THESIS

A STUDY OF THE EFFECT OF THE REVERSAL OF STRESS ON DIFFERENT SIZED FILLETS

B. H. A. BRANDELL H. J. WEBBER

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A Study of the Effect of the Reversal of Stress on Different Sized Fillets

A Thesis Submitted to

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By

B.H.A.Brandell H.J.Webber

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It was the original intention of this thesis to find the effect of different sized radii on the endurance of steel when subjected to a continuous reversal of stresses. At the present time one of the most important points to be determined in connection with machine construction, especially automobile rear axles, is the proper fillet to put on different sixed shafts. After breaking four test bars of different radii the machine upon which the test was being run was destroyed necessitating a change in our plans for the completion of the thesis.

Owing to the fact that there is not much known in regard to the effect of continued reversal of stresses on the microscopic structure of steel, we decided that it would be of value to study the metallography of a cross section of the broken bars at the point of rupture.

The steel upon which these tests were run was a chrome nickel steel stamped CN and furnished by the Frost Gear Works of Jackson, Mich. having the following analysis.

Carbon.............	.41
Manganese..........	.61
Phosphorus.........	.034
Sulphur............	.037
Silicon............	.17
Nickel.............	3.09
Chromium...........	.66

We annealed this steel before running the tests by heating it to 1360 ^{o}F. for two hours and allowing it to cool in the furnace.

After heat treatment this steel had an elastic limit of 122,000 pounds per square inch in tension, and 126,000 pounds per square inch in compression.

The test bars used were single ended bars turned to one inch in diameter where they were gripped in the testing machine, and were turned to one half inch in diameter at the critical point at the base of the radius. The distance from the critical point to the point of application of the load was four and thirty four hundredths inches. The load applied to the bar was 125 pounds which made the maximum fibre stress 45,000 pounds per square inch. The testing machine turned the bar at the rate of 1300 R.P.M. making 2600 reversals of stress per minute, continuously from the time that the test was started until the bar was broken.

Five bars were tested in the above manner giving the following results;

Bar	Radius	Revolutions	Remarks.
1	0.00 inches	44,000.	
2	1/16	81,600.	
3	1/8	323,500.	Bar run slightly out of true.
4	1/4	5,181,000.	
5	3/8	30,000,000.	Bar not broken and appaently in good condition.

The object of this data was to enable us to plot a curve showing the relation of the radius to the number of reversals of stress necessary to rupture the piece. After having plotted this curve it would be possible to tell the number of reversals of stress that a piece would stand before rupture would occur,if you knew the radius at the critical point. Also this curve would have enabled us to derive an emperical formula where by it would be possible for us to estimate mathematically the number of reversals of stress that a piece of this steel would endure if the radius and the fibre stress at the critical section were known. However we have not enough data taken under the different to enable us to write a formula that would be of any value from a theoretical or practical point of view. From what small amount of data that we were able to collect there seems to be relation of the ratios of the radii to the number of reversals.

In the report of the American Society for Testing Materials for 1915 there are formula for the determination of endurance of test bars of identical design when subjected to a reversal of stress under different loading. These formula involve the use of constants which are determined only by - experiment,and are therefor not applicable to our data,in as much as we did not get enough data to determine the constants for our steel.

Further study of this steel consists of a microscopic examination of the steel at and near the point of rupture, The purpose of this examination is to determine if possible some of the causes of failure,and gather such information on the metallography of the steel as might be of value in the continuation of this experiment.

Considerable difficulty was experienced in this connection because this subject had never been taught at this college,none of the apparatus was assembled in readiness for operation,and some of the pieces were lacking which made it necessary to improvise parts for the completion of our experiment.

The polishing table used was of the horizontal type having four spindles and twelve tools,as is shown in an accompaning photograph.

Since there was no one who seemed to be willing to tell us the kind of cloth to be used in covering our tools,and the proper powfers to be used for polishing,it was necessary to make a trip to the experimental labratory of the REO Motor Co.,where through the kindness of Mr.Baker we were shown the proper method of covering the tools,the powders to be used for polishing,and the method to be followed in polishing the specimens.

