CHAPTER V

TEST PIECES: DESIGN, PREPARATION, MEASUREMENT AND PROTECTION

SECTION 50. GENERAL

Test pieces used in fatigue testing may—as already mentioned in Section 20—be classified into specimens and components. The shape and dimensions of a specimen can, to some extent, be arbitrary, and accordingly its shape is usually simple and the dimensions small. The specimen may be unnotched or notched. On the other hand the shape and size of a component is in general given, but simplified test pieces, preserving or simulating the essential fatigue characteristics of an actual component, are sometimes used. In particular cases, the simplification consists in a reduction of the scale only.

Test pieces may consequently be classified into: unnotched specimens, notched specimens, simulated components and scale models, and actual components.

All test pieces are composed of a test portion and a grip portion, and usually also a transition portion joining the grip and the test portions. Stresses defining the stress level applied are calculated on a net section of the test portion by simple theory without taking into account stress concentrations caused by geometrical factors. Such stress raisers are considered by the introduction of a stress concentration factor (see Section 63, paragraph 3).

Localized high stresses, which have no marked effect on the ultimate strength of ductile materials, may have a most detrimental effect on the fatigue strength of practically all materials. In order to avoid failures in the grip portion, the section of the test portion should therefore be considerably reduced. If this precaution is neglected, very misleading values of the fatigue strength of the specimen can result; for example, GILLETT and MACK (1924) reported that a reduction of more than forty per cent was observed due to failure in the grip of a specimen. It is evident that very little information is provided by a fatigue test which is discontinued because of failure outside the test portion. Such a test is, in fact, in spite of the fracture, a run-out test, giving only a lower bound of the fatigue life, and the result should be discarded.

The degree of reduction of the test section in relation to the grip depends upon the shape of the grip and the transition portions. Large reductions are particularly needed when the grip is provided with screw threads. STANTON and BAIRSTOW (1906) found, for example, that the fatigue strength was reduced by 25 to 35 per cent calculated on the area of the bottom of a B. S.

Whitworth thread. This marked effect was confirmed by GOUGH (1924, p. 81) who found a reduction in fatigue strength under reversed bending of fifty per cent due to a B.S. fine thread on a steel of 63 tons/in^2 tenacity. He adds that it is evident that the usual practice of reducing the area of the test section to that at the bottom of the thread is quite unsafe for a specimen subjected to repeated stresses.

Another example relating to smooth specimens may be mentioned. In a repeated-bending test conducted by BENNETT and BAKER (1950) there was some difficulty with the specimens breaking at the grip in spite of the fact that the maximum stress in the reduced section of the specimen was about 25 per cent greater than that at the point where the specimen was clamped. This trouble was almost entirely eliminated by placing several thicknesses of greased paper between the specimen and the clamping plates, but it was felt that it would be better to increase the width of the specimen at the grip.

The present chapter will be divided into seven sections; four of them will deal with the design of unnotched specimens, notched specimens, simulated components, and actual components; the subsequent three with preparation, measurement, and protection of test pieces.

References: BENNETT and BAKER (1950), EDEN, ROSE and CUNNINGHAM (1911), GILLETT and MACK (1924), GOUGH (1924, 80–83), JOHNSON (1949, 30–37), MOORE and KOMMERS (1921; 1927, 111–118), STANTON and BAIRSTOW (1906).

SECTION 51. UNNOTCHED SPECIMENS

51.0 General

The object of fatigue tests on unnotched specimens is generally to determine the fatigue properties of a material under varying conditions and to study the effect of various factors on the fatigue life of the specimen. The unnotched specimen should therefore be designed in such a way that the test portion of the specimen is subjected to a uniform or smoothly varying stress over the test length, of such a magnitude that premature failure does not develop at unintentional stress raisers in the grip or transition portion.

The maximum stress computed from the load and the dimensions of the specimen is assumed to be proportional to the axial load (or moment) and inversely proportional to the cross-sectional area (or moment of inertia). A uniform stress over the length of the specimen can thus be obtained either by a combination of a constant load and constant section or by a combination of a varying load and correspondingly varying section.

