Interlaboratory Study on Standard Test Method for Erosion of Solid Materials by a Cavitating Jet

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Abstract

A test method for erosion of solid materials by using a cavitating jet was standardized by ASTM G02 committee in 1995 as ASTM G134. However, an interlaboratory study ILS was not carried out. In order to revise ASTM G134, ILS was carried out in collaboration with four institutions. Five materials, i.e., pure aluminum A1070B, bronze CAC402, popular nickel NW2201, nickel 200 NW2200 and stainless steel SUS316L were tested in the ILS at each institution by using cavitating jet apparatuses, which were compliant with ASTM G134. It was revealed that the variation of the repeatability coefficient was from about 2 % to 7 % and the variation of the reproducibility coefficient was from 6 % to 22 %. Note that the variation of the coefficient in the same institute was about 1 % - 10 %.

Keywords: erosion; cavitating jet; material test

Introduction

As cavitation erosion causes severe problems on hydraulic machineries such as pumps and valves, experimental evaluation of material resistance to cavitation erosion is a big issue. A test method of cavitation erosion by using a cavitating jet is useful, as the effects of hydraulic parameters such as velocity and cavitation number on cavitation erosion can be examined.

The standard test method for cavitation erosion by using a cavitating jet was standardized in American Standard Testing of Materials ASTM as G134-95 [1], by the ASTM subcommittee G02.10 “Erosion by Solid and Liquids”, based on Lichtarowicz’s research [2, 3]. However, there were no results of interlaboratory study (ILS) presented in ASTM G134. In order to keep ASTM G134, an ILS was required, as it is necessary to investigate repeatability and reproducibility of ASTM G134. In order to maintain ASTM G134, an ILS was carried out by collaboration with four different institutions, i.e., Tohoku University, Nihon University, Fukui University and DYNAFLOW INC. under the task group chaired by Soyama, Tohoku University, who has worked with Lichtarowicz from 1994 to 1996 at the University of Nottingham. The revised ASTM G134 was proposed and voted in 2017, it is now available as ASTM G134-17 [4]. The present paper presents the ILS of ASTM G134-17, and the results of erosion tests on five materials using cavitating jet apparatuses, which were compliant with ASTM G134 at four different institutions are shown.

Experimental Facilities and Procedures

Figure 1 shows a schematic diagram of a test chamber of a cavitating jet apparatus which is compliant with ASTM G134. The pressurized water is injected into the chamber through a nozzle. The size of the test chamber in each institution is shown in Table 1. Table 2 shows test conditions of ILS. Figure 2 shows the geometry of the ASTM G134 nozzle. The aggressive intensity of a cavitating jet depends on the outlet geometry of the nozzle, and the aggressive intensity of the jet issuing from the ASTM G134 nozzle is larger than that of nozzles for water jet [5]. Thus, the nozzle geometry of ASTM G134-95 [1] was used in this ILS and the geometry of nozzle was not changed in ASTM G134-17 [4].

Table 1 Size of test chamber

	Diameter mm	Length mm
Tohoku University	50	50
Nihon University	50	50
Fukui University	40	44
Dynaflow Inc.	44.5	50

Table 2 Test conditions

Diameter of nozzle d	0.4 mm
Upstream pressure p_u	20 MPa
Static pressure in the downstream chamber p_d	0.28 MPa
Cavitation number σ	0.014
Temperature	297 ± 2 K

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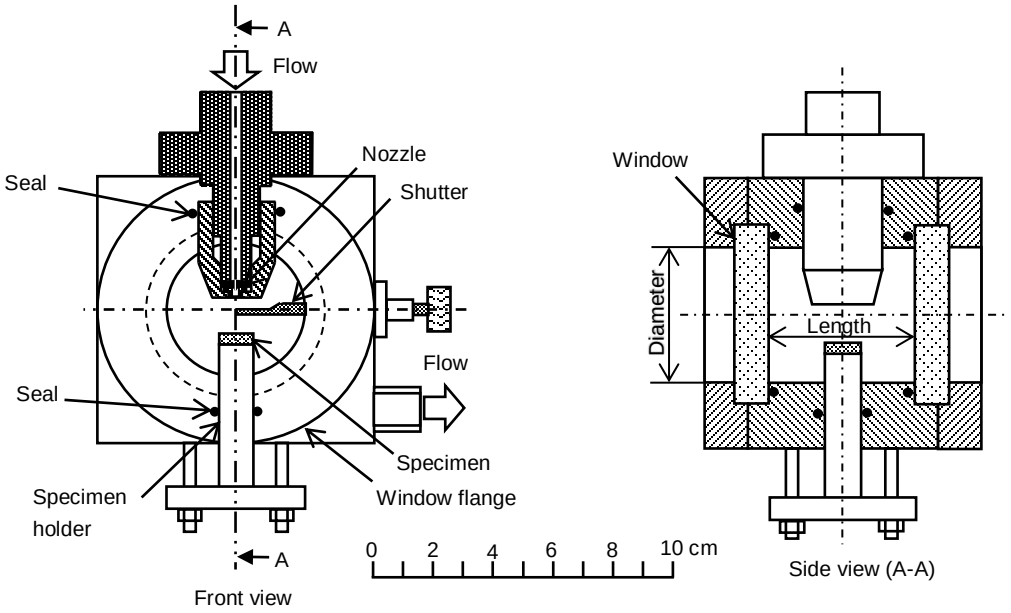