Two kinds of cloth are used for covering the tools. The coarse polishing is done on tools covered with heavy duck ,while the finishing is done on tools covered with good quality of serge or billiard cloth. The cloth can be tied on the tools or cemented on with pitch. We found the latter method to be much more satisfactory since it insured a more even durable surface. When the cloth was tied on we found that the polishing powder gatehered under the cloth in ridges which ground streakes in the surface of the specimen.

The best abrasive to use for polishing is a set of Norton's alundum polishing powders. We were unable to secure a complete set therefor we were compelled to make substitution.

In preparing a specimen it is first necessary to grind a flat surface on a fine emery wheel,next comes the rough polishing which we did on a canvas covered tool using Norton's alundum powder #150. The next polishing operation was also performed on a canvas covered tool with Norton's #F4 alundum powder,the final abrasive operation was performed on a serge covered tool using an alundum powder which we obtained from an optician,the grade of which we could not ascertain. The specimen was now polished on a serge covered tool impregnated with rouge which has no apparent abrasive properties. The polishing was now complete and the specimen was ready to be etched.

The etching solution was composed of two per cent chemically pure nitric acid in alcohol. A specimen was stirred in this solution for approximately twenty seconds,then washed in pure alcohol and dried on a blotter. The specimen was then ready for microscopic examination.

Owing to the fact that the specimen was opaque it was necessary to use an arc light with a Bausch and Lomb vertical illuminating attachment on the microscope.

Since the Chemical department which has charge of this work did not posess a photographic attachment for their microscope,it was necessary for us to improvise one by taking the lens out of an ordinary camera and placing its lens board against the eyepiece of the micro scope. Since this apparatus was not rigid and our first photographs showed indications of vibration,we decided that it would be advisable to take a series of pictures on a photographic micrscope in the Entymology building so that we could get a good idea of how the photographs should look and also obtain information asto the method of making good reproductions. The photographs taken with this apparatus were magnified to about fifty diameters and will be shown on one of the following pages.

Owing to the fine chrystaline structure of this steel (which is charecteristic of all alloy steel) fifty diameters was not sufficient magnification to show any great amount of detail. Resuming work on the apparatus in the chemical depattment we endeavored to take photographs of the specimen magnified to 1600 diameters. Here we encountered difficulties which we were unable to eliminate in the shape of distorted images and shadows, that could not be accounted for, however parts of the plates are free from this distortion and the structure of the steel can be distinctly recognized.

We were unable to obtain a photographic reproduction of the steel as close to the edge of the rupture as we desired because in polishing the edge becomes sufficiently rounded to prevent focusing, and caused interference of the light at such high magnification..

After a close examination of both the low and high magnified reproductions of our specimens we were unable to distinguish any difference in the structure of the fatigued specimen and one that had not been fatigued.

This experiment seems to corroborate the theory that the failure is due to the development of a microscopic crack that gradually increases with the continuation of the number of applications of stress until complete failure is accomplished.

