ENGINEERING TRIPOS PART IIA

Extension Activity (ExA)

FAILURE ANALYSIS – MECHANICAL ENGINEERING

AIMS

To provide experience of problem solving in the context of acting as a consultant or expert witness in the field of Materials Failure Analysis.

OBJECTIVES

1. To investigate the failure which has been assigned to you and hence form opinions as to:
   - The reason(s) for failure;
   - The extent to which the failure was caused by shortcomings in
     - (i) design
     - (ii) materials
     - (iii) manufacture
     - (iv) maintenance
     - (v) service environment.
   - Measures to be taken to avoid a repeat of the failure.
2. To make an oral presentation of your findings to an audience consisting of the other students taking the ExA and the ExA Leader.
3. To respond to questions on your findings from individuals in the audience.
4. To cross-question the other groups in order to probe the technical merits of their investigations.
5. To provide written feedback at the end of the exercise to help the Leader review the ExA for future sessions.

INTRODUCTION

The design, manufacture and maintenance of safe and reliable engineering artefacts in today's conditions of cost-control, dwindling resources and environmental awareness is one of the most challenging of human activities and is well summarised by the title of the 1987 TV series "To Engineer is Human". However, a realist might well suggest that "To Err is Human" would be a more appropriate title. Certainly, the march of engineering achievement has been set back all too often by disaster: the DeHavilland Comet crash (1954); the Flixborough explosion (1974); the Challenger space shuttle fireball (1986); the Boeing 737 Max crash (2019). And, for every engineering failure which hits the headlines, there are many more which result in inconvenience, financial loss, environmental damage or personal injury. Perhaps a limitation of the material has been overlooked; or a particular loading case has been ignored; or integrity has been lost through exposure to the environment. Though the consequences can be tragic, engineers often learn their most important lessons when things go wrong. The analysis of engineering failures is therefore a

vital element in the design process: something useful can be learned from even the most ordinary failures; the most major incidents can lead to radical changes in the way in which things are done. Since most failures are traced ultimately to failures of the materials themselves, they also provide graphic illustrations of the way in which engineering function often depends critically on materials properties.

In this Extension Activity you will have the opportunity of gaining experience of working as a consultant/expert witness in the field of Materials Failure Analysis by investigating an engineering failure. The class will be divided into pairs, and each pair will be allocated a specific failure to analyse. Each failure is a real incident, recently investigated by a professional engineer prior to advising industrial/commercial personnel, lawyers or insurance loss adjusters. You will also gain experience of reporting your findings to a technical audience, of defending your work under critical questioning, and of probing the technical merits of the investigations reported by the other groups. In order to ensure an adequate level of support, the maximum number of students which can be accommodated on the ExA at any one time is limited to 12.

SCHEME OF WORK and TIMETABLE

You should each spend approximately 16 hours completing this exercise.

For the timetable, use the following link:
http://to.eng.cam.ac.uk/teaching/apps/cuedle/index.php?context=3EAC
All sessions are from 11am till 1pm.

1. Introductory Session (Compulsory)

Session Objectives:

(i) Review Aims and Objectives of the ExA
(ii) Introduce the subject of Failure Analysis
(iii) Describe failures to be investigated in the ExA
(iv) Indicate methodology
(v) Form pairs of students
(vi) Assign a failure to each pair of students
(vii) Issue OHP foils and washable pens.
(viii) Allocate times for final presentations
(ix) Point out locations of Case Files, artefacts and Leader's office.

The six failures currently available are as follows.

FaA/l - Fracture of a Pedicle Screw in a Spinal Prosthesis
FaA/2 - Collision Damage to a Bridge Parapet
FaN3 - Distortion and Cracking of a Heat-Exchanger Tubesheet
FaA/4 - Collapse of a Second-Floor Balustrade
FaA/5 - Failure of a Caustic Soda Pipeline
FaA/6 - Failure of Colliery Arches During Cold Forming

Each failure has a Case File which gives basic information on the circumstances of the failure such as would normally be available after an initial site inspection or instruction to investigate. Your Case File must not be removed from the laboratory, as it may contain items (such as photographs) which are not easily replaced. In addition, some failures also have artefacts (e.g. broken components) which are available for examination in the Materials Laboratory. These are unique, and under no circumstances may they be removed from the laboratory.

2. Laboratory Sessions

These provide opportunities to consult the Case File, examine any artefacts etc. You have 8 hours before the Final Presentations (see 3 below) to achieve Objective 1 and to prepare for achieving Objectives 2 and 3. This is not a long time, but it is typical of the time available to a consultant/expert witness (which is usually limited by the chargeable fee) to prepare a preliminary report on a failure. You may not be able to arrive at the definitive scenario for the failure. This does not matter as long as you arrive at your best opinions given the limitations of the available time and information. It is important to assess the strengths and weaknesses of your opinions, and to suggest further work which might help consolidate your technical case. In addition to the Case File and any artefacts, you are free to consult any other source of information which you are able to access. A list of relevant books in the Department Library (not exhaustive) is given below under the heading "Selected Resources". The Leader will be available 11-12.30 during each session for help if you

need more factual information, if you get stuck, or if you need advice about preparing for your presentation. Owing to possible timetable clashes, you may not be able to attend all the Laboratory Sessions at the times shown. This is perfectly acceptable, and in any case you may need to spend some of the allocated time working elsewhere, e.g. in the Library, DPO or in your College room. However, you should make regular contact with the Leader in order to ensure that you are proceeding along the right lines.

Although there is no requirement (or time!) to produce a formal written report, you should make sure that you record the progress of your investigation by making notes, sketches etc as appropriate. Your record will typically include observations of the salient features of artefacts which you examine, details of any stress calculations which you carry out, summaries of relevant information which you obtain from independent sources etc. It should also include a summary of your opinions (see Objective 1) and your reasons for advancing them. Towards the end of the time allocation, you will need to get ready for your presentation (see Objectives 2 and 3). Prepare your powerpoint presentation and review the details of your technical case so that you are ready to respond to questions.

3. Interim Presentation (Compulsory)

These are informal presentations, summarising the failure and findings so far for each pair. 'Brain-storming' and group discussion will be used to generate suggestions and critically assess the preliminary ideas of each pair. All students doing the ExA should make a contribution.

4. Final Presentation (Compulsory)

See Objectives 2-4. Each presentation should last for approximately 15 minutes, followed by questions. The two students in each pair should make an approximately equal contribution both to making the presentation and responding to questions (see Objectives 2 and 3). All students doing the ExA should attempt to make a contribution under Objective 4.

ASSESSMENT

The maximum number of marks which is available for the ExA is 20. Marking is by standard credit, which means that a mark of 20 (which is also the qualifying mark) will be awarded by the Leader at the end of the ExA to each student who participates diligently in all stages of the exercise. Attendance at the Introductory and Presentation Sessions is normally essential if full marks are to be awarded. If the Leader considers that a student's performance merits less than 20 marks, (s)he will explain to the student the reason(s) for awarding a lower mark and will record those reasons in the Leader's File. The 20 marks are awarded to the ExA as a whole without any subdivision into the different parts of the exercise.

STUDENT FEEDBACK FORM - FAILURE ANALYSIS ExA

Please detach, complete and return this form to the Leader as soon as possible after the end of the ExA.

Name: (optional)

College:

Date:

Failure investigated:

Please write below any comments which may help us review the ExA for future sessions:

Athina Markaki