GAZİANTEP UNIVERSITY GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES

DESIGN AND CONSTRUCTION OF AN EQUIPMENT FOR MEASURING THICKNESS OF SHEET METAL IN COLD ROLLING

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IN

MECHANICAL ENGINEERING

By

CEM DURAK

JULY 2005

Design and Construction of an Equipment for Measuring Thickness of Sheet Metal in Cold Rolling

M.Sc. Thesis
In
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Superviser
Cengiz DOĞAN

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ABSTRACT

DESIGN AND CONSTRUCTION OF AN EQUIPMENT FOR MEASURING THICKNESS OF SHEET METAL IN COLD ROLLING

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M.Sc. in Mechanical Engineering

Supervisor: Assoc. Prof. Dr. Cengiz DOĞAN

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In this study, a sheet metal thickness measuring machine is design and constructed for cold rolling process. A linear variable differential transformer (LVDT) with two rollers by points contact is used for measuring the thickness. Variation of the strip thickness, backlash and, inaccuracies are eliminated by using a LVDT transducer with a programmable logic controller (PLC). The rollers are rotate synchronously with a gear pair. The rotation of the rollers is adjusted by using servomotor and driver. The thickness measurement control is an on-line method.

The thickness variation of the sheet metal, the error values graph and the rolling speed, are displayed on PC the screen. In addition, to increase correct the measuring value the roller error is saved. In order to ensure applicability to the wide range of applications appearing thickness measuring research, the thickness measuring machines and PLC system must be highly flexible.

Keywords: Thickness measuring equipment, LVDT transducer, PLC, thickness variation graph, position control.

ÖZET

SOĞUK HADDEEMEDE SAC METALİN KALINLIĞINI ÖLÇEN BİR APARATIN TASARLANMASI VE KONSTRÜKSİYONU

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Tez Yöneticisi: Doç. Dr. Cengiz DOĞAN
Temmuz 2005, 54 Sayfa

Bu çalışmada, soğuk haddehanelemelde sac metal kalınlığını ölçen bir aparat tasarlanarak imal edilmiştir. Sac metal kalınlığı lineer ölçüm probu (LVDT) montaj edilmiş iki döner disk arasından geçirilerek ölçülmektedir. Disk sensörler iki dişli vasıtasıyla sekronize edilmektedirler. Disklerin dönüş hızları servo motor ve sürücüsü vasıtasıyla ayarlanmaktadır. Sac kalınlığıdaki değişimler, sistemdeki boşluklar ve ölçüm belirsizlikler PLC ile LVDT sensörü vasıtası ile doğrudan okunmaktadır.

Hazırlanan program ile gerçek zamanlı kalınlık değişim grafiği bilgisayar ekranında çizilebilmektedir. Ölçüm esnasında silindir hataları, sacın silindir hatalarından çıkarılan gerçek değeri ve hızın etkileri görülebilmektedir. Silindir yüzey hataları tabloya kayıt edilebilmektedir. Okunan sac kalınlık değerlerinden kayıt edilen hata değeri çıkarılarak bilgisayar ortamında kalınlık değişim grafiği çizdirilmektedir.

Anahtar Sözcükler: Kalınlık ölçme aparatı, LVDT probu, PLC, kalınlık değişim grafiği, PLC, pozisyon kontrolü.

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LIST OF SYMBOLS

ε_p	Plastic Deformation
h_1	Entering Thickness of Strip
h_2	Exit Thickness of Strip
LVDT	Linear Variable Differential Transformer
PLC	Programmable Logic Controller

CHAPTER I

INTRODUCTION

The properties of a material or product are evaluated for quality control. The specification conformance, or engineering design, precise and critical data must be obtained. Mass production derive from the efforts of producers of strip and sheet materials to improve the quality of their products. Continuous efforts are being made to provide the consumer with more accurate material as regards to dimensional uniformity [1].

The processing of coiled strip, especially at the high working speeds which now operate, is becoming more and more exicting for the mills and their ancillaries. It is necessary for the material to be of good shape to function satisfactorily. For this reason, it is essential when rolling coiled strip to maintain close control of dimensional variation, especially across the width of the material. This is the only means of ensuring that the finished products are of satisfactory shape. The successful method of production depends on the maintaining of uniform gauge across the width of the material. [2].

