Effect of Folding and Geometrical Change in Fatigue Life of Thin Metallic Strip under Cyclic Flexing

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Abstract- **Fatigue behavior of a component greatly depends on its shape, size and surface irregularities. Geometrical changes in any component would alter its life.**
The presented work is related to failure of strips when geometrical change is implemented on thin metallic strip. The experimental investigation carried out with in-house built test rig for thin metallic strips. The test specimen standardized and geometrical entities implemented of different strips. Testing is done on market available sheets of mild steel.
This work involves a study of fatigue life on various strips of size 180mm*10 mm with different profile on them. The geometry goes from lower order to higher order of complexity in shape and profile. A comparative study is done based on data acquired from testing which is in numbers of cycles. For better understanding test is also carried out by making notch on specimen and compared with obtained data for various profiled specimen.

Index Terms- **Fatigue, Shape, Geometry, Metallic Strips**

I. INTRODUCTION

The life of engineering component always catches designer's eye. Many researchers have been done in the field of fatigue of various specimens with different material with different geometrical changes. Starting from William Albert published an article on fatigue gives a primary understanding and correlation between cyclic load and durability of metal. A pioneer research work done by the August Wohler who introduced concept of rotating – bending test which led to S-N curve which helps to find out Fatigue life and endurance limit of material.[1]Fatigue in metals is very common and most severe phenomenon where component fails under dynamic loading at it's very much below of strength level. At least 90 percentage of engineering component failed due to fatigue.[2] Effect of stress ratio, specimen thickness, notch and surface roughness on fatigue crack growth and fatigue life observed by various researchers.[3-9]

It is very well known now, fatigue manifest with crack formation, crack propagation and then complete fracture of component. Crack initiated at most stress concentrated point in component and propagates in certain direction until complete breakage of material could not take place. [2]

Several machines have been developed over years for fatigue test in plane bending, pure rotation, pure torsion or combination of these. [10-19] Either in heated condition or in room temperature. The fatigue life of material depends on many factors like geometry, loading condition, surface characteristics and many more. A small change in shape and profile causes either improvement in fatigue life or decrement in much higher level. This happen due to either stress prone region becomes less prone or more sensitive to stress concentration. Here in this paper we try to understand and to relate how an abrupt change in profile can alter the fatigue life of metal strips through experiments. An experiment test machine has been developed first and then by testing some specimen under predefined condition of loading life of metallic strips has been noted.

Results are cited in this paper and some conclusions have drawn as per test.

II. DEVELOPMENT OF TEST MACHINE

Test machine has developed by applying product development philosophy. Modular product architecture has been adopted with taking care of design for manufacturing in mind. Design of machine element has been done as per standard empirical relation thus to avoid long design calculations.

Figure 2.1
A - Electric motor, B - Reciprocating block, C - Fixed block, D - Vertical fixed rod, E – Disc, F – Base plate, G – Connecting rod.

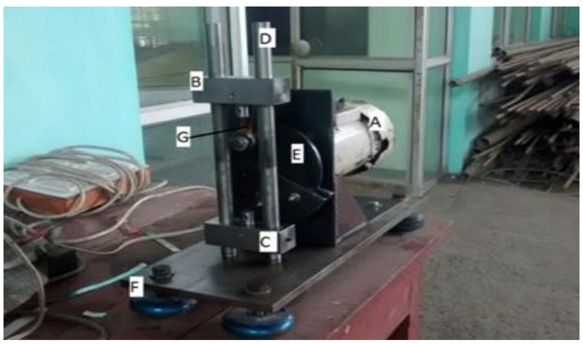


Figure 2.2

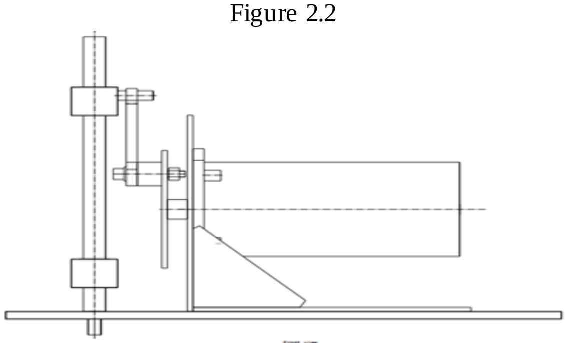


Figure 2.3

The image of test machine is shown in figure 2.1 have one motor, one rotating disc, a connecting rod and two blocks. One of the blocks is static. During operation and it is locked through grave screws and other have reciprocating motion properly guided by two vertical rods which is fixed to base plate. The motion is given to block through four bar link mechanism. Speed of electric motor has controlled by the rpm controller to make speed up to desired limit.

