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Design and Development of Fatigue Testing Machine

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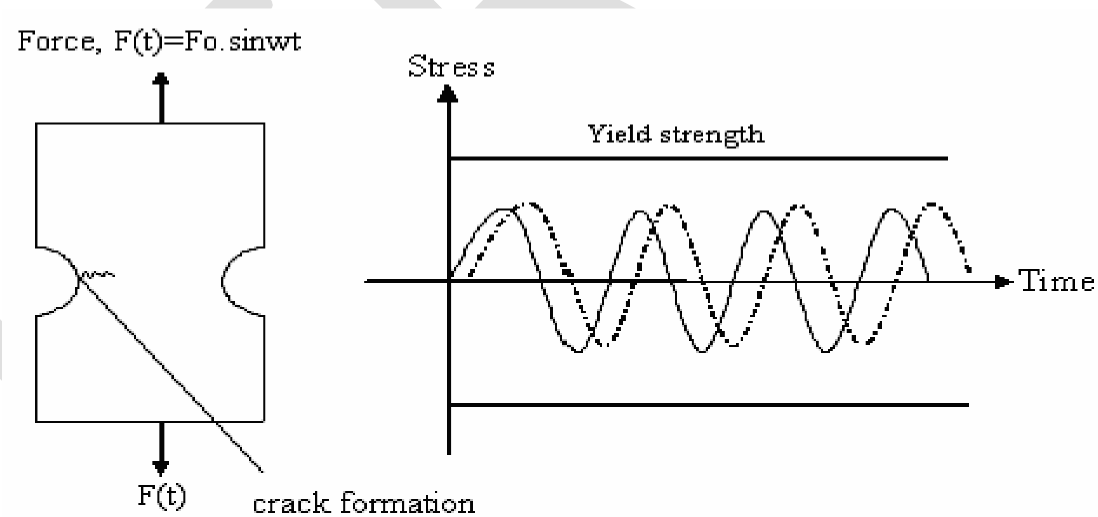
Abstract: Fatigue testing facilities are first classified in accordance with a number of features which include purpose, type of loading, and method of load application and transmit as well as control system. It is built on the understanding obtained from a vibration analysis of the force transfer function from the load cell of the machine to a fabricated calibration bar. Performing the dynamic characterization in practice consists of making a frequency sweep with the strain gage equipped calibration bar. All the proceeding steps of analysis required to predict an upper bound of the linear measurement error is conveniently handled by software. The machine we made is concept machine and we are not taking into account any of the features like efficiency & output of the machine, servicing cost of the machine etc. The machine made by us is based on the machines used in the different industries. We obtain the s-n curves on the basis of the testing of different types of material which are being tested. The result that we get after the testing should match the standard s-n curve of that material

INTRODUCTION: Fatigue occurs when a material is subjected to repeated loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the surface. Eventually a crack will reach a critical size, and the structure will suddenly fracture (break). The shape of the structure will significantly affect the fatigue life; square holes or sharp corners will lead to elevated local stresses where fatigue cracks can initiate. A careful study of the broken parts in almost any scrap yard will reveal that the majority of failures occur at stress below the yield strength. This is a result of the phenomenon called fatigue which has been estimated to be responsible for up to 90% of the in-service part failures which occur in industry. If a bar of steel is repeatedly loaded and unloaded at say 85% of its' yield strength, it will ultimately fail in fatigue if it is loaded through enough cycles.



FATIGUE FAILURE

Fatiuge: It is the process of progressive permanent structural change occurring in a material which is subjected to conditions that produce fluctuating stresses and strains at some point and that may turn in cracks or complete fracture after a sufficient number of fluctuations. If the maximum stress in the specimen does not exceed the elastic limit of the respective material, the specimen returns to its initial condition when the load is removed. A given loading may be repeated many times, provided that the stresses remain in the elastic range. These conclusion is correct for loadings repeated even a few more times. However, it is not correct when loadings are repeated thousands or millions of times. In such cases, rupture will occur at a stress much lower than static breaking strength and this phenomenon is known as fatigue.

