RULE BASED EXPERT SYSTEM ON THE BASIS OF ESTIMATED TECHNIQUE FOR THE SAFETY EVALUATION OF VARIOUS MATERIALS.

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ABSTRACT

The integrity of components in petroleum, chemical and power generation industries in the country is of paramount importance. Flaws and cracks developed in large complex structures due to service and environmental conditions may result in dramatic and catastrophic failures which may cause loss of lives and properties. In this paper an attempt has been made to predict the safe - fail modes of a component by developing rules based on fracture mechanics techniques for the safety evaluation of various materials. The ASME Boiler and pressure vessel code section XI and Article K-4000, ASME code BSI PD 6493:1991, PD6593:1994 were considered in such estimation. Evaluations of defects were determined by Non-Destructive-Testing methods, Ultrasonic and Acoustic Emission. Four methods for safety evaluation were considered here. Necessary knowledge was given by experts in different organizations. The inputs and tedious calculations were minimized to save time and cost. The technique has been validated by existing rules and results obtained from a reputed organization.

INTRODUCTION

We are faced with unexpected material failure due to fatigue, creep and stress corrosion cracking in structures used for public service, and machine structures in many fields of industry. These failures have been energetically researched throughout the world. The operating conditions in high temperature and pressure plants have been dangerous. Many environments, corrosive to structural materials due to environment faced with many serious failures of structural materials due to environment assisted fracture (EAF) resulting in a huge amount of social loss [1].

In many practical applications, it is clear that the sizes of defects needed to produce catastrophic, brittle fractures under services stresses are so large that the defects could always be detected and eliminated, by repair work, before the piece entered service. Nevertheless, catastrophic failures can occur , if initially small defects grow to critical lengths during operation, by subcritical crack growth mechanism such as fatigue. The success of conventional linear elastic fracture mechanics in characterizing the final fracture event in terms of parameters which can be related to the applied stresses on a structure has led to attempts to characterize subcritical crack growth by similar methods [2].

The rule based expert system is based on estimated technique to calculate the Safe-Fail made of different materials by using fracture mechanics. Development of rules are demonstrated by developing semantic network [fig-1].The network describes the decision path by considering the plane stress and plane strain states.Linear elastic fracture mechanics regim is for plane stress state and elastic plastic fracture mechanic (EPFM) regim for plane strain state.

Evaluation of defects

Defect were evaluated by considering four criteria's including Flaw size criteria (FSC), Applied Stress Internality Factor Criteria (ASIF), Failure Assessment Diagram (FAD) and Allowable Flaw Depth by acceptance standard (AFD)

Description for evaluation of defects

Flaw Size Criteria (FSC)

A critical flaw size is determined by using this criterion by considering article IWB-3600 ASEM code. A flaw exceeding the limits of IWB- 3500 is acceptable if the critical flaw parameters satisfy the following.

$a_f < 0.1\ a_c$ [mode is considered safe]

$a_f < 0.5\ a_i$ [mode is considered safe]

Where a_f is the maximum size to which the detected flaw is calculated to row in a specified time period. a_c is the minimum critical flaw size of the flaw under normal operating conditions and a_i the minimum critical flaw size of the flaw under emergency and faulted condition[3].

Applied Stress Intensity Factor (ASIF)

A flaw exceeding the limits of IWB-3500 is acceptable if the applied stress intensity factor and the flaw size a_f satisfy the following:

(a). For normal condition.

$K_1 < K_{1a}$ /SQRT 10 [mode is safe]

$K_1 > K_{1a}$ /SQRT 10 [mode is fail]

Where K_1 is the maximum applied stress intensity factor for normal condition (defined in IWB -3611) and K_{1a} is the available fracture toughness based on crack arrest for the corresponding crack tip temperature.

(b). For emergency and faulted conditions.

$K_1 < K_{1c}$ / SQRT 2 [mode is safe]

$K_1 > K_{1c}$ / SQRT 2 [mode is fail]

Where K_1 is the maximum applied stress intensity factor for the flaw size a_f under emergency and faulted conditions and K_{1c} the available fracture toughness based on fracture initiation for the corresponding crack tip temperature [4].

