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'Techniques for Probabilistic Implementation of Structural Engineering Procedures'

Ujjwal Bharadwaj BEng, MSc, MIET

Research Engineer,
Structural Integrity Group, TWI, Cambridge

Contents

- **Case Study 1 : Engineering Critical Assessments using a Probabilistic method to determine the acceptability of flaws in components**

Case Study 1

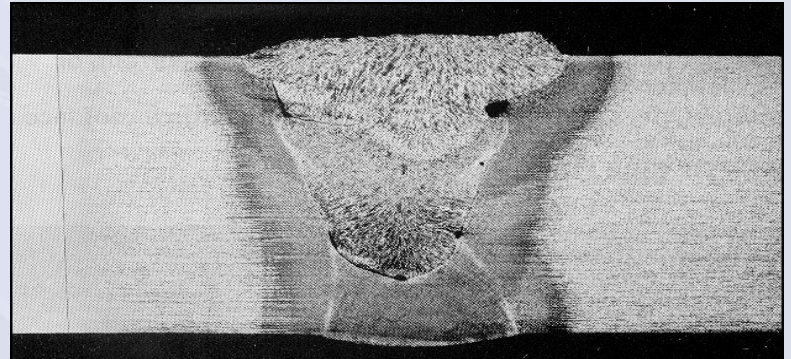
Engineering Critical Assessments using a Probabilistic method to determine the acceptability of flaws in components

– U Bharadwaj, Dr A Sisan

Background

Structural Integrity group, TWI

- **Determination of materials properties and structural behaviour**
- **Development/support of major defect assessment procedures (BS7910, FITNET, API579, R6)**
- **Engineering Critical assessment, ECA**
 - **Assessment of flaws**
 - **Life extension**



ECA

- It is almost impossible to manufacture any component without a defect.
- Defects can be very small cracks inside the material.
- The stresses are higher around the cracks, which have adverse effects on material strength.
- An (ECA) is an analysis, based on fracture mechanics principles, of whether or not a given flaw is safe under specified loading conditions.

What information is needed for an ECA?

