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SOLID CEMENTATION IN AISI 1018 STEEL

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Abstract: A heat treatment was carried out using the solid carburizing process on an AISI 1018 low carbon steel. The purpose of this treatment is to enrich the surface of the steel with carbon by means of the diffusion mechanism, so that the surface layer of the steel contains a higher concentration of carbon than the original concentration of carbon contained in this steel. Consequently, the case-hardened steel acquires a combination of properties. The cementitious components used consisted of 90% charcoal and 10% barium carbonate (BaCO3). The cementitious components used are made up of 90% charcoal and 10% barium carbonate (BaCO3), the temperature in the furnace was 930°C, with a permanence of 8 hours, then the steel piece was cooled in oil for quenching and subsequently tempered at 230°C for a period of 45 minutes. Total depth is defined as the perpendicular distance from the limit of the surface to the end of the hardened zone. On the other hand, the microstructure obtained on the surface was of a martensite phase and the core was of a pearlite and ferrite phase, in this treatment it was possible to obtain a dual phase steel, achieving greater hardness on the surface due to a high carbon content, but keeping a lower content in its core. Dual phase steels are excellent in conditions where there are high impact stresses and constant surface wear, for example: in shafts, bolts, gears and transmission parts which are in constant metal to metal friction, abrasion and impact among others
Keywords: Solid carburizing, Carbon, Steel.

INTRODUCTION

Solid carburizing is a thermochemical treatment, which, by means of a diffusion process, enriches the surface of a steel with carbon, in order to obtain a layer with a higher carbon concentration than that of the core [1]. The saturation of carbon on the surface induces the formation of martensite. This results in a part formed by two microstructural phases that present a combination of properties: the core with a low carbon content, tough and fatigue resistant, and the surface with higher hardness, wear resistance and higher compressive strength [2]. Case hardening depends mainly on the temperature, this must be above the carbon solubility limit [3] being 900°C - 930|° C. And the steel must remain a certain time being from 8 to 12 hours. The depth of carbon diffused into the steel from the surface to the core will depend on the treatment time, which can be 6 to 10 hours [4]. A higher concentration of carbon in the layer will increase the hardness of the steel [5]. With the help of heat treatment, it is possible to prepare parts that will be subjected to frictional wear and stresses, and case hardening is an option to obtain mechanical properties that can guarantee the work of the elements that make up a machine or tool, starting from a commercial steel with low carbon content [6].

EXPERIMENTAL DEVELOPMENT

For the development of this study, specimens were machined for tensile testing under the ASTM E8 standard and half-inch diameter and half-inch length samples for chemical metallographic and microhardness analysis. See figure.1

Chemical analysis was performed on AISI 1018 steel bar used for the solid cementation study, using a HITACHI PMI-Master Smart optical emission spectrometer. The chemical analysis was carried out to corroborate if it corresponds to AISI 1018 steel.

The procedure for the treatment by the solid cementation process was by placing the tension specimen and the AISI 1018 steel sample for metallography and a mixture of charcoal (90%) and BaCO3 (10%) in a metal box that was then covered with a lid, sealing the gaps between the box and lid with clay to prevent the entry of oxygen for the treatment. Once the box containing the specimens and the mixture of carbon and BaCO3 was prepared, it was introduced into an oven heated to a temperature of 930°C

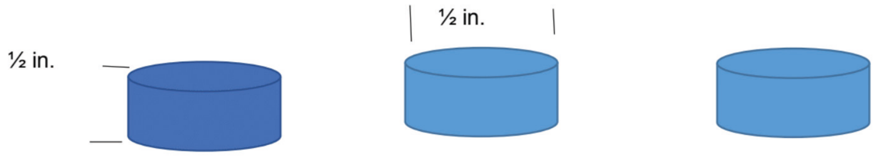


Figure 1. Specimens for Metallography, Chemical Analysis and Hardness.