The design of the specimen depends primarily upon the type of stressing applied, and consequently the first-order classification will be: (1) tension-compression specimens; (2) repeated-bending specimens; (3) rotating-bending specimens; and (4) torsion specimens.

Each of these classes will be subdivided into specimens with circular and those with rectangular (flat) test sections. A third-order classification is obtained by dividing the specimens into those with constant and those with varying maximum stress over the test length.

51.1 Tension-compression Specimens

This type of fatigue specimen is developed from the tensile test specimens, the main difference being a smoother transition from the test portion to the grip portion of the specimen.

In an early design with a cylindrical test portion, used by HAIGH (1912), the change in cross-section from the enlarged threaded ends ($\frac{1}{2}$ in.) to the test portion (0·2 to 0·3 in. diameter) was made gradually by means of a long taper. A similar design where the taper is replaced by a curve with a radius of 49 mm and a test section with a 6 mm diameter has been extensively used at the Swedish Aeronautical Research Institute, Stockholm. Details are given, for example, in a paper by WEIBULL (1956c). It is to be noted that the initial diameter of the test section was 7·5 mm, but this had to be reduced to 6 mm because of frequent failures at the threaded ends which had a diameter of 19 mm. The nominal stress is obviously constant over the length in these two specimens.

The difficulty of avoiding stress raisers at the junction of the tapered portion and the test portion of the Haigh specimen induced IRWIN (1925) to reduce the cross-section from the shouldered ends to the middle by turning down the specimen with a tool swung on the arc of a circle, the radius being $7\frac{5}{8}$ in. and diameter of the test section 0·2 in.

In a more recent, rather similar design by Alcoa and described, for example, in a paper by GROVER, HYLER, KUHN, LANDERS and HOWELL (1953), the radius is increased to $9\frac{7}{8}$ in., the test section again being 0·2 in. in diameter. In the two last-mentioned designs, the maximum stress occurs at the midpoint of the specimen. The fatigue failures are spread around this point.

A specially designed specimen has been used for low cycle fatigue tests, and is described in a paper by LIU, LYNCH, RIPLING and SACHS (1948).

Rectangular test sections are generally used for testing strip and sheet specimens in the as-received condition. In this type of specimen too, the test section may either be constant or have a circular contour.

As an example of the first alternative, reference is made to a report by WÅLLGREN (1949). The unnotched specimen had a width at the test section of 16 mm, joined by a transition curve of 60 mm radius to the grip portion which had a width of 43 mm.

As an example of the second alternative, reference is made to the paper by GROVER *et al.* (*op. cit.*) where an unnotched sheet specimen having a test width of 1·0 in. and a radius of the circular contour of 12 in. is described.

A somewhat modified design used at the National Bureau of Standards, Washington, is described in a report by SMITH, HOWARD and SMITH (1955). The contour is composed of three circular arcs of equal radius (4 in.) but with shifted centres so as to give a slightly reduced width at the test section.

References: GROVER, HYLER, KUHN, LANDERS and HOWELL (1953), HAIGH (1912), IRWIN (1925), LIU, LYNCH, RIPLING and SACHS (1948), SMITH, HOWARD and SMITH (1955), WEIBULL (1956c), WÅLLGREN (1949).

51.2 Repeated-bending Specimens

Circular specimens are seldom used in repeated-bending machines, but reference is made to such a test carried out by GILLETT and MACK (1925).

On the other hand, flat sheet specimens are conveniently tested in repeated-bending machines of the cantilever type. If the sheet specimen has a constant width, then the maximum stress is located at the fillet of the vibrating cantilever specimen where failure then normally occurs.

An illustration of such a specimen, tested in a Quinlan pneumatic fatigue testing machine, is given in a paper by EPREMIAN and MEHL (1952).

If it is desired to produce a constant maximum stress over the test length, the specimen is provided with a tapered test section. The load is then applied at the apex of the triangle formed by extending the sides of the test section. The standard type of specimen recommended by the machine manufacturers is shown in a paper by BENNETT and BAKER (1950), who also introduced an improved shape of this specimen. The straight sides forming the triangle of the test section are replaced by two circular arcs with a radius of 4 in. These curved sides can be milled with a single traverse of an 8-in. diameter milling cutter. This method of preparing the specimen reduces the cost and, in addition, increases the fatigue strength of the specimen and decreases the scatter in fatigue life compared with the standard specimen.

