(19) SPANISH PATENT AND TRADEMARK OFFICE

SPAIN

(11) Publication number: **2 322 416**

(21) Application number: 200602554

(51) Int. Cl.:

G01N 3/60 (2006.01)

(12) INVENTION PATENT B1

(22) Date of presentation: **09.10.2006**

(43) Date of publication of application: **19.06.2009**

Award date: **22.06.2010**

(45) Award announcement date: **05.07.2010**

(45) Date of publication of the patent brochure: **05.07.2010**

(73) Holder/s: **University of Cantabria**
Government Pavilion
Avda. de los Castros, s/n
39005 Santander, Cantabria, ES

(72) Inventor/s: **Carpio García, Jaime;**
Álvarez Laso, José Alberto;
Casado del Prado, José Antonio;
Gutiérrez-Solana Salcedo, Federico and
González Terán, María Amelia

(74) Agent: **Not recorded**

(54) Title: **Tensile for stress corrosion testing.**

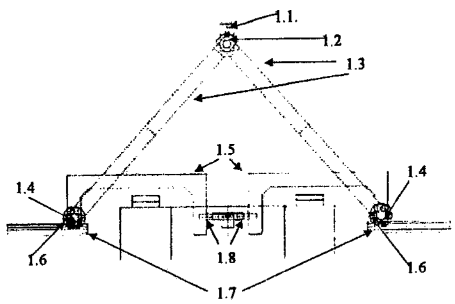
(57) Summary:

Tensile corrosion testing tool characterized by being adapted to fracture toughness specimens and mechanical test specimens, immersed horizontally in an aggressive environment and by being attached to a universal testing machine in vertical arrangement.

The tool solves the technical problem of performing stress corrosion tests with specimens in horizontal arrangement when only universal testing machines in vertical arrangement are available.

The utensil is characterized by the following elements:

- Coupling to the testing machine (1.1).
- Upper axis (1.2).
- Two arms arranged in a similar way to those of a compass (1.3).
- Two lower axles (1.4).
- Two C-shaped bars (1.5).
- Four bearings (1.6).
- Two guides containing bearing rails (1.7).
- Threaded bars suitable for joining with the pins required for fracture toughness tests under stress corrosion conditions (1.8).



ES 2 322 416 B1

Notice: Consultation may be carried out as provided for in article 37.3.8 LP.

Sale of fascicles: Spanish Patent and Trademark Office. Pº de la Castellana, 75 – 28071 Madrid

DESCRIPTION

Tool for stress corrosion tests.

Technology sector

Materials Science and Technology.

Subsector: Devices for stress corrosion testing.

Description

Tool for stress corrosion tests.

Object of the invention

The present invention relates to a tool for performing stress corrosion tests on tensile specimens or fracture toughness in a horizontal arrangement immersed in an aggressive environment when only a universal testing machine is available in a vertical arrangement.

The objective of the present invention is to provide an economically affordable solution to a common problem in stress corrosion tests, which is how to perform stress corrosion tests, with specimens in horizontal arrangement immersed in aggressive environments, when only universal testing machines in vertical arrangement are available, much more common than those in horizontal arrangement.

Background to the invention

The performance of mechanical characterization tests, in general, and fracture toughness in particular, on materials under stress corrosion conditions (usually in horizontal arrangement) is limited at present. This is due to the difficulty of implementing experimental equipment to the universal vertical testing machines common in mechanical testing laboratories, and at the same time an oven that maintains the corrosive environment at high temperature, the condition in which it is more active or simply the condition in which it exists. This forces the use of stable corrosive environments at room temperature, such as solutions of acids, bases, and mercury in liquid metals.

There are universal testing machines on the market that apply loads in both vertical and horizontal directions (you can consult the catalogs of the main brands, for example in www.instron.com, www.mts.com or www.servosis.com, among others). The ideal machines for stress corrosion testing would be those that apply forces in a horizontal direction, as they would allow the immersion of the parts in aggressive environments of different types. However, these machines in most cases have one or more of the following disadvantages:

1.- They are excessively large for the specimens usually used in fracture mechanics, and therefore lack the necessary precision.

2.- They do not have enough space under them and do not leave room to introduce an oven that keeps the aggressive environment at the right temperature

3.- They are excessively expensive for the number of tests to be carried out in conditions of low corrosion tension, which prevents its amortization.

This means that the test procedures, although well defined, are limited to the performance of stress corrosion tests in aggressive environments at room temperature, or limited to the test on the stressed specimen before and after its immersion in an aggressive environment at high temperature. With respect to the procedures Abstracts of the trial are available in KATZ, Y., TYMIAK, N., GERBERICH, W.W. "*Evaluation of Environmentally Assisted Crack Growth*". In "*ASM Handbook, Volume 8. Mechanical Testing and Evaluation*". ASM International. pp. 612-648.

