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Assessment of different methods for fatigue life prediction of steel in rotating bending and axial loading

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Abstract
Generally, fatigue failure in an element happens at the notch on a surface where the stress level rises because of the stress concentration effect. The present paper investigates the effect of a notch on the fatigue life of the HSLA100 (high strength low alloy) steel which is widely applicable in the marine industry. Tensile test was conducted on specimens and mechanical properties were obtained. Rotating bending and axial fatigue tests were performed at room temperature on smooth and notched specimens and *S-N* curves were obtained. Using the obtained *S-N* curve for smooth specimens, the fatigue strength factor for the notched specimens were predicted by Weibull's weakest-link, Peterson, Neuber, stress gradient and critical distance methods and compared with experimental results. It was found that the critical distance and also Weibull’s weakest-link methods have the best agreement with experimental results.

1. Introduction

A component with an unchanging cross-sectional area under a load has a uniform and homogeneous stress and strain distribution. Any type of notch existence or sudden changes in cross-section causes an inhomogeneous distribution of stress and strain. In general, fatigue failure in an element arises where the stress level rises due to the stress concentration effect such as a notch on a surface. Notch is usually defined as a geometric discontinuity. A notch may be introduced either by designing or by a manufacturing process. A hole in a component is an example of a designed notch. Fabrication defects such as weld defects, inclusions, casting defects, or machining marks are notches which are introduced due to the manufacturing process [1].

Theoretically, the nominal strength of a notched component should be lower than that of a smooth one by a factor of k_t. But, experiments show that at the fatigue limit, the fatigue strength of a smooth part decreases by a factor of k_f and not the factor of kt [1]. The presence of a notch on a component causes stress gradient at the notched area. Based on this phenomenon, empirical methods such as Neuber and Peterson were proposed to predict the fatigue life of notched components [2]. Stress gradient method presented by Siebel and Stieler

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[3] and critical distance method presented by Taylor [4] are two other methods proposed for. Critical distance method is based on the critical distance at the notch root. These methods are mainly based on empirical tests, which are conducted on many metals.

It should be considered that these methods are not consistent with finite element results. This shortcoming is solved by weakest-link theory presented by Weibull, in which the probability of fatigue failure is obtained from finite element results [5-10]. In Weibull's weakest-link theory, critical defects are assumed statistically scattered in the volume of a component. In this theory, the size of defects is supposed very small compared to the distance between them and therefore the defects do not interact [11-13]. Just as a chain is as strong as its weakest link, the fracture of the weakest link yields the failure of a complete component. Therefore, the weakest-link theory supposes that probability of survival of the whole component equals to the production of the probabilities of survival of all the elements. In this study, HSLA100 (high strength low alloy) steel is investigated. This material is applicable in marine industry, where different types of severe fatigue loading are applied on the marine structure during its life; therefore, accurate life investigation of this steel is essential for the marine industries [14, 15].

HSLA steels are designed to deliver particular advantageous mixtures of properties such as toughness, strength, weldability, formability and atmospheric corrosion resistance. In order to retain formability and weldability, carbon content in HSLA steel is between 0.05–0.25 percent [16, 17]. HSLA100 steel is designed for the yield strength $\geq$ 700MPa and impact strength $\geq$/ 81 J at 84 ˚C [18, 19].

The main goal of this research is to compare different methods of predicting fatigue life of notched HSLA100 specimens and find which ones yield better results. In order to do that, fatigue tests were conducted on smooth and notched specimens to obtain the *S-N* curves. Neuber, Peterson, stress gradient, critical distance and Weibull's weakest-link methods were used to predict the *S-N* curve for the notched specimens based on the *S-N* curve for smooth specimens. The obtained theoretical results were compared with experimental data.

2. Experimental procedure

2.1 Material Properties and specimens

Experimental results obtained from testing were used for analysing and comparing with the theoretical methods. Tensile tests were performed according to ASTM E8 [20] and mechanical properties of the studied material were obtained. Figure 1 shows a typical engineering stress-strain curve for the tested steel and Fig. 2 shows the test equipment. Tables 1 and 2 summarize the mechanical properties and chemical composition of the used material, respectively.

Rotating bending [21] and axial fatigue tests [22] were carried out on smooth and notched specimens. Figure 3 shows dimensions of the smooth and notched cylindrical specimens for rotating bending and axial fatigue tests.

