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# DESIGN MODIFICATION OF AN AUTOMATIC MOULDBOARD PROFILOGRAPH

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**ABSTRACT -** This paper presents the design modification of an automatic mouldboard profilograph by substituting an optical sensor and a control system, together with its evaluation. The modified profilograph is an electro-mechanical apparatus in which a micro switch and a DC motor were replaced by an optical sensor and a control system for the revolution of a DC motor. Thereby, the considered surface was measured by using a non – contact sensor. This apparatus has the capability of drawing the profilograms of a 3-D object as a 2-D drawing in the same contour lines. The profilograms drawn by this apparatus can be useful for the mouldboard design and its surface modelling. They compared the drawn profilograms before and after modification. In order to verify the apparatus performance, horizontal and vertical profilograms of a cylindroidal mouldboard were drawn. Comparisons of drawing accuracies were conducted for a metal cylindroidal surface with radius of 315 mm and 540 mm in length, by using the two sensors. Our results have shown that the use of the optical sensor and of the control system has reduced the drawing error of the mouldboard surface curvature up to 70%.

**Key words:** mouldboard, profilograph, profilogram, agricultural machinery, sensor

**REZUMAT – Modificarea proiectului unui profilograf privind cormana automată.** Lucrarea prezintă modificarea proiectului unui aparat profilograf privind cormana automată, prin substituirea unui senzor optic şi al sistemului de control. Profilograful modificat este un aparat electro-mecanic, la care microîntrerupătorul şi motorul CC au fost înlocuite cu un senzor optic şi un sistem de control. Deci, suprafaţa analizată a fost măsurată, folosindu-se un sensor cu infraroşii. Acest aparat poate trasa profilograme ale unui obiect 3-D, precum şi 2-D, în aceleaşi linii de contur. Profilogramele trasate de aparat pot fi utile pentru proiectarea cormanei şi pentru modelarea suprafeţei acesteia. S-au comparat profilogramele realizate înainte şi după modificare. Pentru a se verifica performanţa profilografului modificat, s-au

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realizat profilograme orizontale şi verticale ale unei cormane cilindrice. S-a comparat acurateţea trasării unei suprafeţe cilindrice din metal, cu o rază de 315 mm şi o lungime de 540 mm, folosind senzorii optici. Rezultate au arătat că folosirea senzorului optic şi a sistemului de control a micşorat eroarea trasării curburii suprafeţei cormanei până la 70%.

**Cuvinte cheie:** cormană, profilograf, profilogram, maşini agricole, sensor

## INTRODUCTION

There is no specified criterion for the classification of ploughs and accurate discrimination of mouldboards and operational practices are accompanied with some doubts. The design of the mouldboard is affected by its draft force. The improvements in tillage practices and in designing tillage equipments are of great importance. This reveals, if we know that in the United States the disturbed soils or inverted soil are annually amounted to $250\times10^9$ tones, that this requires around $2\times10^9$ litres of diesel fuel.

It is obvious that the proportionality between the shape and design of a mouldboard has a momentous share in energy consumption modification. For this purpose, an awareness of the performance of the mouldboard in agronomical soils is essential that it needs the preparation of the profilogram (two-dimensional drawing of the mouldboard) (Kepner, et al., 1978). In addition, for controlling the accuracy of mouldboard surfaces before fabrication and mouldboard surface and its angles after fabrication, a blade needs to be considered on the profilograph (Bernacki et al., 1979).

Thomas Jefferson has developed a physical approach for analysing a mouldboard surface. White and Ashby have developed graphical methods for this purpose. The first photograph was developed by Soehne (Kepner, et al., 1978). Ringleman has invented a manual profilograph, which could draw vertical profilograms. In the latter profilograph, the mouldboard attached to a holder platform was moved by a manipulated screw at equal intervals to draw vertical profilograms (Coupan, 1915).

Marvel et al. have developed a profilograph, which had two arms at different directions. The arms with wheels were used for measuring the considered surface curvature. The measured curvature was transferred to a recorder (Marvel et al., 2000).