From all these reasons it is deduced that it is extremely difficult to carry out a test at load or strain speed constants in an aggressive environment at a higher temperature than ambient when a suitable horizontal traction machine is not available. Until now, each laboratory has sought the solution to its specific problem, so no experimental equipment has been developed that, in general, solves the problem posed. These concrete solutions usually consist of:

1.- Order universal horizontal arrangement testing machines specific to the tests to be carried out. This solution is economically unacceptable in most cases.

2.- Build containers that contain aggressive environments and that adapt to the machine available in the laboratory in question. The disadvantage here is that these vessels are difficult to attach to other testing machines and therefore not very versatile.

Description of the invention

The invention consists of a tool that allows mechanical tests to be carried out in an aggressive chemical environment of tensile or fracture toughness specimens in a horizontal arrangement using conventional universal vertical load testing machines.

The tool consists of two rigid arms joined at the top by a shaft, to which a coupling is added with the load cell of the testing machine. The coupling includes a ball joint, to prevent unwanted tension components.

In their lower part the arms of the utensil are joined with U-shaped bars through two shafts with bearings, and these U-shaped bars contain threaded holes at the end not attached to the arms of the utensil, to which a specimen can be attached that can be for traction, axilsymmetric or several of the specimens used in fracture mechanics (CT, DCB, and others specified below), with their corresponding forks.

This tool allows the application of a vertical force in its upper part, on the axis where the metal arms meet. That vertical force is transmitted along these arms and is divided into a horizontal and a vertical component. The vertical component is compensated by the reaction of the floor or base of the utensil, and it is the horizontal component that acts on the U-shaped bars and on the specimen, which due to the shape of the utensil may be submerged in a container containing the aggressive environment. This horizontal component, which is easily calculable, is which allows the stress corrosion test to be carried out.

The main advantage of the tool is that it allows the use of vertical testing machines with specimens in horizontal arrangement and that can be submerged. Its arrangement avoids contact between the testing machine and the aggressive environment. The utensil must be made of a rigid material that supports the loads to which the specimen will be subjected without suffering permanent deformations due to traction, compression or bending.

It must also withstand the aggressive environment to which the specimen is to be subjected and the test temperature, if necessary. The tool also allows the use of common extensometry devices for mechanical testing of materials. Other advantages of the utensil are:

1.- Portability.

2.- Adaptability to tensile specimens and fracture toughness test with the use of simple threads as adapters.

3.- Flexibility to the test conditions of each laboratory. It can change size depending on the type of machine; the utensil arms and C-shaped bars can be resized to allow the testing of two specimens (submerged or not); The material of construction of all or some of the parts of the utensil can be changed to another that is better adapted to the aggressive environment, provided that it is sufficiently rigid in the conditions of essay. Ball joints can also be added to the joints with the specimen to prevent any unwanted stress components.

4.- Its price, which is much lower than that of a universal horizontally arranged testing machine specific to the needs of the laboratory.

The precautions taken by the inventors of the utensil for its perfect functioning are as follows:

1.- An adequate sizing that allows the rigidity of the entire utensil in front of the specimen, which is the part of the experimental system that must be broken during the tests.

2.- A clear dimension and a mechanical finish as smooth as possible of the shaft-drilled hole areas that allows the correct rotation of the shafts without excessive friction, since in many cases, due to the temperature and aggressive environment nearby, the axes of the tool cannot be greased.

3.- Due to the impossibility of completely eliminating the friction between the components of the tool, a prior validation of the tool with specimens of known mechanical behavior is necessary to evaluate the coefficient of friction to be applied on the force generated by the actuator of the testing machine.

Brief description of the figures

For a better understanding, as an explanatory but not limited example, some drawings representing the utensil object of the invention are attached.

Figure 1 is an elevation view of the utensil with a tensile specimen placed on it.

Figure 2 is a diagram of a tensile specimen and an axilsymmetrical specimen, as examples that can be tested with the tool that is the object of the invention

Figure 3 is an elevation view of the utensil with a CT (Compact tension) specimen placed on it.

Figure 4 is an example, of different specimens of fracture toughness tests that can be tested with the tool that is the object of the invention.

Figure 5 is a plan of the first of the arms of the utensil. Figure

6 is a plan of the second arm of the utensil.

Figure 7 is a U-shaped plane of the bar.

Figure 8 is a plan of the bearing guides used in the utensil.

Figure 9 is a plan of the lower axes of the utensil.

Figure 10 is a plane of the utensil bearings. Figure 11 is a

plane of the upper axis of the utensil.

Figure 12 is a plan of the coupling of the tool with the testing machine.

Detailed Description of the Invention

The specific design characteristics of the tool that is the subject of this invention are described below, as well as the adaptations and variations that each element of the tool may have, and the type of specimens that can be tested on it.