References: BENNETT and BAKER (1950), EPREMIAN and MEHL (1952), GILLETT and MACK (1925).

51.3 Rotating-bending Specimens

Practically all specimens of this type are circular.

In four-point loading machines, where the bending moment is constant over the test length of the specimen, earlier designs consisted of reduced cylindrical test portions connected to the larger ends by fillets. It is important that the radius of these fillets is sufficiently large. In recent designs the reduced test portion is formed by a lathe tool swung on the arc of a circle of radius (R) much larger than the diameter (D). Common dimensions are: $R = 3·5$ to 10 in. and $D = 0·2$ to 0·4 in.

The specimens are provided either with long parallel ends which are gripped in jaw collett chucks [see for example MANN (1950)] or with short tapered ends and internal threads [see for example MACGREGOR and GROSSMAN (1952) or HARDRATH and UTLEY (1952)].

The same specimens may be used in rotating-cantilever machines. The stress will then be distributed along the circular contour with a maximum value at the centre of the contour. This distribution is discussed in a paper by MANN (1950) for a specimen with $D = 0·35$ in. and $R = 4$ in. The stress variation is less than one per cent within a length of 0·16 in. The ratio of failures outside this zone depends entirely on the homogeneity of the material, being in this particular case a 24S–T aluminium alloy giving about 7 per cent outside failures.

The variation of the bending moment along the length of the specimen may be compensated, as suggested by MCADAMS (1921), by tapering the specimen which consists of a conical test section, tangent to the fillets. This design produces a nearly uniform stress over a considerable length of the specimen.

A special type of specimen for rotating-cantilever machines, extensively used at the National Physics Laboratory, as reported by GOUGH (1924, p. 83), is the hollow specimen. It was found that the fatigue limits obtained with the solid and hollow specimens are practically identical, while the S–N curves obtained differ substantially in such a way that for the hollow specimen the curve becomes parallel to the N axis at a much lower number of reversals. This means a considerable saving in time. The practice at the National Physical Laboratory was to run the tests on the basis of 6×10^6 cycles for hollow specimens and 12×10^6 cycles for solid specimens.

References: GOUGH (1924, p. 83), HARDRATH and UTLEY (1952), MACGREGOR and GROSSMAN (1952), MANN (1950), MCADAMS (1921).

51.4 Torsion Specimens

This type of specimen is similar to that used for rotating-bending tests, except that the grip portions of the specimens are provided with keyways or with a flattened portion at the tapered ends of the specimen. The latter design reduces stress concentrations at the grip.

SECTION 52. NOTCHED SPECIMENS

52.0 General

Specimens provided with notches or sharp fillets are used for studying the notch sensitivity of materials and for simulating stress raisers appearing in actual components.

Maximum stresses within a notched specimen are determined by calculating nominal stresses in the same way as for unnotched specimens and correcting these values by means of a stress concentration factor K_t. It has been verified, at least in some specific cases, that the shapes of the S–N curves are practically identical for notches of different shape but with equal values of K_t, which consequently may be regarded as a characteristic of the notched specimen. This factor has been determined theoretically and experimentally for various types of notches and fillets of comparatively simple shapes.

The actual reduction in fatigue strength of a notched specimen compared to an unnotched is given by the fatigue notch factor K_f, which is related to the factor K_t as described in Section 63, paragraph 3. An engineering rule for converting K_t into K_f has been presented by KUHN and HARDRATH (1952), and applied to notches of various forms.

The geometrical form given to the notch depends mainly on whether the specimen is circular or flat. The present section will therefore be divided into these two categories. The effect of the notch also depends, of course, on the type of stressing.

A general review relating to the development of the technique, the effects of notch dimensions and shape, methods of applying the load, the relative dimensions of the test piece, has been made by LÖTSCH (1956).