Figure 2.2 is a side view of machine and figure 2.3 and figure 2.4 are the drawings of machine made by using CAD software.

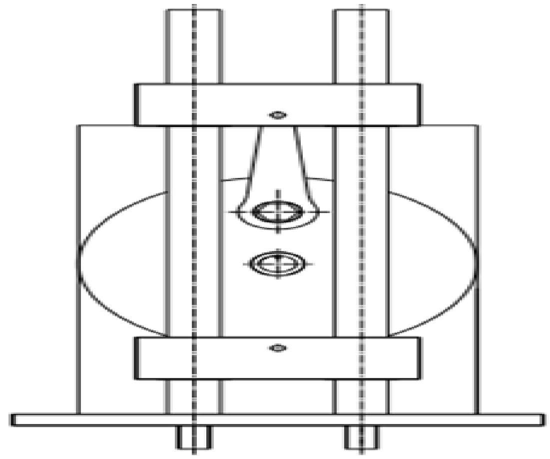


Figure 2.4

III. PREPARATION OF SPECIMEN

Metallic sheet has cut to a size of 180x10 mm and 4 different profile been made (figure 3.2a-3.2e). Thickness of strip fixed and is of .15mm. material of specimen is mild steel. In figure 3.1 the sketch of specimen has shown.

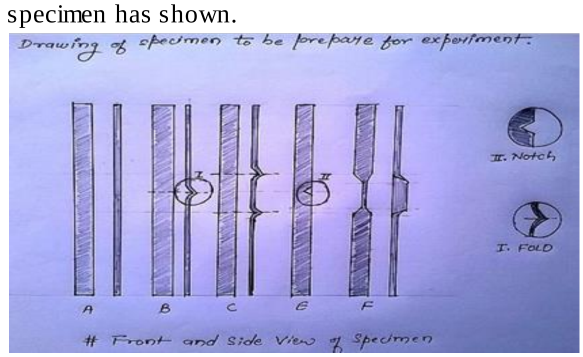


Figure 3.1 Sketch of specimen prepared for experiment.

Table 3.1 Table of specimen with features

S. No.	Specimen name	Specimen feature
1.	Specimen “A”	Plain strip, without any mark notch or fold
2.	Specimen “B”	Strip with single fold at mid of length along width
3.	Specimen “C”	Double folding at 15 mm distance from mid of length both side
4.	Specimen “E”	A V- Notch at mid of strip, without folds
5.	Specimen “F”	A complex profile of length 10 mm symmetric along length of length at mid of strip


Image 3.2(a): Specimen "A"


Image3.2(b): Specimen "B"


Image 3.2(c): Specimen "C"


Image 3.2(d): Specimen "E"


Image 3.2(e): Specimen "F"

IV. EXPERIMENT

Tests are carried out at normal atmospheric condition, temperature 37 0c by fixing speed range between 150-160 rpm. Motion to the block is given by the motor through four bar linkage mechanism. Speed controlling is done with D C dive revolution controller.

20% of actual power is given to drive system to desired rotation some of actual 20 % power consumes to drive the system and rest to move the block. This is calculated below.

1500*.20 = 300 rpm

but due to some power is consumed by system (to overcome friction and other phenomenon) it runs in between 150 to 160 rpm.

Thus power consumed by system is 10 % around

Specimen is so constrained to only flex and bend in one side with flexing limitation of 90mm in length. Load given through motion of block in axially up and down fashion. Specimen is gripped by grave screw in jaws from both side of strip.

