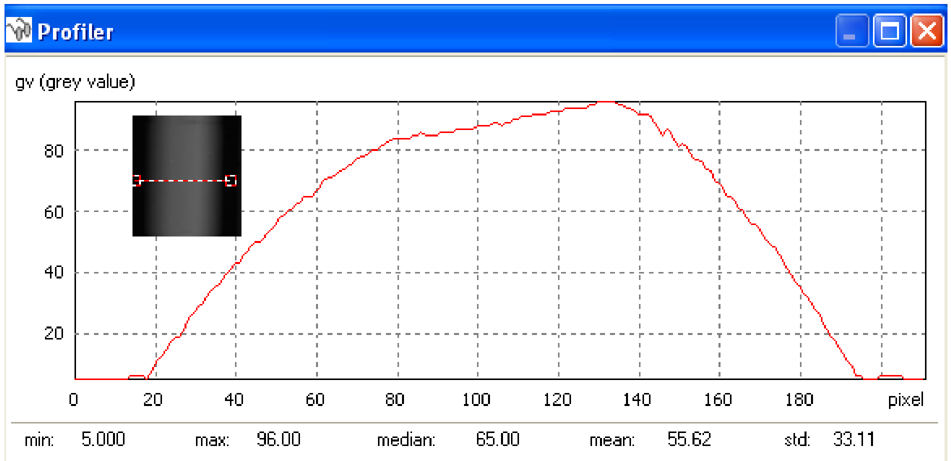

Figure 7 Grey value profile of Radiographic image at 320kv of (U-28%Pu) MOX pellet along diameter of pellet indicating the annular pellet

CONCLUSIONS

The XGAR was used for checking of cross mixing of $DDUO_2$ pellets in a stack of annular (U-28%Pu)O_2 MOX pellet and annular (U-28%Pu)O_2 MOX pellet in stack of solid $DDUO_2$ pellets. It was demonstrated in the paper that high energy radiography at 320 kV can even identify the annular and solid pellet. This gives additional confidence in detection of cross mixing of pellets. The technique can also distinguish between solid MOX and annular MOX pellets and between solid $DDUO_2$ and annular $DDUO_2$ pellets.

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