References: KUHN and HARDRATH (1952), LÖTSCH (1956), PETERSON (1953).

52.1 Circular Specimens

Intentional stress concentrations may be produced in specimens of circular test section by means of fillets, transverse holes, and circumferential grooves. Other types of stress raisers such as threads, keyways, splines, etc., will be regarded as belonging to components.

The geometry of fillets is defined by the two diameters of the test piece and the radius of curvature, and that of transverse holes by the diameter of the shaft and the hole. The most common shape of circumferential grooves are the V-notch and the semicircular or U-notch. The geometry of a V-notch is defined by the maximum diameter (D), the minimum diameter (d), the radius of curvature at the base of the notch (R), and the flank angle (ω). The U-notch is defined by the condition $\omega = 0$.

Stress concentrations factors K_t from 1 to more than 10 may be obtained by V-notches. As an example, reference is made to a report by MANN (1953) in which dimensions of rotating-cantilever specimens with $K_t = 1{\cdot}5$, 2·5, 4·3, 5·5 and >10 are given, together with corresponding S–N curves.

A comprehensive critical review of methods proposed in the literature to compare the fatigue limits of notched rotating-beam specimens with those of unnotched specimens has been presented by YEN and DOLAN (1952).

Various types of notch and corresponding values of K_t are described in the references given below.

References: MACGREGOR and GROSSMAN (1952), MANN (1953), MOORE and JORDAN (1939), PETERSON (1953), PETERSON and WAHL (1936), YEN and DOLAN (1952).

52.2 Flat Specimens

Intentional stress concentrations are produced in flat specimens by means of fillet, hole, and edge notches.

The hole-type notches may be varied not only by changing the ratio of hole diameter to width of specimen but also by locating the hole at different distances from the edges, or by elongating the hole in the longitudinal or transverse direction, or by providing the specimen with two or more holes.

Stress concentrations due to circular holes in a strip under tension have been studied for two particular cases: the hole located in the middle of the strip, by HOWLAND (1929); the hole located near the edge, by MINDLIN (1947). A general solution is given by SJÖSTRÖM (1950).

The commonest type of edge-cut notches are the V and U types.

A variety of fillets and notches in panels are described in a paper by HARDRATH and OHMAN (1951), together with the corresponding elastic and plastic stress concentration factors. The panels were designed to have nominal elastic factors $K_t = 2$, 4 and 6. Other references, describing various notches, are listed below.

References: HARDRATH and OHMAN (1951), HOWLAND (1930), MINDLIN (1947), PETERSON (1953), PETERSON and WAHL (1936), SIEBEL and PFENDER (1947), SJÖSTRÖM (1950).

SECTION 53. SIMULATED COMPONENTS AND SCALED MODELS

In order to reduce the cost of testing large and complicated components, specimens simulating the essential fatigue properties of the actual component have been designed and tested. For the same purpose scale models may be subjected to repeated loading.

No general rules or instructions can be given, as the design depends upon the individual character of the component under consideration; perhaps, a warning should be given against drawing too definite quantitative conclusions from such tests. A few references describing tests of this type are, however, given below.

The correlation of composite structural fatigue behaviour was studied by HYLER *et al.* (1958) on actual aluminium alloy box beams and I-beams, and also, for comparative purpose, on elements simulating key failure locations in the two beams. Results showed that for the box beam the fatigue behaviour at the critical location of failure was apparently correlated with the behaviour of the suggested simple simulation element on condition that the failure mode and the secondary stresses were duplicated. For the I-beam there was a qualitative agreement with a simulation element.

Another investigation of similar character was carried out by HARDRATH *et al.* (1956) on four different designs of box beam in order to find out where crack initiation was most likely to occur, and whether a crack may be discovered before it becomes dangerously large.

As a further example of tests on simulated elements reference is made to an investigation by DOW and PETERS (1955), who conducted experiments on pressurized, stiffened cylinders in order to determine whether the character of failure—which in actual service may appear in different degrees of severity from minor rupture to catastrophic explosion—can be controlled by selection of materials or structural proportions.

