THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

INVESTIGATION INTO METHOD OF FATIGUE TESTING STRIP

Report No. 357

by

C. J. Rushton, B.Sc.

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SUMMARY

An investigation has been carried out into the method of fatigue testing spring steel strip which is currectly used by S.R.A.M.A. to generate fatigue data for strip. The aim of the work was to determine whether or not any element in the set up procedure or test condition has any effect on stress levels generated in the strip. Any variability in the stress level would, as a consequence, produce scatter in the data produced.

The strain gauge work undertaken has established firstly that theoretically predicted stress levels are some ten to twenty percent less than actual stress levels. Secondly, when setting the strip by feel in the test jig at the no load point a range of stresses from -9 to +31N/mm^2 was in fact set up (ideally the stress should have been zero). During the investigation it also became apparent that the stresses set up varied from jig to jig and from machine to machine.

To produce consistent and repeatable stress levels at the no load point, a 'sandwich' jig and new set up procedure were developed. Subsequent tests showed the stresses at the no load point to vary over the range ±5N/mm^2. Using individual machine-jig calibration curves, the stress set up in the strip at each loading level is also repeatable to within ±2% at the worst case. Test temperature was investigated and found to have an insignificant effect on stress levels.

Dynamic work was carried out with equipment which was suited to static work only. However, the work did indicate the stress range to fall off by a maximum of approximately 5% over a test speed range of 0 to 3000 r.p.m.

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1. INTRODUCTION

In recent years S.R.A.M.A. has developed a method of fatigue testing strip in a buckling mode. This method is used to generate fatigue data for spring steel strip and has been described in full previously in Report No. 328. The advantages of using this method are that the position of maximum stress is induced in the centre section of the sample, well away from the clamping points. This is achieved without the need to specially shape the section which introduces a false edge condition. Hence the effect of the true edge condition can be investigated. Further, the jig used requires only a reciprocating motion which ensures that the method is compatible with standard fatigue testing equipment currently in use at S.R.A.M.A.

Recently, however, some doubt has been cast on this method of testing since the results of fatigue tests carried out using this technique have not proven repeatable with considerable scatter and descrepancies being noted in the data produced. This project was therefore undertaken to investigate the test method in order to establish whether or not the method was the cause of the unreliable data and if so to develop and refine the technique to a reliable level.

There were therefore two main parts to the work carried out, these being static and dynamic. The static work involved investigating the actual setting up of the strip in the fatigue testing jig both at ambient and slightly elevated temperatures to determine whether the temperature changes during test could affect the stress levels generated. The dynamic work involved investigating the test speed to see if this had any effect on stress levels.

The object of this work was therefore to examine the test method and alter or develop as appropriate relative to results obtained.

2. EQUIPMENT

The test equipment comprises a single station reciprocating fatigue testing machine to which is attached a previously developed jig for fatigue testing strip in a buckling mode and which is described in an earlier report. (1)

The measuring equipment comprises a piece of 0.5 mm x 20 mm x 75 mm CS80 spring steel strip to one side of which is attached three wire resistance strain gauges, and from which strains are recorded using a portable strain indicator and ten channel switch and balance unit for temperature testing, a hot box and temperature controller were used.

For the dynamic aspects of the work, an oscilloscope was also used.

3. PROCEDURE

This involved repeatedly setting the strain guaged strip in each of four test jigs and each of four test machines under no-load by feel. Readings of strain at this no load position were then taken for each guage on the strip, averaged and converted to a stress value. Using theoretical values of end deflection, the stress was incremented in steps of $100N/mm^2$ up to $1000N/mm^2$, readings of strain being taken at each step.

For the temperature tests, the above procedure was carried out with the strip inside a hot box. The sets of readings were taken at two temperatures at $30^{\circ}C$ and $70^{\circ}C$, time having been allowed for the temperature to stabilise inside the hot box.

The dynamic work involved setting the strip in the machine and setting the machine stroke and preload to give known static stresses. The machine was then run up from 0 to 3000 r.p.m. in increments, with the stress range being displayed on the oscilloscope. Any fall off in stress range could be detected by comparing the size of the oscilloscope trace at different test speeds.