**Material
Properties**

ECA

Flaw size

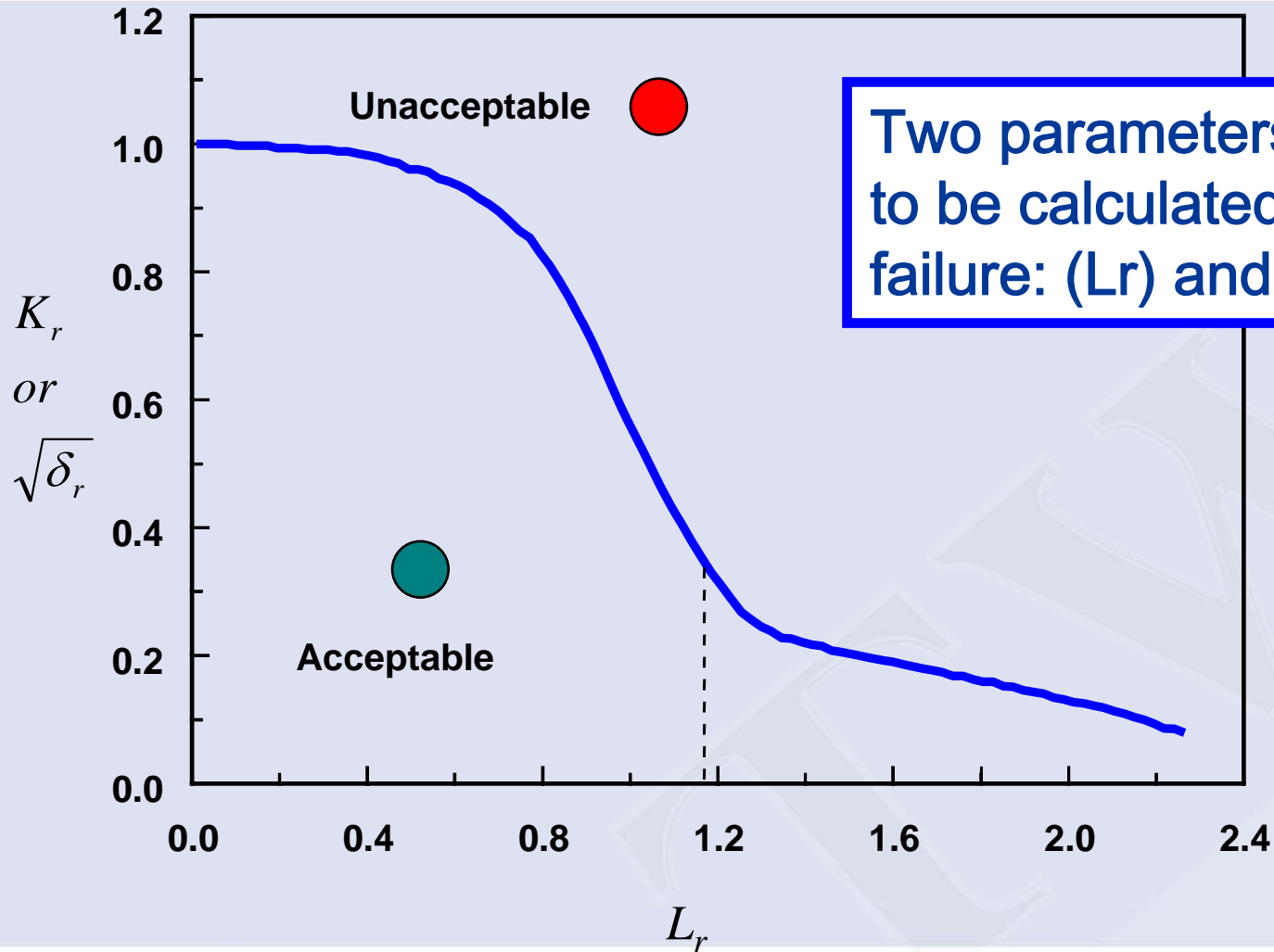
**Loading
Condition**



Approaches in ECA

- **Deterministic**
 - A set of input parameters are used based on procedures such as BS7910
- **Probabilistic**
 - Uncertainties in input data

FAD curve



Two parameters are required to be calculated to define failure: (L_r) and (K_r)

Introduction to Probabilistic Techniques in Structural Integrity Assessments (1 of 3)

- Structural Reliability Analyses (SRA) to analyse failures and compute associated Probabilities.
- Limit state function
 - Function $g(X)$
 - where X is a set of random variables
 $X=(X_1,X_2,X_3,\dots,X_n)$
 - $g(X) < 0$ is interpreted as failure and the probability of failure
 $P_g = P(g(X) < 0)$
 - E.g. $g(X) = X_1 - X_2$ where,
 X_1 = strength variable of the system
 X_2 = load variable of the system

Probabilistic Techniques (2 of 3)

- If the load variable exceeds the strength variable, system failure occurs.
- The difference $X_1 - X_2$ is called the safety margin; if safety margin is less than zero, failure occurs.
- Often limit state functions logically connected as unions and intersections; then

Probability of failure is

$$P([g_1(X) < 0 \cup g_2(X) < 0] \cap g_3(X) < 0)$$

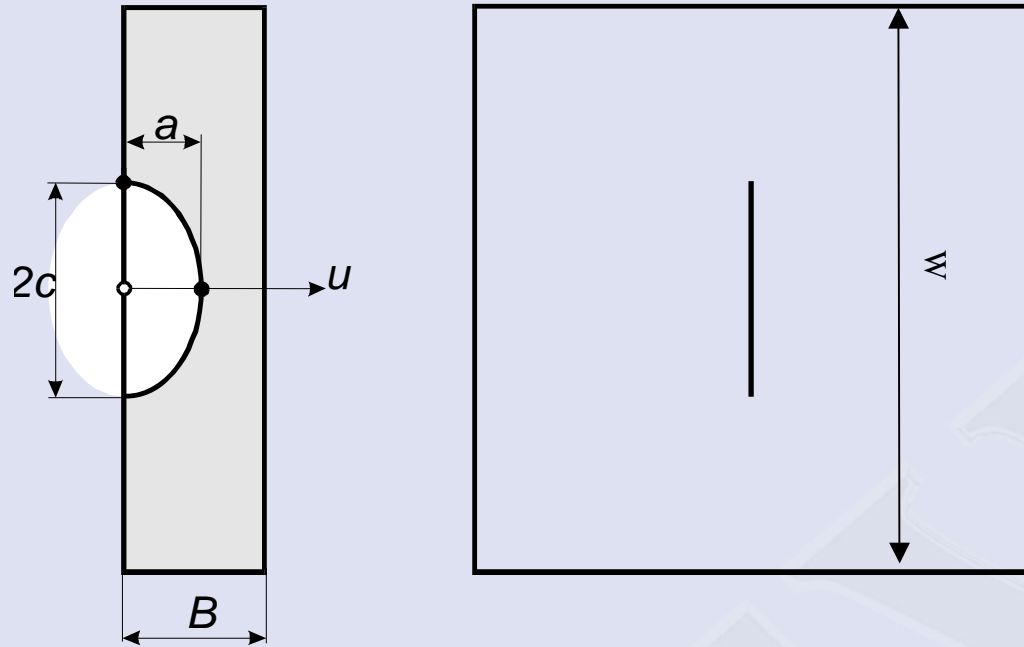
Probabilistic Techniques (3 of 3)

