PROBOSED DESIGN FOR PRIMARY VICKERS HARDNESS STANDARD MACHINE

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Abstract

This paper describes proposed design for a primary Vickers hardness standard machine. The machine will be developed by National Institute of standard - Egypt (NIS). The primary machine will be used to calibrate hardness testblocks at highest level. A mechanical system of the standard machine was designed to support future extension to cover the full scale of Vickers hardness test. Automatic control driving system to select loading or unloading the desired load values. The load shall be applied through five standard scales from 10 to 60 kg. The standard masses of the machine will be calibrated within ± 100 ppm. For accurate measurements of indentation, CCD image processing system will be used. The expected uncertainty of the machine aimed to be ±1% .The details of the design of the machine and the main merits of it are included in this study.

Keywords: Vickers hardness, hardness scale, standard machine, indentation, CCD camera, image processing.

1. Introduction.

Hardness test is widely used in industrial production and also in scientific researches. Also it is one of the main methods utilized to detect mechanical properties of the materials with high efficiency. Vickers hardness testing is one of the hardness testing methods. It is the most widely used due its advantageous where it covers wide scale rang with high accuracy also it is easy to make.

Vickers hardness testing machines are classified in three types [6]:-

(A) Hardness testing machine

The machine which is utilized to detect the hardness values at the user level. At this level hardness reference blocks are used to calibrate the industrial hardness testing machines in an indirect way, after they have been directly calibrated.

(B) Hardness calibration machine

The hardness calibration machine is used at the laboratory levels where at the calibration laboratory level, the primary hardness reference blocks are used to qualify the hardness calibration machines, which also have to be calibrated directly and indirectly. These machines are then used to calibrate the hardness reference blocks for the user level.

(C) Primary hardness standard machine

Primary hardness standard machine is the top of measuring chain where it has the best accuracy and uncertainty, so it is the national level. The primary hardness reference blocks for the calibration laboratory level can be evaluated thought the primary hardness standard machine. Naturally, direct calibration and the verification of these machines should be at the highest possible accuracy.

The following block diagram shows the structure of the metrological chain

Fig (1).

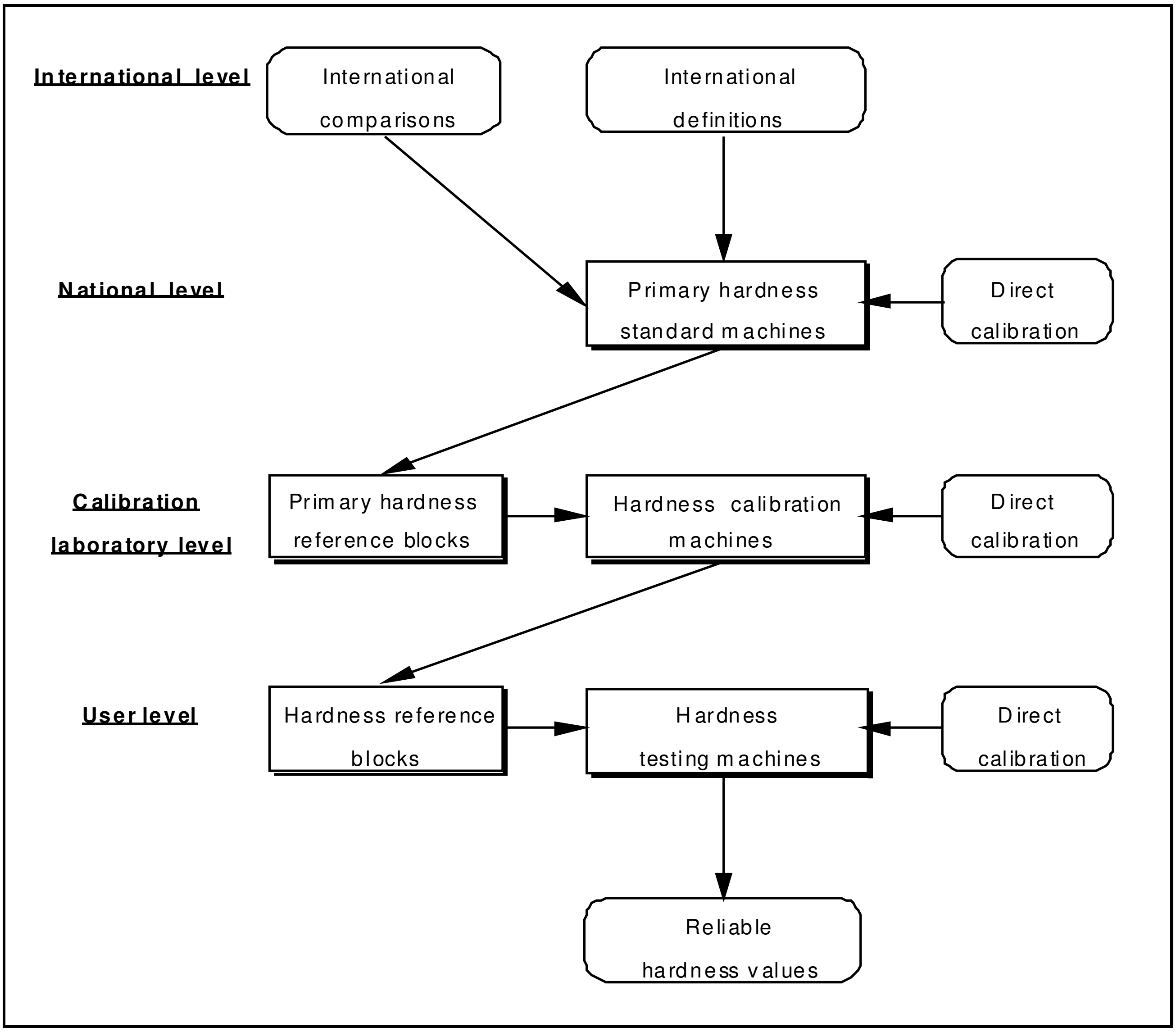

Fig (1).The structure of the metrological chain for the definition and dissemination of hardness scale

The previous metrological chain shows the importance of primary hardness standard machine which is the national primary standard in the country. So there were many primary hardness testing machines that had been developed over the world most of them including Vickers, Rockwell and Brinell hardness testing types on one standard machine.

