Evaluation of Fracture Toughness for Japanese Reactor Pressure Vessel Steel using Master Curve Method

Background

The Master Curve method has been proposed and recognized worldwide as an alternative approach to evaluate fracture toughness of reactor pressure vessel (RPV) steels. The method theoretically provides the confidence levels of fracture toughness in consideration of the statistical distribution, which is a natural property of fracture toughness.

Objectives

In this study, single variable fracture toughness tests to identify the effects of test temperature, specimen size, and loading rate were conducted for one of the modern Japanese RPV steel, SFVQ1A, and the applicability of the Master Curve method was investigated.

Principal Results

1. Valid Master Curves can be determined using the procedure of the ASTM standard. It was verified that the scatter of fracture toughness well fits within the Weibull distribution, which is the important precondition to apply the Master Curve method.

2. The differences in test temperature and specimen size do not affect the Master Curves. In contrast, the increasing of loading rate significantly shifts the Master Curve to the higher temperatures.

3. The lower bound curve based on the master curve can conservatively envelop all of the experimental fracture toughness data. The present rule, in which the lower limit of fracture toughness is indirectly determined by Charpy impact test results, can be too conservative, while the application of the Master Curve method may significantly rationalize the allowable level of fracture toughness.

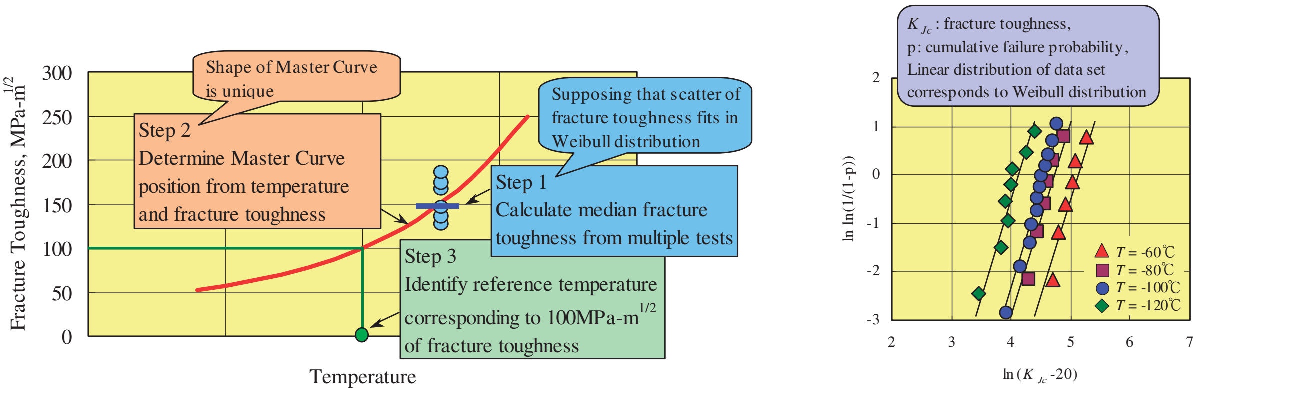
Future Developments

We are working on the establishment of the Master Curve method based on instrumented Charpy impact tests with sub-size specimens.

Main Researcher: Naoki Miura,
Senior Research Scientist, Structural Materials Characterization Sector, Materials Science Research Laboratory

Reference

N. Miura, et.al., 2005, “Applicability of Master Curve Method to Japanese Reactor Pressure Vessel Steel SFVQ1A” , Technical Report Q04020 (in Japanese)



(a) Evaluation Procedure of Master Curve (b) Weibull Plots of Fracture Toughness (1T C(T))

Fig.1 Evaluation Procedure of Master Curve and Statistical Distribution of Fracture Toughness

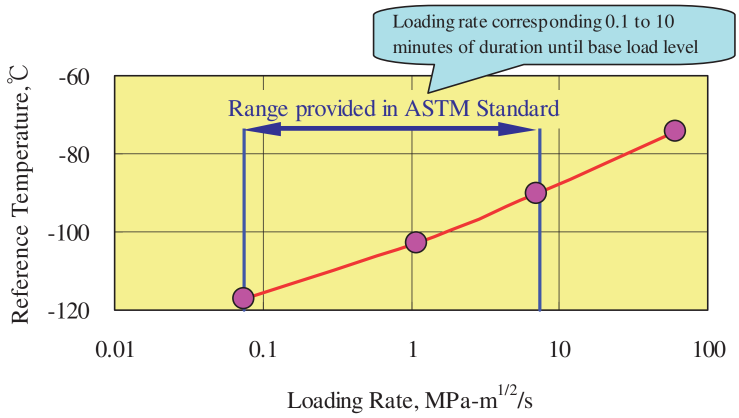


Fig.2 Effect of Loading Rate on Master Curve (Based on Comparison of Reference Stress)

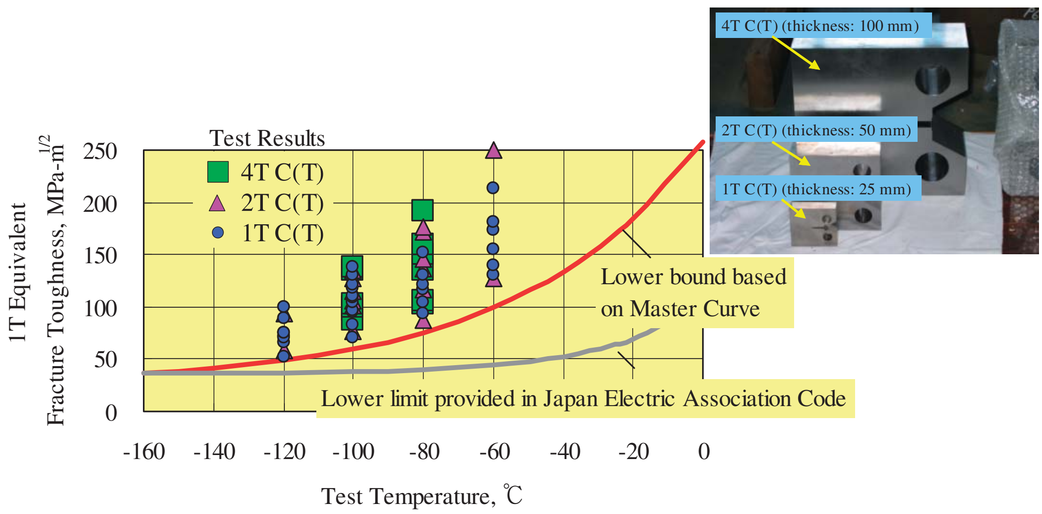


Fig.3 Comparison of Lower Bound of Master Curve with Lower Limit Provided in Present Code