



- (51) International Patent Classification:
G01B 11/16 (2006.01) *G01N 3/06* (2006.01)
- (21) International Application Number:
PCT/SI2012/000067
- (22) International Filing Date:
27 December 2012 (27.12.2012)
- (25) Filing Language: Slovenian
- (26) Publication Language: English
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- (81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP,
KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD,
ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI,
NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU,
RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ,
TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA,
ZM, ZW.

- (84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
ML, MR, NE, SN, TD, TG).

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- (54) Title: PROCESS AND APPARATUS FOR MEASURING OF THICKNESS OF A PROBE DURING A TENSION TEST

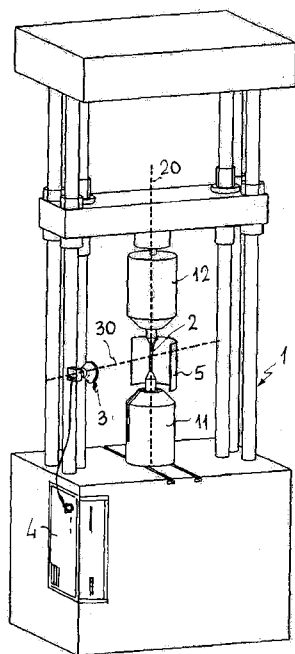


Fig. 1

(57) Abstract: Apparatus for measuring of thickness of a probe (2) during a tension test comprises a tensioning device (1), which is furnished with a fixed jaw (11) and a displaceable jaw (12), which are arranged above each other and are adapted for clamping and tensioning of each disposable standardized probe (2), as well as a video camera (3), which is arranged in the area of said tensioning device (1) at appropriate distance apart of the probe (2), so that the optical axis (30) of the video camera (3) extends towards the longitudinal axis (20) of the probe (2) and rectangular with respect to said longitudinal axis (20) of the probe (2). The apparatus further comprises a screen (5), which forms a contrast background behind the probe (2) and is with respect to said video camera (3) arranged on the opposite side of the probe (2), and moreover also a computer (4), which is adapted for retrieving, saving and processing of data received from the video camera (3).

WO 2014/104983 A1



Published:

— *with international search report (Art. 21(3))*

PROCESS AND APPARATUS FOR MEASURING OF THICKNESS OF A PROBE DURING A TENSION TEST

The present invention refers to a process and apparatus for measuring of thickness of a probe during a tension test.

The aim of the invention is to enable accurate and reliable measuring of thickness of a probe during a tensioning test at least in the location of minimal cross-section of said probe.

A tension test as such is intended for the purposes of determining and/or examining of physical properties of materials, in particular tensile strength, upper elastic limit, contraction or the like. In this, a probe consisting of a known material and having known and standardized dimensions is fastened within a tension testing apparatus having a fixed jaw and a displaceable jaw, in which said probe is fastened. Said displaceable jaw can be displaced apart from said fixed jaw, by which the probe is tensioned. During said tension test, the tension force acting to the probe is permanently measured as well as deformation thereof, in particular strain and contraction.

One of known methods for measuring thickness of the probe provides measuring of a diameter of the probe by means of suitable measuring instrument prior to performing the test, upon which the probe is tensioned and the diameter of such deformed probe is measured. On such basis, conclusions are then made about changing of the thickness during the test, which is not really reliable, in particular since also the thickness prior to testing and after that can actually be measured on different locations along the probe. Moreover, results of such measuring are not automatically and independently collected, which reduces accuracy of such measuring.

A further approach provides use of two laser beams, which are directed towards each other and perpendicularly with respect to the longitudinal axis of the probe, which is then exposed to said beams in two points located in the diametrical plane thereof. When the probe is tensioned, it is also extended, and both points, which are initially exposed to said beams, are displaced along such extending probe. Consequently, such measuring is also not performed always in the same location on the probe, since the measuring location is permanently displaced along the probe during the test, which systematically introduces certain discrepancies into said measuring, and such obtained results are never quite reliable.

The third approach provides monitoring of the thickness by means of two video cameras, and change of thickness of the probe is permanently monitored and calculated by means of triangulation. However, such application of two cameras, two supporting stands and other required equipment leads to essentially complicated concept of the measuring apparatus as such, which essentially increases the price and also the risk of malfunction.

According to the invention, the initially raised problem is solved by means of features of a measuring apparatus as well as of process, which are included in independent patent claims including the embodiments according to dependent claims.

The invention will be described on the basis of an embodiment, which is presented in the attached drawings, wherein

Fig. 1 is a schematically presented perspective view of an apparatus for measuring of thickness of a probe according to the invention; and

Fig. 2 is a probe, which is suitable for such measuring.

The present invention refers to an apparatus for measuring of thickness of a probe 2 during a tension test, wherein such apparatus comprises a tension testing device 1 with a fixed jaw 11 and a movable jaw 12, which are arranged above each other and adapted to hold each disposable standardized probe 2 having a measuring area defined by means of a diameter D_{mm} and the length L_{mm} , such that the longitudinal axis 20 of the probe 2 extends at least approximately in the vertical direction. The apparatus further comprises a video camera 3, which is adapted for monitoring the probe 2 during tensioning thereof and is arranged in the area of the tensioning device 1 appropriately apart from the probe 2, such that the optical axis 30 of the camera 3 is directed towards the longitudinal axis 20 of the probe 2 and perpendicularly with respect to said longitudinal axis 20 of the probe 2. In addition, said video camera 3 is suitable for generating video recordings in the format "jpeg" i.e. 24-bit RGB format, and is optionally for the purposes of transmission of data interconnectable with a corresponding computer 4, which is adapted to receive, store, process and optionally also to display and/or to export the data received from the side of the previously mentioned video camera 3.