4. RESULTS, DISCUSSION AND DEVELOPMENT

The first and most obvious thing noticed was that theoretically predicted stress levels were some ten to twenty percent lower than actual stress levels as can be seen from a graph of average actual stress against theoretical stress (Fig. 1). By using this graph for calibraiton, actual values of end deflection for the required stress levels could be obtained. The reason for the inaccuracy of the theory is no doubt because theory is based on samll deflections whereas in practise under test conditions the strip is subject to large deflections.

Secondly, it became apparent that stress levels vary noticably from machine to machine and from jig to jig. It was also found that a large range of stress, -9 to +31N/mm^2, could be induced at the zero load level when setting the strip by feel into the test jig.

The first requirement therefore was to develop a repeatable and more accurate method of setting the strip in the jig. The idea developed was that of using a 'sandwich' jig (Fig. 2), the theory being that by sandwiching the strip between two pieces of thick flat plate, the sample could not bend and so must be repeatably put into the test jig flat (i.e. with minimal stress).

A 'sandwich' jig was manufactured with a window in it to allow tests to be undertaken using the strain guaged strip. Testing was carried out as before except that the method of locating the strip had been changed so that the strip was actually through-clamped instead of merely located. Initially it was found there was still a varying element when trying to determine precisely at what position the second jaw of the test jig was exactly against the end of the 'sandwich' jig. This was overcome by use of a very thin feeler guage, the exact best size of which was determined for each test jig by trial and error until a size had been selected which caused stresses nearest to zero to be set up at the zero load level.

Whilst recording stress levels after altering the clamping method it was noticed that for the set range of loading levels, the stresses recorded had increased by an amount between 10 and 30N/mm². It was considered that this effect was caused by the effective test length of the strip being reduced by the through-clamping locating method. This also suggests that the previous method whereby the strip was merely located did not rigidly hold the strip thus allowing a complex stress area to be set up at the strip ends.

The new method of setting the strip in the test jig using the 'sandwich' jig after being tried out many times with two different test jigs is much more accurate and repeatable than the previous 'setting up by feel' method. In fact, at the zero load level, stresses are repeatably set up now to within ±5N/mm², and the stresses set up at each loading level are repeatable to within ±2.5N/mm² at 100N/mm² and ±3.0N/mm² at 1000N/mm².

The results of the temperature test indicated that the stress at each level was increased by between one and two percent for a temperature change from 30°C to 70°C. This is considered to have little or no effect on the repeatability of fatigue tests since the temperature difference examined is not typical in range or level with any temperature deviations which could be experienced over a twenty four hour fatigue test.

The dynamic work carried out appears to indicate a five percent fall off in stress range over a speed range of zero to 3000 r.p.m. No point was observed at which the natural frequency of the strip caused an increase in stress levels.

Because dynamic readings were taken visually from an illdefined oscilloscope trace and since also an approximate frequency response curve was used, then the accuracy of the five percent fall-off in stress is in considerable doubt. Another factor to put in doubt this figure is that the measuring equipment is only really intended for static work. There is therefore a high probability that it is loss in amplifier gain at high frequencies which is responsible for the observed fall of in stress.

5. CONCLUSIONS

1. The buckling method of fatigue testing strip previously employed produced inaccurate and unrepeatable results due to the fact that accurate and repeatable stress levels could not be induced in the sample test strip. This was due to three main factors.

   a) The theory used for predicting the stress level at a given deflection is not reliable at large deflections. At a predicted level of 700N/mm^2 the actual stress level in the strip was typically 930N/mm^2.

   b) The method of setting the strip in the test jig and the method of clamping the strip combined to make it impossible to set the strip repeatably in the no load position.

   c) The machine to machine and jig to jig manufacturing tolerances introduced further variability in the stress induced for differenct machine/jig combinations.

2. By modifying the set up procedure using actual machine/jig deflection/stress calibration curves and setting the strip by the 'sandwich' jig method described in the report it is possible to repeatably set the strip in the test jig to within ±5N/mm^2 at the no load level, to within ±2.5N/mm^2 at 100N/mm^2, and to within ±3.0N/mm^2 at 1000N/mm^2. This represents a very considerable improvement in repeatability and will have a consequent improvement on the fatigue data generated.