Failure Assessment Diagram (FAD)

An experimentally evaluated curve was used for the safety evaluation. The curve was drawn by considering different values of K_r and S_r .Material is considered safe below this curve and fail above this curve [FIG-2]

Allowable Flaw Depth (AFD)

(a) Components whose visual examination confirms the absence of the relevant conditions described in the standard table IWB – 3410-1 shall be acceptable for service.

(b) Components whose visual examination detects the relevant conditions described in the standards of table IWB – 3410-1 shall be un acceptable for service.

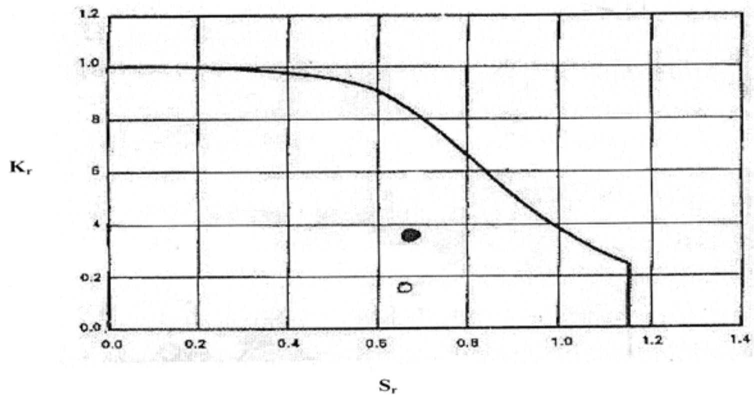
Semantic network

A special type of network which is used to indicate the path for decisions (FIG-1). All variables used in this network described in the variable parameter table.

Variable parameters

These parameters are used in semantic network to demonstrate the rule based programming path.

CODES	**DESCRIPTION**
FM	Fracture Mechanics
LEFM	Linear Elastic Fracture Mechanics
EPFM	Elastic Plastic Fracture Mechanics
PSN	Plain Strain
PSS	Plain Stress
THE	Theoretical Stress Intensity Factor
EXP	Experimental Stress Intensity Factor
EST	Estimated Stress Intensity Factor
EOD	Evaluation Of Defects
FSC	Flaw Size Criteria
ASIF	Applied Stress Intensity Factor Criteria
FAD	Failure Assessment Diagram
AFD	Allowable Flaw Depth by acceptance standard
FNC	For Normal Conditions
FEFC	For Emergency & Faulted Condition
AAL	Above Assessed Line
BAL	Below Assessed Line
CON-IWB	Table IWB3410-1 ASME Boiler &Pressure Vessel Code Section IX
ABS	Absence of IWB3410-1 parameters (acceptable)
PRS	Presence of IWB3410-1 parameters (unacceptable)
K_1LE	K_1 less than K_{1a}/SQRT10 (For normal condition)
K_1GR	K_1 Greater than K_{1c}/ SQRT2
D1,2,3,4	Decisions for corresponding evaluations



Failure Assessment Diagram

Estimated Decisions.

NO	VARIABLE	MODE
1	DIFSC	(Safe)
2	D2FSC	(Safe)
3	D3FSC	(Fail)
4	D1ASIF	(Safe)
5	D2ASIF	(Fail)
6	D3ASIF	(Safe)
7	D4ASIF	(Fail)
8	D1AFD	(Safe)
9	D2AFD	(Fail)
10	D1FAD	((Fail)
11	D2FAD	(Safe)

Development of Rules.

RULE 1:	**RULE 2:**
D1FSC	**D2FSC**
IF science is F.M.	IF science is F.M.
AND regim is LEFM.	AND regim is LEFM.
AND state is Plane strain.	AND state is Plane strain.
AND Material is Brittle.	AND Material is Brittle.
AND Loading Condition is Fatigue.	AND Loading Condition is Fatigue.
AND criteria adopted is FSC.	AND criteria adopted is FSC.

