Brittle Fracture Tests at Low Temperature for Transport Cask Materials*

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1. INTRODUCTION

The IAEA Regulations for the Safe Transport of Radioactive Material were revised in 1985, and brittle fracture assessment at low temperature for transport packages are now required. Several proposals for an international method for brittle fracture assessment of transport packages have been discussed at the IAEA Specialist Meeting. Japan also proposed a method at this meeting.

Type-B transport casks required brittle fracture assessment, and the cask body and bolt materials which comprise sealing systems are made of many types of materials, including ferritic carbon steel, austenitic stainless steel, and ductile cast iron. Accordingly, in practical assessment, the method should be checked for each material.

This report discusses the more practical method for brittle fracture assessment to type-B transport cask materials used in Japan.

2. BRITTLE FRACTURE TESTS

2.1 TEST OBJECT

In Japan, ferritic carbon steel, austenitic stainless steel and ductile cast iron are used in type-B transport cask body, and also ferritic carbon steel and precipitation hardening stainless steel are used in type-B transport casks' bolt material. In these material brittle fracture assessment should be required except only for austenitic stainless steel which shows high ductility (N. URABE, 1992).

Meanwhile, in the practical assessment, it should be the most desirable to use K_{Id} (or J_{Id}) values that directly obtained by dynamic fracture test.

Generally, dynamic fracture test needs special skill and equipment.

So, investigation of an easier test method substitute for the dynamic fracture test method should be desirable.

In this study, dynamic fracture toughness values, K_{Id} (J_{Id}), and RT_{NDT} values of low-Mn carbon steels which are used in type-B transport cask bodies, were also obtained to check whether or not an easier and conventional test method, that prescribed in ASME CODE SECTION III, can be substituted for the dynamic fracture test method.

And for bolt materials, toughness data were obtained for reference.

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2.2 TEST MATERIALS AND TEST ITEMS

Table 1 shows test materials and test items. These materials were chosen from typical materials of type-B transport casks used in Japan.
K_{Id} values were calculated from J_{Id} values that obtained by the dynamic fracture test conducted with ASTM E813 and E399. 10% side-grooved 1 inch (25mm) thick compact tension (ITCT) specimens were used and loading rates in terms of K were about 3×10^5 kgf/mm$^{3/2}$/sec.
And Fig. 1 shows drop weight J_{Id} testing machine which can control displacement.
Charpy V-notch tests were conducted with JIS Z 2242 and transition curves were obtained.
Drop weight tests were conducted with Japanese MITI 501 CODE for nuclear power plant that has same contents as ASME CODE SECTION Ⅲ.

2.3 TEST RESULTS

Examples of obtained test results are shown in Fig.2~ Fig.8, Table 2 and Photo 1. RT_{NDT} value of forging material was obtained as -42 ℃, and that of plate material was as -35 ℃.

3. APPLICABILITY OF ASME CODE SECTION Ⅲ

From the above test results the applicability of the RT_{NDT} - K_{IR} curve method, prescribed in ASME CODE SECTION Ⅲ, is investigated.

3.1 CASK BODY MATERIAL

Originally ASME K_{IR} curve is drawn mainly by Ni-Cr-Mo steels for nuclear pressure vessel, that are SA533 C1.1, SA508 C1.2, SA508 C1.3, etc., and this curve does not depend on sufficient data of the other type of carbon steels which include low-Mn steel.
As shown in Fig. 2 and Fig. 4, all of the K_{Id} values of low-Mn carbon steels are over the ASME K_{IR} curve. So, it is possible that the conventional RT_{NDT} - K_{IR} curve method can also be used for this type of material which used in the cask body.

3.2 BOLT MATERIAL

In ASME CODE SECTION Ⅲ bolt material should be assessed only for Charpy V-notch test, because of the simple and uniform stress condition on bolt material of nuclear pressure vessel. However, stress conditions on cask bolts depend on each cask design and on accident condition, and it may be multi axial and very complex.
Accordingly, as for bolt material except for Austenite stainless steels which shows high ductility, brittle fracture assessment by using K_{Id} (J_{Id}) value should be desirable.
And in this asessment anisotropic of fracture toughness of bolt material, as shown in Fig. 6, Fig. 7, Fig. 8 and Table 2, should be considered.

