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A Study on the Guide Tube Shrinkage Characteristics by Bulge Joint

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1. Introduction

Westinghouse type fuel skeleton assembly is fabricated by bulge joints between guide tube and grid sleeves to obtain structural integrity [1]. Bulge process is the method to joint overlap region between tube and sleeve mechanically by radial expansion causing plastic deformation through interaction between tapered pin and bulge tool as shown in Fig. 1 [2].

Bulge joint is a useful connecting method to overcome the difficulty of welding process in a lot of guide tube structures. But a length of guide tube is decreased due to the diametral expansions in bulge region. Its phenomenon must be considered in compatibility evaluation of guide tube and instrumenta -tion tube with other parts.

In this study, a series of bulge tests were performed for the skeleton design of advanced nuclear fuel. And then the shrinkage characteristics for guide tube material, bulge type and bulge height were analyzed. Also, the prediction equation of guide tube shrinkage rate according to bulge height was derived.

2. Bulge Joint Test

Bulge joint tests were performed using the manual bulge equipment owned by KEPCO NF as shown in Fig. 2. (a). The tapered pin as shown in Fig. 1 is moved along the axial direction by handling the knob of the pulling box in Fig. 2. (b) and then the bulge head is expanded radially. At this time, bulge joint is accomplished by plastic deformation on the overlap region between sleeve and tube specimen.

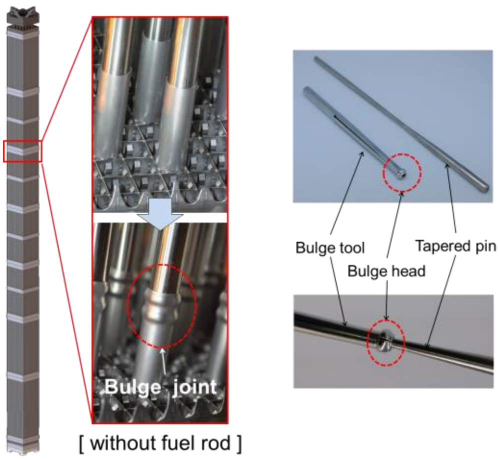

Fig. 1. Bulge Tool and Bulge Formation in Fuel Assembly

(a) Test configuration (b) Bulge pulling box
Fig. 2. Test Arrangement

Table I: Description of Test Specimens

Specimen Type	Material			No.
	DT	GT	Sleeve	
a) Zirc.T−STS S	-	Z1	SS	10EA
	-	Z2	SS	10EA
b) Zirc.T−Zirc.S	-	Z1	Z1	10EA
	-	Z2	Z2	10EA
c) Triple bulge	Z1	Z1	SS	10EA
	Z2	Z2	SS	10EA
d) Single bulge	-	Z1	-	10EA
	-	Z2	-	10EA

** Triple and single bulge mean 3 layers and 1 layer tube, resp.*
DT: Dashpot tube, GT: Guide tube, Zirc.: Zirconium alloy
T: Tube, S: Sleeve, Z1: Zirc.1, Z2: Zirc.2, SS: SS-304L

Test specimens were used to reflect each bulge type of skeleton assembly in Table I. The outer diameter change of tubes and the length shrinkage of guide tube were measured for before and after tests.

3. Guide Tube Shrinkage Characteristic

3.1 Material Effect

Table II represents the shrinkage rates for the bulge types only composed of zirconium alloy guide tubes. Fig. 3 shows the shrinkage rate distributions so as to demonstrate the characteristics between guide tube materials. The distributions of Z2 shrinkage rate are within the range of those of Z1 and the averages of Z1 appear somewhat higher than those of Z2. However, the shrinkage rate differences between materials are within the manufacturing tolerances, so it does not distinguish between zirconium alloy materials.

Table II: Avg. Guide Tube Shrinkage Rates for Materials [%]

Bulge type	Z1	Z2	Remarks
b)	0.211	0.207	Zirc.−Zirc.
d)	0.285	0.282	Zirc.