Weznow has invented a profilograph equipped with three wheels in front, middle and rear. These wheels were arranged in a common direction. The front and middle wheels were located on a common frame, the rear wheel was located on a separate frame and the frame of the rear wheel has been hinged on the middle wheel axle. This profilograph using the latter mechanism could measure the surface curvature (Woznow, 2000).

Massah has designed an electromechanical profilograph (*Figure 1*). The developed profilograph uses a micro switch located on the draw rod tip, which follows the mouldboard surface curvature, and a draw pen on a movable ruler to draw the relevant curvature. After the ruler is reached to the end of its stroke, a micro switch runs to draw the next profilogram (Massah, 2004).


**Fig. 1 - Designed automatic mouldboard profilograph by Massah**

The objective of this research was to improve the performance of the early-developed profilograph, in which an optical sensor and a DC motor with speed controller have been used instead of a micro switch. By using the measuring device with better accuracy and higher frequency response on the studied profilograph, our goal was to diminish the drawing error.

## MATERIALS AND METHODS

The profilograph apparatus as an electromechanical means has been developed to draw the three–dimensional contour lines as the two-dimensional ones. In addition to drawing the mouldboard surface, this apparatus can be also used for assessing the other surfaces, like airplane and automobile bodies, in moulding and maintenance stages. Generally, using this apparatus, the three-dimensional contour lines can be examined as the two-dimensional contour lines (*Figure 1*).

Since the external surface of a mouldboard is similar to a cylindroidal surface and the fact that the drawer rod should move over the external surface of this cylindroidal surface, the Cartesian coordinate is known as the most appropriate coordinate system for this apparatus. This system has three degrees of freedoms, in which three DC motors with gearbox have been used to develop a linear motion. A DC motor located at the bottom of the apparatus, using a chain and sprocket as well as a longitudinal shaft, moves the draw sheet in the direction of the z–axis. A second DC motor using a chain and sprocket moves a movable ruler in the direction of the y–axis. The other DC motor controls the drawer rod in the direction of the x–axis. The effective motion ranges of this apparatus in the direction of x, y and z axes are 90, 130 and 120 cm, respectively (*Figure 2*).

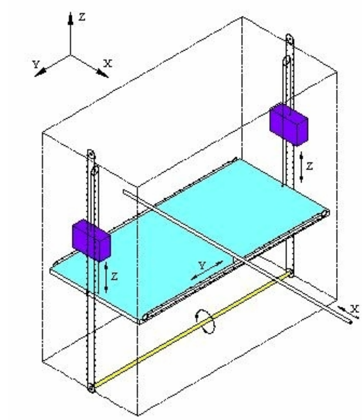


**Fig. 2 - Apparatus degrees of freedom**

In the former profilograph, for following the mouldboard surface, a retard micro switch has been used as shown in *Figure 3*. In this approach, a blade cuts off and connects the two contacts of the micro switch to alter motor turning (x-axis) and ensure the contact of drawer rod with mouldboard. For improving the latter mechanism, an optical sensor (Fotek, model MR–30 XP, Taiwan) has been used to avoid the errors caused by the contact with the mouldboard (*Figure 4*).

