The Improvement of Technology for High-uranium-density Al-base Dispersion Fuel Plates

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Abstract

An Improved rolling process was developed for manufacturing Al-base dispersion fuel plates. When the fuel content in the meat increased up to 50 vol%, the non-uniformity of uranium is not more than ±7.2%, and the minimum cladding thickness is not less than 0.32mm.

Introduction

In the RERTR programm, one of the most important problems is to develop high-uranium-density Al-base dispersion fuel plates. Though the appearance of new fuels with higher-uranium-density, e.g. U_3Si_2 and U_3Si, has reduced the trouble in fabrication, it is still a problem to get a fuel plate with uniform thickness of the meat and the cladding by rolling, when the fuel content is up to 50 vol%. Since the meat hardness increases and the meat ductility decreases significantly under such a high fuel content, the ability for uniform reduction becomes very low, and the meat can not match the Al-cladding at rolling temperature, so the meat thickness of the fuel plates by rolling appears a wavy change, and a serious dogbone appears at the ends of the meat. This is a major problem in fabrication of high-uranium-density Al-base dispersion fuel plates.

Using the method of tappering the ends of the compact is effective for reducing dogbone, but it is still uneffective for flattening the meat(1). In order to solve this problem, the fabricating technology has been studied in our laboratory, and good results have been obtained.

Fabricating Procedures

This work was mainly carried out in the UAl_x-Al system. At the same time, in order to explore the effect of the geometric shape of fuel on the fluctuation of meat thickness, we have also studied the system of Sol-Gel UO_2 spherical particles, which is smaller than 150μm in diameter, as a simulating body of spherical fuel. Pure aluminium powder of 30 μm in diameter was used as matrix material, and Al-Mg-Si alloy as cladding material.

The fabricating technology used in this work is the picture-frame rolling method, but a lot of improvements have been made, e.g. the construction of assembling billet, the rolling procedures, the temperature control and the treatment of cladding surface etc.. The rolling compression ratio used in the experiment is 8:1. The nominal size of the fuel plates rolled are 320X51X1.27 mm, and the meat thickness and cladding thickness are 0.51 mm and 0.38 mm respectively.

In order to show the effectiveness of this procedure on flatting the meat, the fuel content was raised on purpose, that is, 88 wt% UAl_X- 12 wt% Al and 92 wt% UO_2- 8 wt% Al fuel plates were rolled. The 47 wt% UAl_X- 53 wt% Al fuel plates were also rolled by the same fabricating procedure for comparison.

Results and Discussion

1. Bonding quality

The good metallurgical bonding between the cladding and meat, cladding and frame is an essential prerequisite for judging a successful technology. The blister test, ultrasonic test and metallographic examination in the fuel plates rolled by this procedure have shown that the bonding quality is good. Besides the rolling compression ratio, the main factors affecting the bonding quality are usually the cleaning of the cladding and frame, and the welding quality of assembling billets. So long as the special polybasic acid was used to clean the cladding and frame, and the well-welding quality was ensured, the bonding quality at 8:1 rolling compression ratio would be completely reliable.

2. The uniformity of thickness of the meat and cladding

The fluctuation of the meat and cladding thickness was measured by metallographic method, and the uniformity of uranium distribution was examined by γ-ray absorption.

Fifteen samples with 25 mm length were cut away from every fuel plate at the typical part to get the maximum, minimum and average meat thickness(namely, the maximum, minimum and average distance between the two fuel particles at the boundary along the direction of plate thickness), and the minimum cladding thickness (namely, the minimum distance between the fuel particle and the cladding outside surface). The data obtained in this work are shown in Table 1. The typical metallographs are shown in Fig. 1.

The γ-ray absorption was used to measure the uranium density distribution along the central line of every pieces of fuel plates. The results are shown in Table 1 and Fig. 2.

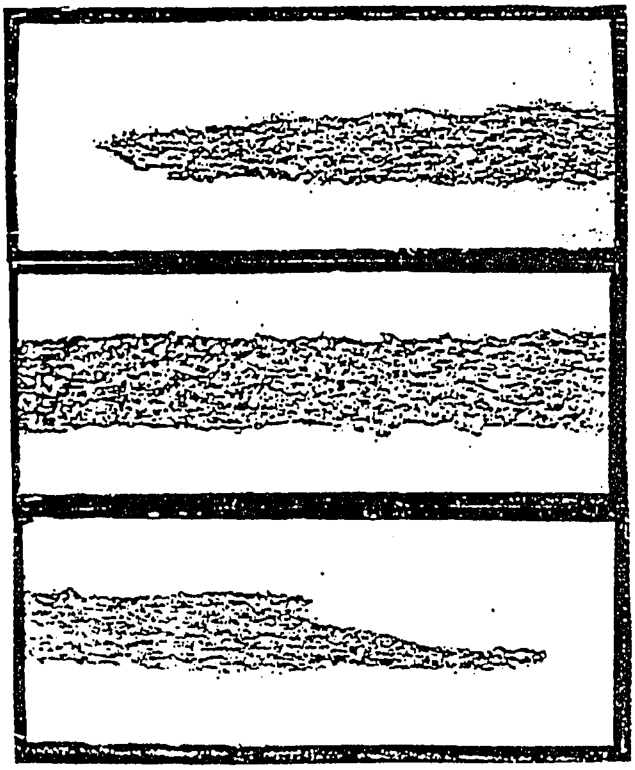

Fig. 1. The metallograph of No.15-2 UAl_x-Al plate with 2.6 gu/cm^3

For comparison, the data of 16-3 plate fabricated by the same technology with low-uranium-density is also shown in Table 1 and Fig.2. Comparing the data in Tab.1 and the curves in Fig.2, we can find that the UAl_X content of 15-2 plate is about twice as much as that of 16-3 plate, but the fluctuation of the meat thickness is only increased to ±13% from ±8%, the non-uniformity of uranium distribution are both about ±7% and minimum cladding thicknees is only decreased to 0.32 from 0.34 mm. These changes are very small and much better than allowed data[2,3].