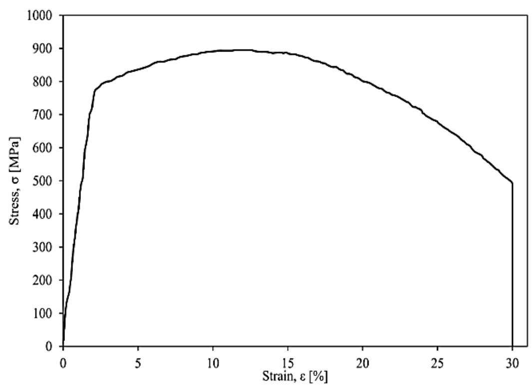

Fig. 1. The engineering stress-strain curve for the tested steel.

Fig. 2. The tensile test equipment.

Table 1. Mechanical properties of the studied HSLA100.

Yield strength S_y (MPa)	Ultimate strength S_u (MPa)	Strain at break E_u (%)	Modulus of elasticity E (GPa)
791	895	31	197

Table 2. Chemical composition of the studied HSLA100 (wt %.).

Ni	Mn	Cu	Cr	Mo	Si	C	Nb	Al
3.59	0.91	1.59	0.59	0.58	0.25	0.03	0.03	0.02

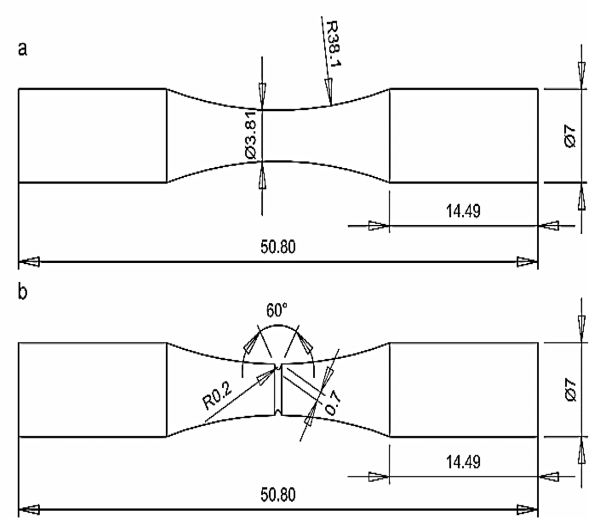

Fig. 3. Detailed drawings of specimens; (a) smooth and (b) notched specimens (all dimensions are in mm).

2.2 Fatigue tests

In the rotating bending test, a constant load was applied perpendicular to the cylindrical specimen rotating at 50 Hz. In the axial test, the cylindrical specimen was cyclically loaded to the failure by servo-hydraulic testing machine using a sinusoidal signal. Fourteen smooth and twelve notched specimens were rotating bending and axially fatigue tested each. Experimental equipment used for testing smooth and notched specimens are shown in Fig. 4 and 5.

2.3 Test results

Fatigue test results are presented in Fig. 6. The number of cycles before failure, N_f, was plotted against the net section stress amplitude, σ_a. Based on the rotating bending test data, fatigue limit for the smooth and notched cylindrical specimens are 310MPa and 170MPa, respectively. Also, based on the axial test data, fatigue limit for the cylindrical smooth and notched specimens are 270MPa and 140MPa respectively. Fatigue strength factor (k_f) for the notched specimen in rotating bending and axial fatigue tests are 1.82 and 1.93, respectively. k_f is obtained by dividing fatigue limit of smooth specimen to fatigue limit of notched specimen. The fatigue strength factor (k_f) is a function of the notch geometry and the type of loading.

