

Student and Weibull Statistical Study applied on Experimental results of the P265GH Steel used for pressure vessel.

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ABSTRACT

This paper is devoted to study probability of survival and probability of failure (Reliability and damage of Weibull) of steel P256 GH used generally in pressure structures. Two statistical study are conducted the first is Student distribution that allowed us to extract the confidence interval for the maximum stress [469.29,473.16] and for elastic stress [308.66; 313.4].The second one is Weibull distribution which identified the characteristic elements of Weibull: the Weibull modulus m and scale factor σ_0 required to calculate material probability of survival and its probability of failure.

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Introduction:

Nowadays, the concern that oppresses the operators of pressure vessel is to ensure the maintenance of these networks without affecting the economic and industrial interests [1], because the slightest failures result in substantial discomfort economically and socially and have also a remarkable environmental impact [2], particularly in flammable or explosive gases. Thus, the necessity to improve and predict the lifetime of its equipment and increase the reliability of these systems is an issue extremely important.

The aim of this statistical study applied on steel P256 GH (used in pressure structures[3]) is firstly select the confidence interval that contain the true value of maximum stress and elastic stress that the material could undergo through the use of Student distribution. Secondly by applying Weibull distribution for both maximum and elastic stress results, the probability of survival and the probability of failure were defined by raising the characteristic elements of Weibull: the Weibull modulus (m) and scale factor (σ_0).

Experimentation:

Mechanical properties of P265GH steel:

The mechanical characteristics of P265GH steel, at the ambient temperature, are reported in the table1

Table1. Mechanical properties of the material [4], [5]

Young's modulus <i>E</i> (MPa)	elastic limit: σ_e (MPa)	Breaking stress: σ_g (MPa)	Elongation %	Poisson's ratio ν
2.10^5	320	470	35	0,3

Student distribution of P265GH steel and the determination of confidence interval:

The STUDENT distribution is used to identify the appropriate confidence limits. STUDENT law determines a confidence interval in which the limit of the maximum stress of the studied specimens is 90 out of 100 to regulate the average distribution of the tensile tests[6].

We have:

$$P \left[-t_{(\alpha,\mu)} ; \alpha \leq \frac{X-\mu}{s/\sqrt{n}} < +t_{(\alpha,\mu)} ; \alpha \right] = 1 - \alpha \quad (1)$$

Where:

X: Average of maximum stresses of different specimens;
 n : Number of specimens
 μ : n-1;

s : Standard deviation;
 α :Risk threshold;
 $t_{(\alpha,\mu)}$: value from STUDENT table;

The limit in probability μ is defined as:

$$P \left[X - t_{(\alpha,\mu)} \cdot \frac{s}{\sqrt{n}} < \mu < X + t_{(\alpha,\mu)} \cdot \frac{s}{\sqrt{n}} \right] = 1 - \alpha \quad (2)$$

To determine the confidence interval by calculating the upper and lower limits of the true average of the breaking load, the relation STUDENT (2) is applied to results obtained in the static tensile tests on specimens.

Weibull Distribution:

Another statistical technique on the experimental results of tensile test of the P265GH steel is studied, it is Weibull statistical method. The purpose of this study is to provide a statistical processing to derive the maximum stress that can be applied on the material so that the failure probability (damage) is less than 1%, and then estimate the survival probability (reliability) and the probability of failure.

Results and Discussion:

The tensile test results of P265GH steel are reported in fig 1.

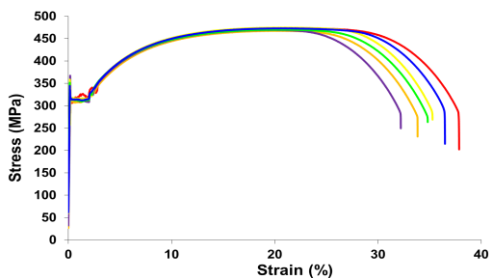


Fig. 1: Stress-strain curves of 6 specimens

Application of student distribution:

The confidence interval (CI) at 60% is an interval of values which have 60% chance to contain the true value of the estimated maximal stress. It is possible to say that the CI represents the interval of values within which we are 60% certain to find the real search value. The confidence interval is the set of values reasonably compatible with the observed result. It provides a visualization of the incertitude.

• **For maximum stress**

The average and standard deviation estimated of maximum stresses are:

X = 471.23MPa ; s =5.04; n = 6 specimens;
 $\alpha = 0.1$; $t \left(\frac{\alpha}{2}; 4 \right) = 0.94$ (value from STUDENT table)

Resulting:

$$\mu = 471.23 \pm 2.015 \sqrt{\frac{25.4}{5}} = [469.29, 473.16]$$

Table 2.shows the values of maximum stress that exist in the confidence interval:

Table 2 .maximum stresses of the tensile test

Specimens	Maximum stress
1	467.665
2	469.341
3	470.31
4	473.229
5	474.234
6	474.794

Table 3.shows the values of the maximum stress that exist in the confidence interval:

Table 3 .P265GH specimens acceptable from the confidence interval

Specimens	Maximum stress
2	469.341
3	470.31

• **For elastic stress**

The average and standard deviation estimated of elastic stresses are:

X = 311.07MPa ; s =6.24; n = 6 specimens;

$\alpha = 0.1$; $t \left(\frac{\alpha}{2}; 4 \right) = 0.94$ (value from STUDENT table)