AND Evaluation of defect is required. AND Normal operating condition. AND a_f<0.1a_c AND Decision is DIFSC. THEN Mode is safe.	AND Evaluation of defect is required. AND Emergency and faulted condition. AND a_f<0.5a_i AND Decision is D2FSC THEN Mode is safe.
RULE 3: **D3FSC** IF science is F.M. AND regim is LEFM. AND state is Plane strain. AND Material is Brittle. AND Loading Condition is Fatigue. AND criteria adopted is FSC. AND Evaluation of defect is required. AND Condition is either normal or emergency. AND DIFSC and D2FSC do not satisfy. AND Decision is D3FSC THEN Mode is fail.	**RULE 4:** **D1ASIF** IF science is F.M. AND regim is LEFM. AND state is Plane strain. AND Material is Brittle. AND Loading Condition is Fatigue. AND criteria adopted is ASIF. AND Evaluation of defect is required. AND Condition is normal. AND K_1 < (K_{1a}/SQRT10) AND Decision is D1ASIF THEN Mode is safe.
ULE 5: **D2ASIF** IF science is FM. AND regim is LEFM. AND state is Plane strain. AND Material is Brittle. AND Loading Condition is Fatigue. AND criteria adopted is ASIF. AND Evaluation of defect is required. AND Condition is normal. AND K_1 >(K_{1a}/SQRT10) AND Decision is D2ASIF THEN Mode is fail.	**RULE 6:** **D3ASIF** IF science is FM. AND regim is LEFM. AND state is Plane strain. AND Material is Brittle. AND Loading Condition is Fatigue. AND criteria adopted is ASIF. AND Evaluation of defect is required. AND Emergency and faulty conditions. AND K_1 < (K_{1c}/SQRT2) AND Decision is D3ASIF THEN Mode is safe.

RULE 7: **D4ASIF** IF science is FM. AND regim is LEFM. AND state is Plane strain. AND Material is Brittle. AND Loading Condition is Fatigue. AND criteria adopted is ASIF. AND Evaluation of defect is required. AND Emergency and faulty conditions. AND $K_1 > (K_{1c}/SQRT2)$ AND Decision is D4ASIF THEN Mode is fail.	**RULE 8:** **D1AFD** IF science is FM. AND regim is LEFM. AND state is Plane strain. AND Material is Brittle. AND Loading Condition is Fatigue. AND criteria adopted is AFD. AND Evaluation of defect is required. AND Conditions IWB3410-1 is absent. AND Decision is D1AFD THEN Mode is safe.
RULE 9: **D2AFD** IF science is FM. AND regim is LEFM. AND state is Plane strain. AND Material is Brittle. AND Loading Condition is Fatigue. AND criteria adopted is AFD. AND Evaluation of defect is required. AND Conditions IWB3410-1 is present. AND Decision is D2AFD THEN Mode is fail.	**RULE 10:** **D1FAD** IF science is FM. AND regim is EPFM. AND state is Plane stress. AND Material is Ductile. AND Loading Condition is Fatigue. AND criteria adopted is FAD. AND Evaluation of defect is required. AND K_r/S_r is below assessment line. AND Decision is D1FAD THEN Mode is safe.
RULE 11: **D2FAD** IF science is FM. AND regim is EPFM. AND state is Plane stress. AND Material is Ductile.	AND Loading Condition is Fatigue. AND criteria adopted is FAD. AND Evaluation of defect is required. AND Kr/Sr is above assessment line. AND Decision is D2FAD THEN Mode is fail.

CONCLUSION

The work is to develop a rule based system on the bases of estimated technique for the prediction of safety or failure of different materials. For developing this system our domain area was Fracture Mechanics and domain experimental analysis are in ed in the the experts in different organization. The knowledge of these experts were extracted through discussions and their knowledge and expertise have been transferred in the forms of rules and then these rules will be helpful in decision making in the field of fracture mechanics for Fail or Safe mode of any component/ material. Importance of such rules increases when there is unavailability of particular expert for solving the problem. When such situation arises, these rules are helpful in decision making.

This research work would be a reference for further work. As fracture mechanics is an important and vast field, a lot of work can be done on this area.