Figure 1 Schematic diagram of test chamber

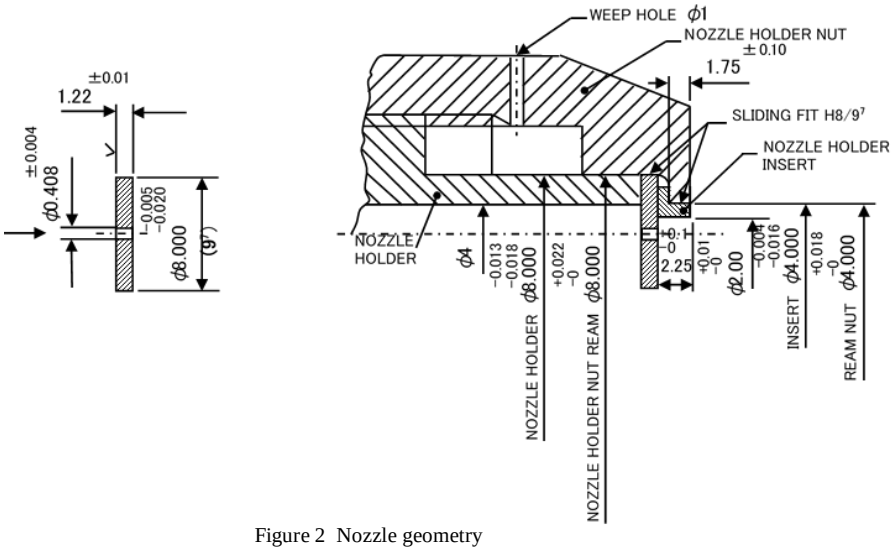

Figure 2 Nozzle geometry

The tested materials in this ILS were pure aluminum Japanese Industrial Standards JIS A1070B, bronze JIS CAC402, popular nickel JIS NW2201, nickel 200 JIS NW2200, and stainless steel JIS SUS316L. The erosion tests were carried out three times using the same materials in each institution.

Results

Figure 3 reveals the mass loss as a function of erosion time for five materials at each institution. As mentioned above, erosion test was carried out three times using each material, and the averaged value of the three results is shown in Fig. 3. For all cases, the erosion curve reveals an incubation period, an acceleration period, a steady state period, and an attenuation period. In ASTM G134-95, the maximum cumulative erosion rate is strongly recommended as the parameter to reveal a material resistance to cavitation. In order to investigate repeatability and reproducibility, the maximum cumulative erosion rate was examined. In Fig. 3, in the case of soft material such as pure aluminum A1070B, the difference between institutions is rather small. On the other hand, in the case of hard material such as NW2200 and SUS316L, the differences are relatively large.