4. CONCLUSIONS

The conclusion of this paper are:

1) All the obtained K_{Id} (J_{Id}) values of SA 350 Gr.LF1 Modify and SA 516 Gr.70 meterial, which used in cask body, were over the ASME K_{IR} curve.

2) So, it is possible that the conventional RT_{NDT} - K_{IR} curve method prescribed in ASME CODE SECTION Ⅲ can also be used for low-Mn carbon steels, which are used in the cask body.

3) But, for bolt materials except for Austenite stainless steels, brittle fracture assessment by using K_{Id} (or J_{Id}) values should be desirable with considering anisotropic of material properties.

REFERENCES

N. URABE : unpublished data "Draft of Hand Book of Stainless Steel, the 3rd. edition", 1992.

Table 1 Test materials and test items

Test Materials		Nominal Thickness (mm)	Test Items	Objective
For Cask Body	1) Low-Mn Carbon Steel Forging JIS G3202 SFVC 2B (equal to ASME SA350 Gr.LF1)	370^T	o Charpy V-notch test o Drop weight test o Dynamic fracture test (J_{Id} test)	o To check for the applicability of the conventional RT_{NDT}-K_{IR} curve method that prescribed in ASME CODE SECTION Ⅲ
	2) Low-Mn Carbon Steel Plate ASME SA516 Gr.70	47.5^T	o Charpy V-notch test	
		118^T	o Drop weight test o Dynamic fracture test (J_{Id} test)	
For Cask Bolt	1) 1.8Ni-0.8Cr-0.3Mo Carbon Steel for Bolt JIS G4108 SNB24-3	175φ	o Charpy V-notch test	o For reference
	2) Precipitation Hardening Type 630H Stainless Steel for Bolt JIS G4303 SUS630 H1075	195φ	o Charpy V-notch test (Several orientation and position) o Dynamic Fracture Test (J_{Id} tset only for -40℃)	o For reference (To check anisotropic of material properties.)