As shown in Figures 1 and 3, the tool consists of an upper shaft (1.2) with a coupling to the testing machine (1.1). Two rigid arms that form the equal sides of an isosceles triangle join this upper axis (1.3). The lower part of these arms are attached to two axles (1.4) attached to bearings (1.6) and U-shaped bars (1.5). These bars are joined together by means of the specimen to be tested, which can be:

- Tensile specimen or axilsymmetric specimen (its arrangement would be the one adopted in Figure 1).

- Fracture toughness test specimens (Figure 3):

  - CT specimen (Compact tension)(3.1).

  - DCB (Double-cantilever beam) specimen(3.2).

  - Arc-shaped tension specimen(3.3).

  - Disk-shaped compact specimen(3.4).

  - Any modifications to the previous specimens, or other fracture toughness specimens that can be attached to the U-shaped rods.

For fracture toughness specimens and all those that require it, they must be used, in addition to forks and appropriate threaded bars connecting these forks to the threaded holes of the U-shaped bars.

The assembled tool is placed under the testing machine and above the container containing the aggressive medium (acid, base, liquid metal, etc.). In this way, only the specimen and the part of the utensil are adjacent to it are submerged in the corrosive medium.

The U-shaped bars are connected to the specimens by means of a threaded hole in the bar, where the threaded area of the specimen or the standard fork with its threaded bar is inserted for the engagement of the fracture toughness specimens (1.8). If desired, you can make the threaded hole of the bar into a U shape is through, so that this type of bar-specimen joint allows the incorporation of ball joints that avoid tensions in unwanted directions, if necessary.

To perform the tests correctly, the weakest part of the system must be the specimen. Therefore, a material and sections of the parts of the tool must be chosen such that the tool is rigid with respect to the forces necessary to break the specimen. The most sensitive points of the utensil in terms of plasticization are:

1.- The lower axes, in which the arms of the utensil are joined with the U-shaped bars (1.4).

2.- The bars in the shape of 1, which can suffer deformation due to bending due to the moments they suffer (1.5).

The conditions that must be met so that plasticization and crushing of the shaft does not occur during the The application of the loads are those expressed in equations (1) and (2):

a)

$$\left(\frac{M}{M_{u,b}}\right)^2 + \left(\frac{Q}{Q_{u,b}}\right)^2 \leq 1 \qquad (1)$$

Where:

H = Force acting on the axis in the horizontal direction. Q =

0.5·H

M = H·(T1+4C+2T_2)/8

$M_{u,b}$ = 0.8·We1·fy/ γ_{Mp}, moment of bolt exhaustion. $Q_{u,b}$

= 0.8·A·fu,b/γ Mp, bolt exhaustion cutter.

We1 elastic resistant pin section module. A pin

section area.

γ_{Mp} Pin safety coefficient = 1.25

fy bolt limit.

$_{FU,B}$ Pin breaking stress.

$$H < \frac{1{,}5 \cdot t \cdot d \cdot f_y}{\gamma_{Mp}} \qquad (2)$$

Where:

t the lowest value between t1 and 2·T2 in

Figure 4. F_{and} yield strength of plate steel.

In U-shaped bars, at your elbows, there is a moment, which could cause the bending of the bar if its dimensions are incorrect. To avoid this bending, the condition imposed by equation (3) must be met:

$$\sigma = \frac{M}{I} \cdot y \leq \sigma_y \qquad (3)$$

Where:

σ = Tension suffered by the U-shaped bar.

I = Moment of inertia. y

= Farthest fiber

M = Moment that the bar undergoes, calculated by:

M = H·d, where d is the distance indicated in Figure 7.

Figures 5 and 6 show the plans of the arms of the utensil. Their specific features are the different design of the hook with the upper axle (5.1 and 6.1), so that they fit perfectly without rubbing, and the space that must be left at the bottom to make room for the U-shaped bar. Their measurements may be different depending on the test in which they are used.

Figure 7 shows the plane of the U-shaped bar. Note that it is modified at the inner corners to avoid concentration of unwanted stresses. At one end it has a drilled hole to join with the lower shaft, and on the other side a threaded hole with the appropriate metric to house the appropriate specimen or threaded bars. This threaded hole can be through. A suitable tolerance degree for the threaded hole is +0-(-0.2) mm, although the most suitable can be defined in each case.

Figure 8 shows the plane of the guide with rails on which the utensil bearings rest (see also 1.7). Its purpose is to ensure that the direction of loading on the specimen is horizontal and rectilinear, without deviations that imply torsional or bending forces for the specimen.

Figure 9 is the plane of the lower axis (1.4). It is a round bar of the material chosen for the utensil. This bar must be matched to the internal diameter of the desired ball bearing (1.6), represented in the Figure 10.

Figure 11 shows the plane of the upper axis. It is another round bar with a diameter equal to or greater than that of the lower axes. The material is the same as the whole utensil.

Finally, Figure 12 shows the two parts that form the coupling of the tool with the corresponding testing machine. These are two parallelepipedic pieces. One of them, the lower one, has a hole drilled to be able to insert it into the upper axis of the utensil and a hemispherical hole. The other part has a hemispherical cap that coincides with the hole of the lower part described above, and a small hole to be able to insert a pin attached to the actuator of the testing machine. The presence of the hemispherical cap and orifice in both parts it has the effect of a ball joint, so that the force exerted by the testing machine on this coupling is effectively vertical.