As a fourth example an investigation carried out at the Glenn L. Martin Co. may be mentioned. In order to obtain data regarding the fatigue properties of hull bottom plating of flying boats, COX, KREPPS and BANKARD (1955) subjected to cycling loading a large number of small specimens, 2 in. wide and provided with stringers of various shapes. The effect on the fatigue life of the following factors was examined: plate thickness, plate cladding, type of rivet, location of rivet holes on stringer flange, plating material, and plate-stringer sealing process.

References: COX, KREPPS and PETERS (1955), DOW and PETERS (1955), HARDRATH, LEYBOLD, LANDERS and HAUSCHILD (1956), HYLER, POPP, GIDEON, GORDON and GROVER (1958).

SECTION 54. ACTUAL COMPONENTS

54.0 General

The only safe method of determining the fatigue characteristics of a component is to subject actual, full-scale specimens to a number of properly chosen stress levels. This principle was actually applied from the first

beginning of fatigue testing, and since then innumerable tests on components of the most widely varied shapes and dimensions have been conducted.

Instead of spending the space available on a detailed description of a—necessarily very limited—number of components used for this purpose, it appeared preferable to present a more extended list of references containing complete data of various test pieces, useful as indications when planning a test of this type. The references are classified under the following headings: (1) bolted and riveted joints; (2) welded and bonded joints; (3) screw connexions, aircraft joints, attach angles; (4) loaded holes, lugs; (5) structural components, beams, sandwich constructions; (6) aircraft wings, tail planes; and (7) fuselages.

54.11 Bolted joints: HARTMAN and DUYN (1952), HARTMAN, HOLT and EATON (1951), JACKSON, WILSON, MOORE and GROVER (1946), LANGDON and FRIED (1948), WÅLLGREN (1953).

54.12 Riveted joints: ANDREWS and HOLT (1945), CRATE, OCHILTREE and GRAVES (1946), HARTMAN (1954), HARTMAN and DUYN (1952), HARTMAN and KLAASEN (1956), HARTMAN, LYST and ANDREWS (1944), HOLT (1950), HOWARD and SMITH (1952), JENKINS and STEPHENS (1956), LANGDON and FRIED (1948), MOORE and HILL (1945), RUSSELL, JACKSON, GROVER and BEAVER (1944, 1948), SELIGER (1943), WEIBULL (1954c), WÅLLGREN (1949).

54.21 Welded joints: HESS, WYANT, WINSOR and COOK (1944), LANGDON and FRIED (1948), RUSSELL, (1943), RUSSELL and JACKSON (1943), RUSSELL, JACKSON, GROVER and BEAVER (1943, 1944a,b), WEIBULL (1954c).

54.22 Bonded joints: HARTMAN and DUYN (1952), SCHLIEKELMANN and COOLS (1952), WEIBULL (1954c).

54.3 Screw connexions, aircraft joints, attach angles: HEYER (1943), LUTHANDER and WÅLLGREN (1944), MCCLENDON, KLAUER and DUSTO (1952), RUSSELL, JACKSON, GROVER and BEAVER (1948), WALKER (1958), WEIBULL (1955c), WÅLLGREN (1954).

54.4 Loaded holes, lugs: HERTEL (1931), HEYER (1943), SCHIJVE and JACOBS (1957), VINCENT (1952).

54.5 Structural components, beams, sandwich constructions: HARTMAN and RONDEEL (1954), HYLER, POPP, GIDEON, GORDON and GROVER (1958), WERREN (1948, 1949).

54.6 Aircraft wings, tail planes: FEARNOW (1951), JOHNSTONE, PATCHING and PAYNE (1950), KEPERT and PAYNE (1956), MCCLENDON, KLAUER and DUSTO (1952), PAYNE (1956a,b), PIERPONT (1947), RAITHBY (1951), WHALEY, MCGUIGAN and BRYAN (1956).

54.7 Fuselages: HOTSON (1949), R.A.E. Report (1954).

SECTION 55. PREPARATION OF TEST PIECES

55.0 General

Mechanical treatment is applied to test pieces in order to produce the required dimensions and a proper surface finish, whereas heat treatment is intended to give the material the desired structure and to relieve it from residual stresses caused by the preceding mechanical treatment.