The invention provides that the apparatus comprises a screen 5, which is suitable to provide contrast relative to the probe 2 and is arranged in the area of said tensioning apparatus 1 adjacent to the probe 2 and at appropriate distance apart from it, namely diametrically opposite to the video camera 3 with respect to the longitudinal axis 20 of the probe 2, wherein said screen 5 is intended to provide a contrast background behind the probe 2, when recorded by means of video camera 3 and is appropriately colored relative to each disposable surface of each corresponding probe 2.

Moreover, the apparatus according to the invention is furnished with a computer 4, which is suitable for cooperating with said video camera 3 and is adapted for

i) converging each particular input picture of the measuring area **L** of the probe 2 as received from the video camera 3, from the ".jpeg" i.e. 24-byte RGB format into a matrix **A** consisting of 8-byte digits with values 0-256 corresponding to each particular points i.e. pixels, wherein the dimensions of said matrix **A** are $m \times n$, and wherein

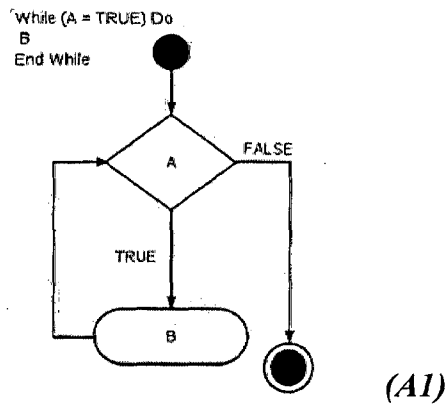
- m is a number of rows of the input picture; and
- n is a number of columns of the input picture;

ii) calculating average value $\bar{x}$ of pixels e.g. in a row corresponding to integer of $m/2$ according to the formula (I)

$$\bar{x} = \frac{\sum_{j=0}^{n-1} x_{i,j}}{n-1} \quad (I)$$

wherein the value $x_{i,j}$ corresponds to a value in the line i and the column j in said matrix, and the average value $\bar{x}$ corresponds to the average values in the row i ;

iii) comparing each disposable values of pixels, wherein in the row $|m/2$ such location i.e. such value j of the first and the last value in the row is determined, which is smaller than the average value $\bar{x}$, as well as the location of two neighboring values, which are not yet larger than the calculated average value, which is performed according to algorithm *A1*



wherein the result of the first transition is

$$A \rightarrow x_{j=0 \rightarrow n} < \underline{x}; B \rightarrow [\{j-1, j\}, \{x_{j-1}, x_j\}],$$

and the result of the last transition is

$$A \rightarrow x_{j=n \rightarrow 0} < \underline{x}; B \rightarrow [\{j, j+1\}, \{x_j, x_{j+1}\}];$$

iv) determining borders as well as the thickness of the probe 2 on the basis of calculation of a pair of lines, which are each per se extending through two points from each particular matrix, wherein a pair of values x is calculated, in which said lines correspond to previously calculated average value $\bar{x}$,

wherein the general formula (II) of each line is

$$y = k_x x + n, \quad (II)$$

where k is a coefficient of inclination, and n is a section on the ordinate axis, so that the first line with the inclination coefficient k_1 and the section n_1 on the ordinate axis is calculated by means of points $T_1(j-1, x_{j-1})$ and $T_2(j, x_j)$, by which it is calculated, in which point x_1 the line corresponds to the value, which is equal to previously calculated average value according to formula (III)

$$x_1 = (\bar{x} - n_1)/k_1 \quad (III)$$

upon which analogously also the value x_2 of the second line is determined, and the thickness of the probe 2 in pixels is calculated by means of formula (IV) on the basis of the difference

$$D_{\text{pix}} = x_2 - x_1 \quad (IV);$$

v) determining the length L_{pix} , along which said measuring of reduction of the thickness of the probe 2 is performed, wherein the ratio of original values of the diameter D_{mm} and the measuring length L_{mm} of the probe 2 according to formula (V) is calculated

$$R = D_{\text{mm}}/L_{\text{mm}} \quad (V)$$

and the length L_{pix} in pixels is determined by means of formula (VI) on the basis of thickness D_{pix} in pixels and the previously mentioned ratio R

$$L_{pix} = D_{pix}/R \quad (VI),$$

by means of which for the purposes of further measuring of the thickness of the probe 2 then a sub-matrix W of size $L_{pix} \times n$ is created, wherein the first row of said sub-matrix is the row numbered $(m - L_{pix})/2$ of the original matrix A , and the step of determining the thickness of the probe 2 is then repeated in each row of said sub-matrix W , so that in each row of the sub-matrix W the thickness D_{pix} of the probe 2 in pixels is determined, and for each image generated by means of the video camera 3 then a matrix DD_{pix} of size $L_{pix} \times 1$ is created.