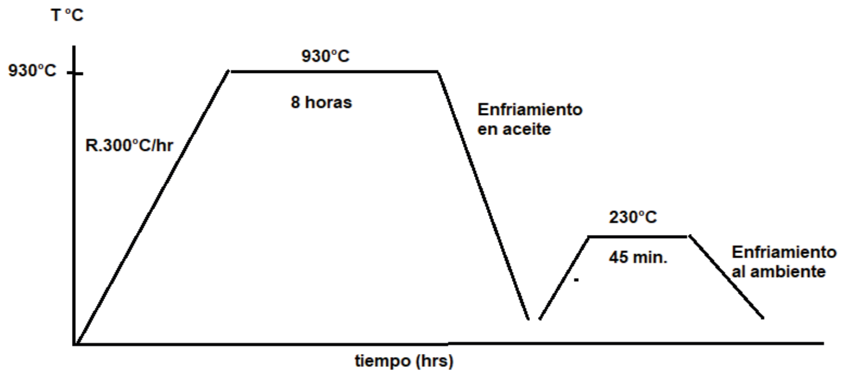


Figure 3. Thermal cycle applied in solid case hardening in AISI 1018 steel.

for 8 hours, then the box was removed from the oven, the lid was removed and the specimens were extracted for tension together with the cores that would be prepared for chemical analysis, hardness and metallography. The specimens are quickly tempered in a container containing quenching oil with a high cooling rate, always maintaining agitation during the cooling of the specimens. Once the specimens have a temperature of 60°C, they are placed in a furnace for tempering at a temperature of 230°C. Figure 2 shows the metal box used for the thermochemical treatment.

Figure 2. Shows the metal box where AISI 1018 steel samples were placed, and the charcoal and barium carbonate mixture, once filled, was covered, sealed with clay and placed in the furnace for treatment.

The solid cementation process is carried out by means of a furnace in which the metal box containing the AISI 1018 steel samples and the charcoal and barium carbonate are placed. When the thermal cycle starts, these cementing agents are ignited where the carbon generates CO2, continuing the reaction until carbon monoxide is produced with the help of the barium carbonate, until the carbon diffusion on the steel surface is achieved by means of the diffusion mechanism. Figure 3 shows the thermal cycle established.

Figure 4 shows the moment when the box is removed from the furnace and the quenching in quenching oil is performed.

Figure 4. Extraction of the steel samples from the box to be subsequently quenched and tempered in mineral oil.

The heat-treated specimens were analyzed by means of a Vickers hardness tester previously mounted and polished in order to obtain the depth of the cemented layer in AISI 1018 steel and the tension specimen was tested in a universal machine.

RESULTS AND DISCUSSION

CHEMICAL ANALYSIS

A chemical analysis was performed on a sample of AISI 1018 steel obtaining the following result.

PM Smart SNr. 57T0056 Optik Nr. 57T0056
Sample :
Alloy : FE_100 Mode : PA 30/11/2017 13:58:42

	Fe	C	Si	Mn	Cr	Mo	Ni
1	98.3	0.198	0.237	0.779	0.0945	0.0276	0.0761
2	98.2	0.206	0.242	0.790	0.0943	0.0298	0.0762
3	98.3	0.189	0.220	0.772	0.0943	0.0285	0.0799
Average	**98.3**	**0.198**	**0.233**	**0.780**	**0.0944**	**0.0286**	**0.0774**

	Al	Co	Cu	Nb	Ti	V	W
1	0.0090	0.0053	0.260	0.0035	0.0019	0.0033	< 0.0400
2	0.0089	0.0077	0.257	0.0041	0.0019	0.0033	< 0.0400
3	0.0097	0.0026	0.258	0.0045	0.0023	0.0037	< 0.0400
Average	**0.0092**	**0.0052**	**0.258**	**0.0040**	**0.0020**	**0.0034**	**< 0.0400**

According to the results obtained, the steel does correspond to an AISI 1018 steel, being suitable to carry out the solid cementation study.