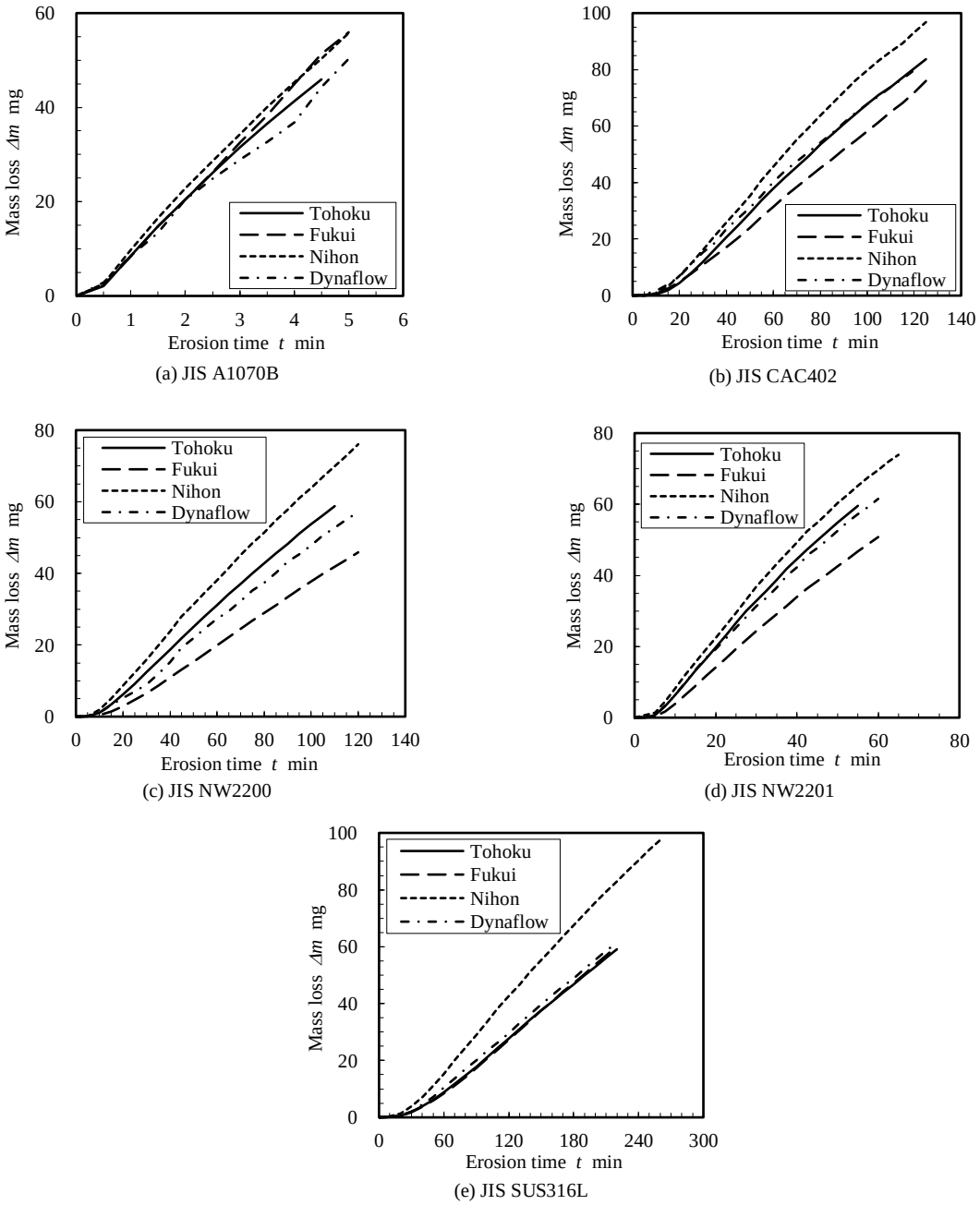

Figure 3 Mass loss changing with erosion time

Table 3 shows the maximum cumulative erosion rate at each institution, and repeatability and reproducibility of the maximum cumulative erosion rate. The coefficient of variation of three times in the same laboratory depends on the materials and it was about 1 % - 10 %. The repeatability and reproducibility were obtained as follows. For example, in the case of pure aluminum A1070B, the average values of each laboratory were 10.54, 11.45, 11.69 and 10.32 mg/min, respectively. Thus, the average of all laboratories averages was 11.00 mg/min. The standard deviation of each laboratory were 0.53, 0.81, 0.70 and 0.95 mg/min, respectively, and the average of laboratory variations was 0.75 mg/min. Thus, the repeatability coefficient of the variation was obtained by dividing 0.75 by 11.00, it was 0.068 = 6.8 %. Reproducibility was obtained from the standard deviation of 10.54, 11.45, 11.69 and 10.32 mg/min, and it was 0.67 mg/min. Then, the reproducibility of the variations was obtained by dividing 0.67 by 11.00, it was 0.061 = 6.1 %.

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Table 3 Maximum Cumulative Erosion Rate (mg/min)

	A1070B	CAC402	NW2200	NW2201	SUS316L
Tohoku University	10.54±0.53	0.685±0.028	0.538±0.017	1.119±0.013	0.271±0.003
coefficient of variation %:	5.1	4.0	3.2	1.2	0.9
Fukui University	11.45±0.81	0.608±0.007	0.383±0.035	0.858±0.024	0.274±0.019
coefficient of variation %:	7.1	1.2	9.2	2.8	6.9
Nihon University	11.69±0.70	0.812±0.055	0.648±0.021	1.244±0.032	0.379±0.005
coefficient of variation %:	6.0	6.7	3.2	2.6	1.4
Dynaflow Inc.	10.32±0.95	0.691±0.072	0.484±0.023	1.077±0.034	0.280±0.015
coefficient of variation %:	9.2	10.4	4.8	3.2	5.3
Average of laboratory averages:	11.00	0.699	0.513	1.074	0.301
	Pooled Variabilities—Absolute Values				
"Repeatability" standard deviation	0.75	0.040	0.024	0.026	0.010
"Reproducibility" standard deviation	0.67	0.084	0.111	0.161	0.053
	Pooled Variabilities—Normalized Values				
"Repeatability" coefficient of variation %	6.8	5.8	4.7	2.4	3.5
"Reproducibility" coefficient of variation %	6.1	12.1	21.6	15.0	17.5

The repeatability and the reproducibility depend on the materials and they varied as shown in Table 3 from 2 % - 7 % and 6 % to 22 %.
In the case of ASTM G32, repeatability and reproducibility coefficient of variation using Nickel 200 were 4.2 % and 10.3 %, respectively [6].

Conclusion

In order to keep ASTM G134, an interlaboratory study ILS was carried out in collaboration with four institutions using five materials, and the maximum cumulative erosion rates obtained were presented. It was revealed that the "Repeatability" coefficient of variation depends on the materials, and it varied from 2 % to 7 %. The "Reproducibility" coefficient of variation also changes from material to material from 6 % to 22 %. Here, "Repeatability" means the average of the standard deviation of each institution. "Reproducibility" was obtained from the standard deviation of the average of each institution. Note that the coefficient of variation in the same institute was about 1 % - 10 %.

References

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