Evaluation of Specimen Geometric Effect for Laser Flash Thermal Diffusivity Test

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1. Introduction

KAERI(Korea Atomic Energy Research Institute) is developing a new type of nuclear reactor, the so called "SMART" (System Integrated Modular Advanced Reactor) reactor[1]. Alloy 690 was selected as the candidate material for the heat exchanger tube of of SMART's steam generator. The SMART R&D is now facing the stage of engineering verification and standard design approval for application of DEMO reactors. Therefore, the material performance under the relevant environment needs to be evaluated. The one of the important material performance issues is thermal conductivity, which the engineering database is necessary for the steam generator design. However, the neutron post irradiation characteristics of alloy 690 are little known. As a result, a PIE (Post Irradiation Examination) of the thermal properties have been plan for a 4 times, so called base line test, 1st irradiation test, 2nd and 3rd irradiation test. But there is some constraint to perform thermal diffusivity test owing to test specimen. Originally thermal diffusivity test are planed using disk shape with 9 mm diameter and 1 mm thick specimen. Due to mismatch of neutron irradiation schedule, thermal diffusivity will be tested by different shape and size specimens at 1st irradiation test. Therefore, verification of geometric and size effect are necessary for test specimen in order to achieve accurate test results.

2. Experimental

2.1 Thermal diffusivity test apparatus

Thermal diffusivity test for verification of geometric and size effect was performed by laser flash method proposed by Parker on 1961. This method is widely used in merit of rapid , accurate and use small specimen. The apparatus of examination is LFA-427 Laser Flash supplied by NETZSCH**.** Diffusivity measurement system is shown in Fig 1.

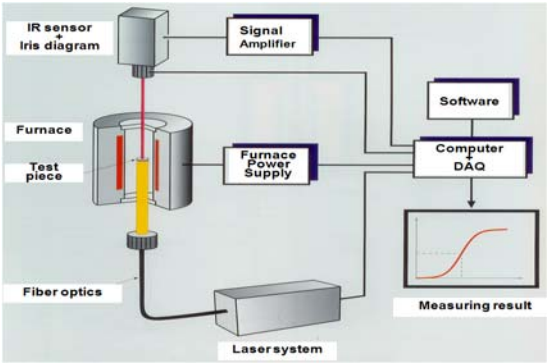

Fig 1. Schematic Diagram of LFA 427

2.2 Test specimens

We prepared two kind of specimen which were standard one having disk shape of 9 mm diameter with 1 mm thick and rectangular shape 10 x 10 mm with 2 mm thick nominal value respectively. Actual measured thickness of specimens are 0.992 mm and 1.982 mm respectively.

2.3 Test Procedures and Conditions

Because SMART heat exchange tube's operating temperature is about 250 ℃, test temperature condition is planed from room temperature to 250 ℃ by increasing 50 ℃ and from 250 ℃ to 350 ℃ by increasing 20 ℃. The test is performed five times for each specimen type. Each test run is repeated three times and averaged at individual test temperature. The test conditions of Laser are 450 V and 0.6 msec pulse width. Ambient gas is Ar with 250 ml/sec flow.

3. Results

3.1 Measurement results

The tables below show the measured thermal diffusivity results for disk and rectangular shape specimens.

Table 1 Measured thermal diffusivity for rectangular shape

(mm^2/sec)

Temp (℃)	1st	2nd	3rd	4th	5th
25	3.024	3.030	3.013	3.022	3.020
50	3.095	3.082	3.096	3.100	3.089
100	3.227	3.236	3.236	3.241	3.243
150	3.394	3.387	3.395	3.392	3.404
200	3.555	3.550	3.550	3.555	3.558
250	3.706	3.707	3.712	3.712	3.711
270	3.759	3.751	3.761	3.753	3.764
290	3.825	3.815	3.818	3.829	3.827
310	3.879	3.879	3.875	3.886	3.897
330	3.950	3.929	3.940	3.946	3.951
350	4.005	3.991	3.991	4.008	4.002

Table 2 Table 2 Measured thermal diffusivity for disk shape

(mm^2/sec)

Temp (℃)	1st	2nd	3rd	4th	5th
25	3.023	3.042	3.025	3.023	3.029
50	3.106	3.122	3.104	3.092	3.096
100	3.259	3.269	3.238	3.247	3.241
150	3.411	3.426	3.397	3.406	3.397
200	3.570	3.589	3.566	3.568	3.563
250	3.715	3.748	3.715	3.722	3.722
270	3.787	3.805	3.776	3.786	3.780
290	3.840	3.862	3.843	3.841	3.837
310	3.900	3.925	3.897	3.898	3.892
330	3.961	3.980	3.943	3.953	3.959
350	4.012	4.031	4.004	4.007	3.998

The figures 2-3 show thermal diffusivity value relevant test runs and temperature for each specimen type. The figure 4 shows difference of thermal diffusivity for rectangular and circular shape specimens.