In accordance with a preferred embodiment of the invention, the computer 4 is further adapted to eliminate each errors due to image noise, by anticipating that said error is statistically distributed in accordance with the *Gauss* distribution curve, and 2/3 of the matrix DD_{pix} are taken into consideration by calculating thickness of the probe 2, wherein

- i) a histogram is created with such number of intervals, which corresponds to $L_{pix} - 1$, while two abscise axis values of the histogram correspond to minimum and maximum value of the matrix DD_{pix} , by which a further matrix G is created with the size $L_{pix} - 1$, in which the first column comprises values on the abscise axis of said histogram, and the second column comprises correlated values on the ordinate axis of said histogram, wherein the maximum value in said second column is G_{max} , upon which the values in said second column are numerically integrated in order to obtain a curve similar to “*error function*”;

ii) all values of the matrix G , are reviewed by means of the “for loop”, and for each particular value between $G_{\max}/6$ in $5 \times G_{\max}/6$, the value from the first column of the matrix G is inserted into a newly created matrix G_{opt} , in which all indexes are considered, in which the measuring results of the matrix G are taken into consideration, upon which a further matrix $G_{za\_izracun}$ is created of size $(2 \times L_{pix}/3) \times 1$, in which all values from the second column of each particular indexes in the matrix G are present, which are included within the matrix G_{opt} .

In accordance with a further aspect of the invention, the computer 4 is further adapted for calculating average thickness D_{AVG} of the probe 2 in accordance with formula (VII):

$$D_{AVG} = \frac{\sum_{h=0}^{\dim G_{za\_izracun}} G_{za\_izracun}(h)}{\dim G_{za\_izracun}} \quad (VII).$$

In accordance with a still further aspect of the invention, the computer 4 is further adapted for determining the thickness D_{AVG} of the probe 2 as the minimum value of the matrix $G_{za\_izracun}$.

Apparatus according to the invention further comprises a bright, in particular white colored screen 5, while the probe 2 is darkened on its surface, in particular in the area of its diametrical plane, which extends throughout the longitudinal axis 20 of the probe 2 and at the same time also perpendicularly with respect to the optical axis 30 of the video camera 3.

The invention further refers to a process for measuring of thickness of a probe 2 during a tension test, wherein each disposable standardized probe 2 having a measuring area defined by means of a diameter D_{mm} and the length L_{mm} is fastened into a tension testing device 1 furnished with at least one fixed jaw 11 and a movable jaw 12, which are arranged above each other and adapted to hold said probe 2, such that the longitudinal axis 20 of the probe 2 extends at least approximately in the vertical direction, and wherein said probe 2 in such fastened state and during tensioning thereof is recorded by means of a video camera 3, which is arranged in the area of the tensioning device 1 at appropriate distance apart from the probe 2, such that the optical axis 30 of the camera 3 is directed towards the longitudinal axis 20 of the probe 2 and perpendicularly with respect to said longitudinal axis 20 of the probe 2, and in addition to that, said video camera 3 is suitable for generating video recordings in the format "jpeg" i.e. 24-bit RGB format, and is optionally for the purposes of transmission of data interconnectable with a corresponding computer 4, which is adapted to receive, store, process and optionally also to display and/or to export the data received from the side of the previously mentioned video camera 3.

The process according to the invention provides that prior to recording by said video camera 3 a screen 5 is arranged adjacent to said probe 2, which is suitable to provide a contrast relative to the probe 2 and is arranged in the area of said tensioning device 1 adjacent to the probe 2 and at appropriate distance apart from it, namely diametrically opposite to the video camera 3 with respect to the longitudinal axis of the probe 2, wherein said screen 5 is intended to provide a contrast background behind the probe 2 during recording by means of video camera 3 and is appropriately colored relative to each disposable surface of each corresponding probe 2.

Besides, the invention provides that the computer 4 cooperating with said video camera 3 is further adapted for

i) converging each particular input picture of the measuring area L of the probe 2 as received from the video camera 3, from the “jpeg” i.e. 24-byte RGB format into a matrix A consisting of 8-byte digits with values 0-256 corresponding to each particular points i.e. pixels, wherein the dimensions of said matrix A are $m \times n$, and wherein

- m is a number of rows of the input picture; and
- n is a number of columns of the input picture;

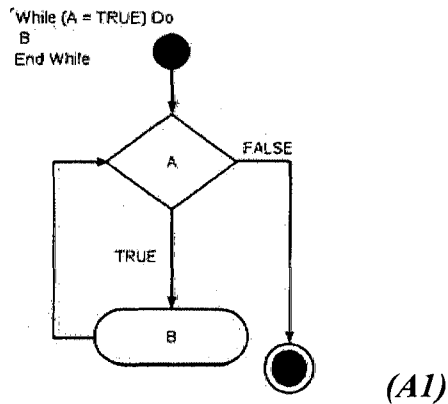
ii) calculating an average value $\bar{x}$ of pixels e.g. in a row corresponding to integer of $m/2$ according to the formula (I)

$$\bar{x} = \frac{\sum_{j=0}^{n-1} x_{i,j}}{n-1} \quad (I)$$

wherein the value $x_{i,j}$ corresponds to a value in the line i and the column j in said matrix, and the average value $\bar{x}$ corresponds to the average values in the row i ;

iii) comparing each disposable values of pixels, wherein in the row $|m/2$ such location i.e. such value j of the first and the last value in the row is determined, which is smaller than the average value $\bar{x}$, as well as the location of two neighboring values, which are not yet larger than the calculated average value, which is performed according to algorithm (AI)