Once the tool has been designed and machined, it must pass a small validation test, to check that the theoretical horizontal component of the applied force coincides with the real one suffered by the specimen, and there are no losses due to friction in the transmission of forces by the utensil.

Description of the preferred embodiment

As an example of indicative, but not limited to, the design of a tool for the transmission of vertical forces from a conventional testing machine located on a rigid bed to a specimen arranged horizontally and immersed in liquid Zn at 450ºC is presented below.

The material chosen for the manufacture of the test tool was a high-temperature resistant steel, of the following chemical composition:

C: 0,08-0,12 %	P: ≤ 0,020 %	Mo: 0,85-1,05 %
Si: ≤ 0,50 %	S: ≤ 0,005 %	V: 0,18-0,25 %
Mn: 0,30-0,60 %	Cr: 8-9,50 %	Nb: 0,06-0,10 %

Heat Treatment: Normalized + Tempered

Its minimum yield strength is 349 MPa at 450ºC, greater than or similar to the resistance of the specimens that were to be tested in a liquid Zn environment. This steel reacts with difficulty with liquid Zn without pre-treatment, thus eliminating contamination problems. The bearings were made with common bearing steel, of the following composition:

C: 0,98-1,1 %	P: ≤ 0,025 %	Cu: ≤ 0,35 %
Si: 0,15-0,35	S: ≤ 0,025 %	Cr: 1,3-1,6 %
Mo: ≤ 0,1 %	Ni: ≤ 0,25 %	

Heat treatment: tempering.

Hardness: 58-63 HRC

The bearings are not in contact with the liquid Zn and the temperature they had to withstand was lower. The guides that are to serve as bearing rails have been made of common carbon steel, since nor was it to be in contact with liquid Zn or at high temperature.

The limiting condition for the sizing of the entire utensil is the space available between the furnace that keeps the liquid Zn at 450ºC and the actuator of the testing machine. Taking into account this conditioning factor and the size of the specimens to be tested, the following parameters must be defined.

For the arms of the utensil:

- Total height.
- Height of the attachment appendages to the upper axle (5.1).
- Total width.
- Thickness.
- The gap for the free passage of the square U-shaped bar.
- The diameter of the drilled holes for the lower shafts (5.2).
- The diameter of the drilled holes for the upper shaft (5.3).
- The separation between the attachment appendages to the upper axle.

For U-shaped bars:

- Choose the shape of the section. In this case, square was chosen, but it can be of another type.
- Length of the main section.
- Height of the hitch section with the lower axle.
- Height of the section of attachment with the specimen.
- Thickness.
- The need or not for reinforcements in the elbows, and their height.
- The threaded hole metric (7.1).
- Choice of whether the threaded hole is through or blind. If you are a through-hole, you may be able to remove the thread from the hole.
- The center of the threaded hole for the specimens was placed at the same height as the center of the drilled hole for the lower shaft (7.2).

For the guides that were to serve as a rail for the tool: It was a steel plate with more thickness at the ends, where two rails are also raised with respect to the center of the guide. The width of each rail must be sufficient to accommodate the bearings without them following a curved path.

For the lower axles: The diameter and length must be defined.

For bearings: Ball bearings were used, although other types can be used. The external diameter, the internal diameter and the thickness must be defined.

For the upper axis: The diameter, preferably equal to or greater than that of the lower axes, must also be defined, although other solutions can be chosen, and its length.

For coupling to the actuator of the testing machine:

It must be adapted to the available universal testing machine. In this case the lower piece was a parallelepiped with a square base, of which the side of the base and the height must be defined. An axis of adequate dimensions was drilled for the passage of the upper axis (12.1), and a hemispherical hole was made in its upper part (12.2).

The upper piece was a parallelepiped with a square base, with a small drilled hole (12.3) for a pin attached to the testing machine to pass through, and another parallelepiped with a square base with a hemispherical cap on one of its bases (12.4), to complete the ball joint effect together with the hemispherical gap of the first piece of the coupling.

Before using the tool in real tests, it was subjected to validation tests, which consisted of testing tensile specimens of steels with known characteristics. The results showed that a factor of 0.96 had to be applied to the force applied by the tool to obtain the force actually transmitted to the specimen. This value must be checked for each utensil that is manufactured.