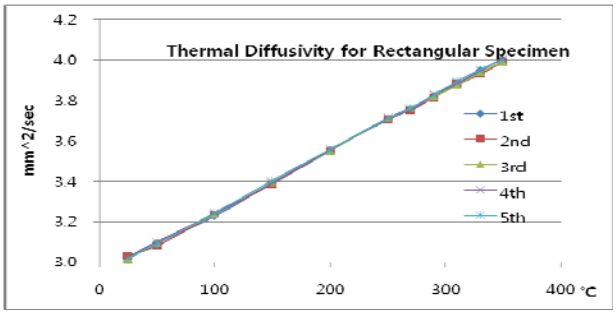

Fig 2. Thermal diffusivity for rectangular specimen

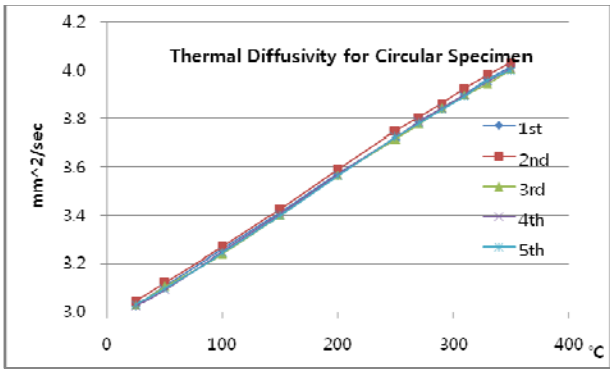

Fig 3. Thermal diffusivity for circular specimen

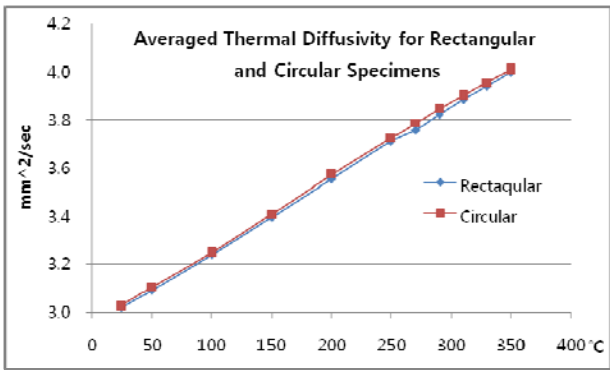

Fig 4. Averaged thermal diffusivity for rectangular and circular specimen

3.2 T-test of mean value

In order to evaluate the effects of specimen geometric effect, t-tests were performed through a null hypothesis, and the mean value of the two population is same. The test conditions can be expressed in statistical form. As

$$H_0: \mu_1 - \mu_2 = 0$$
$$H_1: \mu_1 - \mu_2 \neq 0$$

Table 3 T-test of two population for RT

	Circular	Rectang
Mean	3.0284	3.0218
Variance	6.38E-05	3.82E-05
No of measurements	5	5
Hypothesis for mean difference	0	
Degree of freedom	8	
t statistics	1.461265	
P(T<=t) one-side test	0.091039	
t critical value one-side test	1.859548	
P(T<=t) two-side test	0.182078	
t critical value two-side test	2.306004	

The confidence level of the test set up was 95% and thus the significance level is 5%. This means that the type-1 error is α=0.05. A t-test was carried out using MS Excell under the assumption of different variances for two populations. The t-statistic is within the t-critical value, and thus the null hypothesis is acceptable. We can conclude that the thermal diffusivity mean values of the two populations (rectangular and circular geometry) are the same at a confidence level of 95 %.

3.3 Analysis of variance(ANOVA) for one-way factor

In order to verify the effects of specimen geometric factor using more powerful method, ANOVA(analysis of variance) is adopted and compared with t-test. The null hypothesis is same as t-test and have same type - 1 error (α=0.05). The F-statistic is within the F-critical value, so thus the null hypothesis is acceptable. We can conclude that the thermal diffusivity mean values of the two populations (rectangular and circular geometry) are the same at a confidence level of 95 %. For the all temperature level, test results of statistical verifying method are equal output. Table 4 shows ANOVA result for room temperature.

Table 4 One way ANOVA table for RT

Level	No of Measurement	Sum	Means	Variance
Rect	5	15.109	3.0218	3.82E-05
Disk	5	15.142	3.0284	6.38E-05

source	Sum of Square	D F	Mean of SS	F-Statistic	P-Value	F Critical Value
SSA	0.000109	1	0.000109	2.135294	0.182078	5.317655
SSE	0.000408	8	5.1E-05			
Total	0.000517	9				

4. Conclusion

To verify the effect of specimen geometric factor, t-test and ANOVA(analysis of variance) at a 95% confidence level for all temperature ranges are performed. We can conclude that the thermal diffusivity mean values of the two populations (rectangular and circular geometry) are the same at a confidence level of 95 %. That mean there is no effect of geometric factor for a given specimen conditions.

REFERENCES

[1] S.K. Zee, et al., "SMART Reactor System Development," KAERI/RR-2846/2007, Korea Atomic Energy Research Institute, 2007.