Material properties: A fundamental requirement for any durability assessment is knowledge of the relationship between stress and strain and fatigue life for a material under consideration. Fatigue is a highly localized phenomenon and it's depends very much on the stresses and strains experienced in critical regions of a component or structure. The relationship between uniaxial stress and strain for a given material is unique, consistent and moreover independent of location. However, the most critical locations are at notches even when loading is uniaxial.

Cumulative Damage Analysis: The cumulative damage analysis for a critical region in a component consists of several closely interrelated steps as can be seen combination of the load history (Service Loads), stress concentration factors (Stress Analysis) and cyclic stress-strain properties of the materials (Material Properties) can be used to simulate the local uniaxial stress-strain response in critical areas. Through this process it is possible to develop good estimates of local stress amplitudes, mean stresses and elastic and plastic strain components for each excursion in the load history. The damage contribution of these events is calculated by comparison with material fatigue data generated in laboratory tests on small specimens. The damage fractions are summed linearly to give an estimate of the total damage.

Fatigue Failure Mechanism: A fatigue failure begins with a small crack; the initial crack may be so small and cannot be detected. The crack generally develops at a point of localized stress concentration like discontinuity in the material, such as a change in cross section, a keyway or a hole. Once a crack is initiated, the stress concentration effect become greater and the crack propagates. Consequently the stressed area decreases in size, the stress increase in magnitude and the crack propagates more rapidly. Until finally, the remaining area is unable to sustain the load and the component fails suddenly. Thus fatigue loading results in sudden, unwarned failure.

Factors that affect the fatigue life:

1) The size of the member
2) Environmental operating conditions
3) Type of load (uni-axial, bending moment...etc.)
4) Load history (constant, variable random load etc.)
5) Frequency of cyclic load

Stages of fatigue failure:

Fatigue failures often occur quite suddenly with catastrophic (disastrous) results and although most insidious for metals and polymers are also susceptible to sudden fatigue failures. The process occurs by the initiation and propagation of cracks and, the fracture surface is close to perpendicular to the direction of maximum tensile stress. Applied stresses may be axial (tension-compression), flexural (bending) or torsion (twisting) in nature. There are three possible fluctuating stress-time modes possible. The simplest is completely reversed constant amplitude where the alternating stress varies from a maximum tensile stress to a minimum compressive stress of equal magnitude. The second type, termed repeated constant amplitude, occurs when the maxima and minima are asymmetrical relative to the zero stress level. Lastly, the stress level may vary randomly in amplitude and frequency which is merely termed random cycling small compared with the size of cross section. At the same time, the sizes of these cracks whose depth is small compared with the size of the cross section. This process forms the third stage of fatigue damage. Fatigue is gradual process of damage accumulation that proceeds on various levels beginning from the scale of the crystal lattice, dislocations and other objects of solid state physics up to the scales of the structural components.

1. Fatigue failures generally involve three stages

Crack initiation:

• Areas of localized stress concentrations such as fillets, notches, key ways, bolt holes and even scratches or tool marks are potential zones for crack initiation

• Crack also generally originate from a geometrical discontinuity or Metallurgical stress raiser like sites of inclusions.

• As a result of the local stress concentrations at these locations, the induced stress goes above the yield strength (in normal ductile materials) and cyclic plastic straining results due to cyclic variations in the stresses. On a macro scale the average value of the induced stress might still be below the yield strength of the material.

• During plastic straining slip occurs and (dislocation movements) results in gliding of planes one over the other. During the cyclic stressing, slip a saturation result which makes further plastic deformation difficult.

• As a consequence, intrusion and extrusion occurs creating a notch like discontinuity in the material.

Crack Propagation:

• This further increases the stress levels and the process continues, propagating the cracks across the grains or along the grain boundaries, Slowly increasing the crack size.

• As the size of the crack increases the cross sectional area resisting the

Applied stress decreases and reaches a thresh hold level at which it is Insufficient to resist the applied stress.

Final fracture:

• As the area becomes too insufficient to resist the induced stresses any further a sudden fracture results in the component basic features of failure appearance.