- **Methods of Structural Reliability Analysis**
Limit State Function using:
 - **Deterministic Approaches**
 - » Safety Factor Approach
 - **Probabilistic Approaches**
 - » Monte Carlo Simulation (MCS) technique
 - » FORM, SORM (Analytical Methods)

Outline of case study 1

- Specimen: A plate with a surface crack
- Assessing different cases for the acceptability of flaws using different techniques
- Results
- Demonstration using @Risk+Excel
- Conclusion

Schematic of a plate with a surface crack

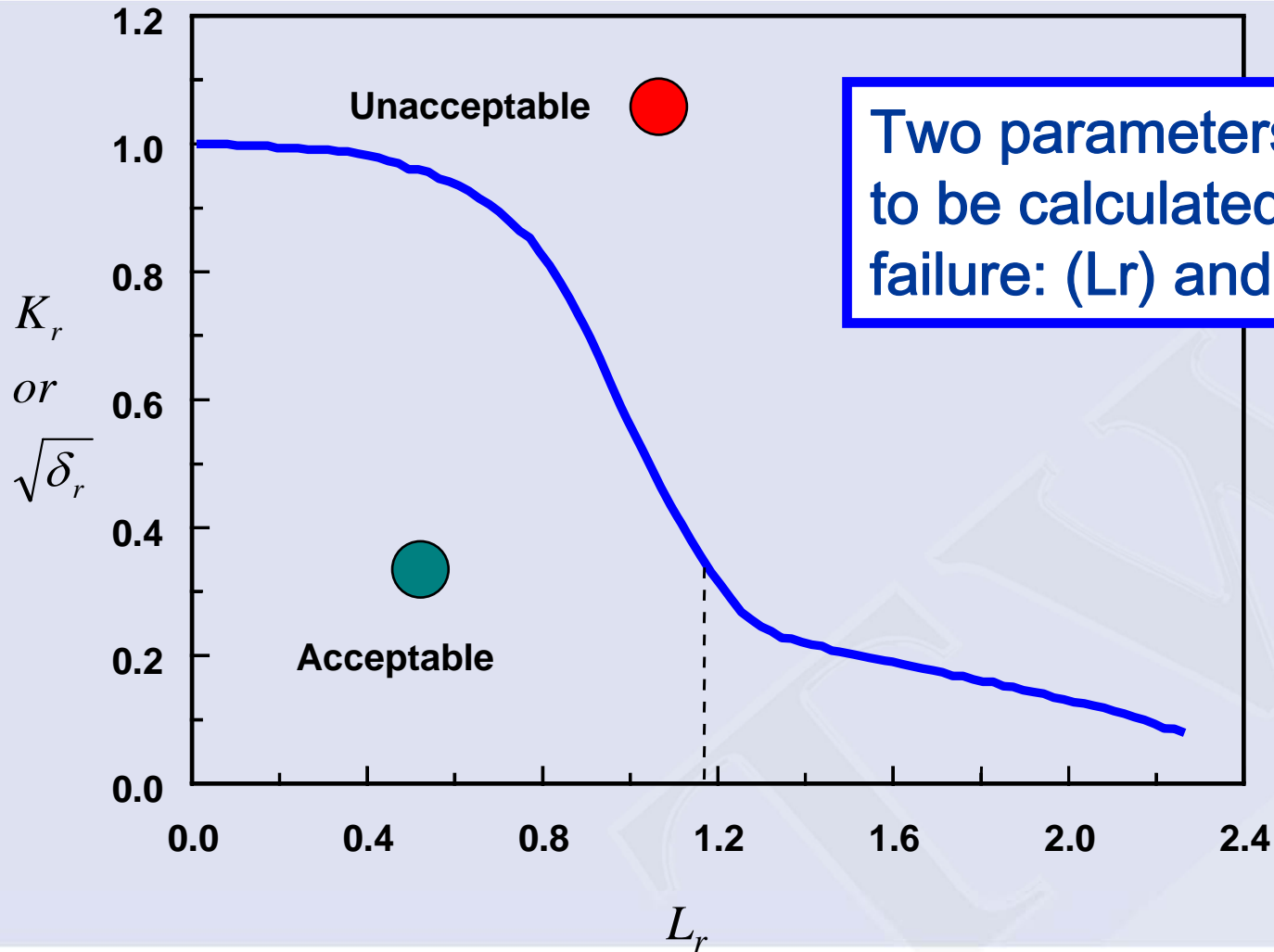


$2C$ =Crack length, a =Crack depth (height),
 B =thickness, W =width of the plate