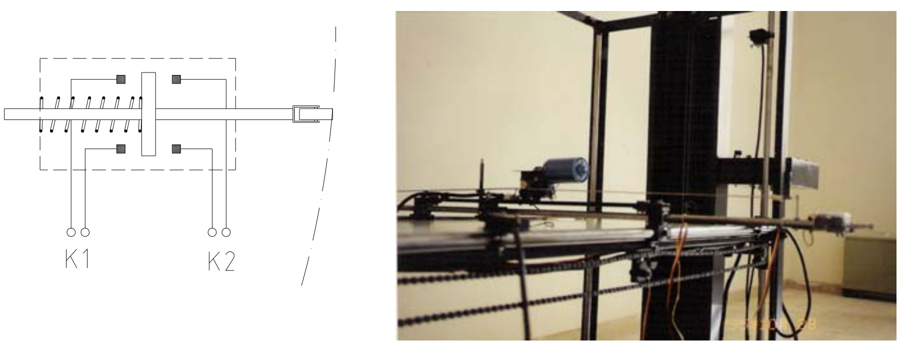


**Fig. 3 - Schematic design of the retarded micro switch and its position on the drawer rod**

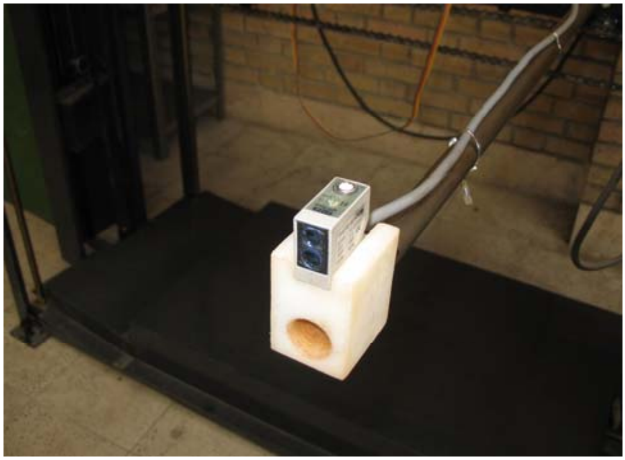

**Fig. 4 - Optical sensor on the tip of drawer rod**

A block diagram of the apparatus is shown in *Figure 5*. The distance between the rod tips where the optical sensor has been installed and the considered surface is measured by means of the optical sensor with an accuracy of ±1mm. When a difference between the predetermined distance and the measured distanced is found, a feedback command is sent to the motor to alter this distance. If this distance is found to be higher than the predetermined distance, a command is sent to the drawer rod to be moved towards the mouldboard and vice versa. The board with regard to input voltages can meet the output voltage within -12 to +12V and it is sent to the DC motor. In this board, two multi turn potentiometers have been applied, so that one of them sets output zero and another is used for output gain of voltage change.

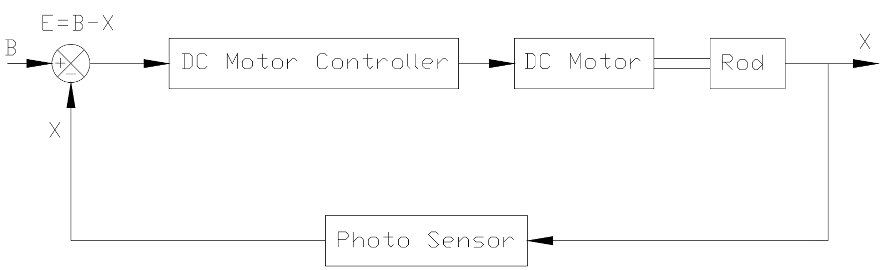


**Fig. 5 - Block diagram of the apparatus**

The automatic profilograph apparatus of the mouldboard consists in two main parts: the mouldboard support and the drawer.

## RESULTS AND DISCUSSION

**The mouldboard support** is a 75 Kg unit and its functions are holding, moving and altering the mouldboard position against the drawer. The capacity of this unit for holding the mouldboard is up to 100 Kg and during the movement, there is a balance. This unit can set the mouldboard at any angular situation, namely two horizontal and vertical situations for drawing the relevant profilograms. Due to the capability of the apparatus set for the mouldboard types, the movable stand in fixed stand has a sliding movement, thereby the movable stand height can be adjusted (*Figure 6*). Two ball bearings have been fixed on the platform using a screw and a nut. These ball bearings provide the possibility of turning the holder and the mouldboard. One end of the mouldboard holder has been attached to the frog and another one to the control rod. The control rod is responsible for determining the situation and the transverse levelling of the mouldboard. The longitudinal levelling is done by using a mechanism attached to the main frame of the mouldboard support.

