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EXPERIMENTAL AND NUMERICAL FATIGUE ANALYSIS OF BRASS SHAFT SPECIMEN UNDER CYCLIC BENDING MOMENTS

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Abstract

Fatigue is a form of failure that occurs in structures subjected to dynamic and fluctuating stresses, where failure can occur at a stress level significantly lower than the tensile or yield strength of a static load under these circumstances. The term "fatigue" is used because, after a long period of repetitive stress or stress cycling, this form of failure typically occurs. Fatigue is important because it is the single largest cause of metal failure, estimated to account for about 90% of all metal failures; polymers and ceramics (except glasses) are also prone to this form of failure. This research is studying the failure analysis, fatigue life and endurance limit of brass metal experimental and numerical under cyclic bending moments.

Keywords: Fatigue, Cyclic, Endurance limit, Fatigue life, Brass metal.

I. Introduction

It is very common for engineering components to encounter. Multiaxial fatigue failure, as most components of the system, is subjected to multiaxial load conditions in operation, and geometry and external loading typically result in multiaxial fatigue. In contrast, multiaxial fatigue analysis is a very complex process. Uniaxial exhaustion. Unlike the issue of uniaxial exhaustion, the multiaxial [I] Hereunder several important topics that are considered via research to be described briefly as much as possible**.** Aldeeb, and Abduelmula, discussed the test of the fatigue life of S275 mild steel at room temperature. The mechanism can be unsuccessful under cyclic loading for a period which is defined as the fatigue phenomenon. To prevent the fatigue that produces failures, the behavior of material must be considered to establish endurance, the limit of the metal in support of safe design and unlimited life as a result leading to reduced efficient cost and loss of in-person life[II]. Beden et al presented a method to calculate the fatigue life of a shell structure of different materials with the purpose of measured changeable amplitude loading. The finite element examination was being used for the typical and simulation. Numerical life calculation results of the shell materials, low and medium carbon steel are obtainable and conversed. Numerous reasons are touching the life calculate the condition of the surface results were exposed. Practical variation come into view through the evaluation of the beyond material[III]. Glinka**,** involved the two different modes of the fundamental multiaxial fatigue construction parameter connected to the maximum fatigue stage were estimated for performing fatigue life calculation less than a variety of loading conditions. The projected fatigue damage parameters had been applied to uniaxial and multiaxial loading conditions for the different main parts. The multiaxial fatigue life prediction remains a difficult problem because of its general large practical request [V]. Kopas et al studied and discuss the results of fatigue life tests achieve for strengthening steel bars which is the mainly widely exercised assembly material in the human race. The low-cycle fatigue behavior of steel bars was experimentally calculated. under bending loading at machined bar specimens. Every type of fatigue testing bending test at resistant steel bars further repeats examination conditions and offers a practical estimation of occurrence by the conclusions was expression is the fatigue resistance of steel increases with lessening stress amplitude incessantly of the cycles number value[VIII]. Kim et al studied the fatigue life destruction of mode stainless steel had been calculated under many types of sequential loading: axial torsion loading, torsion-axial loading. Cross hardening was experimental in axial-torsion loading succession other than in torsion-axial loading progression The numeral of the experiment presented in this study was significantly less and disappear to obscuring any movement in the results[IX]**.** Shreyas et a**l** examined many materials of the fatigue performance had been most important condition before considering the material for a treat in several situations with the continuous changeable load. There had been main development in the modeling of fatigue testing machines for over a century now. The testing machine is different from other fatigue testing machines because it may control two specimens at any certain moment. Fatigue is the requirement whereby a material cracks or fails as a result of repeated (cyclic) stresses applied below the ultimate strength of the material[XI]. Talemi et al investigated the effect of the pre-bending procedure of HSS subject to low cycle fatigue loading conditions. For this objective designed an original test set-up to obtain the results of pre-bending stress when the fatigue load had been applied. after bending and fatigue testing numerical procedure advance was applied to specimen the behavior of experienced material. The urbanized finite element method supplied additional information about the multiaxial stress[XII].