METALLOGRAPHIC ANALYSIS

The AISI 1018 steel was subjected to a metallographic test, for this process of solid cementation, one of the conditions to obtain favorable results is that the sample is in normalized condition, that is to say that it has the pearlite and ferrite phases in its structure. This favors a better diffusion of carbon in the metal after carburizing. The other condition is that the steel has a low carbon content, in this case it contains 0.19% C, which means that it is suitable for this study, since the purpose is to enrich the surface of the steel with carbon up to an average of 1% C. Therefore, the rule that states that the higher the carbon content in the metal, the higher the hardness it will have when hardened, applies. Figure 5 shows a microstructure of the AISI 1018 steel studied.

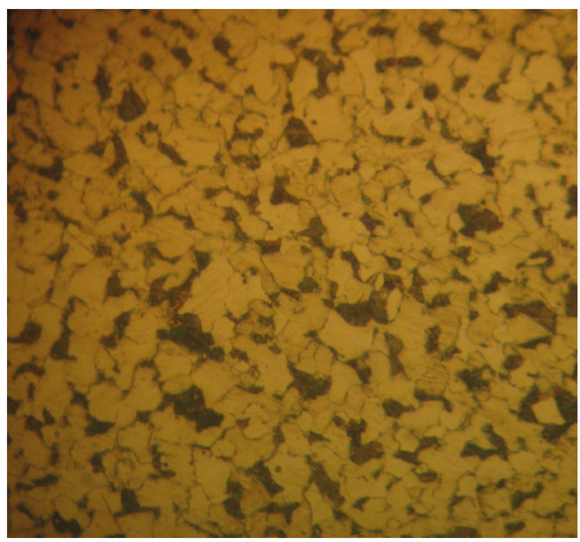


Figure 5. 400x micrograph of AISI 1018 steel. In which a structure formed by a ferritic matrix (light) and pearlite (dark) is observed. Attacked with 2% nital.