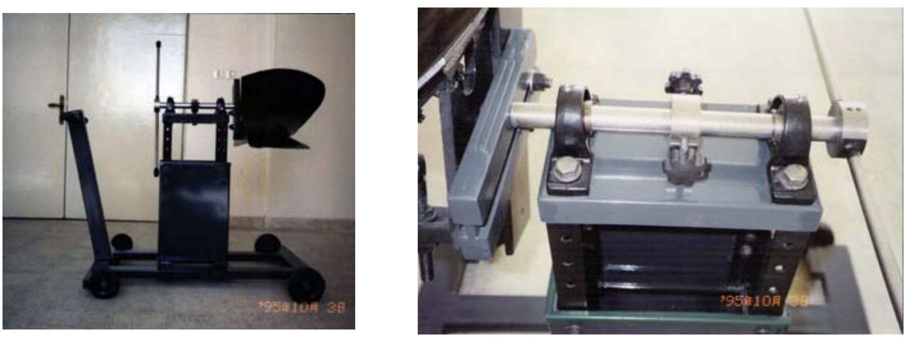

**Fig. 6 - Mouldboard support unit**

**The drawer**. This apparatus has been developed with sizes of 152×72×150 cm and 250Kg in weight. Since the apparatus balance is of great importance, four adjustable stands located in four corners of the frame are used for both longitudinal and latitudinal levelling. In the interior corners of the apparatus, four rails have been installed to conduct the draw sheet towards the top and the bottom. The draw sheet takes its motion by a chain and the sprocket from a gearbox motor, which has been located in the bottom of the apparatus.

The velocity of the draw sheet movement (in the direction of the z–axis) is almost 2 cm/s. For the uniform motion of the draw sheet in its own stroke, several counterweights have been considered (*Figure 7*). The force of the counterweights is equally exerted to the two sides of the draw sheet. These counterweights meet the force required to move the draw sheet up and down, therefore during the draw sheet movement a force is exerted to the DC motor. Two longitudinal rails located at the two sides of the draw sheet are responsible for conducting the movable ruler. The movable ruler takes its motion via a chain and sprocket (in the direction of the y-axis) from a 12V DC motor installed under the draw sheet frame. The velocity of the movable ruler (in the direction of the y-axis) is about 5 cm/s. In the upper part of the movable ruler, there are two guides to help moving the drawer rod in the direction of the x- axis. As shown in *Figure 8*, an optical sensor has been located to maintain the distance between the drawer rod and the considered surface constant, as the movable ruler is being moved in the longitudinal direction of the mouldboard. Therefore, the considered surface is satisfactorily measured without any contact of the sensor to the surface. It should be noted that two micro switches preclude over the movement of the drawer rod at the end of the mouldboard surface.