This paper aims to study the failure analysis, fatigue life and endurance limit of brass metal experimental and numerical under cyclic bending moments

II. Experimental Work

II.i. Material selection

The martial used in the experimental work was from brass DIN(CS629N)-EN(S-CuZn-6). Which selected from available standard in device test machine (type Hi-Tech) and tested to determine it's chemical composition and mechanical properties Table (1) gives the chemical analysis which is done in engineering center for testing and reconditions. The relevant mechanical properties are listed in Table (2).

Table (1): Chemical composition of brass specimen DIN(CS629N)-EN(S-CuZn-6).

Zn%	**Pb%**	**Sn%**	**P%**	**Mn%**	**Fe%**	**Ni%**	**Si%**	**Mg%**	**Cr%**
39.03	2.74	0.22	0.035	<0.004	0.17	0.098	0.004	0.0006	0.003
As%	**Sb%**	**Cd%**	**Bi%**	**Ag%**	**Co%**	**Al%**	**S%**	**Be%**	**Cu%**
0.040	0.10	0.005	0.009	0.005	0.009	0.003	0.013	<0.0001	57.5

Table (2): mechanical properties of brass metal

Brass	σ_u **(Mpa)**	σ_y **(Mpa)**	**E(Gpa)**	**Poisson's ratio**
DIN(CS629N)	345	135	105	0.35

The mechanical composition test in show Table (2) has been prepared at the Production and Metallurgy Eng. Dep. University of technology using the tensile test device (WDW – 200E). The specifications of the tensile test and specimen according to the American Society for Testing and Materials (AST81-8). The above results are the average of three readings.

II. ii Fatigue test machine :

The brass specimens of the fatigue test were prepared according to the Machines manual as shown in Figures (1.a) and (1.b). 15 specimens were manufactured and tested to generate the S-N curve by an alternating bending specification of fatigue test machine rotating bending fatigue testing machine(type Hi-Tech) as shown in figure (2)

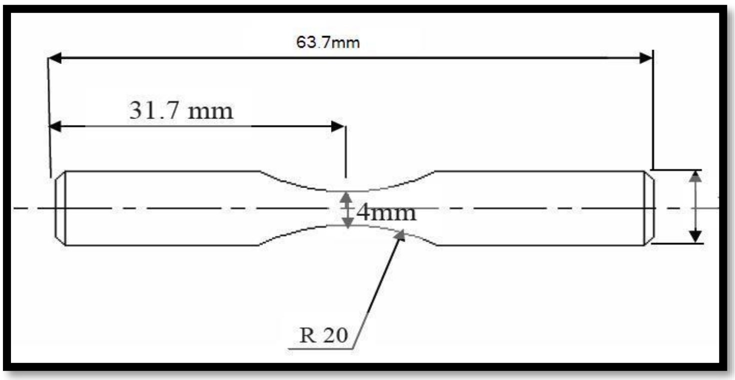

Figure (1.a): Dimensions of fatigue specimens tested. (ASTM D1043-02)

Figure(1.b):The specimens brass on fatigue device Type Hi-Tech

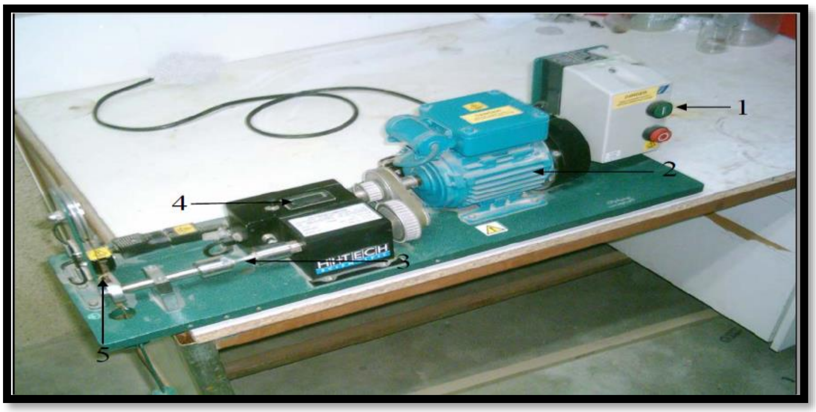

Figure (2) :rotating bending testing machine(type Hi-Tech)