DEMANDS

1. Tensile for stress corrosion tests intended for carrying out tests on tensile and axilsymmetric specimens immersed horizontally in an aggressive environment and adapted to be coupled to the machine universal testing in vertical arrangement. The utensil is **Characterized** by a coupling to the testing machine (1.1), crossed by an upper axis (1.2), which acts as the upper vertex of an isoscellus triangle, and which joins two rigid arms (1.3), which are the equal sides of the triangle, joined in turn to two lower axes (1.4), which are the lower vertices of the triangle, from which two U-shaped bars depart (1.5), which are the two halves of the base of the triangle. At the ends of the lower axles there are two bearings (1.6), four in total, two located at the end of the shafts. two on the rails contained by two flat guides (1.7). At the other end of the U-shaped bars are two threaded holes (1.8), one per U-shaped bar, to which the specimen can be attached (see examples in Figure 2), which forms the central part of the base of the isosceles triangle.

2. A tool for performing stress corrosion tests intended for tensile testing on fracture toughness specimens submerged horizontally in an aggressive environment, according to the claim 1 (Figure 2), **characterized** by the use of appropriate threaded rods bolted to the threaded holes (see 3.8) for connection with the pins required by specimens for fracture toughness tests (see specimen examples in Figure 4).

3. A tensil for carrying out stress corrosion tests, in accordance with claim 1, and which is **characterizes** by the following elements:

- The two rigid arms joined at the top axle (Figures 5 and 6) are to be made of high-resistant steel Chemical Composition Temperatures:

C: 0,08-0,12 %	P: ≤ 0,020 %	Mo: 0,85-1,05 %
Si: ≤ 0,50 %	S: ≤ 0,005 %	V: 0,18-0,25 %
Mn: 0,30-0,60 %	Cr: 8-9,50 %	Nb: 0,06-0,10 %

Heat Treatment: Normalized + Tempered

And 349 MPa minimum yield strength at 450ºC.

- The two identical U-shaped bars (Figure 7), made of similar high-temperature resistant steel to the previous point.

- Two guides containing bearing rails (Figure 8), made of carbon steel.

- An upper shaft made of high-temperature resistant steel similar to that of rigid arms (Figure 9).

- Four ball bearings made of bearing steel of the following chemical composition (Figure 10):

C: 0,08-0,12 %	P: ≤ 0,020 %	Mo: 0,85-1,05 %
Si: ≤ 0,50 %	S: ≤ 0,005 %	V: 0,18-0,25 %
Mn: 0,30-0,60 %	Cr: 8-9,50 %	Nb: 0,06-0,10 %

Heat Treatment: Normalized + Tempered

- The lower axles are made of high-temperature resistant steel similar to that of the rigid arms joined by the upper axle (Figure 11).

- A coupling of the tool to the universal testing machine, made of a high temperature resistant steel (Figure 12) similar to that of the rigid arms joined by the upper axis.