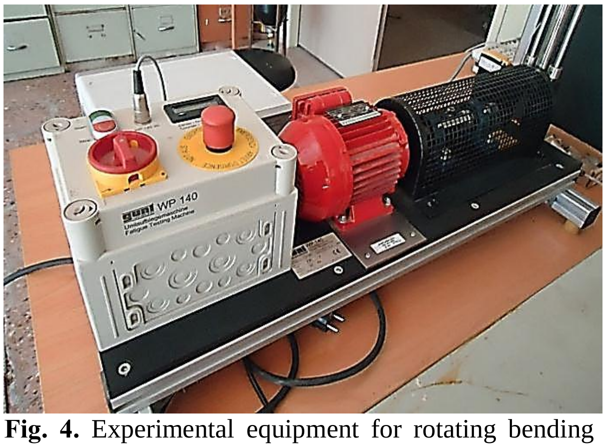

Fig. 4. Experimental equipment for rotating bending tests

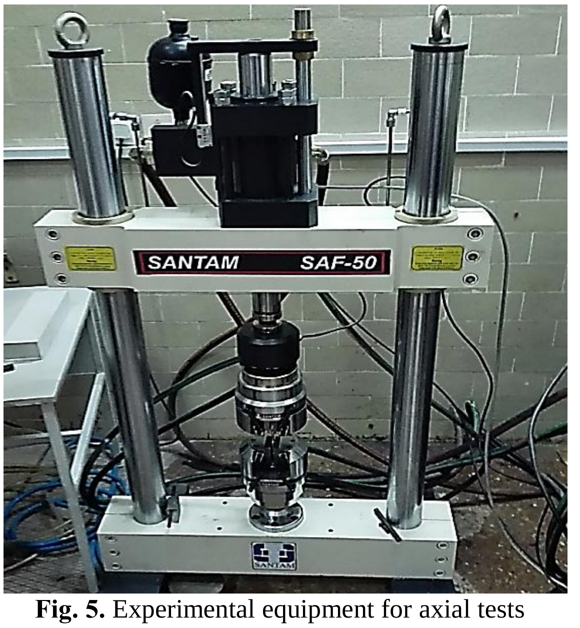

Fig. 5. Experimental equipment for axial tests

Line equation passing through the rotating bending fatigue test results for smooth specimens, is as follow:

$$\log(\sigma_a) = -0.1073 \log(N_f) + 3.1588 \quad (1)$$

and for the notched specimen is:

$$\log(\sigma_a) = -0.1295 \log(N_f) + 3.0239 \quad (2)$$

Also, line equation passing through the axial fatigue test results for the smooth specimens, is as follow:

$$\log(\sigma_a) = -0.1041 \log(N_f) + 3.0843 \quad (3)$$

and for notched specimen is:

$$\log(\sigma_a) = -0.131 \log(N_f) + 2.9626 \quad (4)$$

Usually, Basquin equation is used to describe the *S-N* curve in the high-cycle-region. Basquin equation is as follow:

$$\sigma_a = \sigma_f' (N_f)^{\frac{-1}{m}} \quad (5)$$

where σ_f' is the fatigue strength coefficient and $-1/m$ is the fatigue strength exponent. This curve will be a straight line on a log-log plot and may be found by linear regression analysis of fatigue data points. The logarithm of Eq. (5), gives the following linear relationship:

$$\log(\sigma_a) = \log(\sigma_f') - \frac{1}{m} \log(N_f) \quad (6)$$

or

$$y(x) = ax + b \quad (7)$$

with

$y(x) = \log(\sigma_a)$, $x = \log(N_f)$, $a = -\frac{1}{m}$, $b = \log(\sigma_f')$.

By comparison of line equations for smooth and notched specimens with Eq. (6), the fatigue strength coefficient and the fatigue strength exponent in rotating bending fatigue will be m=9.34, σ_f'=1441.45 for the smooth specimens, and m=7.75, σ_f'=1056.8 for the notched specimens. Also, the fatigue strength coefficient and the fatigue strength exponent in axial fatigue will be m=9.61, σ_f'=1214.2 for the smooth specimens, and m=7.63, σ_f'=917.5 for the notched specimens.