The value of the bending stress (σ_b) measured in (N/mm^2) for a known value of load (P), measured in Newton (N) is calculated from equation (1)[VI] For rotating bending fatigue machine type Hi-TECH:

$$\sigma_b = \frac{P*L*32}{\pi d^3} \quad (1)$$

Where:-

σb : The applied stress (N/mm^2)

Mb: The bending moment (N.mm)

Y: The distance from the neutral position (mm)

I: The moment of inertia (mm^4)

d: Minimum diameter of fatigue specimen (mm)

For Rotating bending fatigue machine type Hi-TECH:

L=125.7 mm, d=4 mm

therefore σ_b = 20F (N/mm^2).

Fatigue life can be estimated by using the stress number of cycles to failure relation, called S-N curve, All the fatigue S-N curves of the metal under RT and elevated temperatures can be analyzed based on Basquin's equation[IV]

$\sigma_{f=A(N_{f})}$

Where :

σ_f is the reversed stress.

N_f is the number of cycles to failure.

A is a material constant.

This known as Basque's equation constantans A and α can be determined from[IX]

$$\alpha = \frac{h\sum_i^h =_1 \ Log\ \sigma_f\ LogN_{f\_}\ h\sum_i^h =_1 \ Log\ \sigma_f\ \sum_i^h =_1 LogN_f}{h\sum_i^h =_1 (LogN_f)^2 - (h\sum_i^h =_1 LogN_f)^2}$$

$$Log\ A = \frac{\sum_i^h =_1 Log\sigma_f - \alpha\sum_i^h =_1 LogN_f}{h}$$

Where :

h is the total number of specimens.

α is the applied stress (Mp_a).

N_f is the number of cycles to failure.

These results of the experimental work of rotating bending testing machine(Hi-TECH) machine Table (3) and figure (3) shown stander of S-N curve for brass metal:

Table (3): The stress and no. of cycles (S-N stander) values for brass metal.

Reversed bending test			
No.	σ_b (MPa)	N_f	$Nf_{ave.}$
1,2,3	267	127700, 107800, 65200	100233
4,5,6	199	319600, 226200, 303600	283133
7,8,9	155	871600, 663700, 558500	697933
10,11,12	138	2918700, 1119600, 2065800	2034700
13,14,15	124	2660200,1366700, 2919000	2315300

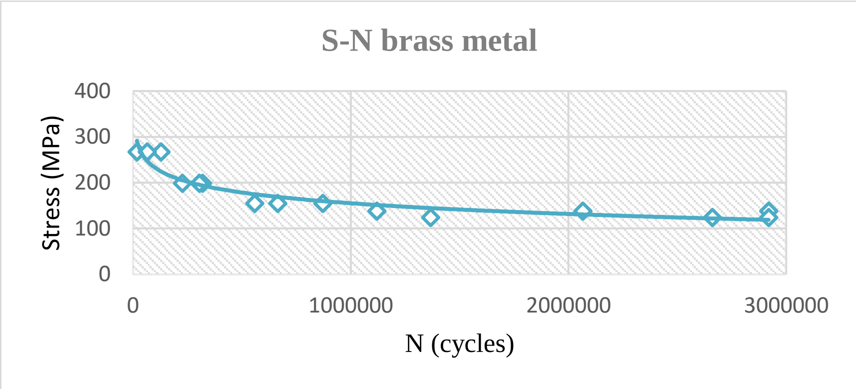

Figure (3): S-N curve standard of brass metal.

