Elasticity modulus variation of the AISI SAE 1045 steel subjected to corrosion process by chloride using tension test destructive

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Abstract. The study of materials corrosion effect is a great importance topic for the manufacturing industry and also for the consumer that requires this. That is why a research study was conducted that aimed to determine the elasticity modulus variation of AISI SAE 1045 steel subjected to corrosion. To achieve this, thirty-five specimens were used, which were exposed to chlorides by immersion processes and salt spray chamber in three periods of time and then subjected to stress test destructive, following the guidelines established under ASTM G-1 standards, ASTM G-31 and ASTM E-8. Variation was found in the elastic behavior of steel and curves that differ from the theoretical ones raised in the documents.

1. Introduction
Due to steel need and importance in the industry, a study has been carried out on AISI SAE 1045 steel in order to observe the elasticity modulus variation over time when subjected to corrosion through a series of tests, such as: immersion test and salt spray chamber. In order to analyze the behavior developed by the material corrosion and its condition, AISI SAE 1045 steel it has been decided to use because it is a material commonly used in the manufacture of parts for the automotive, agricultural, among others, where hardness and toughness is required in the final product. [1]

The AISI SAE 1045 steel study was experimental, and consisted of observing and analyzing the elasticity modulus variation subjecting 30 specimens of this material to corrosion, 15 of them intended for the immersion test method application using Sodium hypochlorite with demineralized water and with 15-day intervals, 5 specimens were removed. Likewise, the corrosion process of the specimens was carried out using the salt spray chamber, using sodium chloride with demineralized water and with the same 15-day interval between specimens, 5 specimens were extracted. To obtain the quantitative data of the elasticity modulus variation of the material, a destructive tensile test was carried out, which consisted of subjecting the specimens in axial direction, to an increasing effort until their breakage in order to determine one or various mechanical characteristics. [2]
In order to find out the corrosion incidence on the material properties, whether it was affected negatively or positively, depending on its nature and the surrounding conditions and passivation presence [3],[4], the study is performed to the elasticity modulus.

2. Work development

2.1. Test Tube Preparation

Compilation using bibliographic information in literatures and applying the standards ASTM G-1 [5], ASTM G-31 [6] and ASTM E-8 [7], the study of elasticity modulus variation proceeded of AISI SAE 1045 steel exposed to chloride ions to accelerate the corrosion process. The shape of the specimens was selected according to the ASTM E-8 standard for destructive stress testing, and for the dimensions the technical specifications were taken into account as maximum applied force capacity of the universal testing machine, the modeled in a CAD software Fig. 1 and manufactured by water jet cutting and grinding in CNC milling machine Fig. 2.

![Figure 1. Tension test tube design.](image1)

![Figure 2. Machined test tube.](image2)

2.2. Trial development

In order to standardize tests, chemical solutions used and exposure times in the test execution, the exposure time diagrams and respective identification of the specimens were made using letters from A to letter F, Table 1.

| Test Tube N° | Amount Test Tube | Exhibition Time (Days) |
|--------------|------------------|------------------------|
| A            | 5                | 15                     |
| B            | 5                | 30                     |
| C            | 5                | 45                     |
| D            | 5                | 15                     |
| E            | 5                | 30                     |
| F            | 5                | 45                     |
In Figure 3 is shown, the salt spray chamber where the specimens corrosion was carried out at the established times and under the standardized process of its use. The term corrosion is used to describe the process of metallic materials deterioration (including both pure metals and their alloys), through chemical and electrochemical reactions[8]. Due the AISI SAE 1045 steel importance, it’s selected to observe its behavior when exposed in a corrosive environment.

When exposing the specimens in the salt spray chamber, Figure 3 and Figure 4 for the time established between them, the physical changes variation in the material was observed, one of them was the characteristic brown colour that increased its intensity with the passage of days and likewise the oxide was appreciated in large proportion when cleaning the specimens.

In the immersion test execution Figure 5, 15 specimens were subjected to sodium hypochlorite exposure with demineralized water and subsequently they were immersed under the established times, according to Table 1.
When extracting the steel specimens, the material surface variations are observed Figure 6, product of material irreversible interfacial reaction with its environment, which causes a consumption or dissolution of the material in the solution.

In Fig. 5, is seen the corrosion attack as small pitting holes, which are irregularly shaped and connected to each other. In the carbon steels case, the resulting corrosion compounds are deposited in these holes and, due to their porous nature, allow the attack to continue. [9]

3. Results
From the results obtained by submitting the specimens of the AISI SAE 1045 material in the universal testing machine, the representation of the stress curve vs. unit deformation Fig. 8 and Fig. 9 was obtained for immersion and fog chamber tests saline respectively.

The graphical representation shows how the average last effort of the specimens is affected with the passage of time and the elasticity modulus is also reflected, being explicit in the Table 2

**Table 2. Elasticity modulus of the different specimens**

| TEST TUBE | TEST TYPE       | ELASTICITY MODULUS E (MPA) |
|-----------|-----------------|-----------------------------|
| A         | Immersion       | 196,469                     |
| B         | Immersion       | 190,547                     |
| C         | Immersion       | 186,459                     |
| D         | Fog chamber     | 197,460                     |
| E         | Fog chamber     | 192,721                     |
| F         | Fog chamber     | 181,547                     |
With immersion corrosion, an elastic modulus was obtained for test tube A of 196.47 GPa, as a result of exposing 5 test pieces to corrosion for 15 days and obtaining the representative value. 190.55 GPa by exposing the B specimens to corrosion, with a duration of exposure to corrosion for 30 days and finally the C specimens, obtained a representative sample of 186.46 GPa which allows to justify the effect of the elastic modulus of the material with the over time.

With salt spray corrosion, it was established that corrosion directly affected the material, reflected in the decrease in the average elastic modulus of each cycle of the specimens, the average elastic modulus of the 5 specimens (D) being 197.46 GPa for the period of 15 days, test pieces (E) 192.72 GPa for the period of 30 days and test pieces (F) 181.54 GPa for the period of 45 days.

Figure 8. Stress – strain diagram test tubes A, B, C. Immersion test.

Figure 9. Stress – strain diagram test tubes D, E, F. Fog chamber test.
With the data obtained in the test with salt spray corrosion, it was observed how AISI SAE 1045 steel lost an average of 1.25% of the modulus of elasticity in the first series of specimens (D), 4% of the elastic modulus in the second series of test pieces (E) and 9% of the elastic modulus in the third series of test pieces (F).

In Figure 9, is see how the decrease obtained by the ultimate effort of the material with the passage of time and how the modulus of elasticity decreases considerably when exposed in an aggressive environment of corrosion. Based on information consulted on the 200 GPa (29000 KSI) elasticity modulus \cite{10}, conclusions could be made regarding the considerable decrease in the AISI SAE 1045 material module.

It’s further observed that the curve shows some variation with the theoretical curve characteristic of ductile materials, showing considerable deformation with small efforts before presenting the slope corresponding to the elastic coefficient. The effect of stress reduction in the creep zone is not shown.

4. Conclusions
It is evidenced that corrosion actually affects the material in an ascending manner with the passage of time, allowing a notable decrease in the modulus of elasticity of the material to be observed when the AISI SAE 1045 steel is subjected to corrosion under the saline effect.

Comparing the corrosion procedures, the immersion is more aggressive, degrading the material at a higher initial speed, but in the long term, the effect on the fog chamber is more critical, which is observed in the results of the elastic constant.

The phenomenon of perfect plasticity, characteristic of ductile materials, does not occur.

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