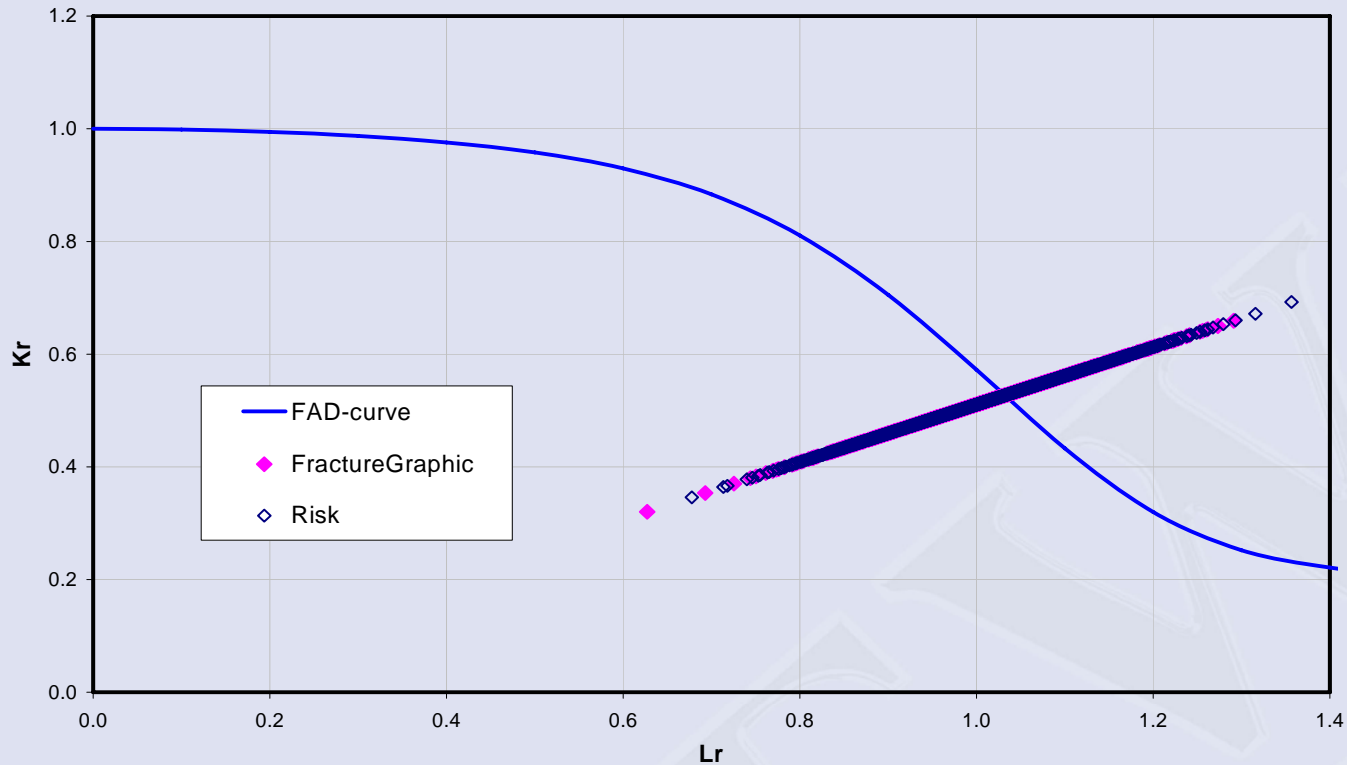
Different Cases and Codes

- Parameters
 - Individual or combination of distributions :
 - Flaw height
 - Primary Stress
 - Toughness
- No of cases studies: 10
- Calculating (Lr) and (Kr) and plotting them on the FAD curve using
 - @Risk+Excel
 - FractureGraphic
 - STRUREL