III . Numerical Analysis of Brass Metal Results

Fatigue analysis in FE is offered to predict the life of a material, or structure when subjected to cyclic loading over some time. The use of FE analysis assists locates the exact areas that accumulate the maximum amount of stress or undergo the highest deformation under cyclic loading. ANSYS Workbench 18.2 is FE software that defines a special fatigue tool for fatigue analysis of materials. The stress against several cycles graph (S-N curve) is used to define the fatigue material properties for stress life. The fatigue life of the brass metal is obtained by the following steps:

III.i. Geometry in the solid work program

To perform the finite element analysis, we need to make the geometry, and elements, to applied boundary conditions. This step is called pre-processing. This geometry has been created by a solid work program as shown in figure (4).

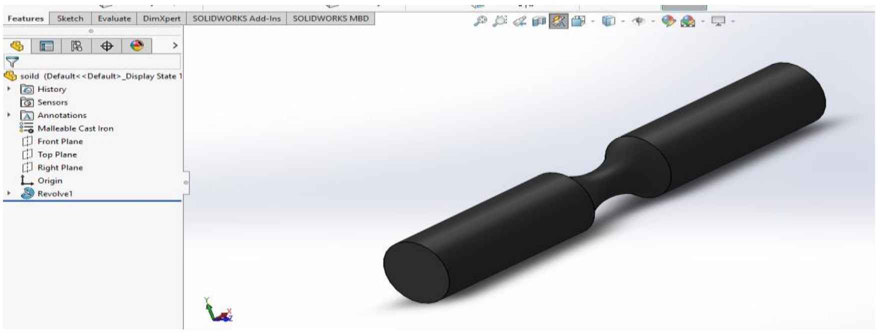

Figure (4): The geometry of the specimen

III.ii. Static structural

This is prepared by dragging “Static Structural” from “Toolbox” to the project schematic and then relating the created box to the geometry box done before, as shown in figure (5).

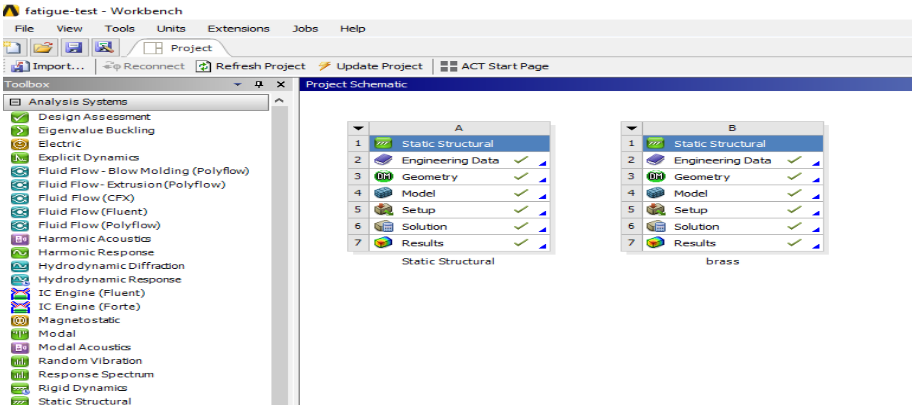

Figure (5): The static structure modeling

III.iii. Material properties

The specimen of the shaft had the identical material properties of the actual experimental specimen used. The shaft martial is made from brass material, it was tested laboratory as mentioned previously. The properties are supplied by ANSYS 18.2 software. Such as shown in figure (6). The material properties can be fed to the model using the following command sequence: “Engineering Data” □ “General Material” □ “Add Material” □ “Input Properties” □ “Save Data”.

