Chapter 2

Failure under mechanical loading

Problem 2.1

According to Eq. (2.3), fracture stress σ_f can be related to the fracture toughness, K_{IC}, and the flaw size, $2a$. Y is a correction factor which depends on the geometry of the part:

$$\sigma_f = K_{IC} / Y(\pi a)^{1/2} = 45/1 \times (3.14 \times 1.25 \times 10^{-3})^{1/2} = 718 MPa$$

Problem 2.2

From Eq. (2.3), the fracture stress σ_f can be related to the fracture toughness, K_{IC}, and the flaw size, $2a$. Y is a correction factor which depends on the geometry of the part:

$$\sigma_f = K_{IC} / Y(\pi a)^{1/2} = 47/2 \times (3.14 \times 0.5 \times 10^{-3})^{1/2} = 593 MPa$$

σ_f is larger than YS, the material will yield first at 462 MPa, which is about 18% higher than the applied stress of 390 MPa. This is probably not high enough if a factor of safety of 1.5 or higher is needed.

Problem 2.3

For the definition of alternating and fluctuating stresses, please refer to Fig 2.8. The rear axel of the motorcar is subjected to fluctuating stresses but the connecting rod is subjected to alternating stresses.

Problem 2.4

Welded joints in steel structures are possible sites for fatigue crack initiation because:

a) They could be associated with internal stresses
b) They could have internal cavities or small cracks
c) They could be associated with stress concentrations
d) They are usually associated with metallurgical inhomogeneities.

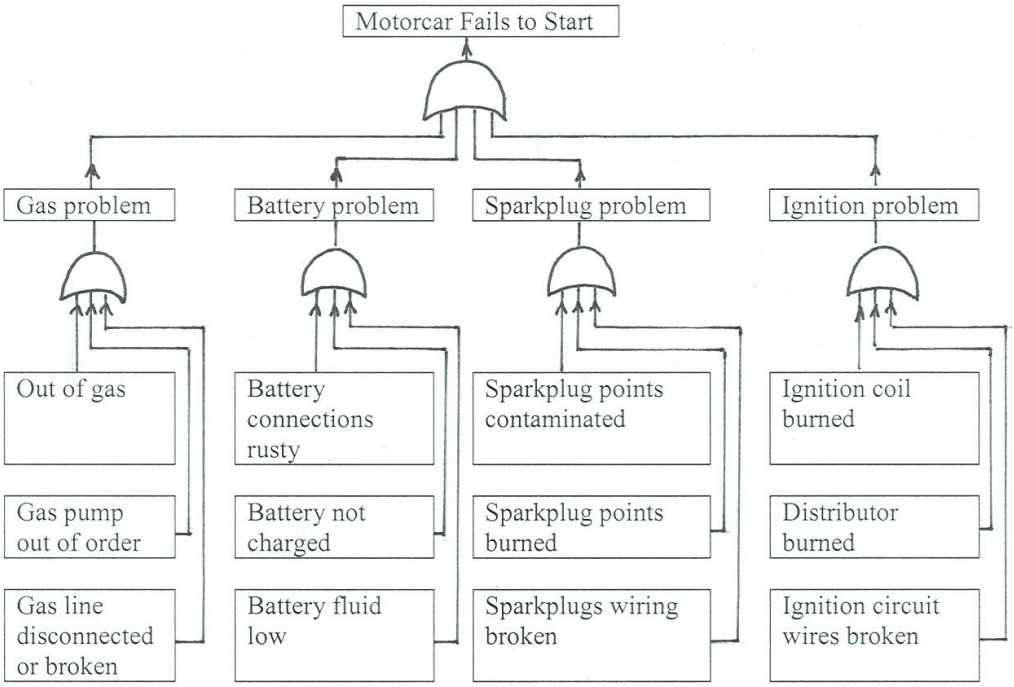
Placing welded joints away from highly stressed areas, stress relieving using thermal or mechanical treatments, careful quality control by NDT, and adhering to codes of practice are among the ways of avoiding fatigue failures of welded structures.

Problem 2.5

Fatigue strength of FRP is normally acceptable (endurance ratio above 0.3 as shown in Table 4.7). The elements of the frame have to be assembled using adhesives, which could present a source of weakness under fatigue loading. To ensure that the joint design and strength are acceptable, it is suggested that a testing program consisting of two groups of tests be devised. The first group of tests is to select the most suited adhesive. The second group of tests consists of different joint designs to select the optimum.

Problem 2.6

2.6 FTA of the possible causes of failure of a motorcar to start.



Problem 2.7

According to Eq. (2.3), fracture stress σ_f can be related to the fracture toughness, K_{IC}, and the flaw size, $2a$, with Y as a correction factor that depends on the geometry of the part.

For Maraging steel:

$$\sigma_f = K_{IC}/Y(\pi a)^{1/2} = 90/1\times(3.14\times1.5\times10^{-3})^{1/2} = 1311MPa$$

Yield strength is 1730 MPa.

Both yield strength and σ_f are higher than the applied stress of 600 MPa.

For AISI 4340(T 260°C):

$$\sigma_f = K_{IC}/Y(\pi a)^{1/2} = 50/1\times(3.14\times1.5\times10^{-3})^{1/2} = 728.9MPa$$

Yield strength is 1640 MPa

The design should be based on the fracture stress, which is only about 20% higher than the applied stress. This may not be sufficient if a factor of safety of 1.5 or higher is needed.

Problem 2.8

FMEA analysis for a flashlight

System / subsystem / Part	Function	Possible failure mode	Consequence of failure	Severity (S)	Possible cause of failure	likelihood of occurrence (O)	Ease of detecting failure (D)	RPN (S . O . D)	Criticality (S . O)	Action to reduce risk
Battery	Supplies power	a)Rundown b)Low charge	a)No light b)Weak light	a)10 b)6	a)Battery too old or leaking b)Battery partly rundown	a)5 b)7	a)5 b)3	a)250 b)126	a)50 b)42	Use long-life battery Inspect regularly
Light bulb	Produces light	Filament broken	No light	10	Filament broken	3	5	150	30	Use good quality light bulb
Switch	Turns power on-off	a)Stuck b)Not connected electrically to battery	No light	10	a)Switch stuck due to mechanical malfunction b)Wire connections broken	a)4 b)2	a)3 b)6	a)120 b)120	a)40 b)20	Better mechanical design using non-rusting materials
Body	Contains parts of flashlight	a)Cracking b)Brittle fracture	a)Water may get in b)No light	a)5 b)9	Flash light dropped	8	a)3 b)2	a)120 b)144	a)40 b)72	Use high toughness materials for making the body
Front glass/plastic	Protects bulb and distributes light	a)Cracking b)Brittle fracture c)Scratched	a)Water may get in b)Light not distributed uniformly c) Dim light	a)5 b)3 c)2	a)Flash light dropped b) Flash light dropped c)front glass/plastic in contact with abrasive material	a)8 b)8 c)4	a)2 b)1 c)3	a)80 b)24 c)24	a)40 b)24 c)8	Use toughened glass or high toughness plastic. Coat the surface non-scratch coating.