The thickness measurement control is an on-line method, which allows, a computational implementation even on a programmable logic controller (PLC). The concept of a computerized thickness measuring machine with digital data acquisition and data reduction has been implemented.

Because of the recent falling cost of digital electronics, it has become cost effective to use small computers for data acquisition, storage and analysis. These computer systems range in versatility from simple one-board machines dedicated to a single task, through the use of low-cost personal computers based on microprocessors to the more expensive and specially designed commercial systems [3].

In rolling operation, the thickness tolerance of strip of sheet metal is the decisive quality characteristic. Highly accurate thickness measurement and reliable, slip-free

speed measurement are the prerequisites for implementing the modern control concept. The aim of this work is design and construction of thickness measuring machine. The manufacturing processes in addition to producing a product of the required properties and dimensions must be designed to develop and maintain the required standard of surface. Improvement of the surface of the strip is produced progressively during the rolling processes particularly in cold rolling

The basic strategies for the thickness control of an cold rolled strip were developed in the sixty, when it became economically reasonable to use electronic components in rolling sheets. In the eighty, digital circuits took place in the automation of rolling sheets. In the ninety, standard programmable logic controls (PLC) provided more computational power at a decreasing price. To get rid of the increasing complexity, the recent development brought a specialisation of the automation components, a division into different hierarchical levels.

This development made it possible to implement more complex control algorithms. Due to the specialisation, this task is to be separated into at least two parts:

1. A modelling process with high complexity and large computing requirement.

2. A real-time part with fast running, computationally efficient algorithms, which has to run on a standard hardware like an industrial PLC.

The developed measurement system produces numeric information about the thickness changes. The data analyses are controlled by a “PLC program” which enables the user with little experience on the computer and PLC with experimentally relevant commands. Once the data collected, the thickness variation graph can be plotted. At the same time, all the data taken were recorded in a table on hard disc for further calculation and analysis with PLC programmer. These tables are important for good surface performance in cold rolling process.

The work deals with the automatic precise control of the on-line strip thickness measurment in a cold rolling of sheet metal. The automation components are selected and implemented with suitable algorithms for the optimal results. A contact type sheet metal thickness measuring machine is produced for cold rolling process. The device includes; thickness measurement with a LVDT, reading and calculation with a PLC unit, position control with an encoder, and a DC servomotor driver. Therefore, the thickness variation of the strip, backlash and inaccuracies are eliminated by using transducer probe with PLC. The thickness is measured between two rollers with one point contact in which are run synchronously with a gear pair.

The thickness variation graph is plotted on the screen with the software written in PLC program. The effect of speed, rollers error value and real value of sheet are displayed on the measured time. In addition, roller error values are saved in a table to reduce the measure value of sheet metal. This table is calculated with PLC and the correct thickness variation curves are plotted.

1.1 Modern Thickness Measuring Machines

Modern finishing and inspection lines are run at high speed with tight tolerances. In parallel with the continuous development of technological processes and plant automation, quality demands also increase steadily. The essential advantage of our measuring system in comparison with conventional methods lies in their fast, continuous, contact type, real-time acquisition of precision measured values.

This challenge is from accepted industry, and contributes to an effective increase in productivity with our high precision contact measuring systems. On-line measuring systems include a lot of types of measuring machines, at different capacity and precision in cold rolling process. Contact types of thickness measuring machines are measure of thickness made by contacting on the sheet surface. During measuring diamond transducers are used at position of the high speeds of sheet making jumping and straching on the material surface. So, the precision measurement can not be performed at high speed. If the sheet surface quality is not in form, the precision measurement of thickness can not be correct.

In the metal industries measurement conditions are frequently difficult. The sensors are expected to perform flawlessly. Their reliability must be high, maintenance requirements must be low and measurement accuracy must never be compromised.

Contact type measurement technology requiring mechanical contact with the workpiece, such as the use of wheels or points to measure dimensions, is too fragile to withstand the mechanically demanding conditions. In addition, its measurement accuracy diminishes at high speeds and when workpiece surfaces are less than perfectly smooth and clean.

In 1950, Taylor and Hobson Ltd. have been made a modern electro- magnetic micrometer which continuously measures the thickness of roll strip [5].