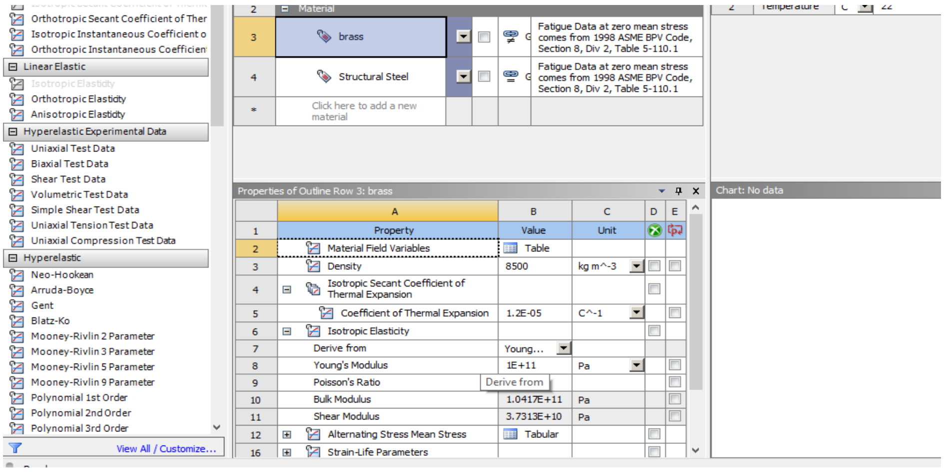

Figure (6): Material properties modeling

III.iv. Meshing process

The specimen can be meshed using the following running: “Mesh” □ “Sizing” □ “Element Size” □ “Input Number”. The meshed model can be seen in the figure as shown below (7)

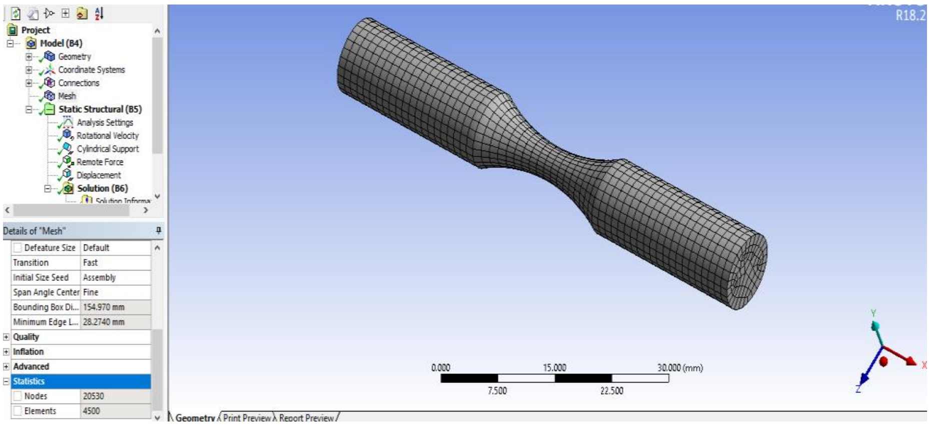

Figure (7**):** Meshing process modeling

III.v. Boundary conditions

The boundary conditions of the specimen were considered fixed cylindrical support in Y, and Z directions, and then a force is applied as bending load (267N/mm) vertically at X direction and rotation velocity (6000 rpm) as shown in figure (8) below.

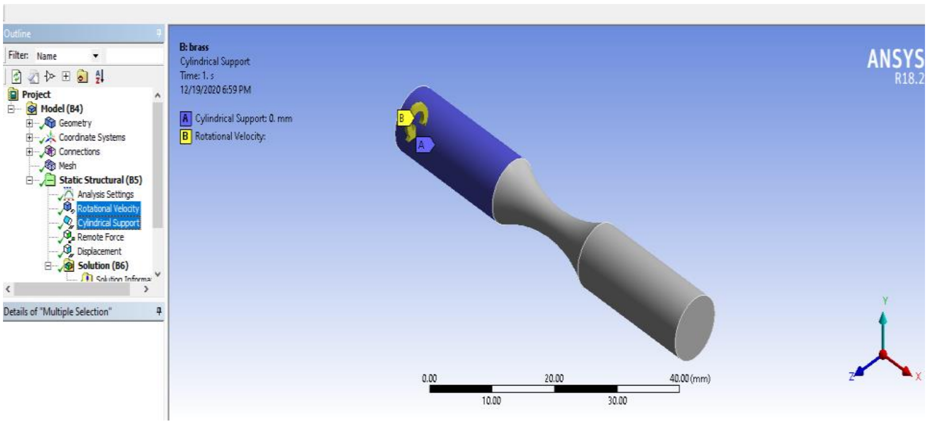

Figure (8): Boundary conditions modeling of brass metal.