Korea institute of standard (KRISS) developed primary hardness testing machine. This machine has been designed to make the indentation on a test block for

Rockwell and Vickers hardness testing by hanging deadweights on the indenter, the indentation load is applied very precisely to the hardness testing block .Automatically selection of the weights according to hardness scale by pneumatic devices and servo motor used to control the speed of indentation. A schematic drawing of the machine shown in fig (2)

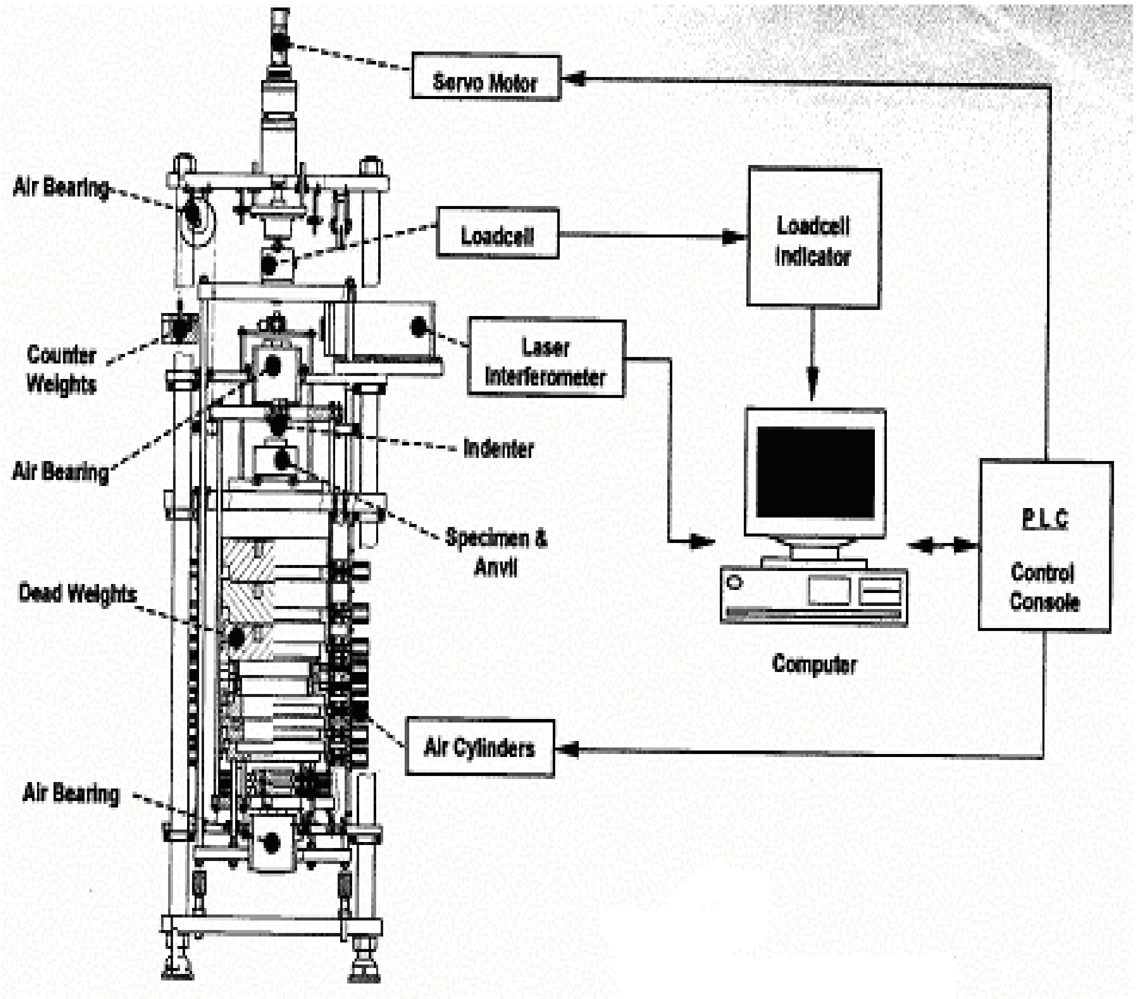

Fig (2) schematic of Kriss primary hardness standard machine

Standard hardness testing machine of the institute of metrology of Italy "G.Colonnetti" (IMGC) has been designed in order to perform hardness test ranging from 10 to 187.5 kg scale weights for Rockwell, Vickers and Brinell hardness testing [4]. Air bearings have been used to support the system and also to avoid friction. The machine structure is made up of four main sub-assemblies [5], as shown in fig. (3).

1) A stationary frame, supporting anvil's A, outer shells of air bearing G1 and G2, and, on top of crosshead H, hydraulic jack J.