In order to permit the correlation of results from different laboratories and to guarantee reproducible values of the fatigue life, the procedure for preparing test pieces should be standardized or otherwise specified.

55.1 Mechanical Treatment

The processes which are applied to circular specimens are: turning, grinding, and polishing. It is not necessary to use all three procedures on a specimen; sometimes the treatment consists only of turning, or of turning and grinding, depending on the surface condition required.

Detailed instructions and recommendations of specimen treatment are to be found in the ASTM Standards. A complete description of the machining of smooth and notched steel rotating-beam specimens, used in an extensive investigation, is given in a WADC Report by CUMMINGS, STULEN and SCHULTE (1955, Appendix III).

The preparation of smooth rotating-cantilever specimens of 24S–T aluminium alloy, including nine alternative procedures (two turned, four ground, and three hand-polished finishes) is described in detail in an ARL Report by MANN (1950). Reference is also made to a description by HARDRATH and UTLEY (1952).

Procedures for polishing metallic specimens followed by the Naval Experiment Station and by the University of Illinois are given in the ASTM Manual on Fatigue Testing, Section IV, by JOHNSON (1949). Recommended procedures of polishing specimens of plastic are described in the 1949 Book of ASTM Standards, Part 6.

As a substitute, not to say improvement, of mechanical polishing it may be convenient, particularly when preparing a large number of notched specimens, to use electrolytic polishing, which is claimed to produce a minimum amount of residual stress. This method is discussed, for example, by FAUST (1948).

A comparatively new process for the specific purpose of producing test specimens for research consists in "chemical milling", developed at the Turco Products Inc. U.S.A. and described by DICKINSON (1956).

Flat unnotched specimens with circular contours may be clamped together in stacks about one inch thick and machined in a lathe to produce the radius of curvature of the reduced test portion of the specimen. Notched specimens are usually machined along the parallel edges in stacks and the notches are then cut with a milling cutter in each specimen separately.

The surfaces of flat specimens are frequently left unpolished, but the edges are then slightly rounded and polished, for example with No. 400 Aloxite paper, in a direction parallel to the edge.

References: CUMMINGS, STULEN and SCHULTE (1955), DICKINSON (1956), FAUST (1948), HARDRATH, LANDERS and UTLEY (1953), HARDRATH and UTLEY (1952), JOHNSON (1949), MANN (1950).

55.2 Heat Treatment

The purpose of heat treating the specimens is to obtain the desired structure of the material and to eliminate residual stresses.

The structure is produced by one or more of the following processes: normalizing, hardening, quenching, tempering, and stabilizing. Temperatures and times for each process have to be specified individually for each type of material.

The stress-relieving process consists of putting the specimen into a furnace—possibly purged for some prescribed time—and heating it to a given temperature during a certain time, followed by a slow cooling.

A refined method of heating steel fatigue specimens is described by HUTCHISON and BEISSEL (1955).

Reference: HUTCHISON and BEISSEL (1955).

SECTION 56. MEASUREMENTS ON TEST PIECES

56.0 General

The various procedures may be classified into measurements of: (1) dimensions; (2) surface geometry; and (3) stress distributions within the specimen.

56.1 Measurement of Dimensions

During the machining of the test portion of the specimen, the dimensions may be measured by means of a micrometer; after the last cut has been taken, however, or the polishing process has been finished, it is recommended that a toolmaker's microscope be used in order to avoid surface damage due to handling.

Dimensions used for calculating the nominal stresses, i.e. for calculating the cross-sectional area, or the moment of inertia, should be measured with an accuracy better than 0·1 or 0·2 per cent, and the nominal applied stresses should be calculated for the actual, not the nominal, dimensions of the specimen.

If the specimen is of a complicated shape, then it may be necessary to design some special jig to determine the location of the maximum stress in the test section, as described by BENNETT and BAKER (1950) in connexion with a new design of bending-test specimen.

If the nominal stress varies over the length of the specimen due to its shape, the dimensions of the fracture should be measured. It is quite acceptable to measure the location of the fracture and to compute the stresses at the fracture surface from the dimensions of the virgin specimen.