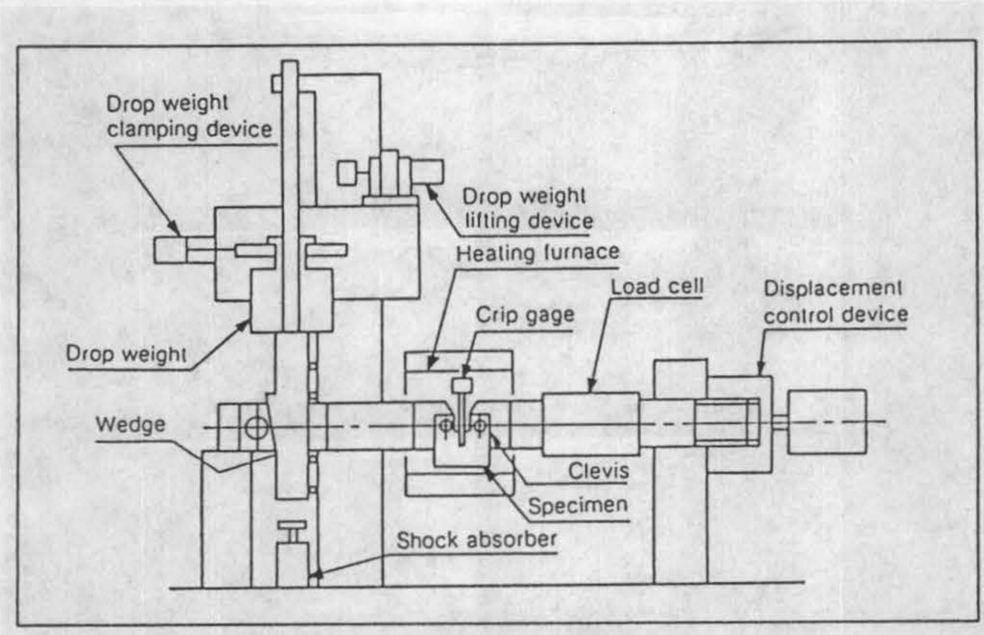


Fig. 1 Drop weight J_{Id} testing machine

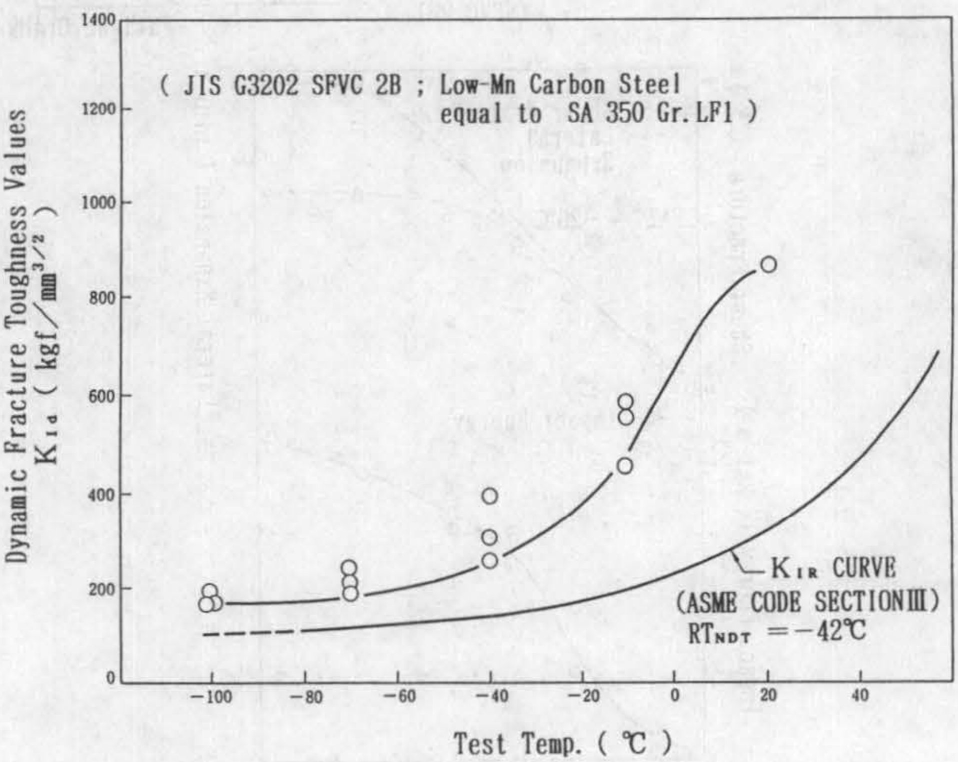
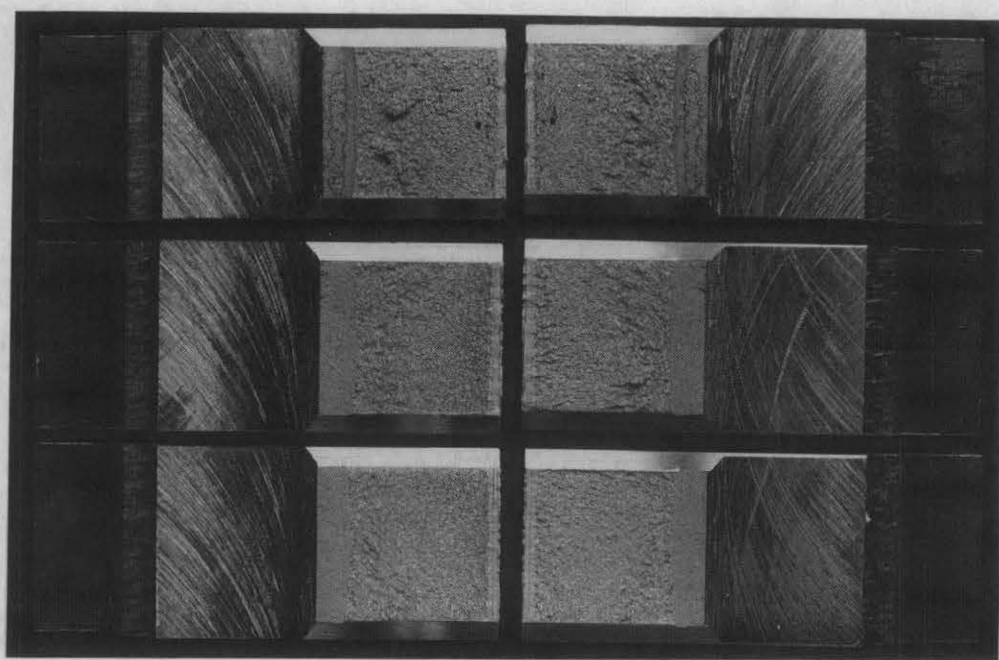
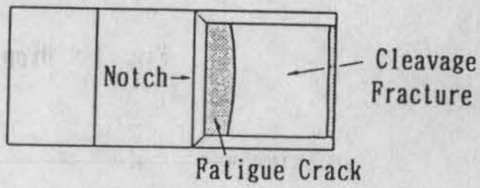