2) Outer lifting frame E, hanging from jack J via elastic hinge F and load cell K , carrying pads B and N respectively for indenter's frame S and weight stack L support ;both sets of pads don't provide side constrains;

3) Stack of weights L, with kinematic location of lower plate on vee- notches M, and facilities for load selection and indication..

4) Indenter's frame S embodying the minor load, fitted with supporting plates mating with pads B, and ball -ended rods O making up with notches M full kinematic support of weights L, thus achieving the required positioning repeatability.

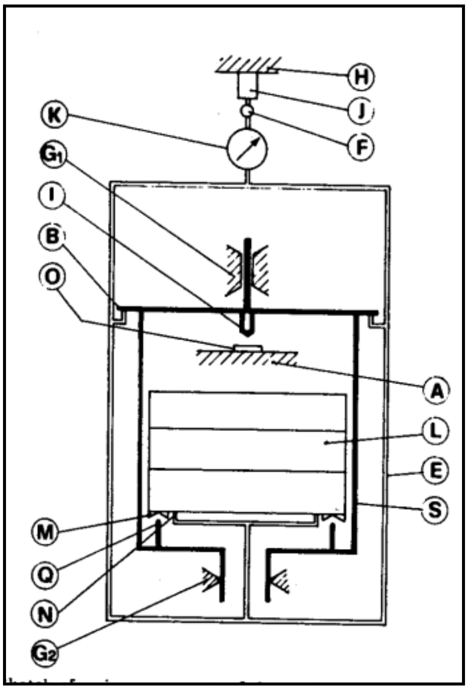

Fig (3). Schematic for IMGC primary hardness standard machine.

Physikalisch -Technische Bundesanstalt Germany (PTB) developed primary Vickers, Brinell hardness testing machine used to perform Vickers and some scales of Brinell hardness test .The machine has deadweights ranging from

10 to 187.5 kgf .weights. Loading and unloading can be performed hydraulically using pump and some control valves Load selection can be achieved manually using cams.

The main components of PTB hardness standard machine are:-

1) Table frame with the testing and loading equipment and the weight set arranged from bottom to top.

2) Control unit include operation and test cycle control commands

3) Hydraulic unit Including pump and some valves to control oil circulation during machine operation to support the machine with a suitable indentation velocity (not more than 1mm/sec).as shown in fig 4 and 5

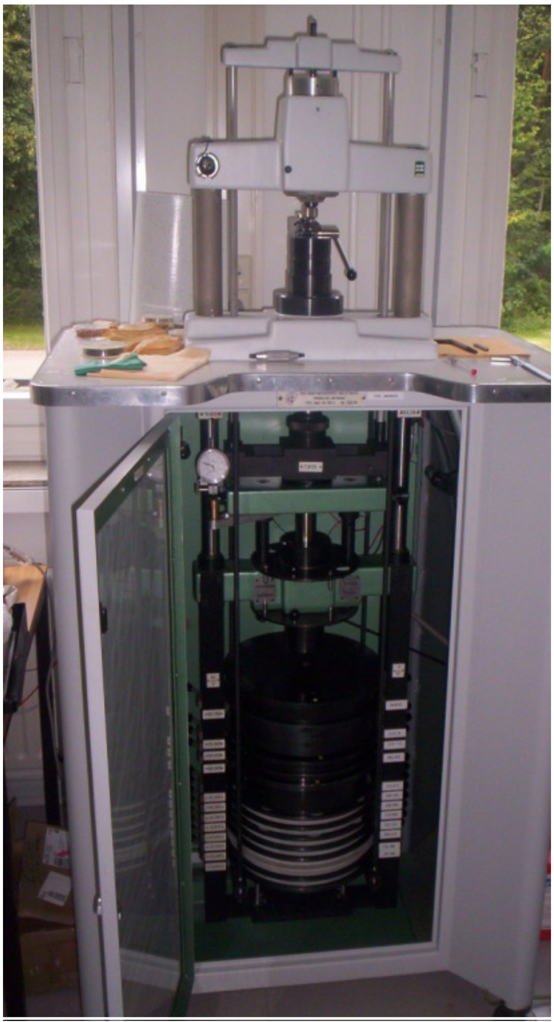

Fig (4) .Picture of the PTB standard machine

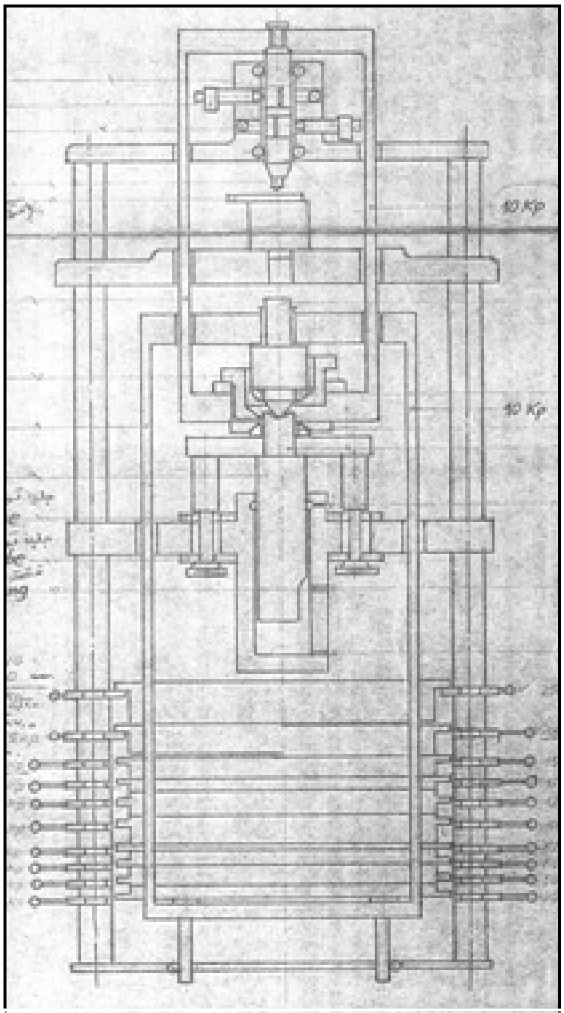

Fig (5) .Schematic of PTB standard machine

4) Separated image processing system used to measure the indentation accurately.

