SI0200036

Nuclear Energy in Central Europe '99
Portorož, Slovenia, 6 to 9 September, 1999

FLAW EVALUATION CHARTS

Darko Korošec, dipl.ing.
Slovenian Nuclear Safety Administration
Vojkova 59, 1000 Ljubljana, Slovenia

Doc. dr. Jelena Vojvodič Tuma
Institute of Metals and Technology
Lepi Pot 11, 1001 Ljubljana, Slovenia

Abstract

The structural integrity of the primary components in pressurized water reactor nuclear power plant is very important in the respect of safe and efficient operation. These components have to be subjected to periodic controls.
In the light of fracture mechanics concept, the acceptance criteria for detected defects (flaws) are developed. Flaw evaluation procedure is necessary, to evaluate the defects regarding their acceptability for further operation.
The objective of the flaw evaluation charts is to provide a series of simple graphs as decision maps, that immediate decision may be taken regarding the acceptability of a detected defects, on the basis of ASME Code XI criteria.

1. Introduction

The reactor pressure vessel is one of the vital parts of reactor primary coolant system. It's structural integrity is controlled periodically within the scope of inservice inspection program, which deals with integrity of the primary reactor coolant pressure boundary. This program is established in Section XI of the ASME Code. Minimum periods required for such inspection are specified in this document. The locations of pressure vessel for inspection are determined in this documents, most critical locations are the longitudinal welds and the welds of the nozzles. Nondestructive techniques (ultrasonic, eddy current, surface tests) are the common techniques used in inservice inspection.
To develop flaw evaluation chart the fracture mechanics analytical analysis is necessary. This analysis is relatively complex because of the large volume of data to be handled, such as the different stress and temperature distributions with time in the different transients contemplated in the design specifications.

2. Objectives of the flaw evaluation chart

The main objective of flaw evaluation chart is to provide a simple graphic presentation of the acceptability of a postulated defects (flaws) on the basis of its characteristic dimensions : shape factor and relative depth.
Characteristic dimensions are those described in relevant articles of the ASME Boiler and Pressure Vessel Code, Section XI. By this code, the following characteristic dimensions are used for characterisation of the flaw:

- **shape factor a/l** : depth of the flaw (a) versus length of the crack (l),
- **relative depth a/t** : depth of the flaw (a) versus thickness (t) of the observed loction of the reactor pressure vessel
- **surface proximity parameter δ/t** : distance from flaw centerline to surface (δ), for embedded flaws only, versus thickness (t) of the observed location

The dimensions of the flaw must not exceed the maximum permissible values established in article IWB-3500 of the ASME Code applicable to the plant. In the case, that the flaw dimensions are exceeded, the flaw have to be repaired. On the other hand, the ASME Code allows the plant to continue with the operation without the flaw to be repaired as long as an analytical fracture mechanics study, performed in accordance with the article of the ASME Code article IWB-3600, demonstrates that the dimensions of the flaw will not grow to a given critical value within a certain evaluation period.
The overall acceptability of the flaw observed is governed by the acceptance criteria in the articles listed in ASME Section XI.
The flaw evaluation chart should be developed in advance for different locations (areas) of reactor pressure vessel inspection, or consequently for other components and its locations in the frame of inservice inspection program, like primary coolant piping, primary reactor coolant pump casing etc.
In the case of indications (flaws) discovered during inservice inspection one can use flaw evaluation chart for immediate comparation of their typical parameters (shape factors) regarding their acceptability without analytical evaluation at that time. Flaw evaluation chart prepared in advance shows the acceptable region regarding flaw depth ratio versus flaw shape, for each period of inservice inspection program.

3. Different evaluations needed

The flaw evaluation is based on the principles of fracture mechanics. Its basic equations relate the following parameters:

- flaw size and shape
  stress field applied to the structure for normal operation or emergency conditions (transients)
- fracture toughness profiles of the material for different evaluation time increments in transients
- stress intensity factor in accordance with the effect of neutron irradiation

- fatigue induced crack growth rate as a function of the fluctuatuion of the stress intensity factor

To establish the flaw evaluation chart for certain position (weld) of a reactor pressure vessel all necessary fracture mechanics parameters shall be collected and used in mathematical expressions, listed in relevant articles.