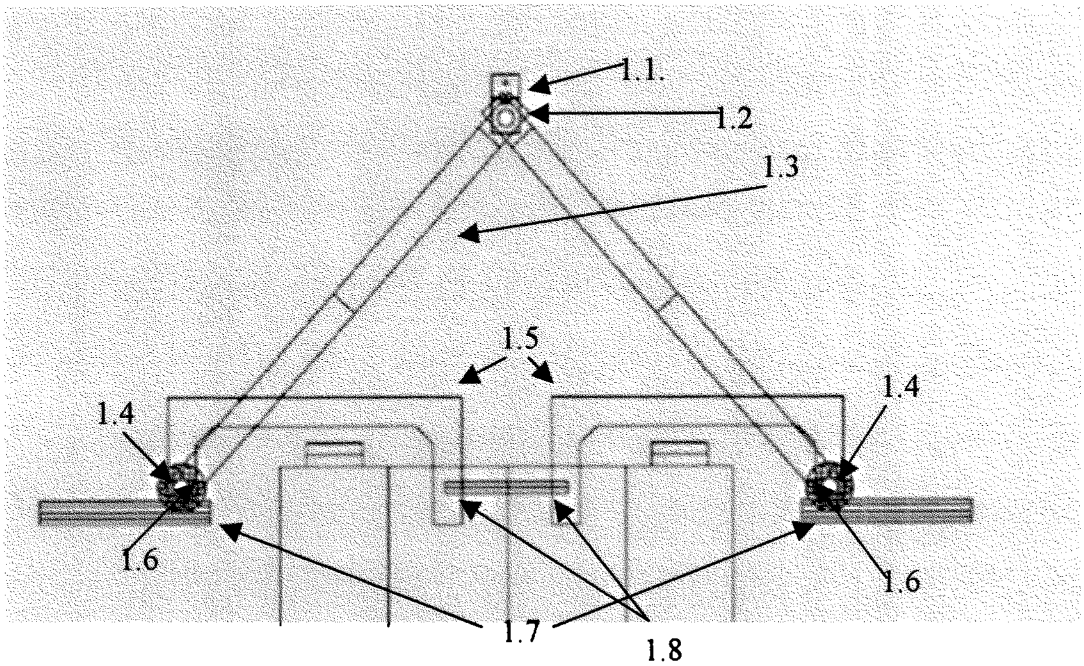


FIGURA 1

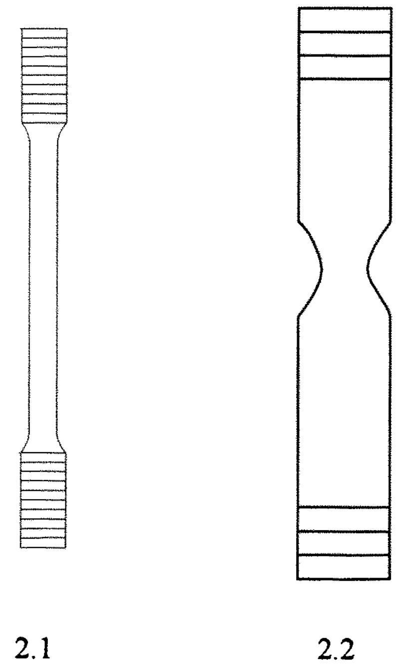


FIGURA 2.

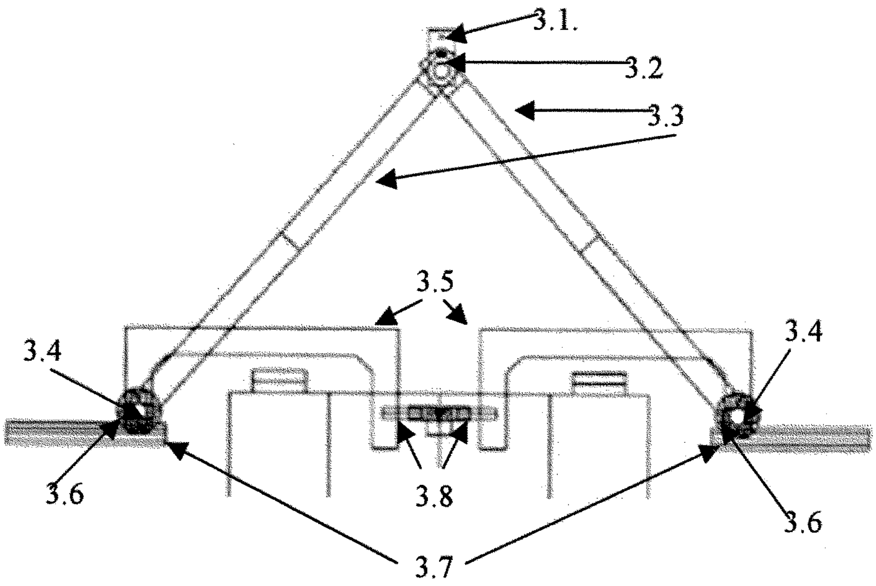
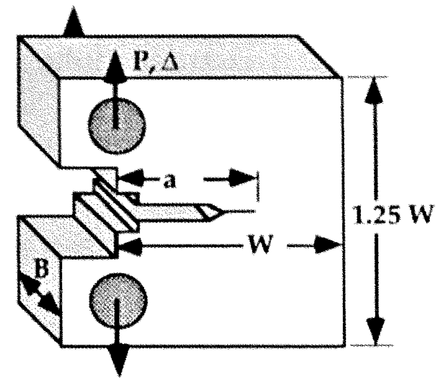
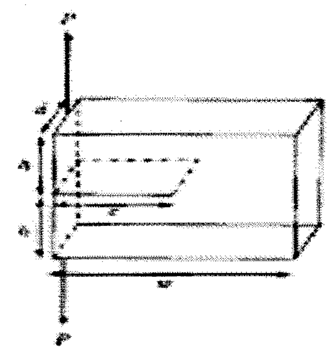


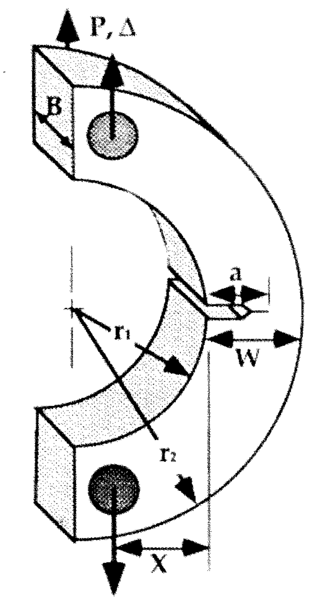
FIGURA 3.



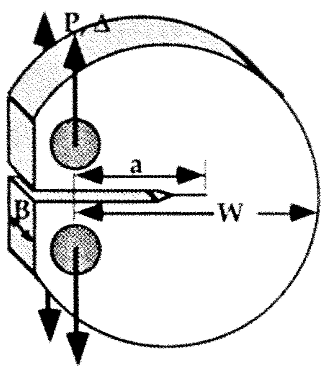
4.1.



4.2



4.3



4.4.