This measuring machine is approximately similar our measuring machine product. To make the necessary measurement, the probe must not contact the surface or disturb the wave motion. In addition, the plate will be vibrating independently of the probe, at used wheels contact on surface, requiring that this motion not affect the probe measurement substantially. This thickness measurement of cold rolling principle was established by UVB, ABB, VOLLMER. Fig 1.1 shows, contact type measuring machine used in cold rolling industrial area.

ABB Automation Technology Products, AB type on-line measurement machine (1980-2005). UVB TECHNIK s.r.o. Republic are made contact type on-line measurement machines model; MTUP-301, MTP - 1301, MTP 2001, MTP – 3001 (1970-2005)., Friedrich VOLLMER Feinmessgeraetebau GmbH VBM 1063, VBM 1076/2076 used up 15 mm thickness, VABL 296/12 used tin metal (1960-2005). Specification of modern thickness measuring machine are include in APPENDIXA-6

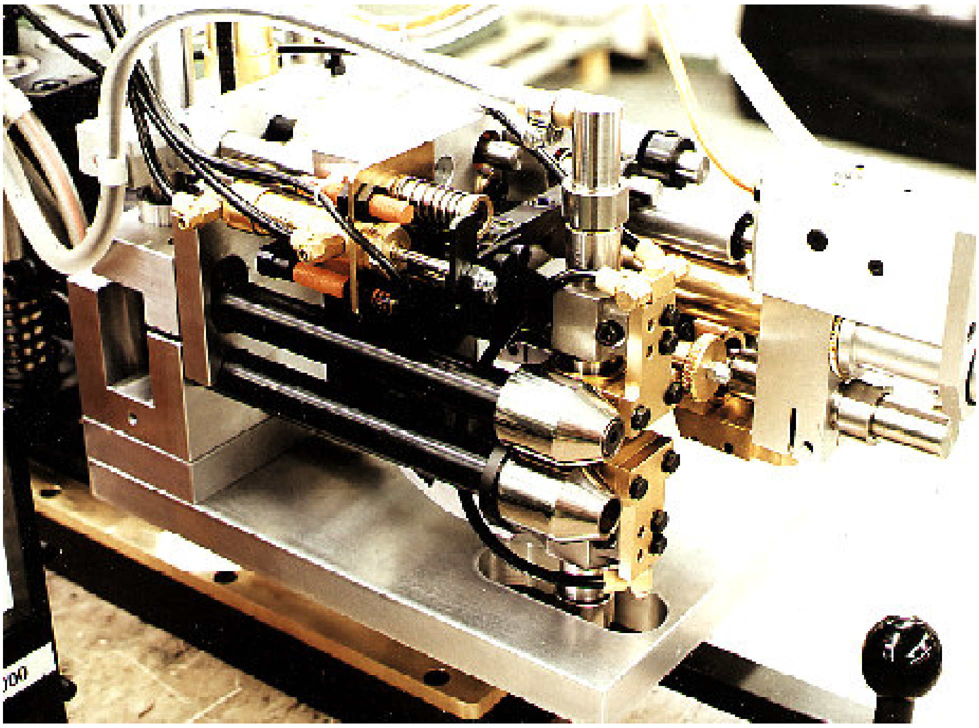


Fig 1.1 Continuous strip thickness gauge for narrow sheet by VOLLMER, model VBK 593/12

1.2 Outline of the Thesis

In the thesis, in the first chapter, a short introduction to the cold rolling process and its thickness control is presented.

Chapter 2 includes information about the rolling of strip and measurement type, effects of thickness variation along the length of rolled strip.

In chapter 3, design and construction of the system is introduced. The operation principles also are explained.

In chapter 4, the written software for thickness measuring machine is given and explained. The test results are presented. The plotted graphs with computerized machine are also included.

Discussion and conclusion are given in chapter 5. The further recommendations also are included in this chapter.

CHAPTER II

THE ROLLING OF STRIP OF SHEET METAL

2.1 Introduction

Many of the economic benefits resulting from mass production derive from the efforts of producers of strip and sheet materials to improve this quality of their products and continuous efforts are being made to provide the user with more accurate material regarding to dimensional uniformity. Also, with the modern, highly mechanized rolling plant described, the processing of coiled strip, especially at the high working speeds, is becoming more and more exacting for the mills and their ancillaries. Good-shaped strip is also of paramount importance, since large numbers of presses and similar machines are continuously fed from coiled stock [5].