With the upsurge of the technological development and of material science in the last decade one can observe a series of development tendencies of hardness metrology. At present worldwide in about 20 National Metrology Institutes hardness laboratories are established which mainly care about the traceability of hardness measurements in accredited calibration laboratories so It is important for all of them to develop their own primary standard machines in order to keep and maintain the best metrological capabilities. These primary hardness standard machines are proven by international comparisons. This is organised by the Working Group on Hardness of the Consultative Committee of Mechanical quantities of the CIPM. National institute of standards of Egypt (NIS) aims to establish its primary Vickers hardness standard machine to help it to be included through this working group. This paper describes the proposed design of the machine and image processing system used to measure the indentation.

2. Primary Vickers Hardness Standard Machine

2.1 Overview

Primary Vickers hardness machine which will be developed by National Institute of standard (NIS) will be a national standard appliance with high accuracy and high efficiency .This machine has been designed to perform hardness testing ranging from 10 to 60 kg through five scale load (10, 20, 30, 50, 60) kg .The machine can be developed in the future to perform hardness testing until 120 kg scale loads.

2.2 The structure of the standard machine consist of

2.2.1. Machine fixed frame;

2.2.2. Mechanical driving system;

2.2.3. Weights;

2.2.4. Control system;

2.2.5. Image processing system.

Fig 6, 7 and 8 shows a view of the machine design, isometric view of the machine design and block diagram for the main components of the machine ...resp