FIGURA 4

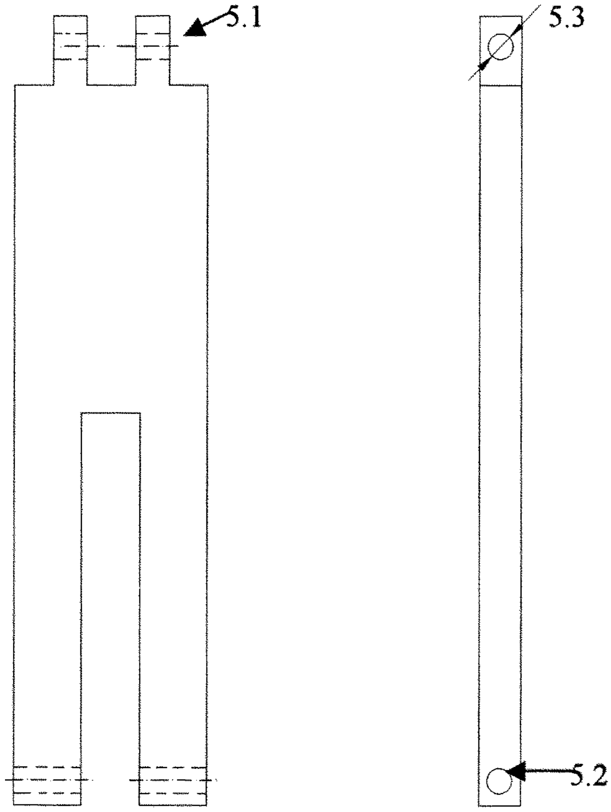


FIGURA 5.

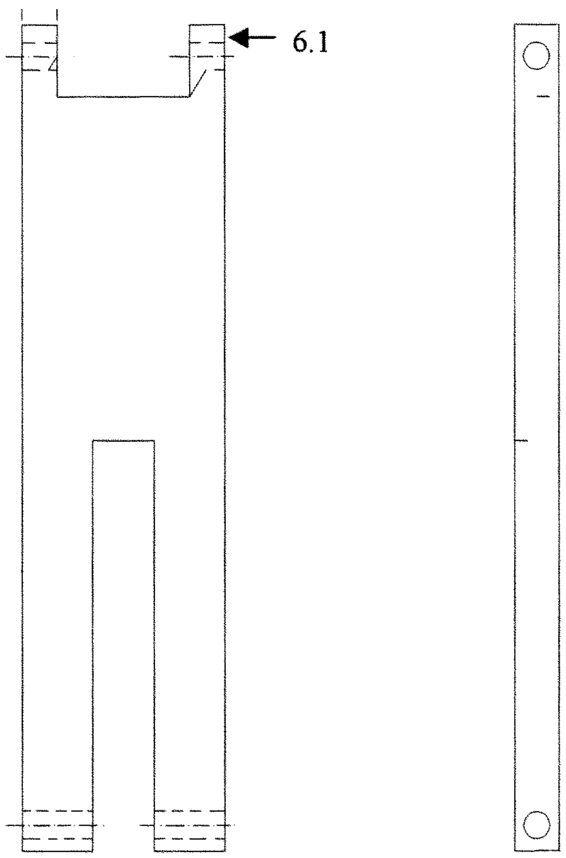


FIGURA 6.

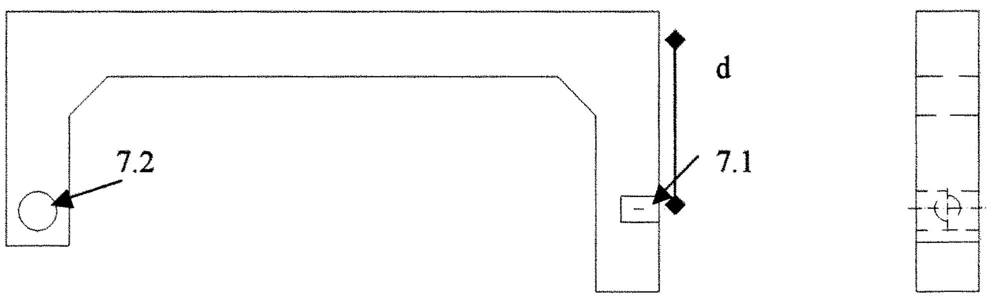


FIGURA 7.

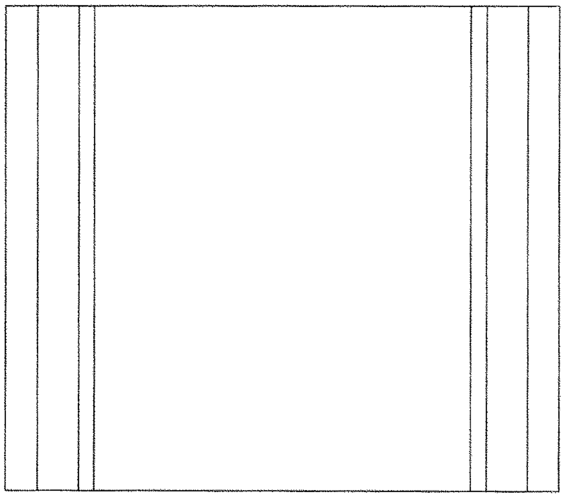


FIGURA 8.