The importance of gauge uniformity across the width of rolled strip and sheet materials a study will be made of the main operating factors which govern the obtaining of this quality, namely, the correct shaping or cambering of the rolls, the correct loading conditions, both with respect to the design of the camber and to the rolling of the material, and the means employed to generate the desired camber on to the face of the rolls. Modern industry demands a high standard of surface finish on steel strip [6].

2.2 Plastic Working by Rolling

Plastic working of metals is one of numerous methods permitting the manufacture of products of desired shape and size. It consists in applying compressive forces of appropriate magnitude to the metals being deformed. Industrial practice uses various plastic working techniques such as rolling, forging, pressing, stamping, extrusion or drawing. [2]

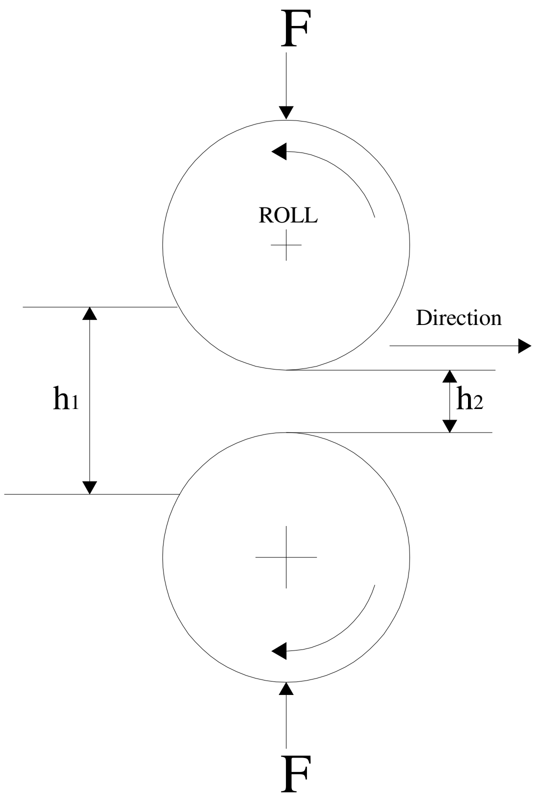


Fig. 2.1 The longitudinal rolling process

During rolling the desired shape of metal is obtained by plastic deformation taking place between two rolls with parallel axes, revolving in opposite directions. In addition to change of shape affected in a purely mechanical way, the metal undergoes structural changes, which in turn result in a variation of physical properties. Fig. 2.1 briefly shows cold rolling process shape with sheet motion.

During longitudinal rolling (Fig. 2.1) deformation takes place between the rolls with parallel axes, revolving in opposite directions. Due to friction the metal is drawn into the rolls and undergoes deformation. During this deformation the ingoing height of the stock h_1 is reduced to h_2, while breadth and length of stock increase; the latter usually much more than the former. In longitudinal rolling the metal moves forward along a straight line perpendicular to the roll axes and the (ε_p) plastic deformation takes place mostly in this direction [5].

2.3 Fundamental Phenomena of Cold Rolling

Any solid matter changes its shape and dimensions in nature when subjected to the action of external forces. This change is called as deformation being elastic or plastic. The former occurs when a deformed body entirely recovers its original shape and size on removing the external load. The latter occurs when the body does not recover its shape and dimensions on removal of the external load.

Up to a certain stress, if the load is removed, the specimen will return to its original length. For stresses between zero and this value, the response is elastic, and the uppermost stress is known as the elastic limit. For some materials, the elastic limit and proportional limit are almost identical. [7].

When metal is rolled, it is squeezed between two revolving roll. The crystals are elongated in the direction of rolling, and the material emerges at a faster rate than it enters. Annealing or normalizing processes heat the metal above its recrystallization temperature and reform and relax the grains [8].

2.4 Cold Rolling

The aim of the rolling process is to reduce the thickness of a strip to a desired value. This is done by applying a force to the strip while moving through the roll gap.