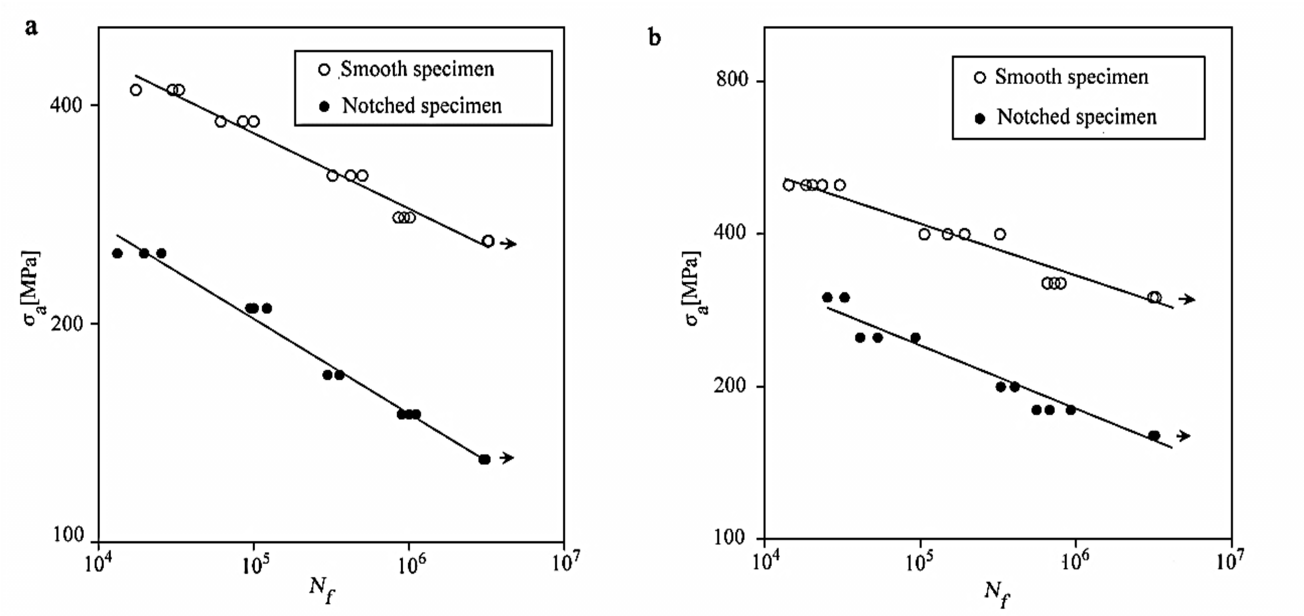

Fig. 6. Fatigue behaviour of the HSLA100 cylindrical specimens with and without notch (a: rotating bending loading and b: axial loading).

3. Prediction of notch effect on fatigue life of HSLA100 specimens

In this section, Weibull's weakest-link, Neuber, Peterson, stress gradient and critical distance methods are used to predict notch effect on fatigue life of the HSLA100 steel. Stress concentration factor, k_t, is required to use Neuber, Peterson and stress gradient methods. This factor is obtained by simulation of stress distribution for both smooth and notched specimens by finite element method. k_t is obtained by dividing maximum stress at the notch root by average cross section stress.
Stress concentration factor for the notched specimen, Fig. 3, is k_t =2.73 for the bending load and k_t =2.86 for the axial load. However, the tests indicated that at the fatigue limit, the presence of a notch on a component under cycling nominal stresses reduces the fatigue strength of the smooth component by a factor of k_f and not the factor of k_t. A formula, which is acceptable in engineering applications and expresses fatigue strength factor is as follow [1]:

$$k_f=1+q(k_t-1) \quad (8)$$

As can be seen, this formula empirically relates fatigue strength factor to the elastic stress concentration factor by a notch sensitivity factor q. In critical distance method, it is required to determine stress gradient at the notch root. So the bending and axial load were applied on the notched specimen and stress gradient was obtained.

3.1 Weibull's weakest-link theory

In the weakest link theory, the probability of component failure [5] is described as:

$$p_{f,v}=1-\exp\left[-\left(\frac{\bar{\sigma}_a}{\sigma^*_{A_0}}\right)^{b_\sigma}\right] \quad (9)$$

Equation (9) is called Weibull fatigue strength distribution and corresponds to a two-parameter Weibull distribution. b_σ, is the Weibull shape or shape parameter and refers to the measure of reference specimens fatigue strength scatter. σ^*_{A0}, is the scale parameter and refers to the fatigue characteristic of the reference fatigue test specimen. $\bar{\sigma}_a$ is the Weibull stress amplitude and illustrate the fatigue-effective stress amplitude.
There are two different methods based on the weakest link theory for estimating the probability of failure of specimens [5, 23]. In the first approach, called the volume method, the critical defect is assumed to lie somewhere within the volume of the specimen. In the second approach, the controlling defects are assumed to be located on the surface of the specimen. This approach is therefore called the surface method.
In the volume formulation of Weibull's weakest-link method, $\bar{\sigma}_a$ is defined as:

$$\bar{\sigma}_a=\left(\frac{1}{v_0}\int_v {\sigma_a}^{b_\sigma}\,dv\right)^{\frac{1}{b_\sigma}} \quad (10)$$

where v_0 is an arbitrary reference volume or the volume of reference fatigue test specimen and v is the component volume.
In the surface formulation of Weibull's weakest-link method, $\bar{\sigma}_a$ is defined as:

$$\bar{\sigma}_a=\left(\frac{1}{A_0}\int_A {\sigma_\mathrm{a}}^{b_\sigma}dA\right)^{\frac{1}{b_\sigma}} \quad (11)$$

where A_0 is an arbitrary reference surface or the surface of reference fatigue test specimen and A is the component surface. Weibull fatigue strength distribution (Eq. (9)) can be transformed into a Weibull fatigue life distribution through the Basquin equation (Eq. (5)), and finally Weibull fatigue life distribution will be obtained as follow:

$$P_{f,v}=1-\exp\left[-\left(\frac{n}{N^*_0(R,\bar{\sigma}_a)}\right)^{b_n}\right] \quad (12)$$

where b_n and N^*_0 are shape parameter and scale parameter, respectively. The b_n is related to b_σ by following equation:

$$b_\mathrm{n}=\frac{b_\sigma}{m} \quad (13)$$

where m is the fatigue strength exponent. Weakest-link theory assumes that if the component is divided into small elements, the probability of survival of a component is the product of the probabilities of survival of the (small) elements.