• A fatigue failure, therefore, is characterized by two distinct regions. The first of these is due to progressive development of the crack, while the second is due to the sudden fracture. The zone of sudden fracture is very similar in appearance to the fracture of a brittle material, such as cast iron, that has failed in tension. The crack propagation zone could be distinguished from a polished appearance.

How to Analyze Fatigue:

Two principal factors govern the amount of time it takes for a crack to start and grow sufficiently to cause component failure:

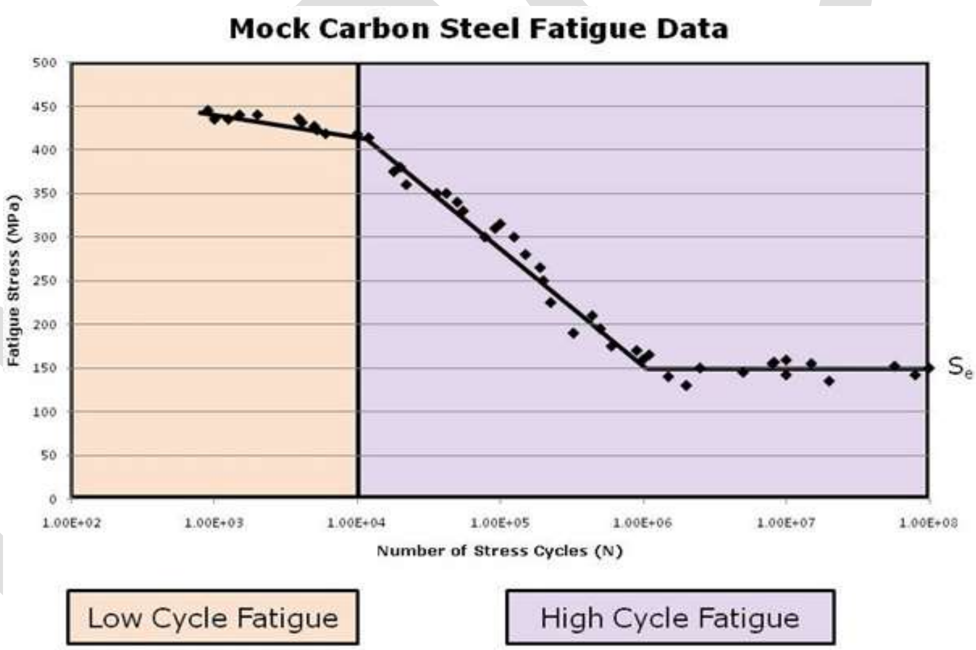
The component material and the stress field. The main ways to calculate fatigue life: Stress Life (SN)

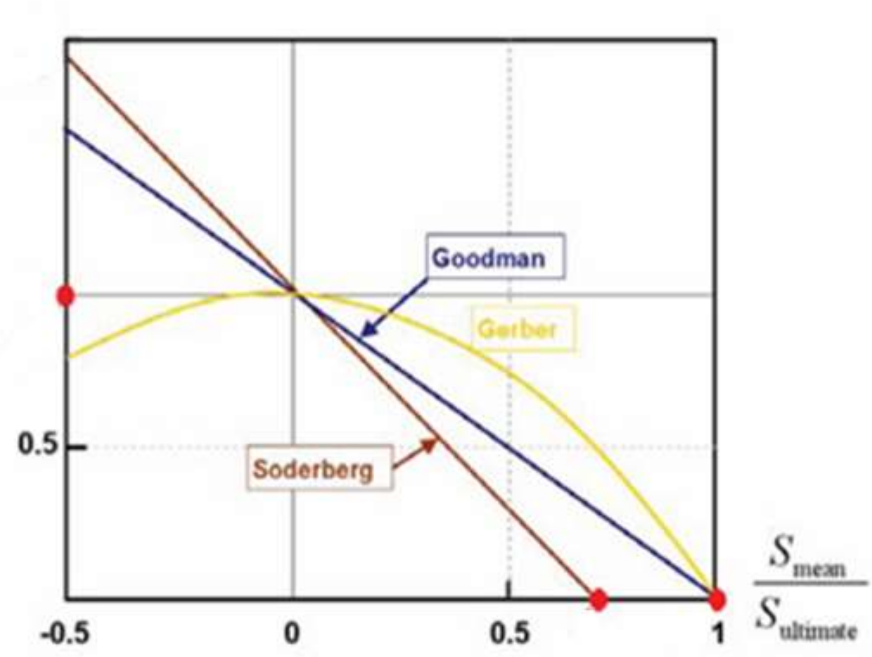
STRESS-LIFE BASED APPROACH (S-N METHOD)