Fig. 2.2 shows, the rolls making contact with the metal surface. The rolls make contact with the metal over make a length of contact depicted by arc AB. At some point of contact the surfaces of the material and roll move at the same speed. From C to the exit at *A* the metal is in effect being extruded and moves faster than the roll surface. The metal is moving slower than the rolls between points C and B, and the resultant friction force over arc CB draws the metal between the rolls. The position of the no-slip point C in arc *AB* depends upon the amount of reduction the diameters of the rolls, and the coefficient of friction. Point *C* tends to move to *A* as the amount of reduction and the angle of contact increase. [9].

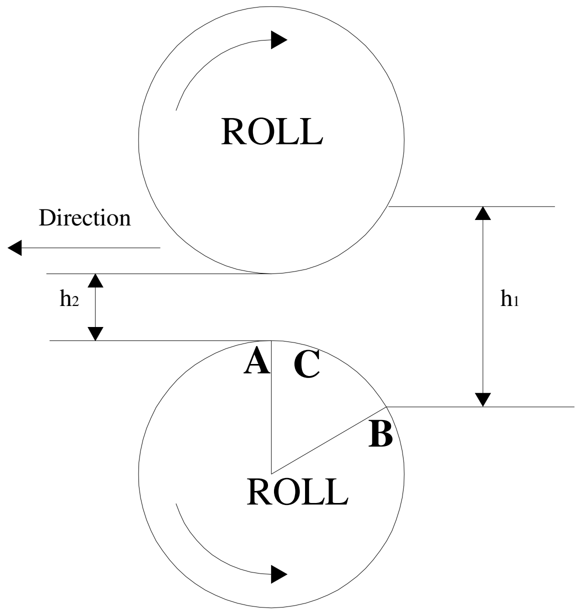


Fig. 2.2 Rolls contact with the metal surface

Thickness variations across the width are however a complicated function not only of roll bending and compensating chamber, but also of the differential thermal expansions along the barrel caused by the heat of deformation.

The surface finish imparted to the strip depends upon the surface finish of the rolls, the total reduction and the number of passes and upon the strip lubricant. With good technique, cold rolling can achieve an accuracy of ± 0.002 mm in thickness both across the width and along the length of a coil. Special precautions are necessary to maintain a higher accuracy than this on normal finished gauges [10].

2.5 Effects of Thickness Variation During Rolling of Sheet

Methods of measuring the thickness of rapidly moving strip as it leaves the mill and to recent proposals for minimizing gauge variation, which, to a greater or lesser degree, is invariably present throughout the length of cold rolled materials.

The causes responsible for variation in thickness along the length of cold-rolled strip may be divided into three main groups, namely, those associated with the rolling operation itself, those which are due to dimensional and other inaccuracies in the material after the preparatory stages of cold rolling, and those which result from the non-concentric running of the rolls. Regarding to the rolling operation itself, variation in speed during rolling and changes in the magnitude of the tension applied to the strip are the more important factors. Although if temperature changes in the rolls occur while the material is passing through the rolls, this can introduce significant changes of thickness along the length of the strip [11].

If, the strip grows thicker, this will lead to a force change in the roll gap. Due to the compliance of the rolls, the bearings, the hydraulic system and the mill stand, the gap will increase and the outgoing strip will have a thickness deviation from its desired value. The rolling speed has also an influence. The rolling force is the dominant control factor when rolling hot strip and thick cold strip, whereas on thin strip and foil the tension and speed are dominant.

2.5.1 Roll Effect

Sheet thickness measurements may be carried out at the centre or the edge of the sheet so long as they are both carried out in the same place. Differences in thickness between centre and edge of sheets are from 2% to 10%. The minimum value of 2% applies to modern efficient mills, and 10% to rolling of sheet on old type sheet mills using old-fashioned rolling methods. If a two-high mill, having parallel rolls, is employed to reduce the thickness of metal dimensional variations such as these, not only adversely affect the quality of the finished material, but they also impede the rolling process, and for efficient and smooth production it is essential, at every stage of rolling, to control the variation of thickness across the width of the material [12].Variation of surface temperature of the roll should be as small as possible in cold rolling, as it causes variations of thickness of the rolled stock. The ideal rolling condition is when the heat lost by cooling is equal to that gained during rolling.