The probability of survival of an element is a function of the stress cycle, the fatigue strength characteristic, material scatters and also the size of the element.

For applying the weakest-link theory, an in-house developed software was used in this research. This software is a fatigue post-processor which uses the results from a standard finite element stress analysis. In order to compute the fatigue life of a component by this software, the required inputs are as follows:

- Mechanical properties of the HSLA100 (ultimate strength, fatigue strength) obtained from the tensile and fatigue tests in section 2.
- The parameters of *S-N* curve for the smooth specimen (fatigue strength coefficient, fatigue strength exponent) obtained from the rotating bending and axial fatigue tests in section 2.
- Weibull constants for the smooth specimen (-shape parameter, scale parameter) which will be obtained in section 3.1.
- Finite element file of the simulated notched specimen (a file containing the element topology, nodal coordinates, and nodal coordinate stresses) which will be explained in section 3.2.

The volume of reference fatigue test specimen v_0 and the surface of reference fatigue test specimen A_0, in this research, is calculated as 1536 mm^3 and 1053 mm^2, respectively.

3.1.1. Statistical analysis of fatigue data to find the Weibull distribution constants

In this section, statistical analysis of fatigue test results is performed to find the Weibull distribution constants. If several specimens are tested until fatigue failure, the obtained fatigue lives will differ from specimen to specimen. If a sufficient number of test specimens at each stress level are available, and then the Weibull distribution is fitted to each stress level, an *S-N* curve for different probabilities of failure can be obtained [24]. In this research, 14 smooth specimens were tested in two rotating bending and axial fatigue tests each. This number of replications was not sufficient to create *S–N* curves for different probabilities of failure at each stress level. Therefore, a special curve fitting technique used by the authors in their other published works was applied [25]. *S–N* curves for various probabilities of fatigue failure will be moved by a uniform value in the vertical direction (stress direction) if it is supposed that the coefficient of variation in strength is constant. Thus, as shown in Fig. 7, if k data points are accessible, it is practical to move k parallel *S–N* curves (on a log-log plot) through these data points and from each *S–N* curve one probability of failure will be obtained.

With this technique, different probabilities of fatigue failure (k) can be obtained and at each fatigue strength, σ_a, there will be k number of life values. Then by applying Weibull distribution to these k lives at an arbitrary stress level, b_n and N^*_0 are obtained for the studied material (b_n=2.78, N^*_0=5.76×10^5 for the rotating bending load and b_n=2.71, N^*_0=5.96×10^5 for the axial load). Also with these two values (b_n and N^*_0) and using Eq. (5 and 13), b_σ and σ^*_{A0} are obtained (b_σ=25.91, σ^*_{A0}=347.32 for the rotating bending load and b_σ=26.04, σ^*_{A0}=304.55 for the axial load). It should be noted that m and σ_f' belong to the smooth specimen equation. In the following sections, it will be explained how parallel *S-N* curves are drawn.

As mentioned in section 2, it is often assumed that the *S–N* curve follows the Basquin equation and will be a straight line on a log-log plot. In standard S–N curves, stress is an independent variable and number of cycles to failure is a dependent variable so in this curve stress is plotted on the ordinate and number of cycles to failure is plotted on the abscissa. The standard method in curve fitting assumes that independent and dependent variables are plotted on the abscissa and ordinate, respectively. But it should be noted that with fatigue data, stress is actually the independent variable which should be plotted on the abscissa. To treat cycles as the independent variable, it can lead to errors in the curve fitting [26]. So in this section, life-stress curve is plotted (life on the ordinate and stress on the abscissa) and the standard least squares method can be used for curve fitting. Passing line equation for rotating bending load is obtained as follow:

$$\log(N_f) = -8.90 \log(\sigma_a) + 28.35 \quad (14)$$

and for axial load is:

$$\log(N_f) = -9.36 \log(\sigma_a) + 29 \quad (15)$$

The slope of these parallel S-N curves is equal to the slope of the rotating bending S-N curve and the axial S-N curve, -8.90 and -9.36 respectively.

3.1.2 Stress analysis of axial and rotating bending notched specimen

In axial fatigue loading, stresses can easily be obtained. In the weakest link theory, maximum stress in notched specimen under fatigue loading is required. This can be obtained by the use of available commercial finite element softwares. Therefore, the notched specimen is simulated in the finite element software under axial loading and the stresses are calculated.

But stress amplitude distribution in an axisymmetric specimen under rotating bending cannot directly be obtained by a finite element analysis. However, by superimposing suitably weighted FEA stress distributions from bending about the *y*- and *z*-axes, Fig. 7, the stress amplitude distribution in rotating bending can be readily obtained [27].