Fig. 2 Relationship between K_{Id} (J_{Id}) values of forged materials and temperature (1/2 T x 1/4 T , L-T Direction)



-40°C

Photo. 1 One example of fracture surface of 1TCT specimens after dynamic fracture tests (SFVC 2B)



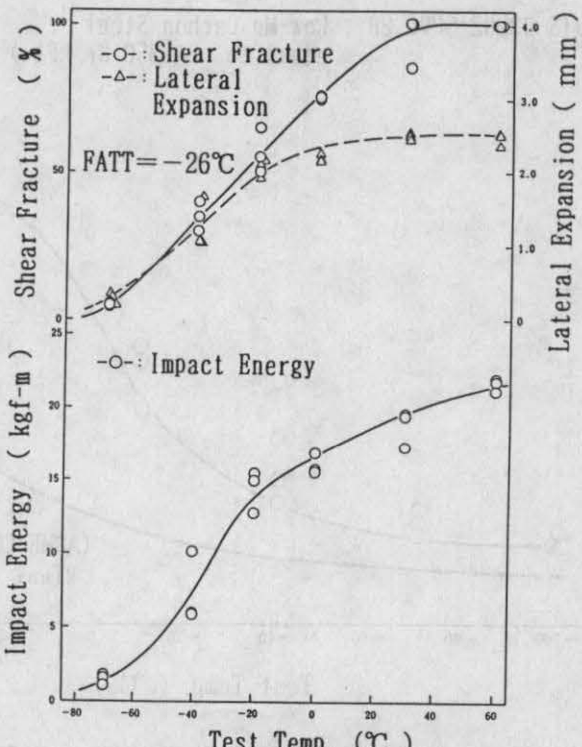


Fig. 3 Charpy V-notch test results of forged material (SFVC 2B) (T x 1/4 T , axis of forging)

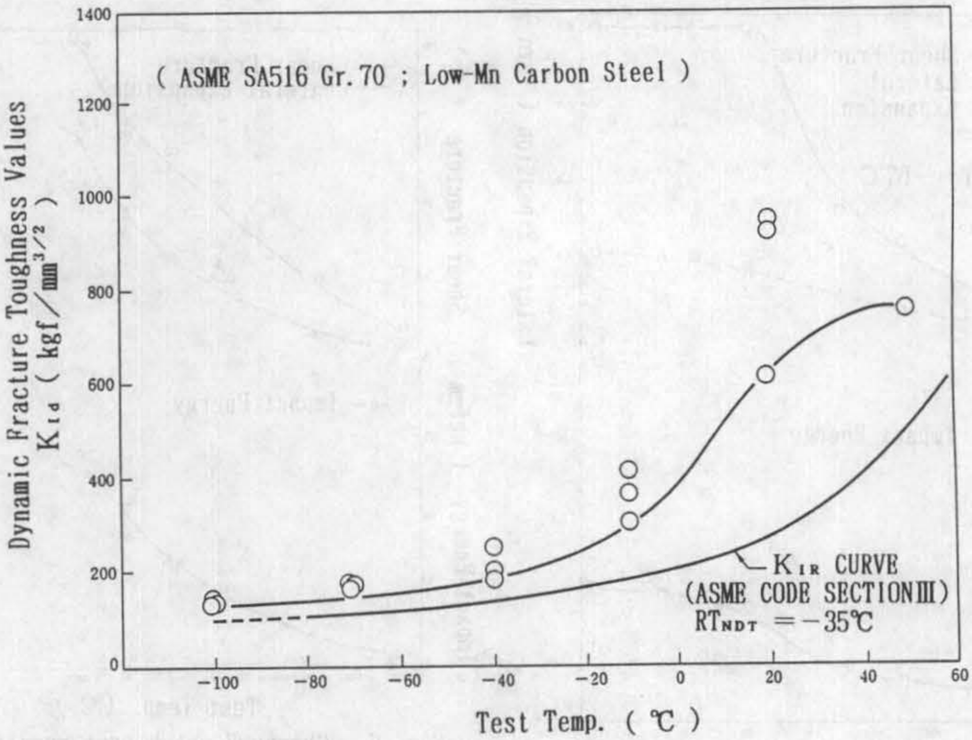
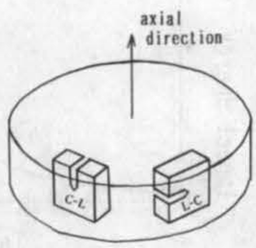