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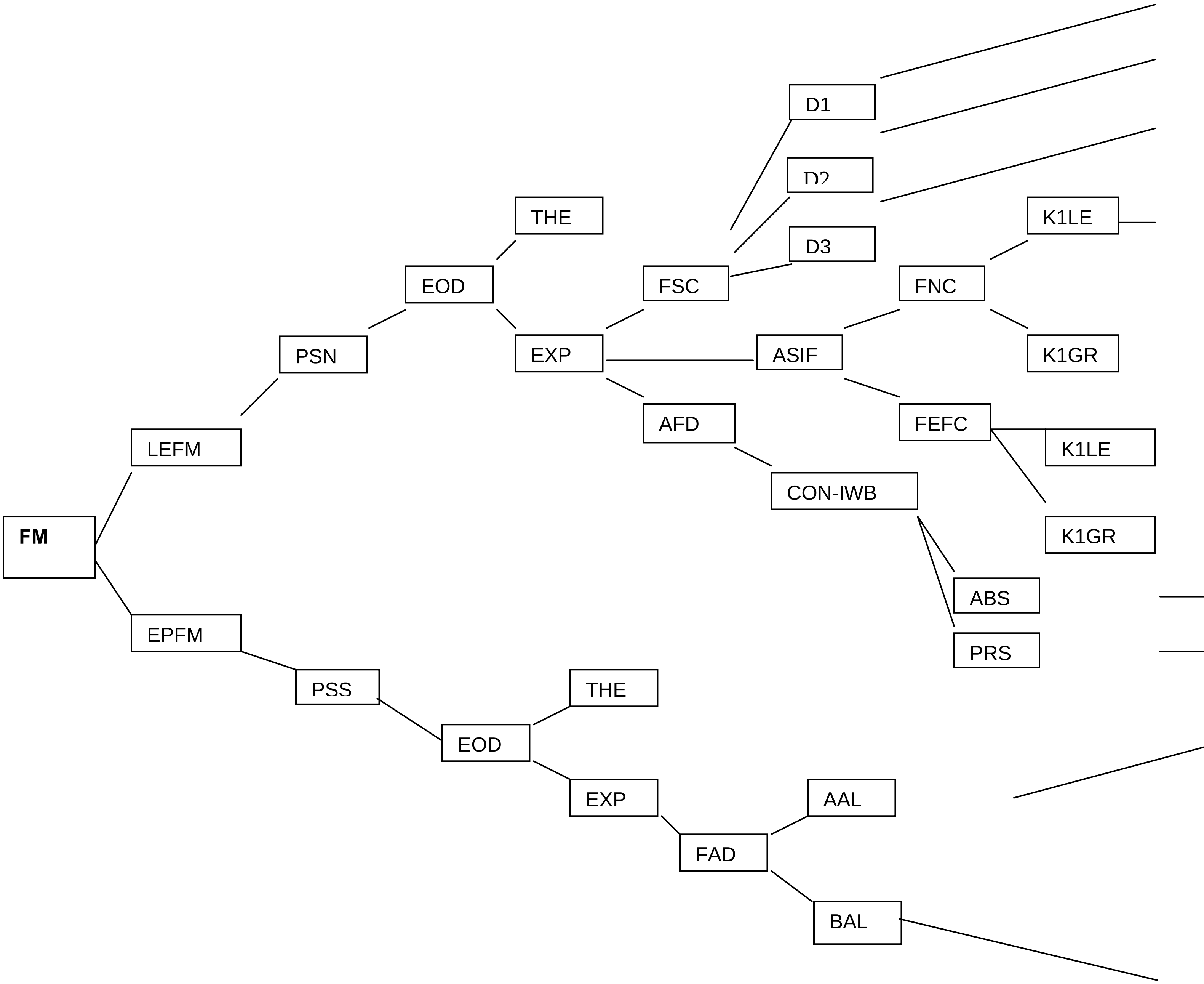
REFERENCES

[1] Masateru Ohnami,1992 “Fracture and society” ISO Press.

[2] J.F.knott,1973 “Fundamentals of Fracture Mechanics” .

[3] ASME Boiler & Pressure Vessel Code Sec XI. 1994 Article K-4000, ASME code BSI PD 6493:1991, PD6593:

[4] G.C Shih,1973 “Hand Book of stress intensity factor for researchers and engineers” Institute of Fracture and Solid Mechanics, Lehigh University Bethlehem, PA.


FM
LEFM
PSN
EOD
THE
EXP
FSC
D1
D2
D3
ASIF
FNC
K1LE
K1GR
FEFC
K1LE
K1GR
AFD
CON-IWB
ABS
PRS
EPFM
PSS
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THE
EXP
FAD
AAL
BAL

FIG-2