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wherein the result of the first transition is

$$A \rightarrow x_{j=0 \rightarrow n} < \underline{x}; B \rightarrow [\{j-1, j\}, \{x_{j-1}, x_j\}],$$

and the result of the last transition is

$$A \rightarrow x_{j=n \rightarrow 0} < \underline{x}; B \rightarrow [\{j, j+1\}, \{x_j, x_{j+1}\}];$$

iv) determining borders as well as the thickness of the probe 2 on the basis of calculation of a pair of lines, which are each per se extending through two points from each particular matrix, wherein a pair of values x is calculated, in which said lines correspond to previously calculated average value $\bar{x}$,

wherein the general formula (II) of each line is

$$y = k_x x + n, \quad (II)$$

where k is a coefficient of inclination, and n is a section on the ordinate axis, so that the first line with the inclination coefficient k_1 and the section n_1 on the ordinate axis is calculated by means of points $T_1 (j-1, x_{j-1})$ and $T_2 (j, x_j)$, by which it is calculated, in which point x_1 the line corresponds to the

value, which is equal to previously calculated average value according to formula (III)

$$x_1 = (\bar{x} - n_1)/k_1 \quad (III)$$

upon which analogously also the value x_2 of the second line is determined, and the thickness of the probe 2 in pixels is calculated by means of formula (IV) on the basis of the difference

$$D_{pix} = x_2 - x_1 \quad (IV);$$

v) determining the length L_{pix} , along which said measuring of reduction of the thickness of the probe 2 is performed, wherein the ratio of original values of the diameter D_{mm} and the measuring length L_{mm} of the probe 2 according to formula (V) is calculated

$$R = D_{mm}/L_{mm} \quad (V)$$

and the length L_{pix} in pixels is determined by means of formula (VI) on the basis of thickness D_{pix} in pixels and the previously mentioned ratio R

$$L_{pix} = D_{pix}/R \quad (VI),$$

by means of which for the purposes of further measuring of the thickness of the probe 2 then a sub-matrix W of size $L_{pix} \times n$ is created, wherein the first row of said sub-matrix is the row numbered $(m - L_{pix})/2$ of the original matrix A , and the step of determining the thickness of the probe 2 is then repeated in each row of said sub-matrix W , so that in each row of the sub-

matrix W the thickness D_{pix} of the probe 2 in pixels is determined, and for each image generated by means of the video camera 3 then a matrix DD_{pix} of size $L_{\text{pix}} \times 1$ is created.

In a preferred embodiment of the process according to the invention, the computer 4 is further used for the purposes of eliminating errors due to image noise, by anticipating that said error is statistically distributed in accordance with the *Gauss* distribution curve, and 2/3 of the matrix DD_{pix} are taken into consideration by calculating thickness of the probe 2, wherein

- i) a histogram is created with such number of intervals, which corresponds to $L_{\text{pix}} - 1$, while two abscise axis values of the histogram correspond to minimum and maximum value of the matrix DD_{pix} , by which a further matrix G is created with the size $L_{\text{pix}} - 1$, in which the first column comprises values on the abscise axis of said histogram, and the second column comprises correlated values on the ordinate axis of said histogram, wherein the maximum value in said second column is G_{max} , upon which the values in said second column are numerically integrated in order to obtain a curve similar to “*error function*”;
- ii) all values of the matrix G , are reviewed by means of the “for loop”, and for each particular value between $G_{\text{max}}/6$ in $5 \times G_{\text{max}}/6$, the value from the first column of the matrix G is inserted into a newly created matrix G_{opt} , in which all indexes are considered, in which the measuring results of the matrix G are taken into consideration, upon which a further matrix $G_{\text{za_izracun}}$ is created of size $(2 \times L_{\text{pix}}/3) \times 1$, in which all values from the second column of each particular indexes in the matrix G are present, which are included within the matrix G_{opt} .

In accordance with a further aspect of the invention, an average thickness D_{AVG} of the probe 2 is determined in accordance with formula (VII):

$$D_{AVG} = \frac{\sum_{h=0}^{\dim G_{za\_izracun}} G_{za\_izracun}(h)}{\dim G_{za\_izracun}} \quad (VII).$$

In accordance with a still further aspect of the invention, each thickness of the probe 2 is determined on the basis of the minimum value of the matrix ($G_{za\_izracun}$).

When desired, each particular scalar value of each particular image is transformed into a matrix of values of the thickness $D_{izracun}$, on the basis of which then also a contraction can be calculated by means of Formula (VIII)

$$D\% = 100 \times [1 - D_{izracun}(k)/D_{izracun}(0)] \quad (VIII)$$

The apparatus and process according to the invention enable permanent monitoring of the thickness of the probe 2 on the same location on the probe 2 during the tension test, when the probe 2 is fastened within the tension testing device 1 and exposed to each known and measured force, and also to calculate a relative contraction and other physical properties of the material of the probe 2. All the data is permanently and independently recorded, and such retrieved data about identified changes during the whole testing up to destruction of the probe 2 can later serve as an input data for the purposes of simulating various loading examples in the finite element analysis, by which stresses and deformations in mechanically loaded parts can be foreseen not only in the area of elastic deformations but also in the area of plastic deformations.