FAD curve

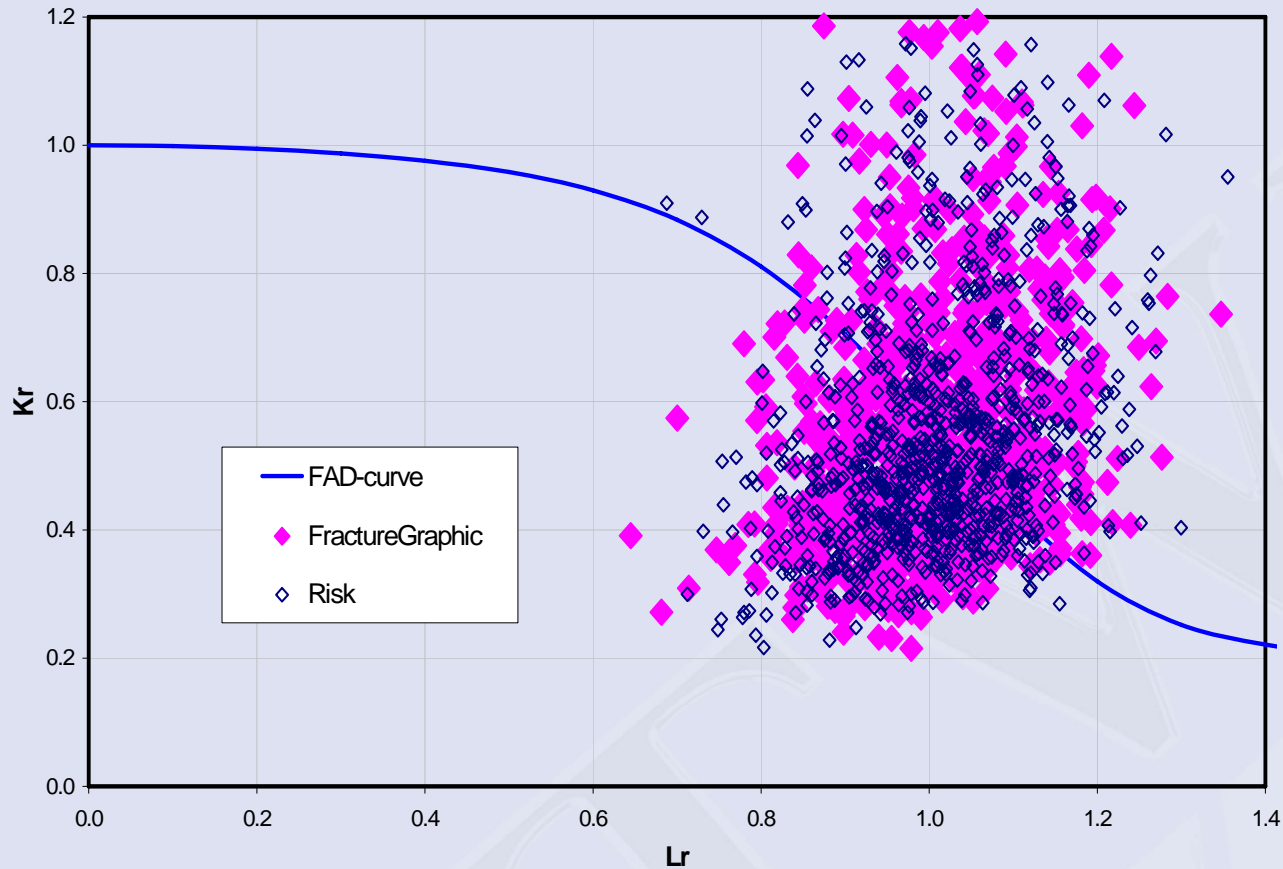


Case 6



• Distributed Primary stress, other parameters fixed

Case 8



•Distributed flaw height, Primary Stress and Toughness

Typical Results

Case	Run	Probability of failure, %				
		@Risk+ Excel	FractureGraphic	STRUREL		
				Monte Carlo	FORM	SORM
5	1	7.2	8.4	8.5, (Cov, 10%)	7.3	7.3
6	1	40.5	40.8	39.0, (Cov, 4%)	40.4	40.4
7	1	39.8	40.5	38.0, (Cov, 4%)	40.0	40.0
8	1	44.5	45.3	45, (Cov, 3.5%)	43.0	43.0
9	1	0.2	0.2	0.2, (Cov, 71%)	0.125	0.125

Demonstration using @Risk+Excel

- Distributed flaw height 'a', Primary stress 'Pm' and Toughness 'Kmat'
- Recall Spread Sheet with @Risk [link](#)

Conclusions

- @Risk+Excel is a good option for the probabilistic implementation of BS7910 to determine the acceptability of flaws.
- Good agreement between @Risk+Excel and other codes

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