# Overview

The *Case Studies for Fatigue Education* special technical publication (STP) was planned to provide engineering educators and students with a broad range of non-trivial, real-world fatigue problems/situations and solutions for use in the classroom. Hopefully, these cases will provide stimulation for a better understanding of the major causes of mechanical failure. The 13 cases included in this publication involve new designs, rework designs, failure analysis, prototype decisions, environmental aspects, metals, non-metals, components, structures, and fasteners. As Rice points out in his case involving railroad rails, the cases bring out the need for students to integrate elements of engineering that commonly enter into a fatigue design or failure analysis. These elements include mechanics of deformable bodies, materials science and characterization, fractography, nondestructive inspection, design of experiments, performing and evaluating experiments, data acquisition and reduction, damage modeling, life prediction, and reliability. Rice also points out that most fatigue problems do not have one unique solution, and in fact, the "best" solution can often be dictated by financial constraints, time limitations, availability of pertinent material and processing information, liability concerns, and public perception. Based upon the above, the solutions for these cases range from complex to simple.

In order to provide real-life cases rather than technical research papers, authors were requested to use a format suitable for educational case studies. A variety of different formats could be successful in achieving this end. Authors were given excerpts from an American Society for Engineering Education (ASEE) paper, on writing engineering cases. It was suggested that each case should have specific comments, questions, instructions, and so forth for student/faculty readers to consider. The three referees of each paper were also given these instructions concerning format to aid them in their review decisions. Thus, the authors and referees worked very hard to hopefully bring together quality case studies on fatigue that will be beneficial in an educational environment. This educational environment includes undergraduate and graduate level courses and continuing education such as short courses and telecommunication media courses. The cases are also applicable to practicing engineers involved with fatigue problems either on a single involvement basis or as a group learning situation. Thus, the market or interest for these cases has actually expanded from the original goals of principally university/college usage to include the practicing engineer.

Faculty, students, and practicing engineers may have a difficult time in choosing cases for specific goals. In order to simplify this choosing and to provide a better understanding and content of each case, the following table is provided in this overview. The table includes headings that emphasize the principal aspects of each case. The paper number agrees with the number in the table of contents. The second column, entitled Major Topic, includes one to six words that best describe the product involved. It is quickly seen that a variety of different products are involved in the thirteen cases. The Author column includes the names of all authors for each case. In the Material column, it is seen that a variety of carbon steels (1010, 1018, 1040, 1080), alloy steels (HSLA, 4340, D6AC), stainless steels (A312, 304), aluminum alloys (5454, 6063), wood and wood composite, and a polymer composite are involved with these cases. Both low- and high-strength materials are involved. The next three columns provide information as to the type of fatigue model involved. An X in the $\epsilon$-$N$ column means that case involves the local notch strain methodology involving strain-life data. An X in the $S$-$N$ column means the case involves the nominal stress methodology involving stress-life data. An X in the LEFM column means that the case involves linear elastic fracture mechanics using fatigue crack growth rate, $da/dN$, which is a function of the

stress intensity factor range, $\Delta K$. Seven cases involve $\epsilon$-$N$, three cases involve $S$-$N$, and five cases involve $da/dN - \Delta K$. Two cases have more than one fatigue methodology. The next two columns, FEA and Experimental Stress Analysis, provide whether stresses/strains were determined through finite element analysis and/or through experimental means. In other cases, stress calculations using a strength of materials approach were used if needed. Three cases include FEA and four cases include experimental stress analysis. The next two columns, Fatigue Life Predictions and Fatigue Tests are involved in every case; that is, every case involved fatigue life predictions and/or fatigue tests, which is probably expected. The last column indicates six cases that involved some form of fractographic analysis. This included both macro and micro analysis using optical and/or scanning electron fractography. Hopefully, this table will aid in making appropriate case selections for a given objective. It is suggested that potential case users review this table before considering a specific case.

Case reproduction as class handouts will be a very important consideration for users. ASTM offers quantity discounts for this STP, as well as for reprints of individual cases. Please call ASTM customer service for more information at (215) 299-5585. As for photocopying, this authorization is addressed in a paragraph that appears in the front matter of this, and all ASTM STPs. Please refer to this paragraph for photocopying requirements.

The thirteen cases in this publication involve authors representing six universities, six private companies, and two government agencies. The cases come from ten different states within the United States and one province in Canada. They represent a broad spectrum of engineering fatigue problems. Not the least of these problems is product liability litigation. Two additional papers had to be withdrawn by the authors during the refereeing stage due to lawyer requests, based upon active products liability litigation. This just points out additional difficulties in fatigue education and that hopefully this publication will contribute to quality engineering education involving fatigue.

The editor would like to thank the authors, referees, symposium session chairpersons, the organizing committee, and the ASTM staff for making this publication possible. The organizing committee included R. I. Stephens, The University of Iowa, Chairperson; R. C. Rice, Battelle Memorial Institute; N. C. Dowling, Virginia Polytechnic Institute and State University; B. I. Sandor, The University of Wisconsin; and H. Sehitoglu, The University of Illinois.

*Ralph I. Stephens*

Mechanical Engineering Department
The University of Iowa,
Iowa City, IA 52242;
symposium chairperson and STP editor.

Case Summary Table

| Paper Number | Major Topic | Authors | Material | $\epsilon$-$N$ | $S$-$N$ | LEFM | FEA | Experimental Stress Analysis | Fatigue Life Predictions | Fatigue Test | Fractography |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | auto wheel assembly | Landgraf, Thangjitham, and Ridder | 1010 and HSLA steel, 5454 aluminum | X | | | X | | X | X | |
| 2 | boat trailer roller arm | Salivar | 1040 steel | | | | | | | X | X |
| 3 | hip prosthesis | Liao and Reifsnider | polymer composite | | X | | | X | X | X | X |
| 4 | landing gear actuator beam | Kantimathi and White | D6AC steel | X | | X | X | X | | X | X |
| 5 | paddle shaft | Jhansale | 1018 steel | X | | | | X | X | X | |
| 6 | paper mill roll | Zapata and Anderson | welded mild steel | | | X | | | X | | X |
| 7 | pipeline weldment | Socie and Segan | A312 stainless steel | | | X | | | X | X | X |
| 8 | recuperator | Bhat | 304 stainless steel | X | | | | | X | | |
| 9 | railroad rails | Rice | 1080 steel | X | | X | | X | X | X | X |
| 10 | thick-walled pressure vessel | Stephens, Adams, and Carlson | A723 steel | X | X | X | | | X | X | |
| 11 | tubular threaded connection | Liebster and Glinka | 4340 steel | X | | | X | | X | | |
| 12 | wind turbine | Sutherland, Veers, and Ashwill | 6063 aluminum | | X | | | | X | X | |
| 13 | wood gun stock and bowling pin | Kyanka | wood and wood composite | | | | | | | X | |