Fig. 4 Relationship between K_{Id} (J_{Id}) values of plate materials and temperature (1/4 T , T-L Direction)

Table 2 K_{Id} (J_{Id}) values of bolt material (Type 630 H1075 stainless steel)

Position	Orientation	Test Temp. (℃)	Dynamic Fracture Toughness Values K_{Id}(kgf/mm$^{3/2}$)
(*1)	L-C	- 40	521.5
			602.8
			653.6
1/4D	L-C		437.2
			592.1
(*1)	C-L		429.2
			406.0
1/4D	C-L		329.6
			413.7
			416.7

(*1) 20mm apart from the surface of the bar.



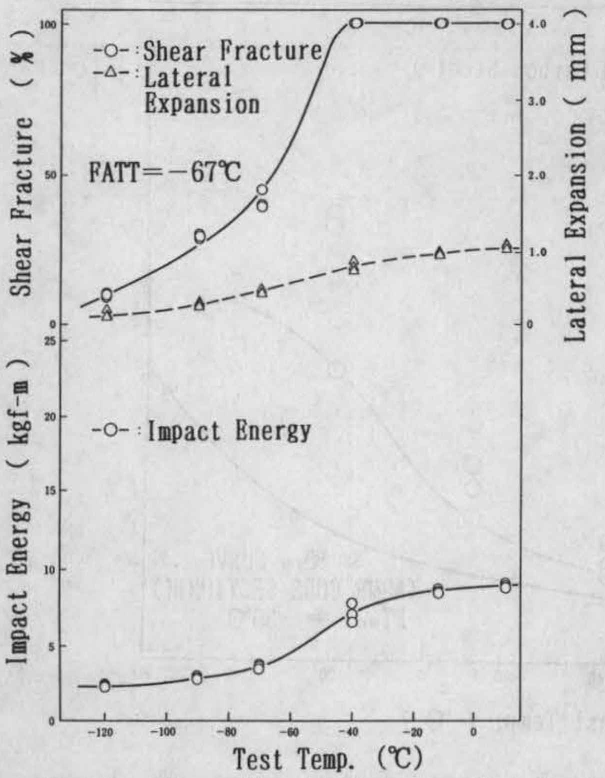


Fig. 5 Charpy V-notch test results of bolt material (SNB 24-3) (According to JIS , axial)