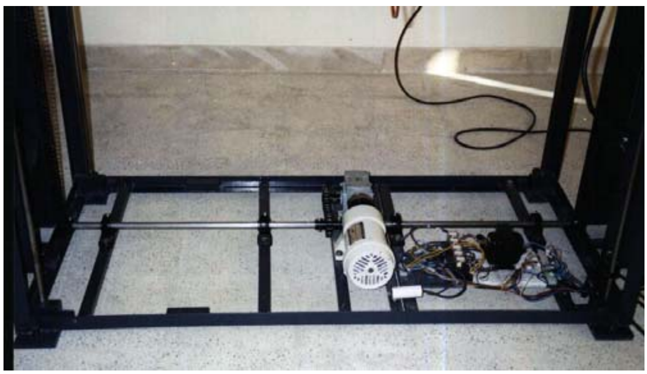

**Fig. 7 - Movement shift to the drawer stand**

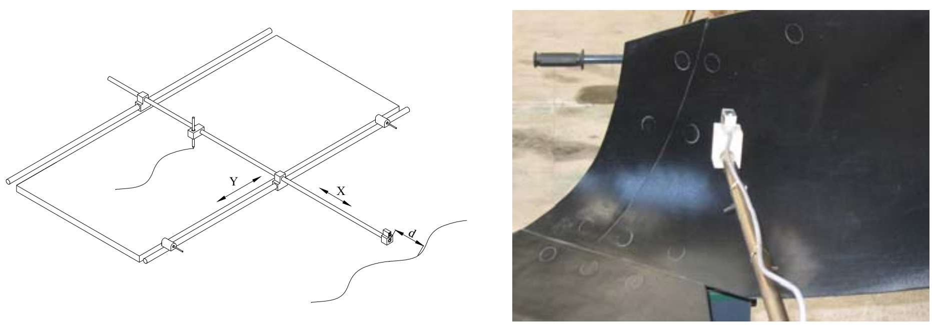


**Fig. 8 - Working mechanism of movable ruler and drawer rod with optical sensor**

This apparatus can be controlled both manually and automatically. At first, considering the mouldboard sizes, the horizontal stroke of the movable ruler and the vertical stroke of the drawer sheet are set by changing the local situation of the micro switch. Then, the drawer sheet is manually brought in the lowest point of the mouldboard. After locating the drawer rod in the desirable situation, the drawer automatically runs. The movable ruler having an optical sensor at a certain distance to the mouldboard surface is conducted by using a DC motor. At the end of the horizontal stroke of the movable ruler, a micro switch runs a timer. This timer, based on adjusted time, makes the motor move the drawer sheet upward. In fact, by setting the timer, the distance between the two contour lines is adjusted. In each stroke of the movable ruler, a curve of contour lines of the mouldboard is drawn. After drawing the contour lines, the drawer sheet reaches the highest points of its work that in this instant draw sheet using a micro switch (vertical stroke controller) comes automatically to the beginning point of its work for drawing the next surface (*Figure 9*).

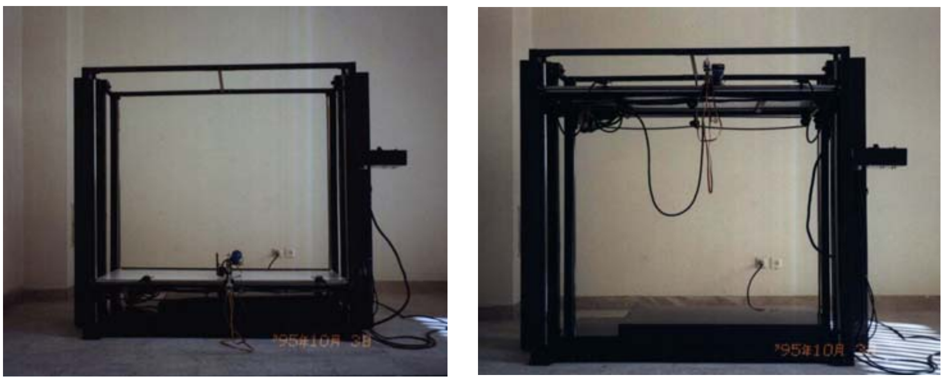

**Fig. 9 - Drawer stand at the highest (Right) and lowest (Left) positions**

Two covers located at the sides of the apparatus cover the trajectory of counterweights and two other plates located on the chassis floor cover the relays and the power transmission system. To increase the stroke of the draw sheet, one of the two covers installed on the chassis floor has a lower height.

**Evaluation of the Apparatus**

For evaluating the apparatus, the modified system was compared to the former system and then the vertical and horizontal profilograms, related to a type of the cylindrical mouldboard, were drawn.

**Comparison of the drawing accuracy between the sensors**

In this experiment, the comparison of the drawing accuracy between the micro switch (*Figure 10a*) and the optical sensors (*Figure 10b*) was made for a metal cylindroid surface with the radius of 315mm as a drawing pattern. Drawings with 540 mm in length from the surface of cylindroid mouldboard were obtained by using the two above-mentioned sensors. The experiments for each sensor were replicated three times and the output curves were compared with a semicircle with 315 mm in radius. The drawings obtained from the two sensors were stepwise curves instead of a curve of a circle. Then, for comparing the two obtained drawings, at the same points, height and length of the steps were measured and compared (*Figure 11*). The results have indicated that the area under the steps drawn by the optical sensor was 30% of the area of the former system. In other words, using the optical sensor in this system may diminish the curvature drawing error up to 70%.