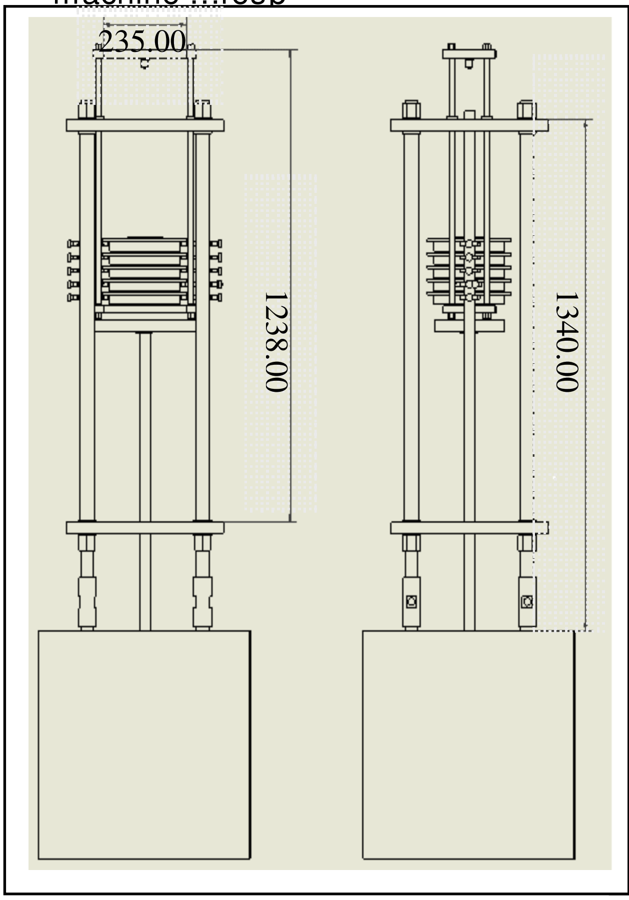

Fig (6) .Schematic view of the standard machine

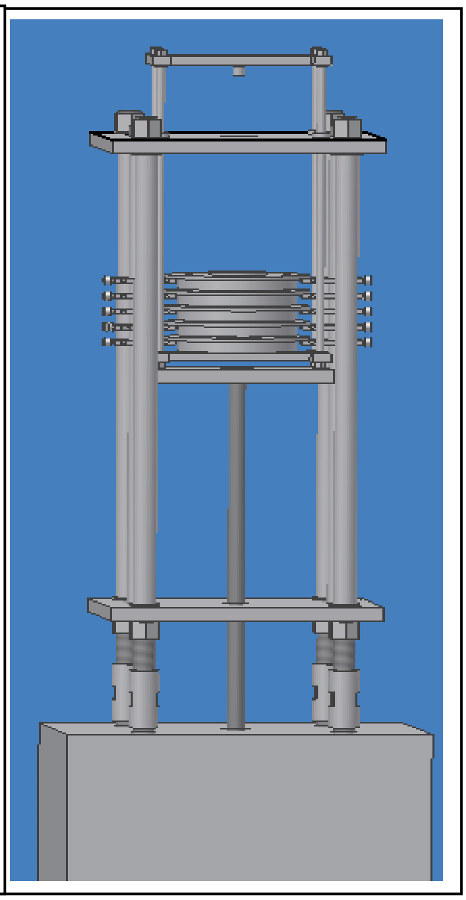

Fig (7) .Isometric view of the standard machine

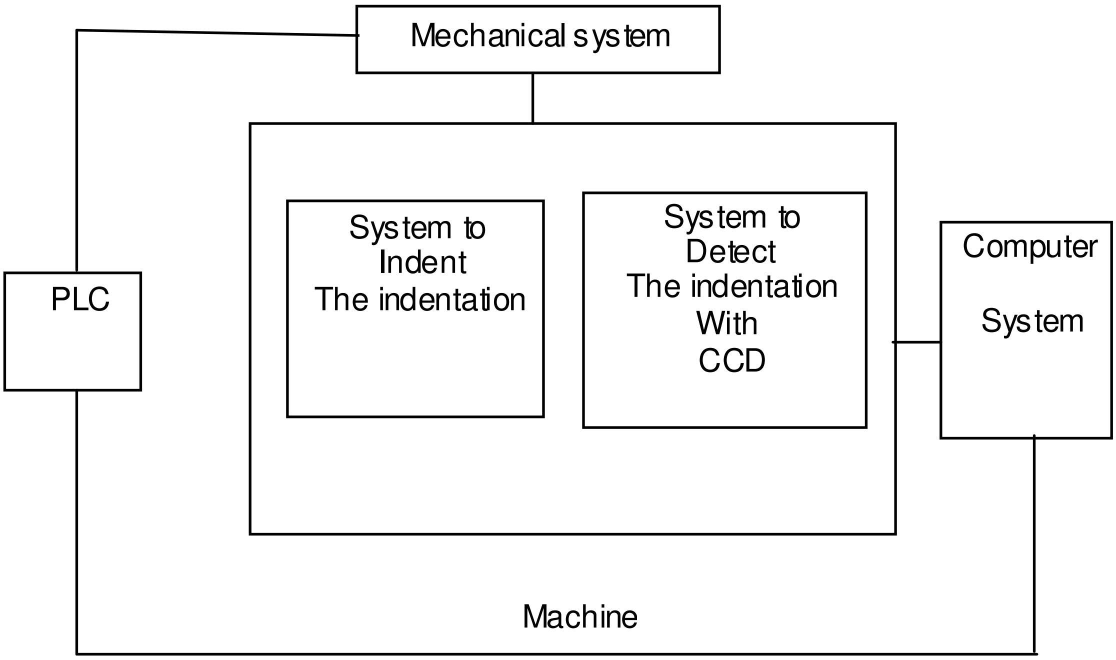

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Fig (8). Block diagram for the main components of the machine

The machine fixed frame consists of:

a- Upper plate;

b- Lower plate;

c- Four carrying column;

d- Leveling nuts;

e- Connecting nuts;.

Machine fixed frame which carrying the test loads. It must be rigid enough to resist deflection or buckling due to load applying and removing. Machine frame should be fixed on leveling nut which can be utilized to adjust the machine axially.

The proposed metal to make this frame is St.37 which is suitable due to its good compressive strength.

The following figure show the main design of the machine frame

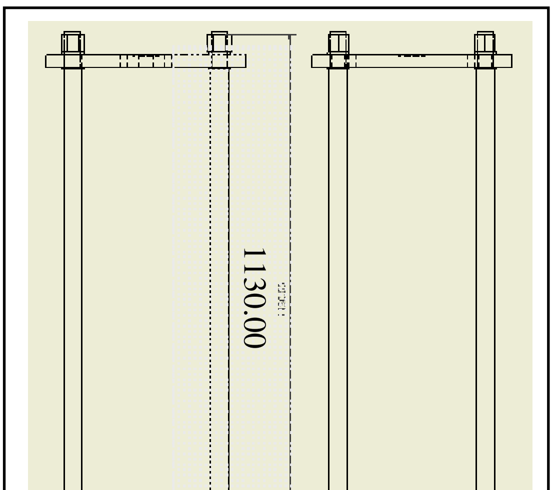

Fig (9). The view of the fixed frame

Mechanical driving system.

By the action of the mechanical system of the standard machine loading, maintaining, unloading of the testing force using gearbox and power screw system with linear velocity about 1 mm/sec which is consider the indentation speed. As shown in the following block diagram.