PATENT CLAIMS

1. Apparatus for measuring of thickness of a probe (2) during a tension test, comprising a tension testing device (1) with a fixed jaw (11) and a movable jaw (12), which are arranged above each other and adapted to hold each disposable standardized probe (2) having a measuring area defined by means of a diameter (D_{mm}) and the length (L_{mm}), such that the longitudinal axis (20) of the probe (2) extends at least approximately in the vertical direction, as well as a video camera (3), which is adapted for monitoring the probe (2) during tensioning thereof and is arranged in the area of the tensioning device (1) appropriately apart from the probe (2), such that the optical axis (30) of the camera (3) is directed towards the longitudinal axis (20) of the probe (2) and perpendicularly with respect to said longitudinal axis (20) of the probe (2), and in addition to that, said video camera (3) is suitable for generating video recordings in the format "jpeg" i.e. 24-bit RGB format, and is optionally for the purposes of transmission of data interconnectable with a corresponding computer (4), which is adapted to receive, store, process and optionally also to display and/or to export the data received from the side of the previously mentioned video camera (3), **characterized in that** the apparatus comprises a screen (5), which is suitable to provide contrast relative to the probe (2) and is arranged in the area of said tensioning device (1) adjacent to the probe (2) and at appropriate distance apart from it, namely diametrically opposite to the video camera (3) with respect to the longitudinal axis (20) of the probe (2), wherein said screen (5) is intended to provide a contrast background behind the probe (2) when recorded by means of video camera (3) and is appropriately colored relative to each disposable surface of each corresponding probe (2), **and in that** the computer (4) cooperating with said video camera (3) is adapted for

i) converging each particular input picture of the measuring area (L) of the probe (2) as received from the video camera (3), from the “*jpeg*” i.e. 24-byte RGB format into a matrix (A) consisting of 8-byte digits with values 0-256 corresponding to each particular points i.e. pixels, wherein the dimensions of said matrix (A) are $m \times n$, and wherein

- m is a number of rows of the input picture; and
- n is a number of columns of the input picture;

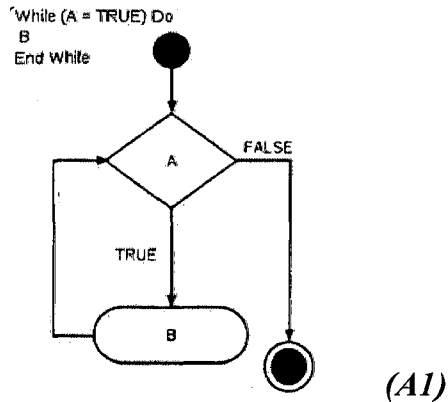
ii) calculating average value ($\bar{x}$) of pixels e.g. in a row corresponding to integer of $m/2$ according to the formula (I)

$$\bar{x} = \frac{\sum_{j=0}^{n-1} x_{i,j}}{n-1} \quad (I)$$

wherein the value $x_{i,j}$ corresponds to a value in the line i and the column j in said matrix, and the average value ($\bar{x}$) corresponds to the average values in the row i ;

iii) comparing each disposable values of pixels, wherein in the row $\lfloor m/2 \rfloor$ such location i.e. such value j of the first and the last value in the row is determined, which is smaller than the average value ($\bar{x}$), as well as the location of two neighboring values, which are not yet larger than the calculated average value, which is performed according to algorithm (A1)

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wherein the result of the first transition is

$$A \rightarrow x_{j=0 \rightarrow n} < \underline{x}; B \rightarrow [\{j-1, j\}, \{x_{j-1}, x_j\}],$$

and the result of the last transition is

$$A \rightarrow x_{j=n \rightarrow 0} < \underline{x}; B \rightarrow [\{j, j+1\}, \{x_j, x_{j+1}\}];$$

iv) determining borders as well as the thickness of the probe (2) on the basis of calculation of a pair of lines, which are each per se extending through two points from each particular matrix, wherein a pair of values (x) is calculated, in which said lines correspond to previously calculated average value ($\bar{x}$),

wherein the general formula (II) of each line is

$$y = k_x x + n, \quad (II)$$

where k is a coefficient of inclination, and n is a section on the ordinate axis, so that the first line with the inclination coefficient (k_1) and the section (n_1) on the ordinate axis is calculated by means of points $T_1(j-1, x_{j-1})$ and $T_2(j, x_j)$, by which it is calculated, in which point (x_1) the line corresponds

to the value, which is equal to previously calculated average value according to formula (III)

$$x_1 = (\bar{x} - n_1)/k_1 \quad (III)$$

upon which analogously also the value (x_2) of the second line is determined, and the thickness of the probe (2) in pixels is calculated by means of formula (IV) on the basis of the difference

$$D_{\text{pix}} = x_2 - x_1 \quad (IV);$$

v) determining the length (L_{pix}), along which said measuring of reduction of the thickness of the probe (2) is performed, wherein the ratio of original values of the diameter (D_{mm}) and the measuring length (L_{mm}) of the probe (2) according to formula (V) is calculated

