SOME AIDS TO REDUCE FAILURES OF ORTHOPEDIC PARTS

By FRANCIS L. SMITH, Fellow
With JOHN L. YOUNG, Ph.D., Senior Fellow

The Sarah Mellon Scaife Foundation's Multiple Fellowship on Orthopedic Appliances
at Mellon Institute, Pittsburgh, Pennsylvania

Most bracemakers have probably had the experience of making an orthopedic part for a number of years without any trouble and then suddenly they have a patient who keeps breaking a part over and over again. The final result is usually valuable time and money lost and a dissatisfied or lost customer.

A large number of these broken parts may be classified as fatigue failures. Fatigue failures generally plague any manufacturer that must constantly make a product as lightweight as possible. The aircraft and orthopedic industries definitely are alike in this respect. Lightweight but strong is easier said than done.

What causes fatigue failure? *First of all*, fatigue failures occur only on parts that are subjected to repeated loading. For example, the average man puts his weight on an artificial leg or leg brace about one million times a year. This is repeated loading.

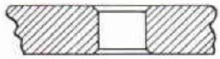
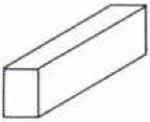
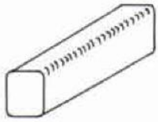
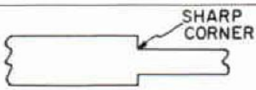
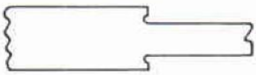
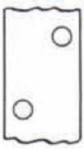
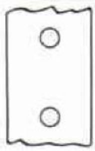
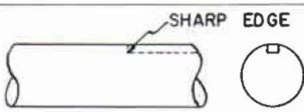
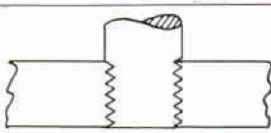
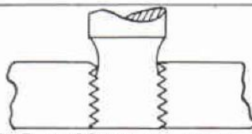
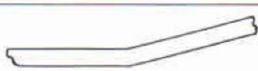
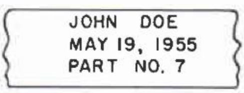
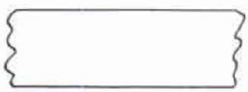
Secondly, most fatigue failures involve a stress raiser such as is shown in the accompanying series of illustrations. Stress raisers give the same effect as increasing the load on part of the metal. Some people find it difficult to believe that a file mark, a scratch, or a hammer dent can eventually lead to the failure of a machine part. Of course, without experience, it is also hard to believe the story of the one rotten apple in a barrel.

Thirdly, in order for the failure to occur, there must be stress in the area of the stress raiser. If the stress in this area is low, even a stress raiser cannot raise the stress high enough to do harm. This is probably the main reason many people will look at the the illustrated examples, (see Table) and say, "I've been doing those things for years and never had any trouble."

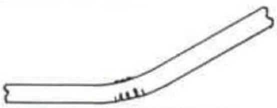
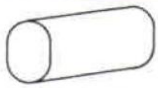
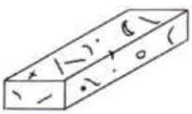
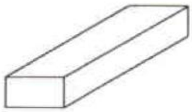
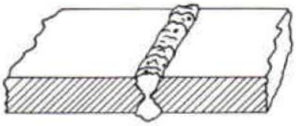
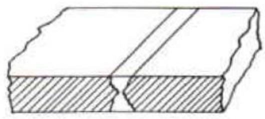
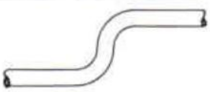
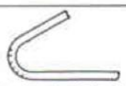
How can a fatigue failure be recognized? The answer can probably be best made by explaining how the failure occurs.

For instance, let us consider a side bar on an ischial seat leg brace. Every time the patient puts his weight on the brace the side bars are stressed. The back of the side bar is compressed and the front side of that bar is stretched or put into tension. Since fatigue failures are usually caused by tension rather than compression, the front side is the dangerous side. If this front side is polished smooth and the stress is not too large, no damage will be done. If the front side has a stress raiser on it, such as a sharp indentation, then whatever stress happens to be at the sharp indentation will be increased by two, or three, or maybe ten times. If, after this multiplication, the stress is still below what the material can take, no harm will be done. For the purposes of explaining the process, we will assume that the stress at this small pinhead area is too large. One grain or a small particle of the material will fail and the load it was carrying will have to be borne by the neighboring grains. Small individual grains will continue to fail, and eventually a crack, so small no method yet known can detect it, will form. This process, which may take a week, a month or a year to occur, only proceeds every time the man puts his weight on the brace. The initial crack