Reference: BENNETT and BAKER (1950).

56.2 Measurement of the Surface Geometry

Various methods of examining the surface of a specimen are discussed in Section 45. The most usual methods for measuring the surface geometry of specimens are the non-destructive stylus method and the destructive taper sectioning method. A broad outline of the taper sectioning method is to be found in a paper by MOORE (1948) and in another by NORRIS (1948).

Results from both of the above-mentioned methods are given in a report by MANN (1950) where typical surface finish traces, recorded by means of a

Brush Surface Analyser, are given for course-turned and diamond-turned finishes, for four different ground finishes, and for two different hand-polished finishes. The vertical magnification used was 4000, and the horizontal magnification 80. Taper sections of the ground and the polished finishes are also presented, using a vertical magnification of 2000 and a horizontal magnification of 200.

A summary measure of the surface roughness, less precise than the complete trace, is obtained by indicating the microinches the distance from the highest peak to the lowest valley on the surface, measured by a surface analyser.

References: MANN (1950), MOORE (1948), NORRIS (1948).

56.3 Measurement of Stress Distributions

It may be advisable to check the stress distribution in new designs of specimens by photo-elastic analysis to avoid unexpected stress concentrations, and also to examine notches for which stress concentration factors cannot be calculated according to known reliable formulae.

Stress distributions in actual smooth specimens can be determined by means of electrical resistance strain gauges or by optical and electromagnetic extensometers. If applied to notches, the ratio of notch dimensions to gauge length of the strain gauge should be as large as possible.

As an illustration, reference is made to a comprehensive investigation carried out by HARDRATH and OHMAN (1951). The sheet specimens examined had dimensions as large as 48 by 142 in. Baldwin SR–4 type A–5 strain gauges and Tuckerman optical gauges with a $\frac{1}{4}$-in. gauge length were used. Elastic and plastic stress concentration factors for fillet-type, hole-type, and edge-cut notches were successfully determined over a wide range of load.

Reference: HARDRATH and OHMAN (1951).

SECTION 57. PROTECTION OF TEST PIECES

57.0 General

The detrimental effect of mechanical surface damage on the fatigue properties of specimens was early detected. It was observed by SONDERICKER (1892) that a reduction in fatigue strength of not less than forty per cent resulted when a soft steel specimen was scratched with a diamond point to a depth of 0·003 in. A similar observation was reported by EDEN, ROSE and CUNNINGHAM (1911) who found an appreciable reduction in fatigue strength of a polished rotating-beam specimen of mild steel which had its surface scratched with a sewing needle.

Chemical aggression may be equally harmful. Even touching the unprotected surface of a specimen with the hand may cause corrosion. Corroding environment and its influence on the fatigue properties is discussed at length in Section 65, paragraph 4.

It is thus evident that test pieces must be protected as much against mechanical damage as against chemical aggression.

References: EDEN, ROSE and CUNNINGHAM (1911), SONDERICKER (1892).

57.1 Protection against Mechanical Damage

After the specimen has been polished, it is recommended that measurements of the diameter of the test section should not be made by means of measuring devices such as micrometers which are based on mechanical contact with the specimen.

The test piece should be handled carefully, and immediately after the preparation it should be soaked in some suitable fluid, cleaned with a fine brush, and stored in a box in such a way that no damage to the test section can occur.

Some of the coatings, primarily intended for preventing corrosion, are also useful as protection against damage in handling the specimen.

57.2 Protection against Chemical Aggression

The unprotected surface of the test section should not be touched by hand. Immediately after preparation a coating of mineral oil or non-corroding grease should be applied to the test piece.

For aluminium alloys it is recommended that the surface be protected by a coat of zinc-chromate primer. This primer may be applied to each face of the sheet when received and allowed to remain during the machining procedure. It must be removed before electropolishing. After such an operation the specimen may be coated with vinyl seal for protection against both corrosion and damage due to handling. This coating is removed with acetone immediately before testing the specimen.

Reference: GROVER, HYLER, KUHN, LANDERS and HOWELL (1953).