$$R = D_{\text{mm}}/L_{\text{mm}} \quad (V)$$

and the length (L_{pix}) in pixels is determined by means of formula (VI) on the basis of thickness (D_{pix}) in pixels and the previously mentioned ratio (R)

$$L_{\text{pix}} = D_{\text{pix}}/R \quad (VI),$$

by means of which for the purposes of further measuring of the thickness of the probe (2) then a sub-matrix (W) of size $L_{\text{pix}} \times n$ is created, wherein the first row of said sub-matrix is the row numbered $(m - L_{\text{pix}})/2$ of the original matrix (A), and the step of determining the thickness of the probe (2) is then repeated in each row of said sub-matrix (W), so that in each row of the sub-

matrix (W) the thickness (D_{pix}) of the probe (2) in pixels is determined, and for each image generated by means of the video camera (3) then a matrix (DD_{pix}) of size $L_{\text{pix}} \times 1$ is created.

2. Apparatus according to Claim 1, **characterized in that** the computer (4) is further adapted to eliminate each errors due to image noise, by anticipating that said error is statistically distributed in accordance with the *Gauss* distribution curve, and 2/3 of the matrix (DD_{pix}) are taken into consideration by calculating thickness of the probe (2), wherein

- i) a histogram is created with such number of intervals, which corresponds to $L_{\text{pix}} - 1$, while two abscise axis values of the histogram correspond to minimum and maximum value of the matrix (DD_{pix}), by which a further matrix (G) is created with the size $L_{\text{pix}} - 1$, in which the first column comprises values on the abscise axis of said histogram, and the second column comprises correlated values on the ordinate axis of said histogram, wherein the maximum value in said second column is G_{max} , upon which the values in said second column are numerically integrated in order to obtain a curve similar to “*error function*”;
- ii) all values of the matrix (G), are reviewed by means of the “for loop”, and for each particular value between $G_{\text{max}}/6$ in $5 \times G_{\text{max}}/6$, the value from the first column of the matrix (G) is inserted into a newly created matrix (G_{opt}), in which all indexes are considered, in which the measuring results of the matrix (G) are taken into consideration, upon which a further matrix ($G_{\text{za\_izracun}}$) is created of size $(2 \times L_{\text{pix}}/3) \times 1$, in which all values from the second column of each particular indexes in the matrix (G) are present, which are included within the matrix (G_{opt}).

3. Apparatus according to Claim 2, **characterized in that** the computer (4) is further adapted for calculating average thickness (D_{AVG}) of the probe (2) in accordance with formula (VII):

$$D_{AVG} = \frac{\sum_{k=0}^{\dim G_{za\_izracun}} G_{za\_izracun}(h)}{\dim G_{za\_izracun}} \quad (VII).$$

4. Apparatus according to Claim 2, **characterized in that** the computer (4) is further adapted for determining the thickness (D_{AVG}) of the probe (2) as the minimum value of the matrix ($G_{za\_izracun}$).

5. Apparatus according to anyone of Claims 1 - 4, **characterized in that** the contrast screen (5) is bright, in particular white colored, while the probe (2) is darkened on its surface, in particular in the area of its diametrical plane, which extends throughout the longitudinal axis (20) of the probe (2) and at the same time also perpendicularly with respect to the optical axis (30) of the video camera (3).

6. Process for measuring of thickness of a probe (2) during a tension test, wherein each disposable standardized probe (2) having a measuring area defined by means of a diameter (D_{mm}) and the length (L_{mm}) is fastened into a tension testing device (1) furnished with at least one fixed jaw (11) and a movable jaw (12), which are arranged above each other and adapted to hold said probe (2), such that the longitudinal axis (20) of the probe (2) extends at least approximately in the vertical direction, and wherein said probe (2) in such fastened state and during tensioning thereof is recorded by means of a video camera (3), which is arranged in the area of the tensioning device (1) at appropriate distance apart from the probe (2), such that the optical axis (30) of the camera (3) is directed towards the

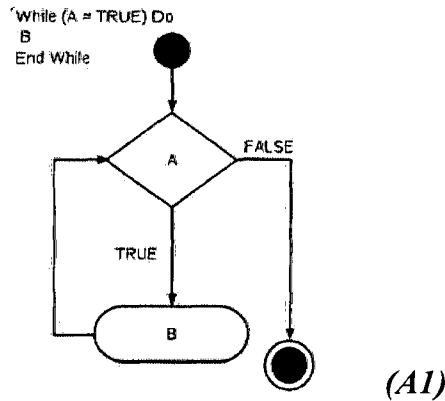
longitudinal axis (20) of the probe (2) and perpendicularly with respect to said longitudinal axis (20) of the probe (2), and in addition to that, said video camera (3) is suitable for generating video recordings in the format “jpeg” i.e. 24-bit RGB format, and is optionally for the purposes of transmission of data interconnectable with a corresponding computer (4), which is adapted to receive, store, process and optionally also to display and/or to export the data received from the side of the previously mentioned video camera (3), **characterized in that** prior to recording by said video camera (3) a screen (5) is arranged adjacent to said probe (2), which is suitable to provide a contrast relative to the probe (2) and is arranged in the area of said tensioning device (1) adjacent to the probe (2) and at appropriate distance apart from it, namely diametrically opposite to the video camera (3) with respect to the longitudinal axis of the probe (2), wherein said screen (5) is intended to provide a contrast background behind the probe (2) during recording by means of video camera (3) and is appropriately colored relative to each disposable surface of each corresponding probe (2), **and in that** the computer (4) cooperating with said video camera (3) is adapted for