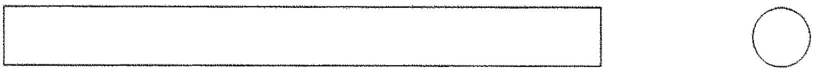


FIGURA 9.

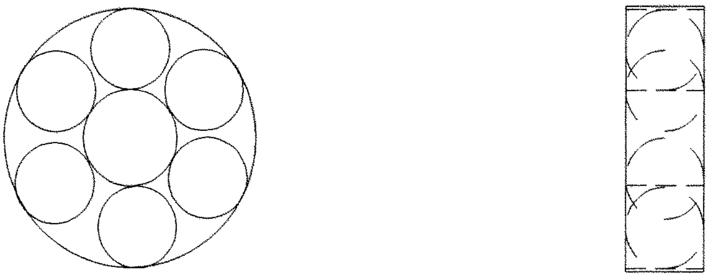


FIGURA 10.

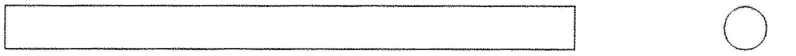


FIGURA 11

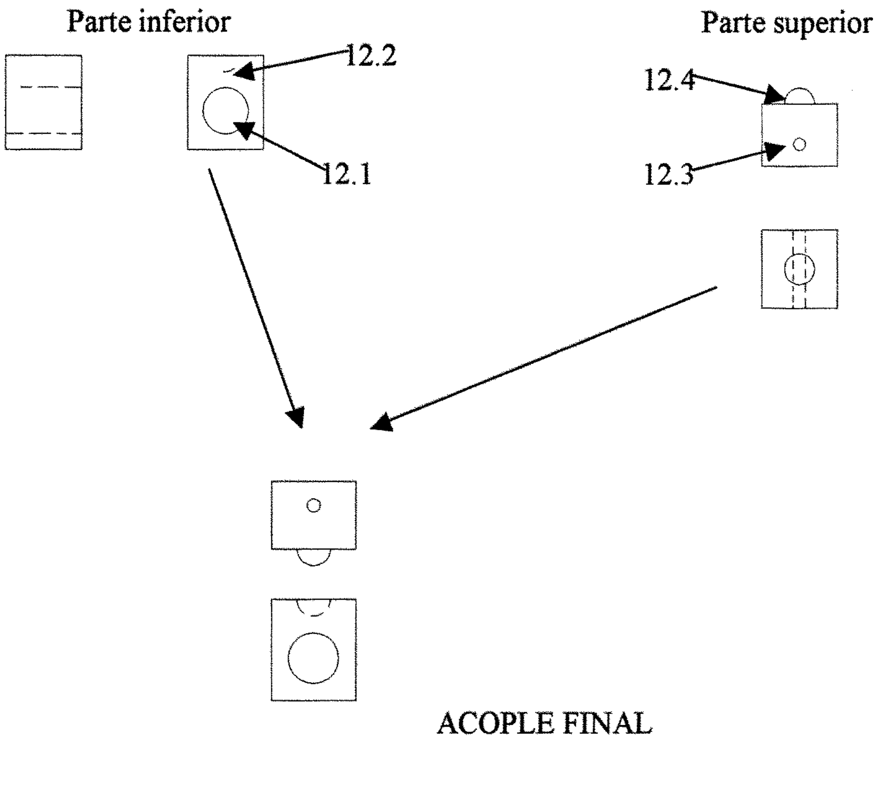


FIGURA 12

SPANISH PATENT AND TRADEMARK OFFICE

SPAIN

(11) ES 2 322 416

(21) Application number: 200602554

(22) Date of application: **09.10.2006**

(32) Priority Date:

REPORT ON THE STATE OF THE ART

(51) **Int. Cl.:** ***G01N 3/60*** (2006.01)

RELEVANT DOCUMENTS

Category	(56) Documents cited	Affected claims
X	CARPIO et al. "Design and validation of a tool for tensile and fracture tests of specimens submerged in liquid Zn". Annals of Fracture Mechanics. volume 23 (2006. Vol. 1) pp. 45-50 & "XXIII Meeting of the Spanish Fracture Group. Albarracín (Teruel). 29-31 March 2006" [Retrieved on 29.05.2009]. Retrieved from the internet: <URL: http://www.gef.es/ Congresos/23/gef23.asp?page=7>	1-3

Category of documents cited

X: of particular relevance
And: of particular relevance combined with others of the same category
A: reflects the state of the art
Or: referred to unwritten disclosure
P: published between the priority date and the filing date
E: previous document, but published after the date of submission of the application

This report has been prepared

X for all claims

for claims no:

Date of preparation of the report	Examiner	Page
29.05.2009	J. Olalde Sánchez	1/1