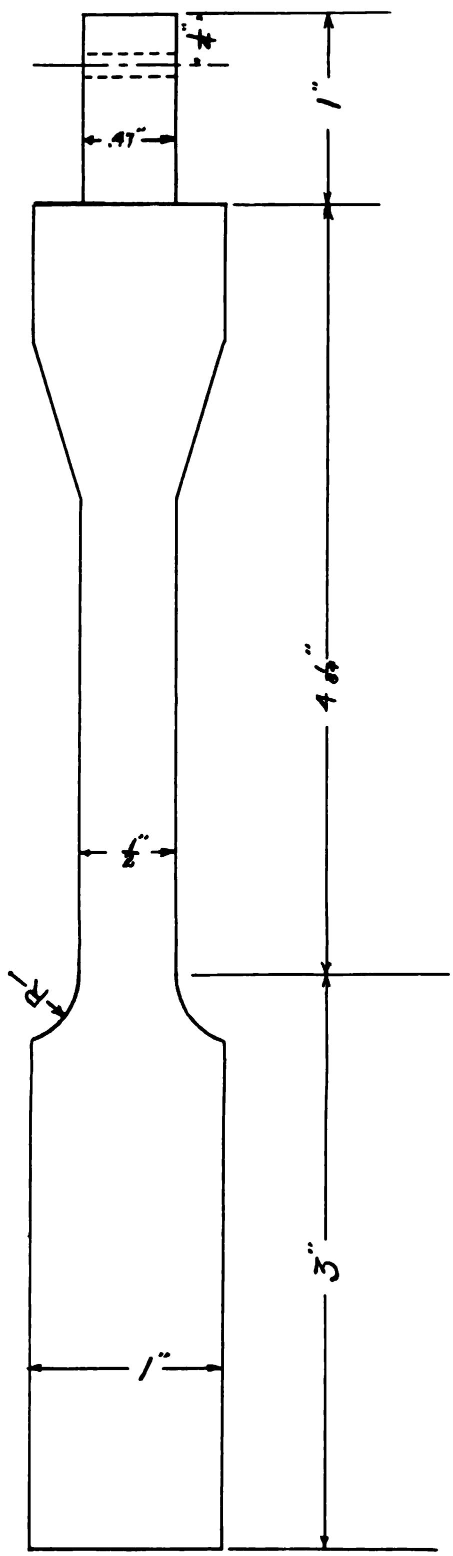
References.

The Failure of Materials under Repeated Stress - H.F. Moore and F.B.Seely. Published in thé transactions of the A.S.T.M. Vol. XV part II.

The Metallography of Iron and Steel by Albert Sauveer. Professor of Metallurgy and Metallography in Harvard University.

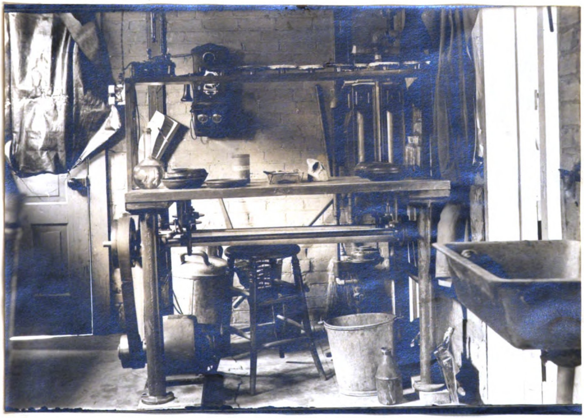
The metallurgy of Iron and Steel by Bradley Stoughton.

Iron Steel and other Alloys by H.M.Howe.

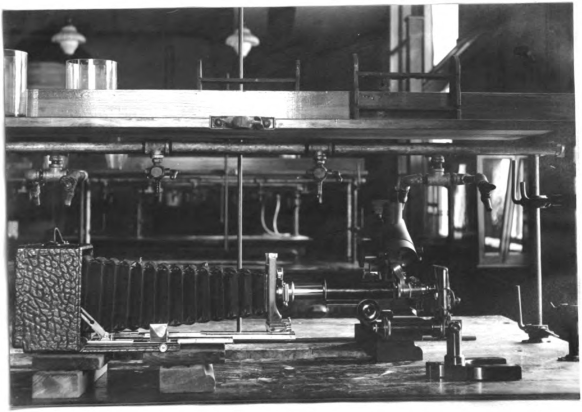


A drawing showing the design of the test bar which varied 0.00 inches to one and one quarter inches.