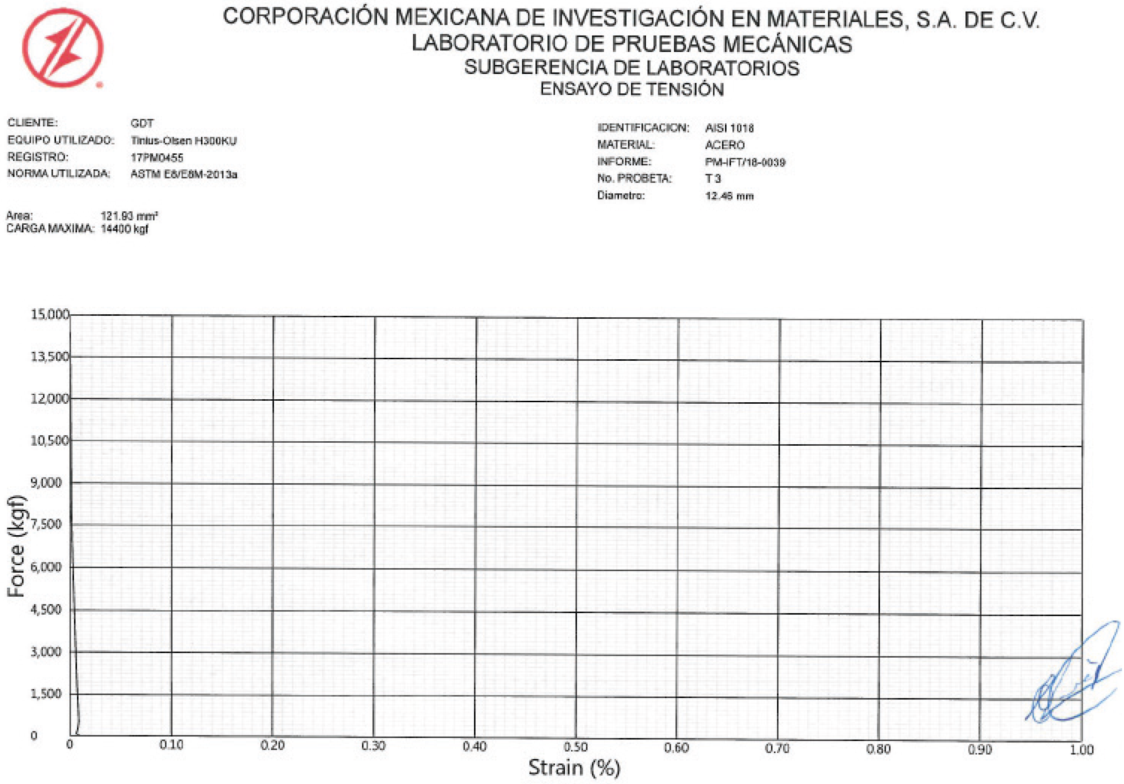
MECHANICAL TESTS

AISI 1018 steel was subjected to a hardness test prior to solid case hardening and the results obtained are as follows.

AISI 1018 (SIN CEMENTAR)	
MEDICION	**PROBETA 0**
1	120,1
2	142,8
3	128,5
4	116,4
5	110,7
6	128,6
PROEDIO	**124,52**
DUREZA HV	**125,25**

The hardness obtained corresponds to AISI 1018 steel in normalized condition, for carbon steels there is a table used to estimate the tensile strength based on the hardness, for this hardness result is estimated to have a tensile strength of 64,000 psi.

The AISI 1018 steel was subjected to a tensile test after being subjected to the solid cementation process and the tensile strength value obtained was 167,964 psi. It can be seen that the tensile strength increased in the cemented specimen to more than double its original strength. Figure 6 shows the graph of the tensile test.



Results obtained from a sample of AISI 1018 steel cemented with charcoal, where a maximum stress of 167,964 psi was obtained.

CEMENTATION DEPTH

The result obtained from the cementation depth contemplates a general study where the cementation depth and microhardness are annexed, which is obtained when the value of 50 Hrc or 550HV found in the mapping according to the SAE J423 standard is registered, the graph and the microstructures in the superficial zone, intermediate zone and core were obtained. Figure 7 shows the cementation depth graph with a value of 1.61 mm. It is an acceptable value which guarantees better properties in this steel.

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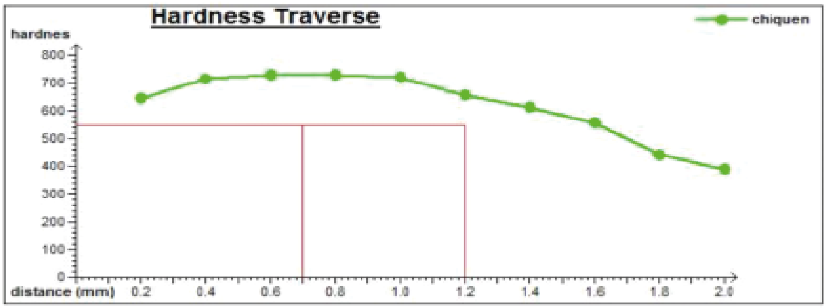

Result

Eht 550 HV 0.5 = 1.61 mm

Row 1

Point	Distance	Hardness	Conv Hardness 1	Comment
1	0.2000	645 HV 0.5	645 HV 0.5	
2	0.4000	716 HV 0.5	716 HV 0.5	
3	0.6000	729 HV 0.5	729 HV 0.5	
4	0.8000	729 HV 0.5	729 HV 0.5	
5	1.0000	721 HV 0.5	721 HV 0.5	
6	1.2000	657 HV 0.5	657 HV 0.5	
7	1.4000	614 HV 0.5	614 HV 0.5	
8	1.6000	557 HV 0.5	557 HV 0.5	
9	1.8000	443 HV 0.5	443 HV 0.5	
10	2.0000	390 HV 0.5	390 HV 0.5	

Figure 7. Graph showing Vickers hardness values in AISI 1018 steel when mapping depth of case hardening.