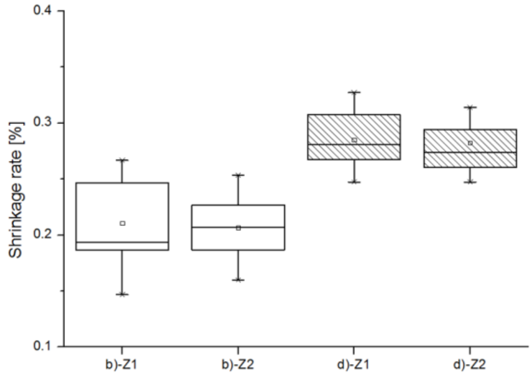

Fig. 3. GT Shrinkage Rate Distributions for Materials

3.2 Bulge Type Effect

Fig. 4 shows the shrinkage rates according to bulge types in order to determine shrinkage characteristics by design differences of bulge joint. a) and b) use the same tapered pin. But elastic modulus of SS-304L that was used as a sleeve material of a) is higher than that of zirconium alloy and a) appears higher shrinkage rate than b). d) is same condition with a) but the single bulge situation of d) that has no sleeve is higher shrinkage rate than a). Through these, the case increased guide tube shrinkage rate can be demonstrated into two kinds of reason. First, shrinkage rate is proportional to elastic modulus of sleeve because the bigger load is needed to make same diameter, the larger deformation appears in this process. Second is the single bulge case, since deformation is free due to absence of constrained component.

3.3 Bulge Height Effect

The guide tube shrinkage rates are represented in accordance with bulge height as shown in Fig. 5 to determine the correlation between two variables. The distributions of shrinkage rate are higher as compared with those of bulge height in all cases. This is the reason that the guide tube shrinkage is influenced by bulge shape as well as bulge height. The averages of test result for each bulge type are represented as shown in Table III. It can be known that the shrinkage of guide tube is increased as the bulge height is larger.

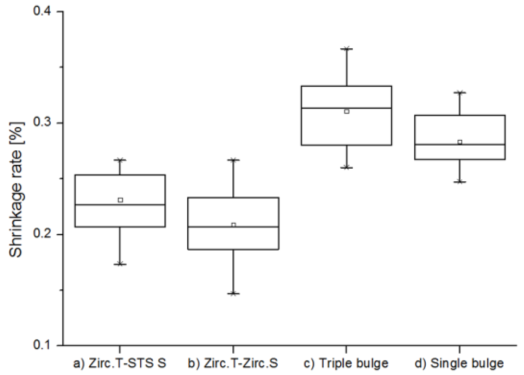

Fig. 4. GT Shrinkage Rate Distributions for Bulge Types

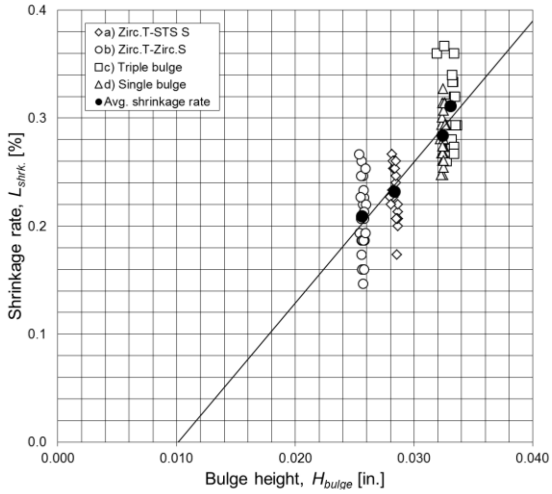

Fig. 5. Prediction Curve of Guide Tube Shrinkage Rate

Table III: Avg. Test Results for Bulge Types

Category	a)	b)	c)	d)
Shrinkage rate [%]	0.231	0.209	0.311	0.284
Bulge height [in.]	0.0284	0.0257	0.0331	0.0325

The relationship between two variables has derived as eq. (1):

$$L_{shrk.} = 13.056 \times H_{bulge} - 0.1319 \qquad (1)$$

where, $L_{shrk.}$: Length shrinkage rate of guide tube
H_{bulge}: Bulge height

The shrinkage rate of guide tube in accordance with bulge height by bulge joint is able be to predict through above equation. It will be applied to evaluate the compatibility of tubes (guide tube and instrumentation tube which has the same dimensions related to diameter with guide tube) with other components in the preliminary design of nuclear fuel development.

4. Conclusions

In this study, the axial shrinkage characteristics of guide tube by bulge joint were analyzed. The influences of guide tube material, bulge type and bulge height on the guide tube shrinkage were demonstrated. And then the prediction equation of guide tube shrinkage rate according to bulge height was derived and it will be useful for the nuclear fuel design and evaluation.

In the future work, the guide tube shrinkage rate equation will be improved by adding more data for bulge design of commercial fuel.

REFERENCES

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[2] J. Y. Yoo, N. G. Park, J. M. Suh, and K. L. Jeon, Shape Optimization Analysis of the Bulge Tool, Korean Nuclear Society Spring Meeting, 2011.