III.vi. Modal analysis

In this section, analyzer the equivalent max. stress (Von-Misses) is (231.7 MPa) and fatigue life is (2.2713 e^5) as shown in the figures (9) and (10) below respectively

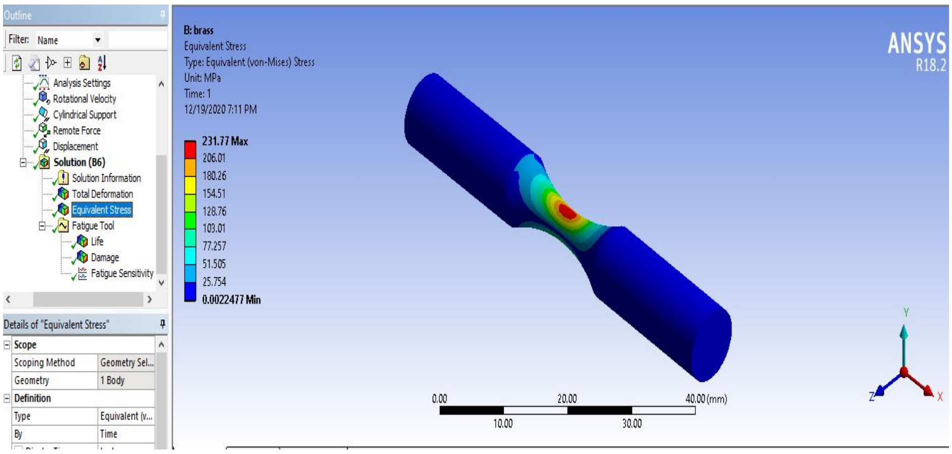

Figure (9): Max. stress (Von Misses) of the brass shaft

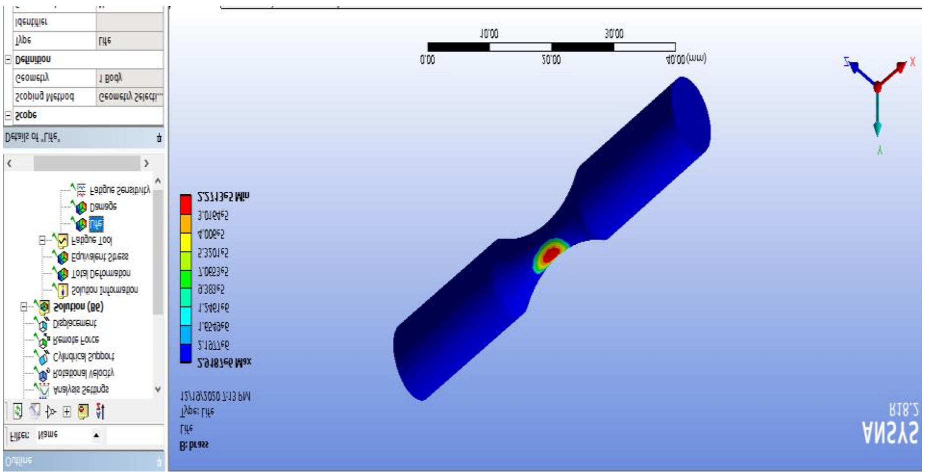

Figure (10): Fatigue life of the brass shaft.