Figure 8 shows some metallographs of the cemented sample, where photomicrographs A and B are the surface of the steel where hardnesses higher than 50 Hrc were obtained, being a typical martensite structure, reaching a layer depth of 1.61 mm , photomicrograph C is the transition zone where the hardness is less than 50 Hrc, it should be noted that from values below 50Hrc is no longer considered cemented layer depth because it begins the transition zone of the formation of traces of pearlite and ferrite structure. And the photomicrograph D, is from the center of the piece where its hardness values are less than 20 Hrc. And it is a structure containing the pearlite and ferrite phase.

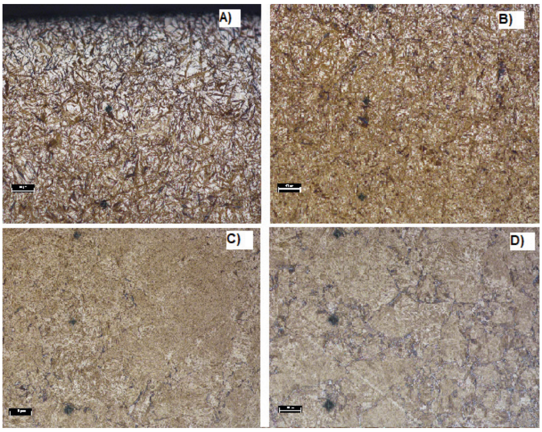

Figure 8. photomicrographs taken of AIISI 1018 steel cemented with charcoal at a temperature of 930°C and 8 hours of permanence. Microstructure (A and B) is the surface zone, martensite phase present taken at 200X, microstructure (C) is the transition zone presenting traces of pearlite and ferrite phases taken at 200X, and microstructure (D) is the core of the analyzed piece and presents completely pearlite and ferrite phase taken at 200X.

CONCLUSIONS

The result this study was a surface layer with a higher percentage of carbon than the original AISI 1018 steel. This can be verified with the metallographic results, hardness tests and tensile tests.

- The hardness values obtained increase as time goes by in the case hardening process. This shows that the longer the time, the higher the carbon concentration and therefore the higher the hardness and tensile strength.
- It was observed that the specimen cemented with charcoal reached a cemented layer of 1.61 mm with a hardness greater than 550 HV which is a satisfactory value.
- The metallographic analysis clearly shows a superficial cementation layer, which demonstrates that the structure present is a martensite phase constituent of a high hardness phase.
- the availability of the materials and equipment used for these solid cementing treatments is feasible to develop it in the metal-mechanical area, which makes it a very good option to implement it in the work area.
- Using the solid case hardening process ensures that a low carbon steel will be able to be satisfactorily case hardened, resulting in improved mechanical properties.

REFERENCE

[1] Askeland, D. R. (2004). Ciencia E Ingeniería De Los Materiales. México: Thomson.

[2] Avalos, J. E. (1994). Endurecimiento Superficial Por Difusión Del Carbono En Acero Gamma (Tesis). Tesis, Universidad Autónoma De Nuevo León, San Nicolas De Los Garza.

[3] Avner, S. H. (1988). Introducción A La Metalurgia Física. Mcgraw-Hill.

[4] Bautermic, S. (2013). Tratamientos Térmicos. Los Tratamientos Térmicos En La Industria, 136, 23.

[5] Belzunce, F. (2001). Aceros Y Fundiciones: Estructuras, Transformaciones, Tratamientos Térmicos Y Aplicaciones.

[6] Bernd, S. E. (2003). Introducción A La Metalurgia. Santiago De Chile.