- i) converging each particular input picture of the measuring area (L) of the probe (2) as received from the video camera (3), from the “jpeg” i.e. 24-byte RGB format into a matrix (A) consisting of 8-byte digits with values 0-256 corresponding to each particular points i.e. pixels, wherein the dimensions of said matrix (A) are $m \times n$, and wherein
 - m is a number of rows of the input picture; and
 - n is a number of columns of the input picture;
- ii) calculating average value ($\bar{x}$) of pixels e.g. in a row corresponding to integer of $m/2$ according to the formula (I)

$$\bar{x} = \frac{\sum_{j=0}^{n-1} x_{i,j}}{n-1} \quad (I)$$

wherein the value $x_{i,j}$ corresponds to a value in the line i and the column j in said matrix, and the average value ($\bar{x}$) corresponds to the average values in the row i ;

iii) comparing each disposable values of pixels, wherein in the row $|m/2|$ such location i.e. such value j of the first and the last value in the row is determined, which is smaller than the average value ($\bar{x}$), as well as the location of two neighboring values, which are not yet larger than the calculated average value, which is performed according to algorithm (A1)



wherein the result of the first transition is

$$A \rightarrow x_{j=0 \rightarrow n} < \underline{x}; B \rightarrow [\{j-1, j\}, \{x_{j-1}, x_j\}],$$

and the result of the last transition is

$$A \rightarrow x_{j=n \rightarrow 0} < \underline{x}; B \rightarrow [\{j, j+1\}, \{x_j, x_{j+1}\}];$$

iv) determining borders as well as the thickness of the probe (2) on the basis of calculation of a pair of lines, which are each per se extending through two points from each particular matrix, wherein a pair of values (x) is calculated, in which said lines correspond to previously calculated average value ($\bar{x}$),

wherein the general formula (II) of each line is

$$y = k_x x + n, \quad (II)$$

where (k) is a coefficient of inclination, and (n) is a section on the ordinate axis, so that the first line with the inclination coefficient (k_1) and the section (n_1) on the ordinate axis is calculated by means of points $T_1(j-1, x_{j-1})$ and $T_2(j, x_j)$, by which it is calculated, in which point (x_1) the line corresponds to the value, which is equal to previously calculated average value according to formula (III)

$$x_1 = (\bar{x} - n_1)/k_1 \quad (III)$$

upon which analogously also the value (x_2) of the second line is determined, and the thickness of the probe (2) in pixels is calculated by means of formula (IV) on the basis of the difference

$$D_{\text{pix}} = x_2 - x_1 \quad (IV);$$

v) determining the length (L_{pix}), along which said measuring of reduction of the thickness of the probe (2) is performed, wherein the ratio of

original values of the diameter (D_{mm}) and the measuring length (L_{mm}) of the probe (2) according to formula (V) is calculated

$$R = D_{mm}/L_{mm} \quad (V)$$

and the length (L_{pix}) in pixels is determined by means of formula (VI) on the basis of thickness (D_{pix}) in pixels and the previously mentioned ratio (R)

$$L_{pix} = D_{pix}/R \quad (VI),$$

by means of which for the purposes of further measuring of the thickness of the probe (2) then a sub-matrix (W) of size $L_{pix} \times n$ is created, wherein the first row of said sub-matrix is the row numbered $(m - L_{pix})/2$ of the original matrix (A), and the step of determining the thickness of the probe (2) is then repeated in each row of said sub-matrix (W), so that in each row of the sub-matrix (W) the thickness (D_{pix}) of the probe (2) in pixels is determined, and for each image generated by means of the video camera (3) then a matrix (DD_{pix}) of size $L_{pix} \times 1$ is created.

6. Process according to Claim 6, **characterized in that** the computer (4) is further used for the purposes of eliminating errors due to image noise, by anticipating that said error is statistically distributed in accordance with the *Gauss* distribution curve, and 2/3 of the matrix (DD_{pix}) are taken into consideration by calculating thickness of the probe (2), wherein

i) a histogram is created with such number of intervals, which corresponds to $L_{pix} - 1$, while two abscise axis values of the histogram

correspond to minimum and maximum value of the matrix (DD_{pix}), by which a further matrix (G) is created with the size $L_{pix} - 1$, in which the first column comprises values on the abscise axis of said histogram, and the second column comprises correlated values on the ordinate axis of said histogram, wherein the maximum value in said second column is G_{max} , upon which the values in said second column are numerically integrated in order to obtain a curve similar to “error function”;

ii) all values of the matrix (G), are reviewed by means of the “for loop”, and for each particular value between $G_{max}/6$ in $5 \times G_{max}/6$, the value from the first column of the matrix (G) is inserted into a newly created matrix (G_{opt}), in which all indexes are considered, in which the measuring results of the matrix (G) are taken into consideration, upon which a further matrix ($G_{za\_izracun}$) is created of size $(2 \times L_{pix}/3) \times 1$, in which all values from the second column of each particular indexes in the matrix (G) are present, which are included within the matrix (G_{opt}).