III,vii. S-N Curve of the Brass Material

The S-N graph used in this study was obtained after cycling porcine coronary artery samples to failure. The S-N graph between the number of cycles and stress used in this study was obtained after cycle loading until the specimen reach failure. Its known that the ANSYS Program supplied the values of the number cycle and the stresses obtained from the practical results to drawing S- N curve by the Axel Program. Table (4) and figure (11) represent the stress-number of cycles (S-N curve) for brass metal.

Table (4):The stress and No of cycle value for brass metal.

Reversed bending test		
No.	σ_b (Mpa)	N_f (cycles)
1	267	153550
2	199	362430
3	155	981200
4	138	3492245
5	124	3398700

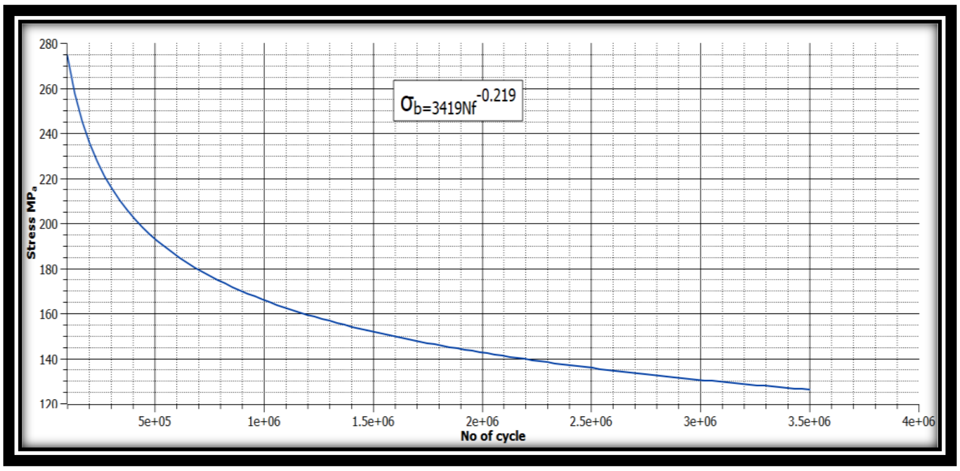

Figure (11): S-N Curve for brass metal.

IV. Results and Discussion:

The results obtained from the experimental work and the numerical analysis solution From these results shown in tables (3) and (4), the fatigue limit on the numerically maximum stress load (267MPa) is (153550) and on the minimum stress load (124MPa) is (3298700) at the same value of the maximum and minimum stresses load by standard value the fatigue limit were (127700), and (2919000) respectively, as the average results of the previous values conclude that it is the percentage error between the results of fatigue life obtained numerically and the results standard fatigue life is (19%) and endurance limit (11%) in this study the percentage error is which is considered in reasonable results.

Numerical result (brass specimen)	Experimental result (brass specimen)
$\sigma_f = 3419Nf^{-0.219}$	$\sigma_f = 3501Nf^{-0.227}$
Fatigue Life Cycle at (σ_u)	
35343	27124
Endurance Fatigue Limit (MP_a)	
100.20	90.197

V. Conclusion

In this study considerable conclusions have been pointed out hereunder by outcomes:

I. The maximum percentage error gives about (19%) of the fatigue life numerical results of brass with experimental results.

II. The maximum percentage error gives about (11%) of the Endurance Fatigue Limit numerical results of brass with experimental results.

III. Validation for the percentage error is due to many factors, the most important of which are: Mainly of the ferrous metals contain different defects and internal stresses before heat treatment process carried out for them, and these defects are eliminated by heat treatment (annealing process) and therefore the ratio of these defects and stresses varies from one specimen to another, which causes the error rate to vary from specimen to another. Also, the design since there are tolerances in designing samples minus – plus, also results in an error ratio between one sample and another. And in some specimen that is subjected to fatigue testing, and as a result of the loads exerted on them, a modulation occurs that leads to an increase in the sample's resistance to failure, resulting in a certain error ratio

Conflict of Interest:

Authors declared: No conflict of interest regarding this article

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