4. Flaw evaluation charts

The results of previous listed evaluation lead to the chart on which the shape factor a/l (shape factor) varying from 0 to the ASME Code Section XI limit 0,5 is represented on the abscissa and on the ordinate side are the maximum permissible values of the a/t (depth/thickness) relationship.
An example of the flaw evaluation chart is presented on Figure 1.
Such chart should be developed in advance, that means in the case some of flaws were found during inservice inspection periodic examination, their indication parameters may be plotted directly on the chart to determine their acceptability. In such case, real flaws are compared to the flaws previously analysed and on which characteristics flaw evaluation chart was developed.
On such chart more curves should be established on the basis of the time intervals from fatigue crack growth calculation, tipically such as 1, 10, 20 and 30 EFPY (Effective Full PowerYears).

5. Conclusions

For development of flaw evaluation chart it is necessary to perform detailed analysis of all above mentioned parameters and what is most important, consideration of all transient conditions. Usually, only the governing transients for different operational modes are considered.
It is obvious that for the calculation of all input parameters the computer code specially developed for this purpose is needed, specially in the case of adjusting important values as a result of destructive testing of reactor vessel material samples or changes in some guidelines and rules for analytical fracture mechanics procedure.
ASME Code in Section XI provides guidelines and evaluation procedures with acceptance criteria for pressure retaining components of different classes. Some of the important parameters are idealised, like for example, representation of stresses in pressure vessel shell or method for stress intensity factors determination. Using the results of different relevant studies for behaviour or pressure vessel during transients the procedure for flaw chart development should be significantly improved.
Nevertheless flaw evaluation charts shall be treated as a tool for quick and reliable evaluation of the indications discovered during inservice inspection and no further time is needed for analytical fracture mechanics evaluation at that time since it is in such form already done in advance.