8. Process according to Claim 7, **characterized in that** average thickness (D_{AVG}) of the probe (2) is determined in accordance with formula (VII):

$$D_{AVG} = \frac{\sum_{h=0}^{\dim G_{za\_izracun}} G_{za\_izracun}(h)}{\dim G_{za\_izracun}} \quad (VII).$$

9. Process according to Claim 7, **characterized in that** thickness of the probe (2) is determined on the basis of the minimum value of the matrix ($G_{za\_izracun}$).

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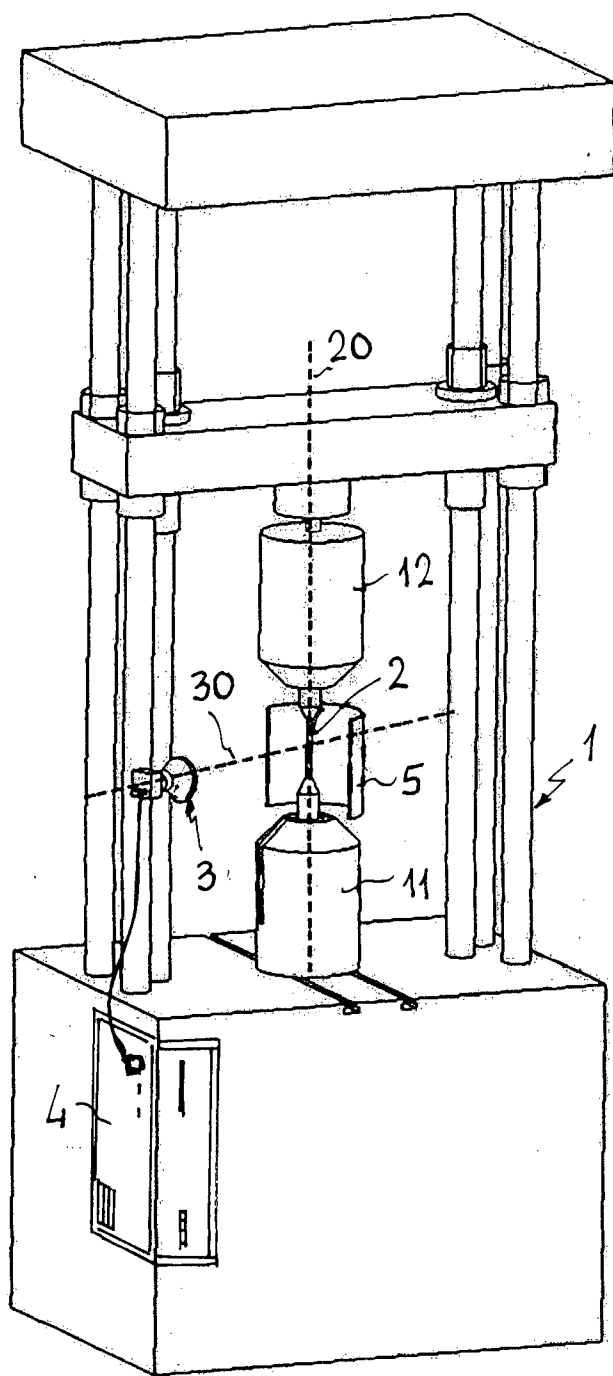


Fig. 1

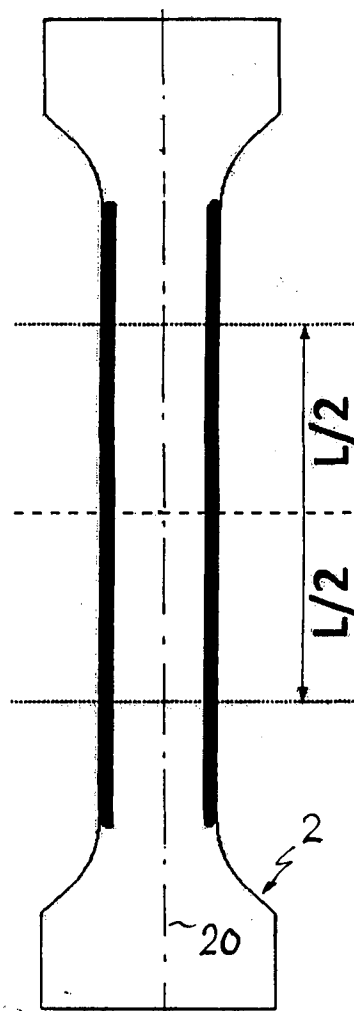


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/SI2012/000067

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B11/16 G01N3/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01B G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 033 096 A (MORRISON BRUCE R [AU] ET AL) 16 July 1991 (1991-07-16) column 9, line 44 - column 12, line 62; figures 2-5	1-9
X	----- JP 2000 146787 A (NIPPON STEEL CORP) 26 May 2000 (2000-05-26) abstract; figure 1	1-9
X	----- US 2003/182069 A1 (BANES ALBERT J [US] ET AL) 25 September 2003 (2003-09-25) paragraph [0026] - paragraph [0034]; figure 1	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

14 May 2013

Date of mailing of the international search report

29/05/2013

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SI2012/000067

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