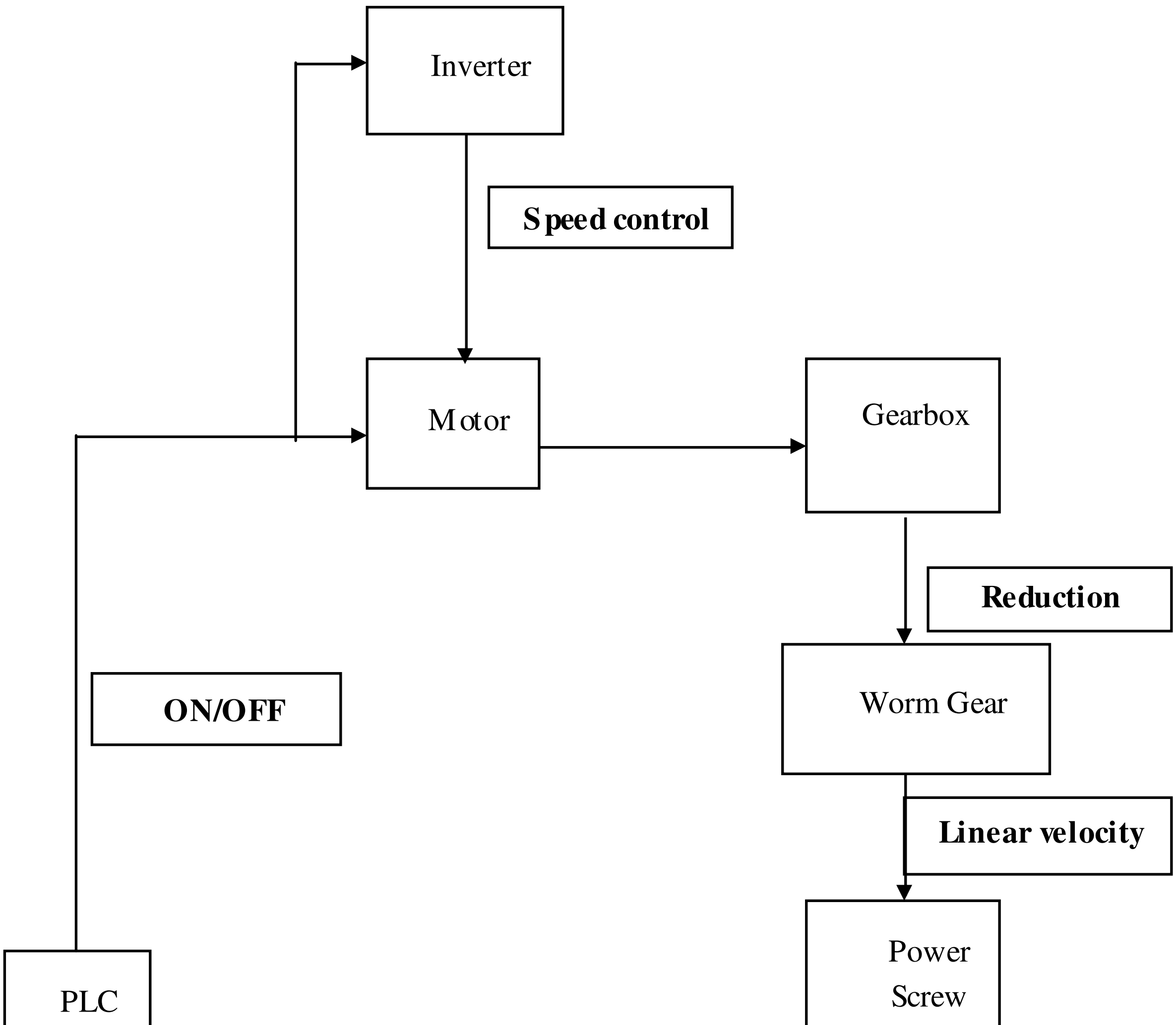

Fig (10) Block diagram for mechanical driving system operation

Weights

The weights are include

a- Five masses every one weights 10 kg as shown in fig (11).

b- Indenter's frame weight 10 kg.where it consist of

I) Upper plate;

II) Lower plate;

III) Four column;

IV) Connecting nuts. As shown in Fig 12, 13.

The required testing scale obtained thought applying different weights statically by using mechanical driving system to produce the required indentation. The weights are arranged to be selected cumulatively by using solenoids. These weights will be calibrated using primary reference standard weights and they should have accuracy less than ± 100 ppm. The proposed metal to make these weights is AISI-304 (Cr 25%, Ni 20% and density 7900 kg/m³) where it has non magnetic properties and also it's hard enough to resist scratching.