A bending moment M is applied to a rotating cylindrical specimen. Cross section of this specimen is shown in Fig. 8. At the particular instant, the radius OA is perpendicular to the moment vector and the axial stress at this moment (point A in Fig. 8) reaches its maximum. During rotating bending, the stress state at the position x for an arbitrary angle of rotation (point *A*), θ, is:

$$\sigma_x(A) = \frac{M\cos\theta \,.\, OA\cos\theta}{I} + \frac{M\sin\theta \,.\, OA\sin\theta}{I} \quad (16)$$

or

$$\sigma_x(A) = \sigma_{My}(A)\cos\theta + \sigma_{Mz}(A)\sin\theta \quad (17)$$

where $\sigma_{My}(A)$ and $\sigma_{Mz}(A)$ are the resulting stress tensor fields for bending around the specimen's *y*- and *z*-axis, respectively for point *A*. *y* and *z* are perpendicular to each other and also to the length axis (*x*-axis) of the specimen.

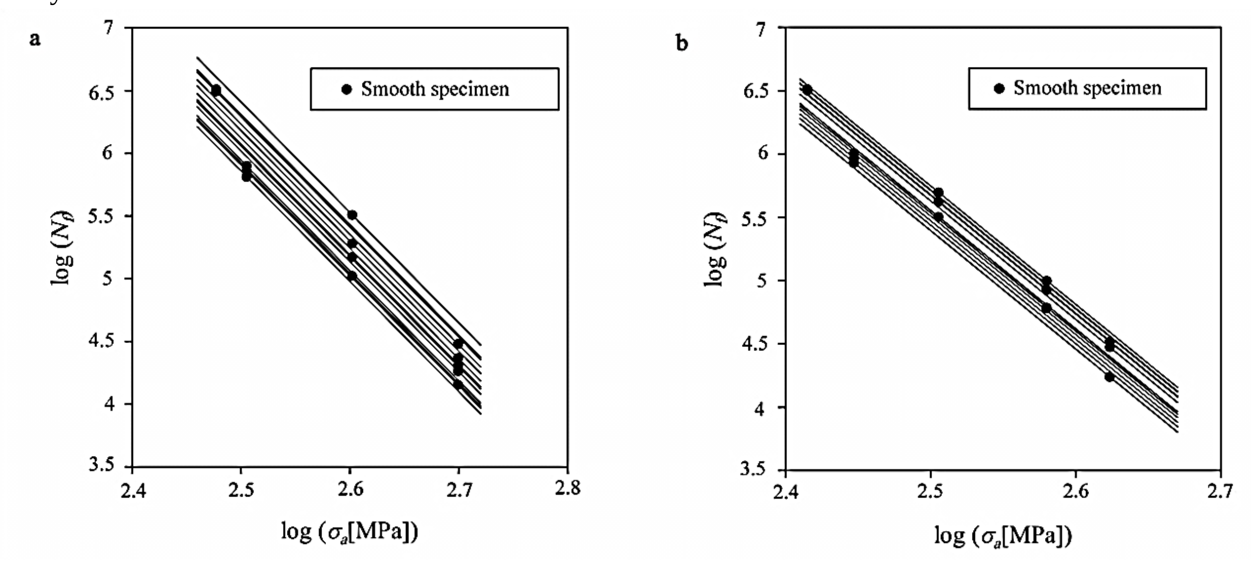

Fig. 7. A family of *S–N* curves passing through each data point for the smooth specimens (a: rotating bending and b: axial

The stress fields $\sigma_{My}(A)$ and $\sigma_{Mz}(A)$ can be determined by means of two separate load cases for a finite-element model of the rotating bend specimen. Similarly, for all points of the specimen (all nodes of the simulated specimen by finite element method) the stress field is obtained.

By applying the above-mentioned methodology, an axisymmetric stress field is obtained for the notched specimens, Fig. 9, to be used in the weakest-link analysis.

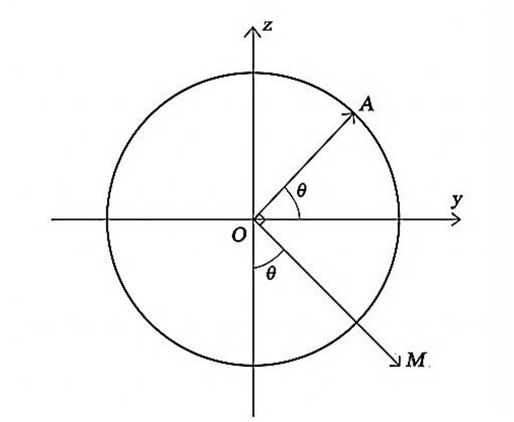

Fig. 8. Cross-section of a rotating bending specimen subjected to a bending moment *M*.