Roll wear is kept to a minimum by the use of hard material resistant to abrasion e.g. chilled cast iron or hardened alloy steel with a hardness of 570-670 Brinell. Under operational conditions, a correctly chosen rolling schedule should keep down roll wear, and minimize dimensional variations of the finished product [13].

Surface finishes on work rolls differ, depending upon the mill product. Rolls used for rolling tinplate are ground to a much finer or brighter finish than those for a mill rolling sheet product. This is of particular importance, for the rolls used in the last stands of a tinplate mill where the product of a very good surface is essential [14].

2.5.2 Speed Effect

During rolling, similar frictional forces operate, as can be seen the speed conditions in the throat of the rolls. Considers that the main factor which contributes to longitudinal gauge variation consequent upon change in roll speed is a gradual change in the length of the arc of contact due to elastic deformation of those parts of the surface of the rolls which are in contact with the material, the pressure sometimes developed in the throat of the rolls often being high in magnitude [13].

The magnitude of the reduction and thickness involved both influence the extent of gauge variation due to changes in speed, and, unfortunately, but among the few quantitative results quoted by him it is stated that during acceleration the variation in thickness of the strip leaving the last stand was 30 per cent [15].

2.5.3 Friction Effect

In the cold rolling of strip steel, friction is a necessity between the rolls and the strip because all the deformation energy is transmitted from the rolls to the strip by shear stresses set up at the working interfaces. A new strip surface is being produced at this stage, and too high a level of friction can adversely affect this surface, resulting in poor quality strip and high levels of rejection [6].

2.5.4 Lubricant Effect

The control of friction during cold rolling is dependent upon the rolling oils. On modern high-speed mills the requirements of rolling oils are, therefore, exacting, and the selection of the right type of oil is vital to the successful production of high-quality strip. Replacement by a poorer lubricant will increase the rolling force and lead to strip with full edges [8].

The change in the appearance of the strip surface with a change in the lubricity of the rolling lubricant is attributable. The neutral point is moved towards the entry plane and the slip between the outgoing strip and each roll surface is increased with the result that more buffing occurs to produce a brighter strip.

In the cold rolling of steel sheet and strip, good shape or flatness and a uniform surface finish are two of the principal qualities sought in the rolled product [3].

2.5.5 Longitudinal Gauge Variation

Longitudinal thickness variation is non-uniformity of hardness which sometimes occurs along the length of the hot-rolled stock. Also, at the earlier stages of cold rolling, quantities of the tightly wound coils are annealed in what are termed batch furnaces, and in order to ensure that the material is satisfactorily annealed it is necessary for the furnace temperature, and the time it is maintained, to be fairly accurately related to the mass and the grade of material placed in the furnace [15].

The total amount of gauge variation that is to be expected along the length of individual coils depends on the operating conditions which obtained during the preceding stages of the production of each coil and these conditions may vary from coil to coil. On the other hand, if another coil, reasonably uniform in gauge, had soft ends before rolling, then the variation in thickness along the length, after rolling, may be greater than for the coil characterized by thick ends before rolling[11].

Having now generally indicated the extent of thickness variation to be dimensional quality of the finished material markedly depends upon the amount of thickness variation induced during the preparatory stages of rolling, attention will be directed to some of the main causes which contribute to the production of longitudinal gauge.

2.6 Thickness Measuring Instruments

Part of every measurement is identifying how "good" the measurement. This is a complex combination of a number of factors: the quality of the transducer used to pick up the measurement, the connection of transducers to the object made tested, and the quality of the data acquisition/conversion devices. Fig. 2.3 shows, thickness measuring region in cold rolling process.

The controlled pass-line allows the strip gauge to be more conveniently measured continuously by a strip thickness measuring machine. The thickness of strip material issuing from the rolls was within specified a limit was the simple hand micrometer. The type of measurement that can be made performed as the continuous non-contacting and contacting type [17].