Table 4.1 observation table

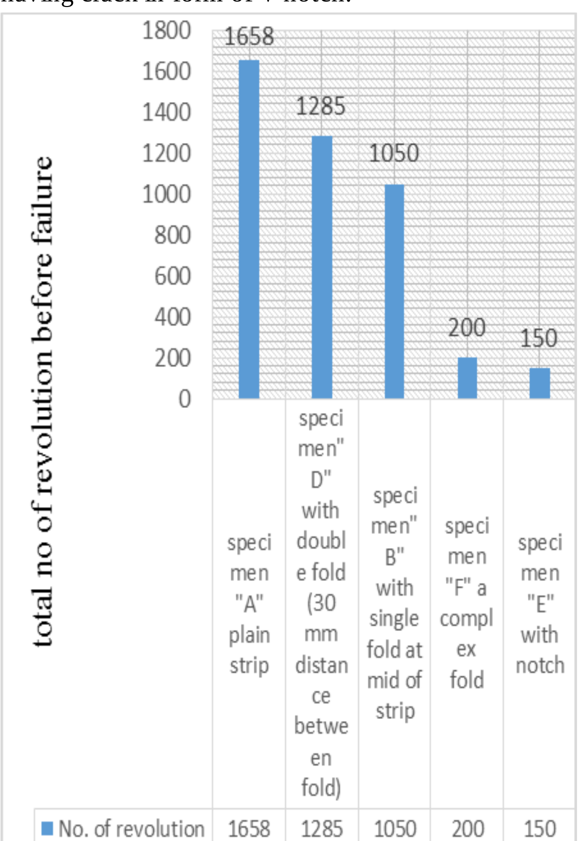
S. No.	Specimen name	Revolution count	Remark
1.	Specimen "A"	1658	At starting cycles no fold or mark seen strip flex smoothly and do not resist the motion of block. Few cycles before the fracture a line clearly visible at almost the mid of length which is the point of crack initiation finally after a few cycles strip break off in two parts
2.	Specimen "B"	1050	As a fold already been made in strip which is most stress concentrated point. Fold is first unfolded. After a number of cycles a line clearly visible at the fold just before fracture crack initiated at fold and strip break off in two parts.
3.	Specimen "c"	1285	Same as specimen "B" strip first unfolded. Unlike previous, in this specimen, two stress concentrated zone already made. Initially strip flex smoothly. After that there is two line seen in specimen both are same as the folding line but first crack initiated at upper line and strip fails from there.
4.	Specimen "E"	120	The line of failure seen very early in testing at the notch and strip fails within a minute
5.	Specimen "F"	200	Complex fold zone was the stress concentration zone and strip fails suddenly just before the starting of complex geometry.

V. CONCLUSION

Obtained data by the experiments conducted are used to make bar chart. Through experimental data it can be concluded as compare to plain strip with fold (specimen “A”) other strips have lesser life in same loading condition there is around 37 % reduction in life in single folded specimen (specimen “B”) and likewise 23 % in double folded specimen (specimen “C”), 93 % in notched specimen (specimen “E”) and 88 % reduction in life of complex profile specimen (specimen “F”).

It is seen as compare specimen “C” to specimen “B”, specimen “B” have lesser life even though having less complexity in geometry by single folding.

The specimen “E” and specimen “F” are more prone to fatigue due to higher complexity and abrupt changes in geometry, shape and profile. But it is observed the a complex profiled specimen (specimen “F”) have 66 % higher life than to notched specimen (specimen “E”) because notched specimen already having crack in form of V-notch.



change in shape complexity of specimen

Figure 5.1: Reduction in Fatigue Life of Specimens

REFERENCE

[1] Wohler, A. Versuche Uber Die Festigkeit Der Eisenbahnwagenachsen, Zeitschrift Fur Bauwesen, 10; English Summary (1867), Engineering, Vol.4, pp.160-161, 1860.

[2] George E Dieter, Mechanical Metallurgy, Third Edition, McGraw Hill Education (India) Pvt. Ltd, New Delhi, pp 375-431.

[3] R. Kumar, K. Singh, "Influence of Stress Ratio on Fatigue Crack Growth in Mild Steel", Eng. Fracture Mech. 50, pp. 377-384, 1995.

[4] J.D.M. Costa & J.A.M. Ferreira," Effect of Stress Ratio and Specimen Thickness on Fatigue Crack Growth of Ck45 Steel”, Engineering Fracture Mechanics 68, pp. 129-147, 2001.

[5] N. Beachgoer, A. Hadjoui & M. Benachour, “Stress Ratio and Notch Effect on Fatigue Crack Initiation and Propagation in 2024 Al-Alloy", World Academy of Science, Engineering and Technology Vol: 5 2011-07-20.