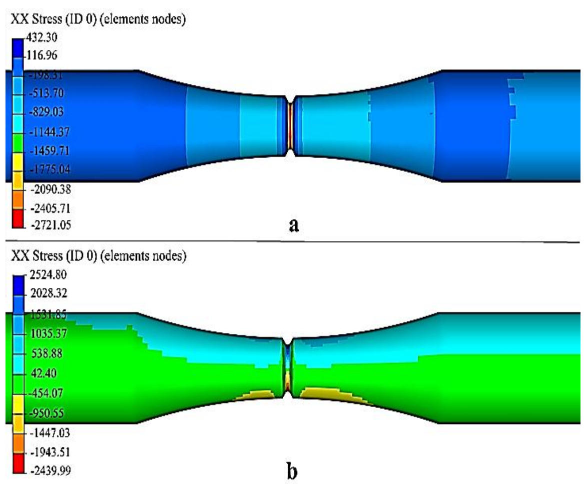

Fig. 9. Stress distribution for the notched specimen; (a) rotating bending load and (b) static load.

3.1.3 Weibull's weakest-link results

k_f in weakest-link theory is obtained by dividing the effective stress to the stress amplitude. As specified in Table 3, the surface method yields more conservative predictions than the volume method. The fatigue-effective stress amplitude is calculated by integrating the stress over the surface in the surface method and over the volume for the volume method. Since surface stresses are larger than volume stresses, the calculated fatigue-effective stress amplitude in the surface method is larger than volume method at the same applied stress amplitude.

3.2 Peterson method

Peterson assumes that fatigue failure occurs when stress at a point in a critical distance (a_p) away from the notch root is equal to the fatigue strength of a smooth specimen. The following empirical equation is proposed for q:

$$q=\frac{1}{1+\frac{a_{\mathrm{p}}}{r}} \tag{18}$$

where a_p is the material constant which is dependent on the loading and size and r is the notch root radius [28]. a_p is obtained from experimental curves that are provided by Peterson [28]. By applying Eq. (8 and 18), the fatigue strength factor for the rotating bending and axial fatigue tests is obtained 2.09 and 2.17, respectively.

3.3 Neuber method

In Neuber method [29] it is assumed that fatigue damage occurs if the average stress over a distance (a_n) from the notch root equals to the fatigue limit of a smooth specimen. Neuber presented the following empirical equation for q:

$$q=\frac{1}{1+\sqrt{\frac{a_n}{r}}} \tag{19}$$

where r is the notch root radius and a_n is the Neuber's material constant related to the grain size. Neuber's material constant is determined versus the ultimate tensile strength. By applying Eq. (8 and 19), the fatigue strength factor for the rotating bending and axial fatigue tests is obtained 2.16 and 2.25, respectively.

Table 3.Weibull's weakest-link results for probability of fatigue failure of 50 percent.

Method	Axial load			Rotating bending load		
	stress amplitude σ_a(MPa)	effective stress $\overline{\sigma_a}$ (MPa)	N_f (cycle)	stress amplitude σ_a(MPa)	effective stress $\overline{\sigma_a}$ (MPa)	N_f (cycle)
Volume method	213.03	342.7	650611	198.09	342.7	650611
Surface method	181.47	342.7	650611	172.21	342.7	650611

3.4 Stress gradient method

Siebel and Stieler [3] used the stress gradient effects on the fatigue strength reduction instead of the notch root radius. They introduced a new parameter, the relative stress gradient (RSG), defined as follow:

$$\mathrm{RSG}=\frac{1}{\sigma^e(x)}\left(\frac{d\sigma^e(x)}{dx}\right)_{x=0} \tag{20}$$

where x is the normal distance from the notch root and $\sigma^e(x)$ is the theoretically calculated elastic stress distribution. By testing fatigue strength of the smooth and notched specimens, they provided empirical curves relating $k_t\,/\,k_f$ to RSG for various materials. These curves can be expressed by the empirical formula. The fatigue strength factor for the rotating bending and axial fatigue tests is obtained 2.53 and 2.66, respectively.

3.5 Critical distance method

Theory of critical distance contains three different approaches [4]. This section starts with point method and then the line method and area method. In these methods, the stress gradient in front of the notch root and a critical distance from the notch root are required. Stress gradient in front of the notch root obtained by finite element analysis and critical distance is as follow:

$$L=\frac{1}{\pi}\left(\frac{\Delta k_{th}}{\Delta\sigma_0}\right)^2 \tag{21}$$

This equation relates critical distance to two materials constants, Δk_{th} and $\Delta\sigma_0$, where Δk_{th} is stress intensity threshold and $\Delta\sigma_0$ is fatigue limit.