HELPFUL HINTS TO REDUCE STRESS RAISERS

CAUSE	REMEDY
 1. DRILLED OR TAPPED HOLES	 REMOVE SHARP EDGES BOTH SIDES
 2. SHARP EDGES ON BARS	 REMOVE SHARP CORNERS
 3. SUDDEN CHANGE IN CROSS-SECTIONAL AREA	 USE LARGE FILLET IF POSSIBLE  IF SHOULDERS ARE NECESSARY
 4. OFFSET HOLES IN BARS	 PLACE HOLES IN CENTER
 5. KEYWAY	 REMOVE SHARP EDGE
 6. THREADED JOINT	 REMOVE MATERIAL ON BOLT. ANNEAL AND RETEMPER CUT TH'D
 7. SHARP BEND IN BAR	 MAKE BEND MORE GRADUAL
 8. NAME STAMPING	 DO NOT STAMP, USE STICK-ON LABEL

HELPFUL HINTS TO REDUCE STRESS RAISERS

CAUSE	REMEDY
 9. VISE CLAMPING MARKS	 PLACE SOFT COPPER ON VISE JAWS
 10. CRACKS IN PLATED OR SURFACE HARDENED PARTS	 PLATE OR SURFACE HARDEN AFTER BENDING
 11. FLASHING ON FORGING	 REMOVE FLASHING
 12. SHARP BEND IN CABLE OR WIRE	 MAKE BEND GRADUAL
 13. FILE MARKS, HAMMER MARKS, SCRATCHES, NICKS, ETC.	 MAKE SURFACE AS SMOOTH AS POSSIBLE
 14. WELDED JOINT	 MACHINE SMOOTH; ANNEAL IF NECESSARY
 15. ANY COLD WORKING	REMOVE COLD WORKING BY ANNEALING. RETEMPER IF NECESSARY
16. WELDING AND HEAT TREATMENT	FOLLOW MANUFACTURER'S RECOMMENDATION
 17. CRACKS DUE TO BENDING	 BEND AND ANNEAL IN STEPS
18. CHROME PLATING	BAKE IN OVEN 3 TO 4 HRS. AT 350°F
19. CORROSION 	USE ALUMINUM, STAINLESS STEEL, PLATED STEEL, OR SUITABLE NONTOXIC COATING

sometimes appears as a very shiny spot that can be seen after the fracture is completed.

Such a crack continues to grow until the remaining area is too small to support the load. The crack may be detected at this time and caught before failure takes place. If not detected, in a very short time failure will suddenly occur. It will be a quick failure, such as happens with brittle material.

Examination of the failed section will frequently show two distinct nearby areas in addition to the shiny spot mentioned previously. The area close to the shiny spot on the front of the side bar will usually be smoother than the back half of the area. Sometimes the front part will have grooves like those of an oyster shell. The back area will appear the same as an ordinary piece of material pulled apart by one loading. In general, necking or yielding, such as would occur if the patient fell and bent the brace, will not be visible.

The first fourteen stress raisers, or causes of failure that are pictured, can be avoided by proper initial design and by taking a little extra care in machining or handling the parts.

Cold working metal, No. 15, can sometimes do good and occasionally do harm. Unless the type and location of residual stress remaining in the metal and also the type and location of applied stress are definitely known, it is best to remove any effects of cold working. Of course, if no failing of these parts has occurred, the added expense of annealing and retempering them is not warranted.

Welding and heat treatment (see No. 16) have caused many a failure when improperly done. The safest procedure is to follow the manufacturer's recommendations. A Mellon Institute article, entitled, "Heat Treating for Orthopedic Appliances," by John L. Young, published in the May 1951 issue of the *Journal of OALMA*, may be of some help.

Metal pieces can only be bent so far without causing cracks. If the ductility is so low that a bend cannot be completed in one step without causing cracks, the proper procedure is to bend in small increments, annealing after each small bend.

Bracemakers should realize that any type of metal plating will reduce the fatigue strength of a part. Baking of chrome-plated parts in an air medium will restore some of this lost strength. Although 350°F. is shown in the illustration, the best results are obtained by baking at as high a temperature as possible. Naturally the tempering temperature must *not* be exceeded.

Any part that might be exposed to corrosion should be made of noncorrosive material or covered with a nontoxic coating. Corrosion and repeated loading together form a most dangerous team. Plating is to be preferred to corrosion.

Since a number of orthopedic parts are exposed to perspiration of the body, corrosion fatigue probably causes a large percentage of the failures that do occur.

Surface hardening, such as obtained by cyaniding or nitriding, is very beneficial. Often a part that has been lasting only a month or two can be made to last a year or more.