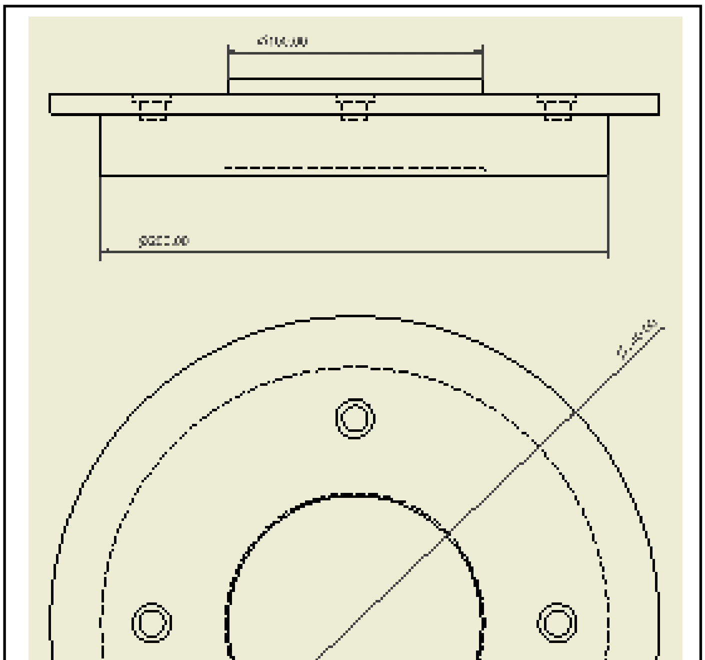

Fig (11) Weight design

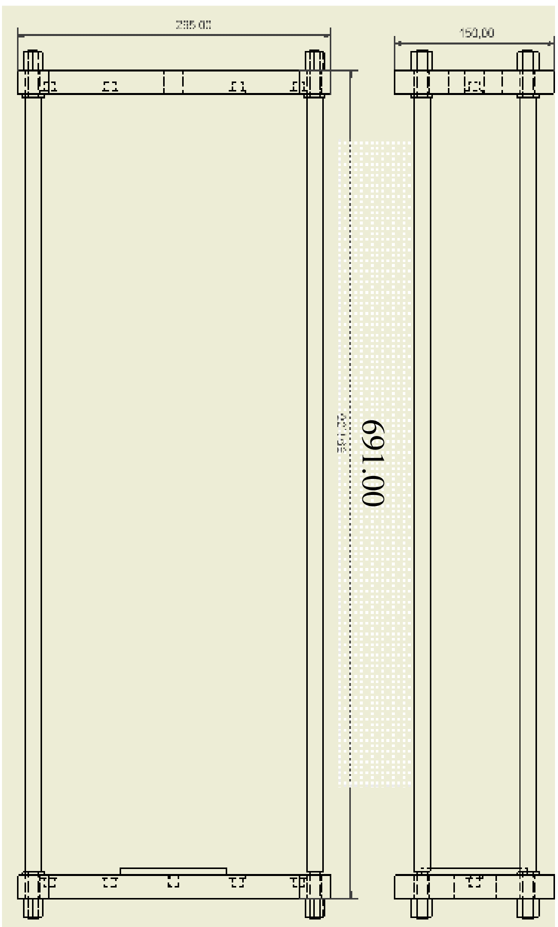

Fig (12). Indenter's frame

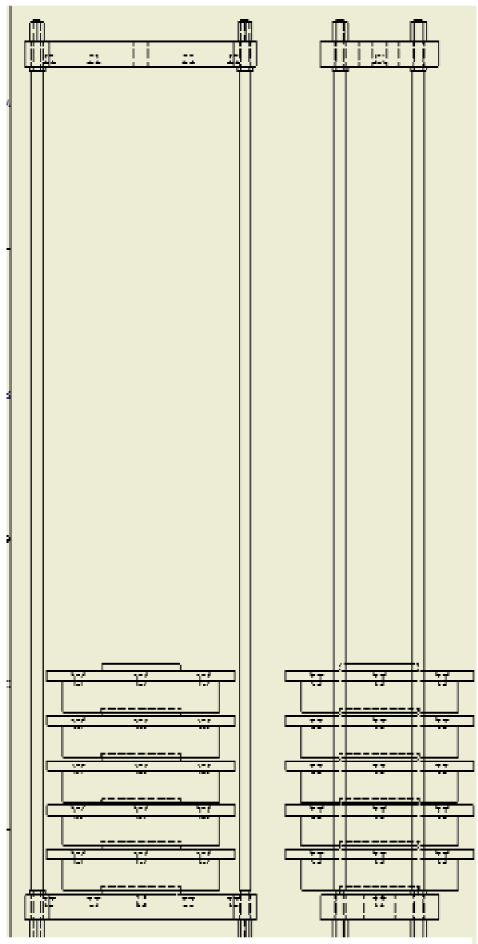

Fig (13). Indenter's frame with weights

Electric controlled system.

Electric controlled system used to control the standard machine thought controlling the movement of the power screw to give the desired speed which is the indentation speed and also used control the on/off of solenoids to select the desired weights.

Image processing system

Image processing system used for automatic measurement of the indentation using CCD image system interfaced with software

The following hardware setup is required [2].

a- Personal Computer;

b- Frame Grabber;

c- CCD camera;

d- Optics with magnifications of 140 X and 250 X;

e- High intensity lights source;

f- Software (image processing and image acquisition toolbox).

As shown in Fig (14).

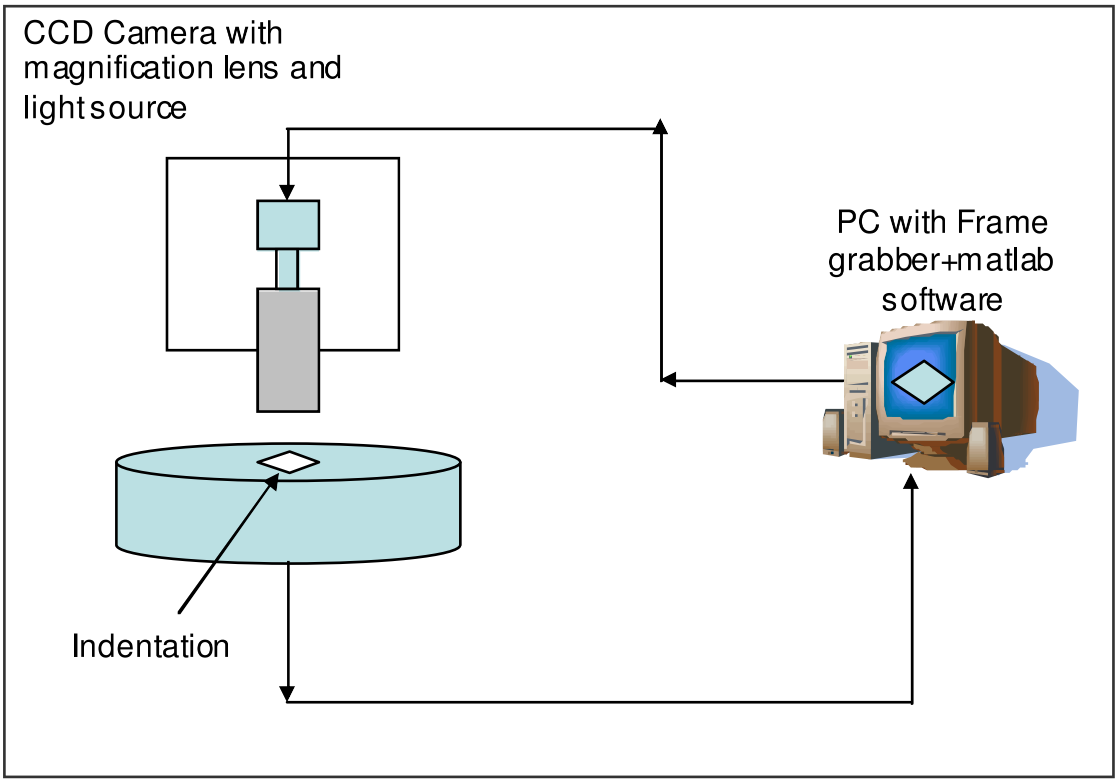

Fig (14). Show the components of image processing system

The methodology of measuring and calculating the Vickers hardness numbers (HV) using the techniques of image processing system involves the following steps [2].