Distance on the stress–distance curve is denoted by r and stress by $\Delta\sigma(r)$.

According to the point method, fatigue failure occurs when the stress value reaches the strength of a smooth specimen in half of the critical distance, i.e.:

$$\Delta\sigma\left(r=\frac{L}{2}\right)=\Delta\sigma_0 \tag{22}$$

In the line method, the average stress over r = $[0,L/2]$ is used, and fatigue failure occurs when this average stress is equal to the strength of a smooth specimen. The area method involves averaging the stresses over some areas in the vicinity of the notch. In the area method, fatigue failure occurs when this average stress is equal to the strength of a smooth specimen [4].

To obtain critical distance, the stress intensity threshold (Δk_{th}) and the fatigue limit ($\Delta\sigma_0$) should be available, but the stress intensity threshold of HSLA100 is not available; therefore, an alternative method is used.

Peterson [28] presented an empirical equation that relates critical distance to ultimate strength for bending load:

$$L(mm) = 2\times 0.0254\times\left(\frac{2079}{s_u\ (\mathrm{MPa})}\right)^{1.8} \tag{23}$$

Through this method, for the HSLA100, the critical distance is obtained (L=0.2316). Since in critical distance method it is required to calculate stress gradient at the notch root, the bending and axial load are applied on the notched specimen.

Table 4. Fatigue strength factors (k_f) predicted by experiments and also different methods.

Method	Experiment	Peterson	Neuber	Stress Gradient	Weibull's weakest link		Critical Distance		
					Volume method	Surface method	Point Method	Line Method	Area Method
k_f	1.82	2.09	2.16	2.53	1.61	1.89	1.89	1.92	1.96
k_f	1.93	2.17	2.25	2.63	1.73	1.99	2.02	2.06	2.09

Table 5. Different classical methods prediction error percent (ep).

method	Peterson	Neuber	Stress Gradient	Weibull's weakest link		Critical Distance		
				Volume method	Surface method	Point Method	Line Method	Area Method
ep	0.15	0.19	0.39	0.11	0.04	0.04	0.05	0.08
ep	0.12	0.16	0.36	0.10	0.03	0.05	0.07	0.08

stress gradient at the notch root, the bending and axial load are applied on the notched specimen.

The obtained fatigue strength factor, k_f, in rotating bending fatigue is 1.89, 1.92, and 1.96 for point, line, and area methods, respectively. In axial fatigue, this factor is 2.02, 2.06, and 2.07 for point, line, and area methods, respectively.

4. Results and discussion

The predicted fatigue strength factors of the foregoing analysis are summarized in Table 4. Also different classical methods prediction error percent have been summarized in Table 5. According to Tables 4 and 5, the fatigue strength factors predicted by critical distance and Weibull's weakest-link methods are the closest to the experimental results. But it should be noted that to apply critical distance, stress intensity threshold is required which is not available for the studied material. Therefore, an empirical equation is used to obtain critical distance. Neuber, Peterson, and stress gradient methods are the mainly empirical approaches and easy to use. According to Tables 4 and 5, the predictions made by these methods are conservative, which is some consolation for engineering designers, but nevertheless, the errors are high.

It should be considered that these methods are not consistent with the finite element results. To select an appropriate method of assessing the notch effect in components subjected to fatigue, availability of the required materials data, the predictive capability and the compatibility with FEA stresses are usually the most important criterion for a design engineer. So with considering these points, Weibull’s weakest-link theory is recommended to predict fatigue life among the studied methods in this research.

5. Conclusions

Tensile, axial and rotating bending fatigue tests were conducted on cylindrical specimens. Fatigue experiments were carried out on two sets of - notched and smooth specimens in rotating bending and axial fatigue loads. The material under investigation was HSLA100 steel, which is widely applicable in the marine industry. Mechanical properties of the HSLA100 steel and fatigue properties for notched and smooth specimens were presented. Notch effect on fatigue strength of the HSLA100 steel in rotating bending and axial fatigue loads was experimentally evaluated, and *S–N* curve was obtained.

Weibull's weakest-link, Neuber, Peterson, stress gradient and critical distance methods were used to predict fatigue strength factor for the notched specimen based on the obtained S-N curve of the smooth specimen. The obtained theoretical results were compared with experimental data. It was found that the critical distance and Weibull’s weakest-link methods have the best agreement with experimental results.

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