Table 1. The uniformity of the meat and cladding thickness of typical fuel plates

plate number	Meat composition wt%	U-density gu/cm^3	Minimum cladding thickness mm	Fluctuation of meat thickness (%)	U-uniformity % +	U-uniformity % -
16-3	$47UAl_x$-53Al	1.1	0.34	±8	6.0	6.8
15-2	$88UAl_x$-12Al	2.6	0.32	±13	7.2	6.3
13-6	$92UO_2$-8Al	(6.2)	0.34	±10	5.0	4.5

From the data of 13-6 plate in Table 1 and Fig. 2, we can find when the fuel is changed from polygonal UAl_x to the simulating body of spherical UO_2, though the volume content of the fuel has increased about three times, that is above 60 vol%, the fluctuation of the meat thickness is ±10%, and the uranium uniformity is between +5.0% and-4.5%, the minimum cladding thickness is 0.34 mm. The changes are very small.

Fig. 1 and Fig. 2 show that there is no dogbone in each fuel plate mentioned above.

These results indicated that using the improved rolling technology, though the fuel content is 50 vol% high, we can still get the satisfactory fuel plates, in which the fluctuation of the meat thickness is not more than ±13%, the non-uniformity of uranium distribution is not more than ±7.2%, and the minimum cladding thickness is not less than 0.32 mm. The bonding quality is reliable. If the fuel is ball shape, the uniformity of the meat thickness can be improved more notably.

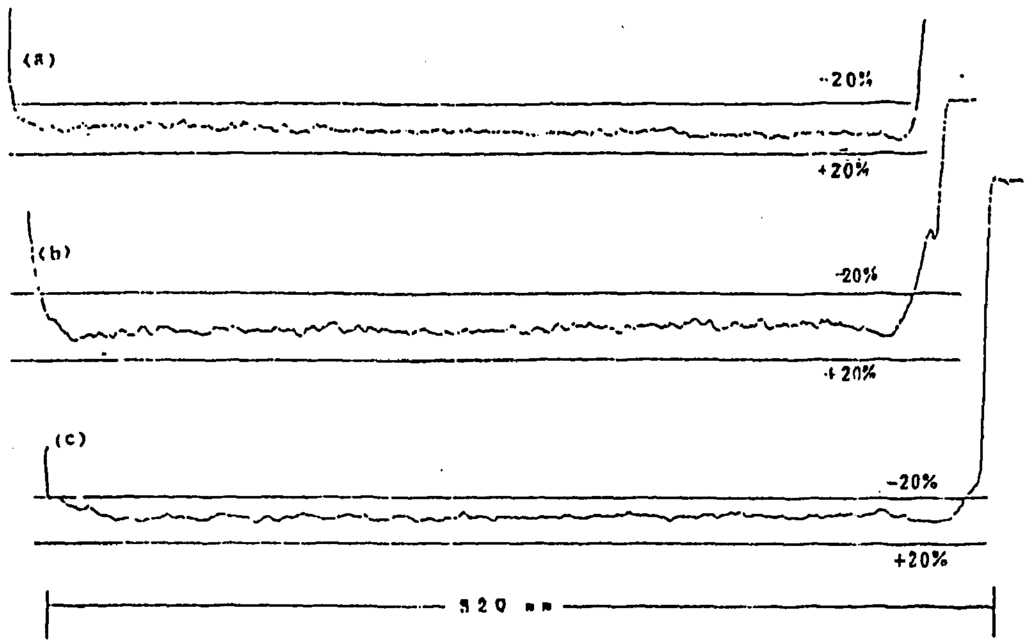

Fig. 2. The distribution curves measured by γ-ray absorption along the central line of fuel plates and the acceptable line of uranium distribution, i.e. fluctuate ±20% in the fuel element design

(a) 16-3 plate,low-uranium-content(47.2% UAl_x-52.8% Al) fuel plate

(b) 15-2 plate, high-uranium-content(88% UAl_x-12% Al) fuel plate

(c) 13-6 plate, 92% UO_2-8% Al spherical simulating fuel plate

(γ-ray collimation hole 4x4 mm)

As mentioned above, this paper only discribes the rolling technology of the fuel plates with uniform meat thickness. The fuel plates fabricated by this technology have not irradiated. We have also done some research work on the fabrication of U_3Si_2-Al fuel plate by the improved fabricating technology, and the preliminary results prove the effect is good. In addition, some simulating tests in which the spherical UO_2 was used showed that if fuel, e.g. U_3O_8, can be made into the compact tiny ball, the higher uranium density fuel plates can be expected, and strength of the meat and bonding quality can be improved.

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