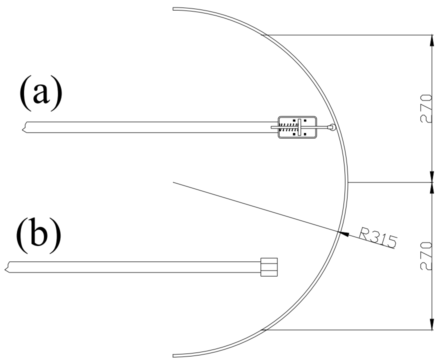


**Fig. 10 - Comparison test between (a) micro switch and (b) optical sensors**

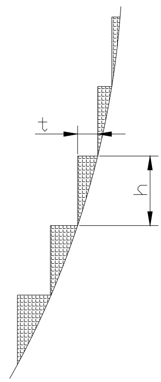


**Fig. 11 - Tracking drawing errors between two sensors**

### The apparatus performance test

In this regard, a semi-cylindroidal mouldboard was selected. The mouldboard was placed in the vertical and horizontal position on the support (*Figure 12*). Then, in addition to the support levelling, the vertical and horizontal levelling of the edge blade for drawing the profilograms was accurately controlled (*Figure 13*). After setting the support, the contour lines of the mouldboard were drawn. Afterwards, the peripheral lines of the mouldboard concerning the ends of lines were corrected.

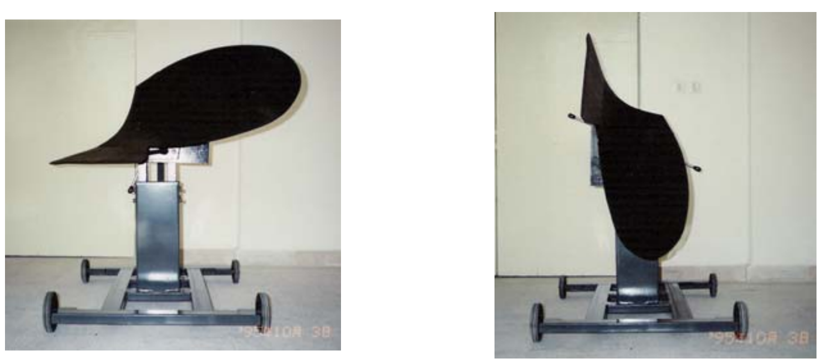

**Fig. 12 - Adjusting the mouldboard on the support for horizontal and vertical positions**

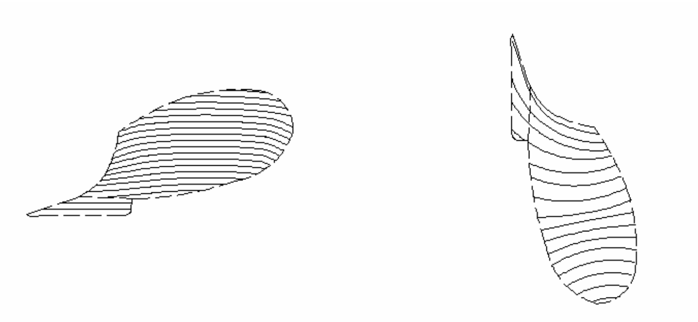

**Fig. 13 - Drawn horizontal and vertical profilograms for the semi-cylindroidal mouldboard**

## CONCLUSIONS

This paper presents the design modification and evaluation of a modified automatic mouldboard profilograph. Instead of a micro switch and DC motor, an optical sensor and a control system were employed in the modified profilograph, for providing the 2-D drawings of the 3-D object, such as a mouldboard plough bottom. The drawn horizontal and vertical profilograms of the revised profilograph, before and after modification, for a cylindroidal mouldboard were compared to evaluate the system. Comparisons of drawing accuracies were conducted for a metal cylindroidal surface with radius of 315 mm and 540 mm in length, by using the two above-mentioned sensors. The experiments for each sensor were replicated three times and the output curves were compared with a semicircle with 315 mm in radius. Since the drawing obtained from the two sensors was represented by stepwise curves instead of a curve of a circle, for comparing the two drawings obtained in the same points, the height and length of steps were measured and compared. The results indicated that the area under the steps drawn by the optical sensor was 30% of the area of the former system. Therefore, the use of the optical sensor and the control system has reduced the curvature drawing error up to 70%.

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