The Stress Life approach predicts the component's fatigue life based upon a standard material test for failure. It gives results based upon the whole fatigue life and as such does not break down the process into the three stages. The Stress Life Approach is based upon the calculation of varying elastic stresses, which means it cannot be applied to low cycle fatigue (failures with 10,000load cycles). However, this approach is very accurate for high cycle fatigue, which is the realm of most industrial applications. Considerable material data has been published for materials tested using this method.

The basis of the stress-life method is the Wohler S-N curve, that is a plot of alternating stress, S, versus cycles to failure, N. The data which results from these tests can be plotted on a curve of stress versus number of cycles to failure. This curve shows the scatter of the data taken for this simplest of fatigue tests. The approach known as stress-based approach continues to serve as a widespread used tool for the design of the aluminum structures. Comparing the stress-time history at the chosen critical point with the S-N curve allows a life estimate for the component to be made. Stress-life approach assumes that all

stresses in the component, even local ones, stay below the elastic limit at all times. It is suitable when the applied stress is nominally within the elastic range of the material and the number of cycles to failure is large. The nominal stress approach is therefore best suited to problems that fall into the category known as high-cycle fatigue. High cycle fatigue is one of the two regimes of fatigue phenomenon that is generally considered for metals and alloys. It involves nominally linear elastic behavior and causes failure after more than about 104 to 105 cycles. This regime associated with lower loads and long lives, or high number of cycles to produce fatigue failure. As the loading amplitude is decreased, the cycles-to-failure increase.





The Gerber, Goodman and Soderberg methods denote the predicted failure behavior according to the mean correction lines shown with the same names. The Gerber method uses a quadratic, non-conservative approach related to the endurance limit and ultimate tensile strength, which is generally applicable to ductile materials. The Goodman approach relies on a conservative, linear relationship between the same parameters. The soderberg line is the most conservative of all relationships as it links Se to the tensile yield strength. The intersection of the alternating and mean stresses can provide some sense of the likelihood of failure according to the different standard lines.

All three methods apply only when all associated S-N curves are based on fully reversed loading. Moreover, these corrections only become significant if the applied fatigue load cycles have large mean stresses compared to the stress range. Testing has shown that fatigue failure generally occurs somewhere in the region between the Goodman line and the Gerber line. Thus, to give some leeway in a design, it is most practical to use the more conservative of the two as the upper boundary.

Design:

Materials used to made equipment:

Motor

Specimen

Bearing

Shaft

Nut

Collet

Design calculation for shaft diameter:

$P = 2*\pi*N*T/60$,   P = Power Transfer,   T = Torque Transfer

N = R.P.M. of Shaft,   Power of Motor = 1Hp

* T =π\16*Shear Stress*D^3, T = Torque

D = Diameter of Shaft

Design calculation for bearing:

* P = W/A, P = Pressure Exerted on Bearing

A = Area of Bearing, A = 3.14*r^2

r = Radius of Shaft

* Total Frictional Torque, T = .667*1*W*r/m

W = Load Applied

r = Radius of Shaft

1/m = Poissions Ratio

* Power Lost in Friction, P = 2*3.14*N*T/60

P = Power Lost,

N= R.P.M. of Shaft,

T = Total Friction Torque

* Heat generated at bearing, H = P*60 (KJ/min)

P = Power Lost

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Conclusion:

After successfully performing, "the conclusion is given that in the starting in initial condition at normal motor speed there is no breakdown in the component, But after some time if we apply some load to the down side of the component then crack is initiated and at certain point and time there is sudden breakage in component".

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