A) Display the indentation image.

B) A snapshot of the displayed indentation is taken using the CCD camera .the image is then saved into 16bit BMP format

C) After getting the image of BMP format into the software the following procedures are applied to used to analyze the indentation image.

I) Image enhancement

Image enhancement techniques are used to improve an image to make certain features easer to be seen these techniques such as intensity adjustment by remapping the image to increase the contrast of the image.

II) Noise removal

Where there are several ways that noise can be introduced where CCD detector can introduce noise into indentation image noise can be removed by filtering.

III) Threshold

Here the threshold value is selected by selection value of two peaks points of the histogram of the image where histogram is the intensity graph of the image after application of threshold on the image the image background is eliminated and so the required region is selected.

IV) Edge detection

With the application of the horizontal and vertical edge detection the boundary of the image can be found and also image can be analyzed and diagonals of indentation can be measured, area of indentation can be calculated.

2.2 Calculating the Vickers hardness value

After determining the area of indentation automatically the software will pick up this value to calculate the HV [1].

Vickers hardness value (HV) can be obtained by dividing the test force by the contact area of indentation.

Where

$$\mathrm{HV}=\frac{2F\sin\frac{136^\circ}{2}}{d^2} \qquad\qquad HV = 1.8544\frac{F}{d^2}$$

F = force (in N)

d = mean indentation diagonal length (in mm) .

2.3 System Evaluation

2.3.1. Uncertainty evaluation

Uncertainty budget of the system can be calculated after measurements [6] from the formula for calculating the value of Vickers hardness we can see that the main factors affecting Vickers hardness value are test force and geometrical shape of the diamond indenter which affected the shape of indentation.

So the sources of uncertainty can be summarized as follow

(I) uncertainty of the diamond indenter

(II) uncertainty of the measuring system

(III) uncertainty of the mechanical system include

a) Uncertainty of the test force (standard weights).

b) Uncertainty caused by system friction.

c) Uncertainty caused by the deflection of the mechanical structure.

Uncertainty of the diamond indenter

The indenter must be selected strictly.

The main specifications of the indenter are

a) The angle between the opposite faces at the vertex of pyramidal indenter is 136º±0.1º.

b) Ridge at the apex of the pyramid is less than 1μm

c) Diamond pyramidal must be mounted in indenter body firmly

d) Axis of the pyramid coincides with axis of the indenter body of which the batter is less than 0.3º.

$$\frac{\Delta HV1}{HV} = \frac{\Delta\alpha}{2\tan\frac{\alpha}{2}}$$

Where:- α = plane angle of the indenter (136°)

The uncertainty due to indenter angle between the opposite faces is expected to be about ±0.05% [1] i.e.

$$\frac{\Delta HV1}{HV} = 0.05\%$$

Uncertainty of the measuring system

It include uncertainty caused by the optical system through the magnification and image analysis It can be examined using dividing rules having 0.01 mm division.

It aimed to be not more than 0.8 [1].

$$\frac{\Delta HV2}{HV} = 0.8\%$$

Uncertainty of the mechanical system include

Uncertainty caused by system friction

Required to be about 0.4%.

So

$$\frac{\Delta HV3}{HV} = 0.4\%$$

Uncertainty caused by system deflection

Required to be about 0.1%.

$$\frac{\Delta HV4}{HV} = 0.1\%$$

Uncertainty of the test force

Uncertainty of the test forces depends only on the uncertainty of standard weights and also the friction with guiding columns.

From Partial derivatives

$$\frac{\Delta HV5}{HV} = \frac{\Delta F}{F}$$

So the uncertainty due to force for masses will be

$$\frac{\Delta HV5}{HV} = 0.4\%$$

So the Budget uncertainty can be calculated from

$$\frac{\Delta HV}{HV} = \sqrt{\left(\frac{\Delta HV1}{HV}\right)^2 + \left(\frac{\Delta HV2}{HV}\right)^2 + \left(\frac{\Delta HV3}{HV}\right)^2 + \left(\frac{\Delta HV4}{HV}\right)^2 + \left(\frac{\Delta HV5}{HV}\right)^2}$$

$$\frac{\Delta HV}{HV} = \sqrt{(0.05)^2 + (0.8)^2 + (0.4)^2 + (0.1)^2 + (0.4)^2} = 0.98\%$$

The uncertainty of the system aimed to be about 1%

4. Conclusion

1- Vickers hardness standard machine which will be developed by NIS will be national appliance with high accuracy and high efficiency.

2-This design utilize optics and mechanics, control, computer based software, and image processing technique for precise measurement of Vickers hardness which will be automatically measured.

3-CCD image system helps to eliminate the human error in measurement of hardness also help to automate the process whereby the input of the CCD camera can be fed to the developed software to analyze the image and compute the hardness value.

4- The calculated uncertainty shows precise and accurate Vickers hardness measurement.

Acknowledgements

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