Resulting:

$$CI=[308.66; 313.4]$$

Table 4.shows the values of elastic stress that exist in the confidence interval:

Table 4 .elastic stresses of the tensile test

Specimens	Elastic stress
1	306.64
2	311.5
3	314.13
4	314.4
5	314.76
6	315.5

Table 5.shows the values of elastic stress that exist in the confidence interval:

Table: 5. P265GH specimens acceptable from the confidence interval

Specimens	Elastic stress
2	311.5

i) **WEIBULL DISTRIBUTION**

We define Weibull characteristics using statistical software (Fig 2) and it is found that:

• **For maximum stress**

$$m =214.63 \text{ and } \sigma_0 = 472.88$$

with m: Weibull modulus

σ_0 :scale factor

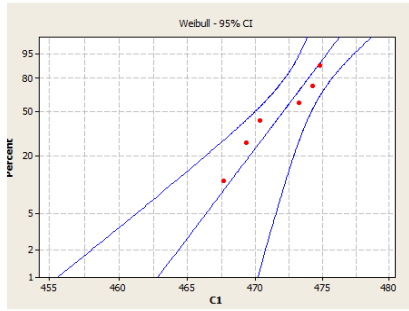


Fig. 2: Weibull distribution curve of the P265GH steel maximum stress

The probability of survival of specimen undergoing stress could be modeled using the following Weibull model:

$$Ps = e^{-\left(\frac{\sigma}{\sigma_0}\right)^m} \quad (3)$$

The probability of survival curve and the probability of failure in function of stress are presented in Fig3.

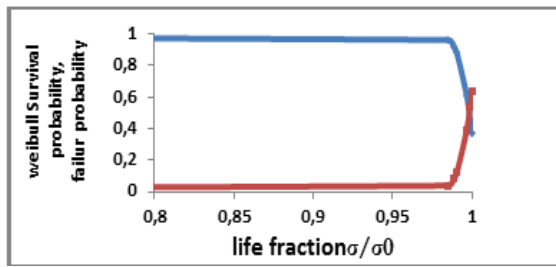


Fig. 3: Probability of survival-Probability of failure curve for maximum stress in function of life fraction

The task is to estimate the maximum stress that can be applied to the material so that the failure probability is lower than 1%. This means that:

$$Ps > 0.99 \quad \text{and we have: } e^{-\left(\frac{\sigma}{\sigma_0}\right)^m} = 0.99$$

The value of the maximum stress obtained that could be applied on the material so that the failure probability is less than 1%:

$$\sigma = 462.85$$

- **For elastic stress**

$$m = 167.36 \text{ and } \sigma_0 = 314.09$$

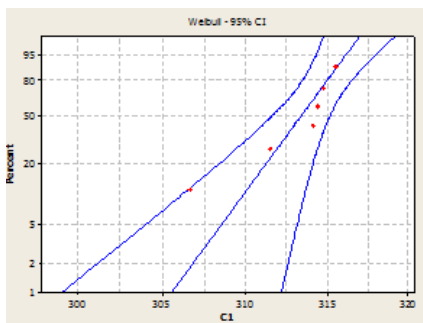


Fig. 4: Weibull distribution curve of the P265GH steel elastic stress

The probability of survival curve obtained using Weibull model and the probability of failure in function of life fraction are presented in Fig 5.

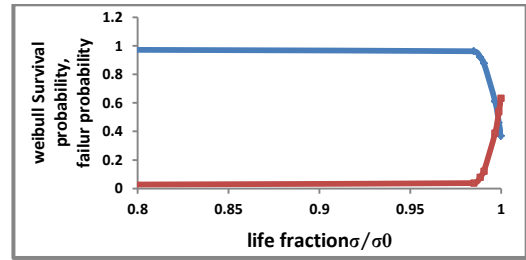


Fig. 5: Probability of survival-Probability of failure curve in function of life fraction

- **Superposition of elastic stress and maximum stress curves**

The probability of survival and the probability of failure curves in function of stress for both maximum and elastic stress are presented in fig6

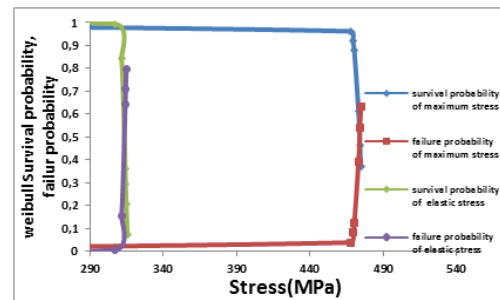


Fig. 6: Probability of survival and the probability of failure curves in function of stress for both maximum and elastic stress

According to the curve in fig6, we could distinguish three zones: elastic zone [0;315 MPa], stable plastic zone [315 MPa;465 MPa] and unstable plastic zone ($\sigma > 465$ MPa).

Conclusion:

In this statistical analysis, it is noticed that tensile test results of P265GH steel have an important dispersion; STUDENT distribution helped us to refine the confidence interval. In addition to that Weibull distribution allows us to define the appearance of probability of survival and probability of failure for elastic stress and maximum stress and therefore distinguish the elastic zone, the stable plastic zone and the unstable plastic zone for a predictive maintenance in order to ensure the efficiency of the P265GH steel specially and the Pressure vessels in general.

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