3. Temperature variations can be considered to have negligible effect on stress levels.

4. The recorded fall off in stress range experienced during dynamic testing should not be taken as being accurate since the equipment used was intended only for static work. The effect should however be noted.

6. RECOMMENDATIONS FOR FURTHER WORK

A strain gauged strip should be obtained which is suitable for repeated short term dynamic tests. A strain gauge signal conditioning and amplifier unit should also be hired such that it will then be possible to supply accurate information from dynamic testing so that the effect of test speed on stress levels can be accurately and confidently observed.

Also, fatigue tests should be carried out to quantify the improvement in data generated using the techniques developed by the work.

7. REFERENCES

1. Hood, A. R., "The fatigue properties in bending of 'as sheared' pre-hardened and tempered CS80 spring steel strip". S.R.A.M.A. Report No. 328.

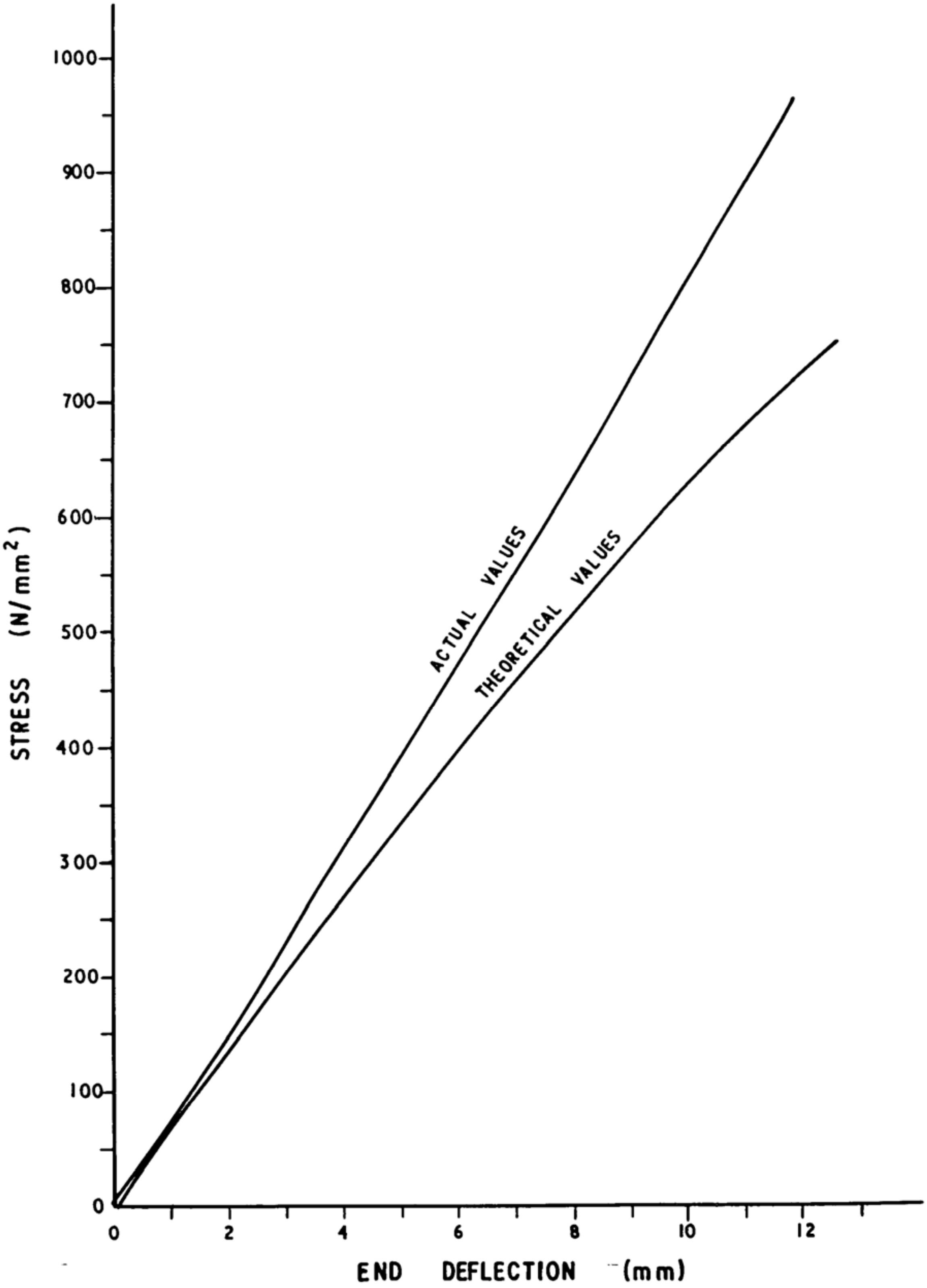

FIG. I. STRESS / END DEFLECTION.

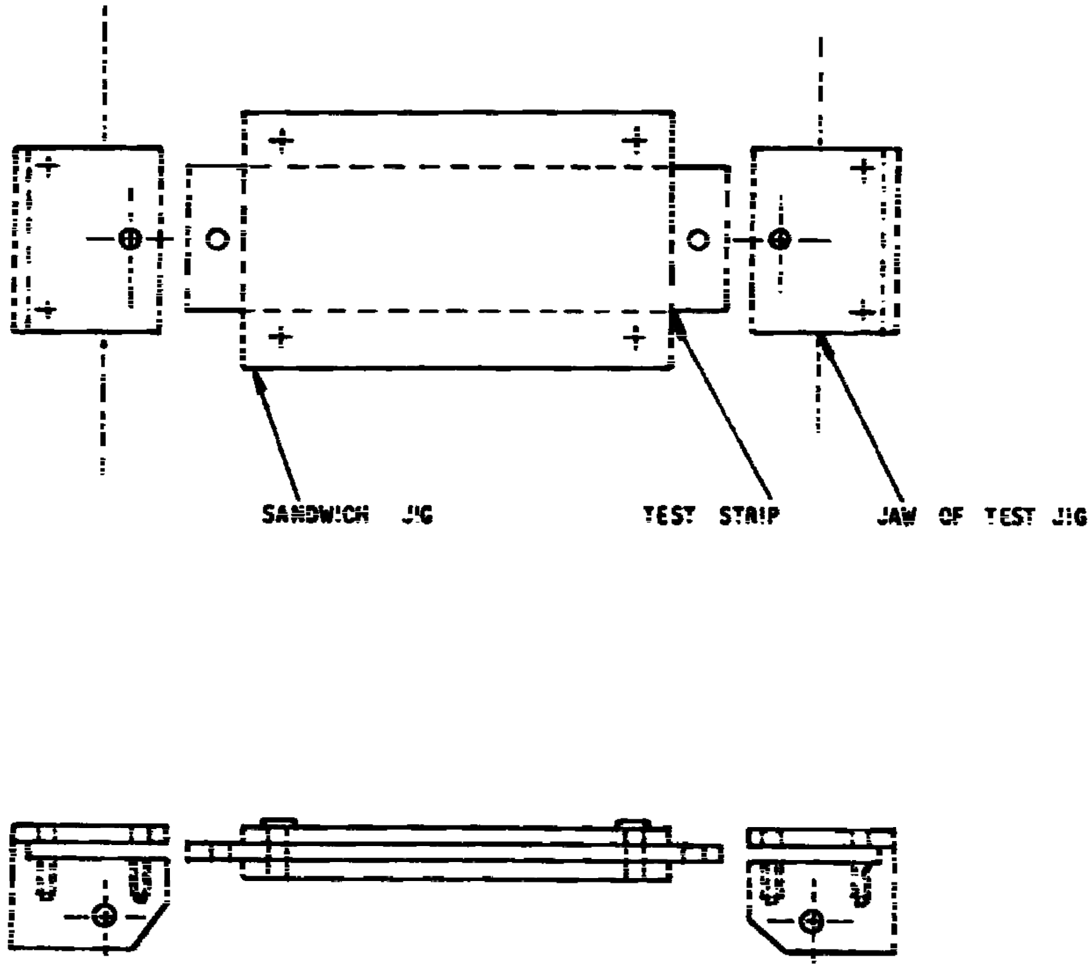

FIG. 2. SETTING JIG.