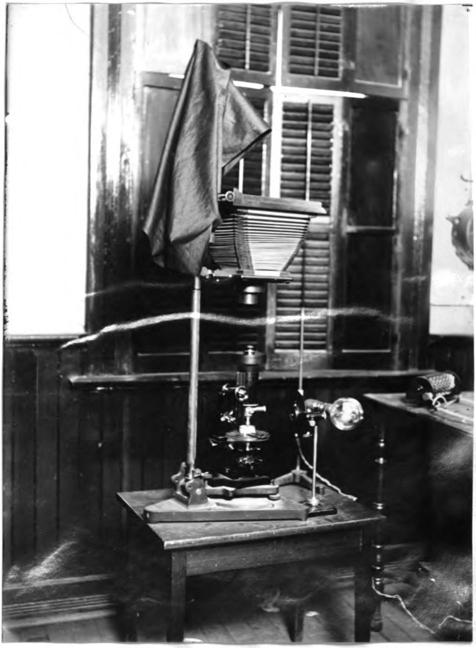
A photograph showing the polishing table upon which the specimens were polished. This table was manufactured by the engineering shops at the University of Michigan.



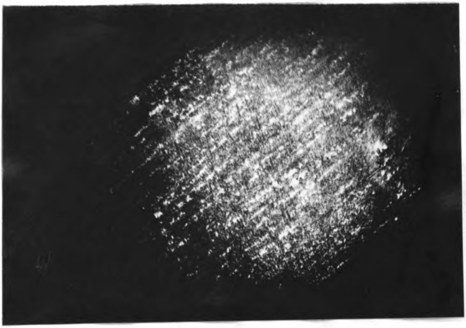
A Photograph showing the setup of the Photo-microscopic apparatus in the chemical department. This apparatus consists microscope equipped with a Bausch and Lomb vertical illuminator,and an ordinary four by five camera with a long bellows.

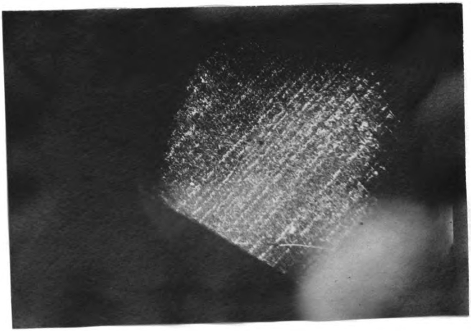


A photograph showing the photo-microscopic apparatus in the Entymology building.

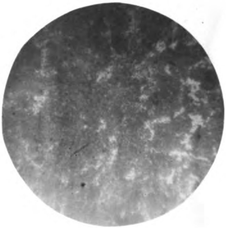


Specimens number one and two magnified 50 diameters.





A reproduction of the specimens magnified 600 diameters.



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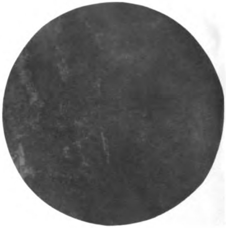

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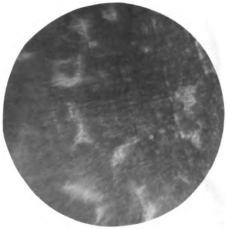

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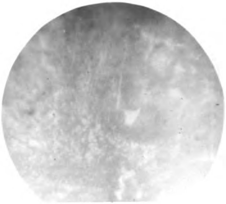
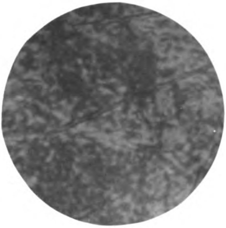


4

A reproduction of the specimens magnified 1600 diameters.



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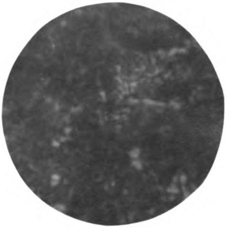

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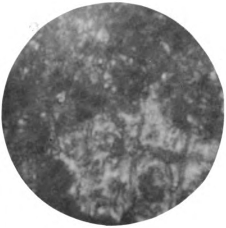

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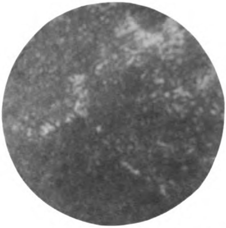

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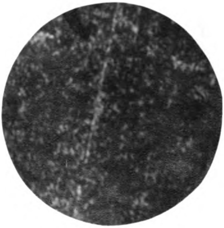
A specimen which has not been fatigued magnified 1600 diameters.



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