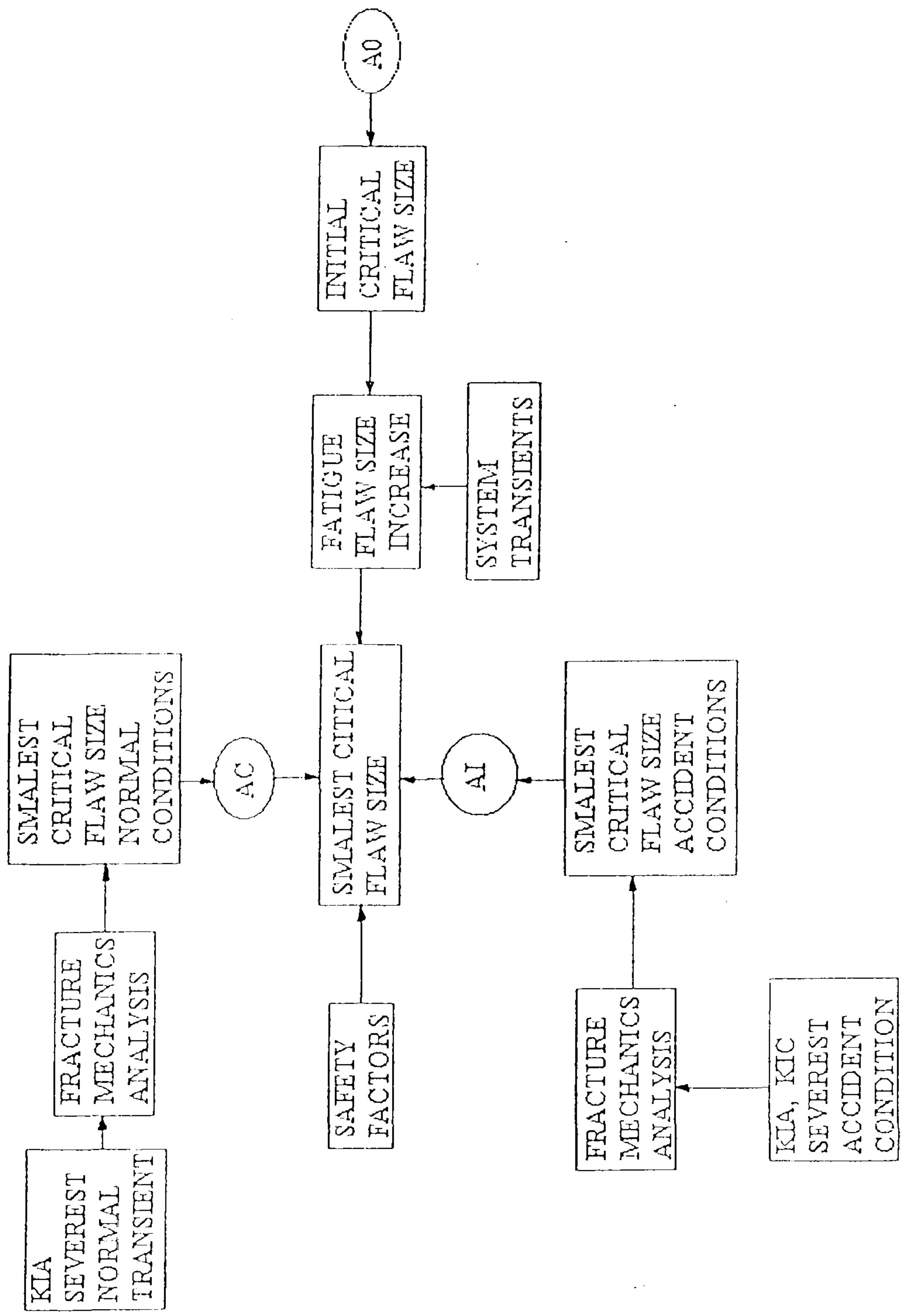

Figure 1. Determination of the initial flaw size

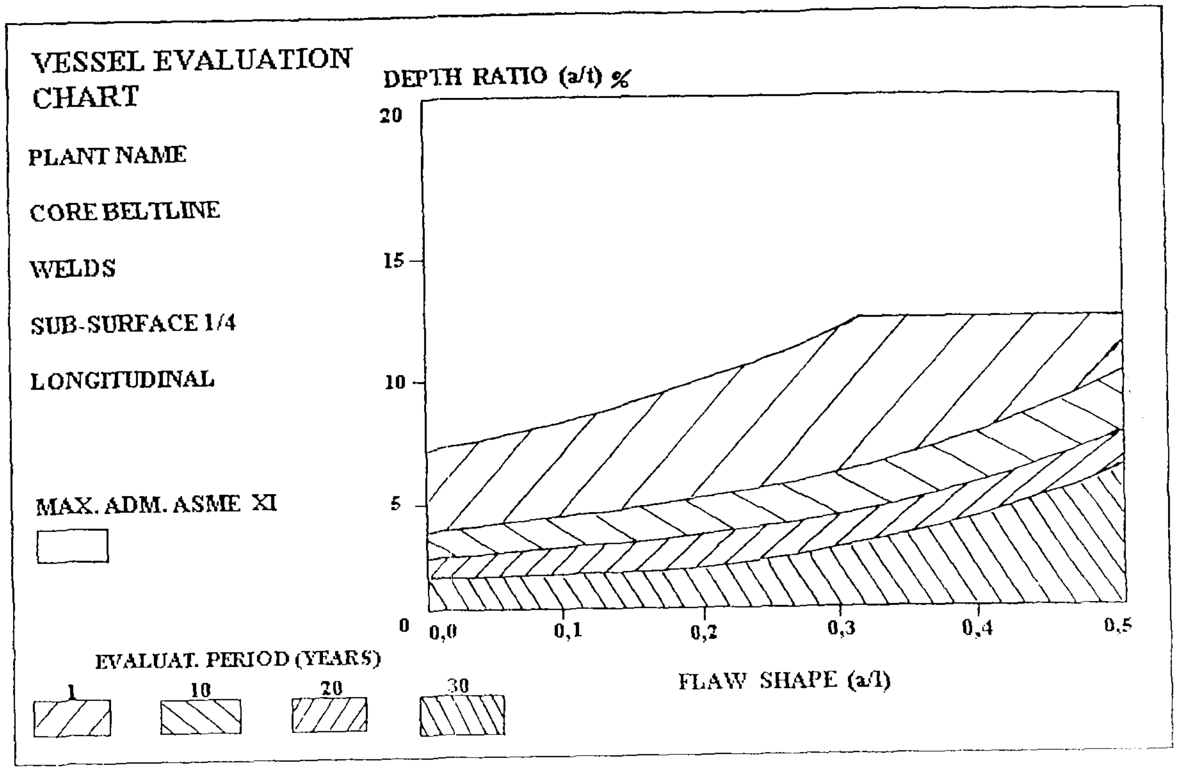

Figure 2. Example of the flaw evaluation chart

6. References

[1] ASME Boiler&Pressure Vessel Code 1992 Edition , Section XI, Rules for Inservice Inspection

[2] Radiation Embrittlement of Reactor Vessel Materials;U.S.Nuclear Regulatory Commission. Regulatory Guide 1.99, Rev. 2, May 1988

[3] Tecnatom S.A.: Specification for the Realization of the Flaw Evaluation Handbook of a Reactor Vessel