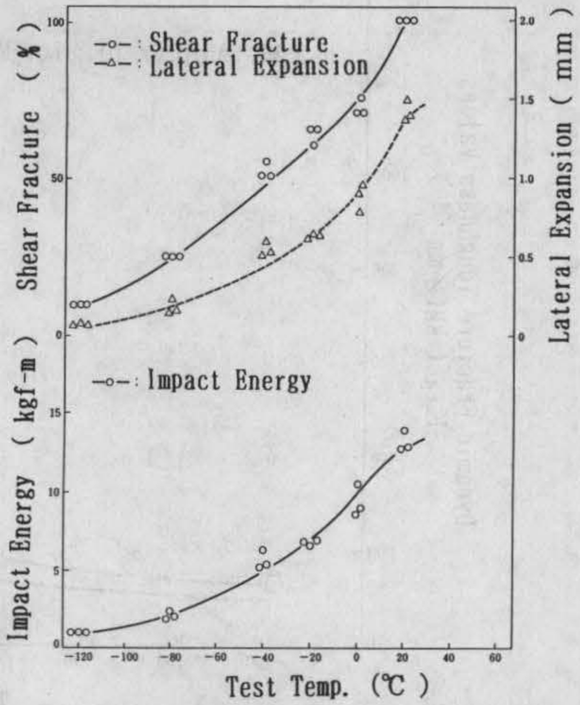


Fig. 6 Charpy V-notch test results of bolt material (Type630 H1075) (1/4 D , axial)

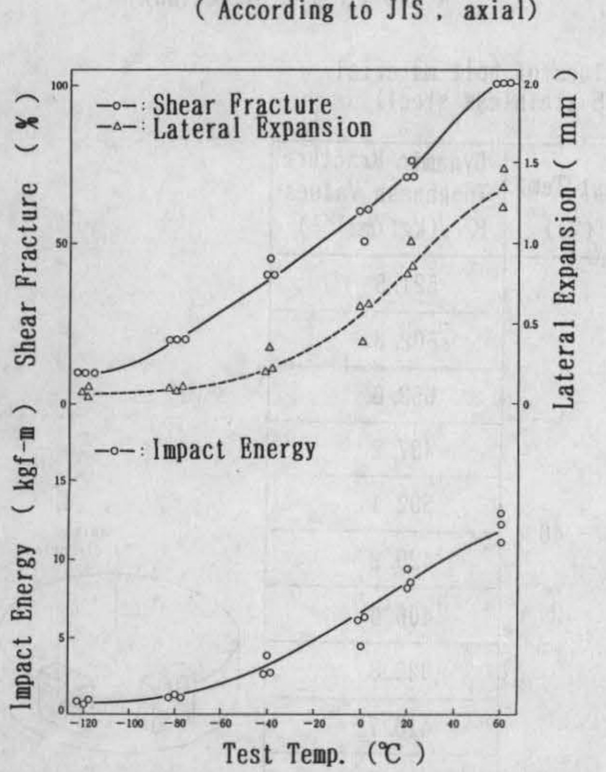


Fig. 7 Charpy V-notch test results of bolt material (Type630 H1075) (1/4 D , circumferential)

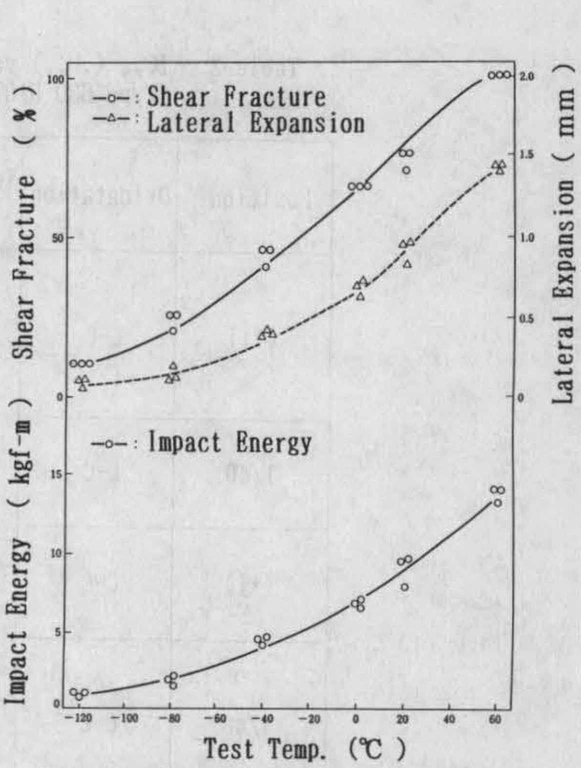


Fig. 8 Charpy V-notch test results of bolt material (Type630 H1075) (20mm apart from surface, circumferential)