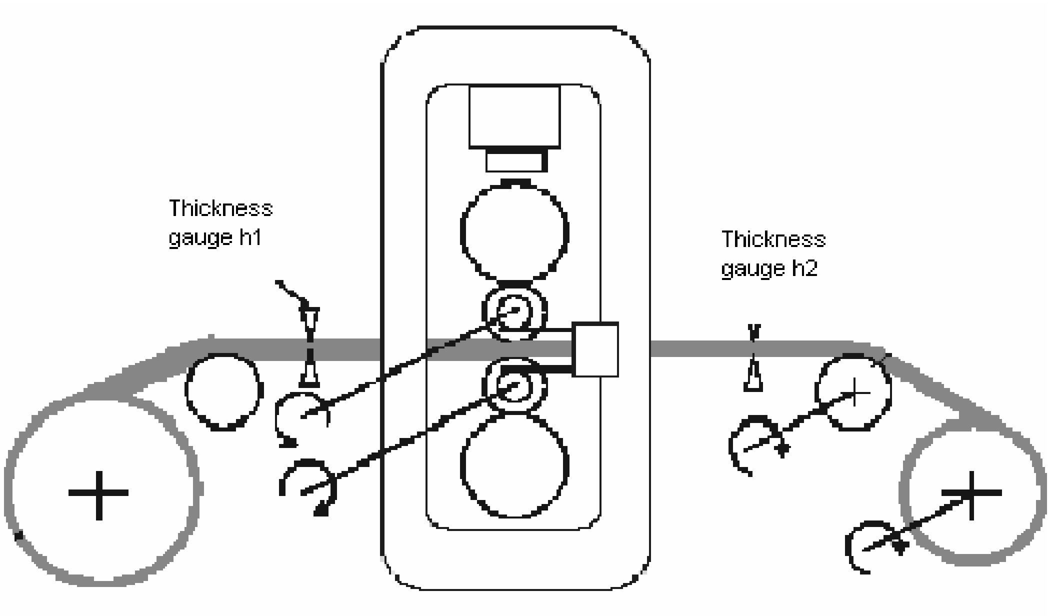


Fig. 2.3 Thickness measuring regions

2.6.1 The Continuous Non-contacting Type

Measurement of thickness by means of radiations associated with atomic and nuclear physics has been studied for a number of years and during the last decade, or so, instruments utilizing beta, gamma. Disadvantages of systems employing radioactive(and X-ray) radiation are seen. However, even radiation is reduced when penetrating water, particulates and steam and is also affected by dirty workpiece surfaces. Besides, the hazardous nature of radioactive radiation makes this technology particularly difficult to implement.

Any variation in light intensity at the upper measuring head automatically regulates the position of the deviation wedge so that the change of thickness becomes equal to zero. Therefore the position of this wedge is always a function of strip thickness, and the difference between actual and nominal value of thickness of the rolled strip is indicated on one or several dials by means of electrical relays. [12]

The instruments are so constructed that either the amount of radiation transmitted through the material is used as a measure of its thickness or the amount of back scatter from one surface, these two types of behavior being termed the transmission and the back-scatter type respectively. [12]

Regarding the amount of radiation transmitted or back-scattered, this for any one material of a given thickness depends primarily on the density of the material and, although only to a limited extent, on the chemical composition, but metallurgical condition plays no part. In consequence for materials of the same commercial composition, since the density will be virtually constant, calibration of the appropriate dials can be effected in terms of thickness, although most instruments are so constructed that deviations from a set thickness are recorded and not the thickness itself. For materials of different densitities, different calibration scales are needed but facilities for changing these are usually provided. As with the contacting type of instrument, certain operating conditions can lead to erroneous readings being recorded. [12].

2.6.2 The Continuous Contacting Type

Continuous gauge measurement provides continuous control during the rolling process, which gives an improved operation of the mills, and reduces the quantity of reject products when the strip thickness tolerances are exceeded.

Automatic gauge control consists of three interconnected operations, one which detects the amount of deviation from the desired thickness, one receives and the other amplifies the signal. However, regarding to the first, which involves the means used to detect deviations from the required gauge. One has concentrated on development in which thickness measuring machine are used as the monitoring device. [18].

Fig 2.4.a is shown, different viewed measurement position, measurement made by diamond tip transducer. This transducer making jumping and straching on the material surface at the high speeds of sheet.

Linear differential transducers with rounded natural or synthetic diamond inserts contact the strip surface from above and below. The evaluation of the differential signal results in the strip thickness.

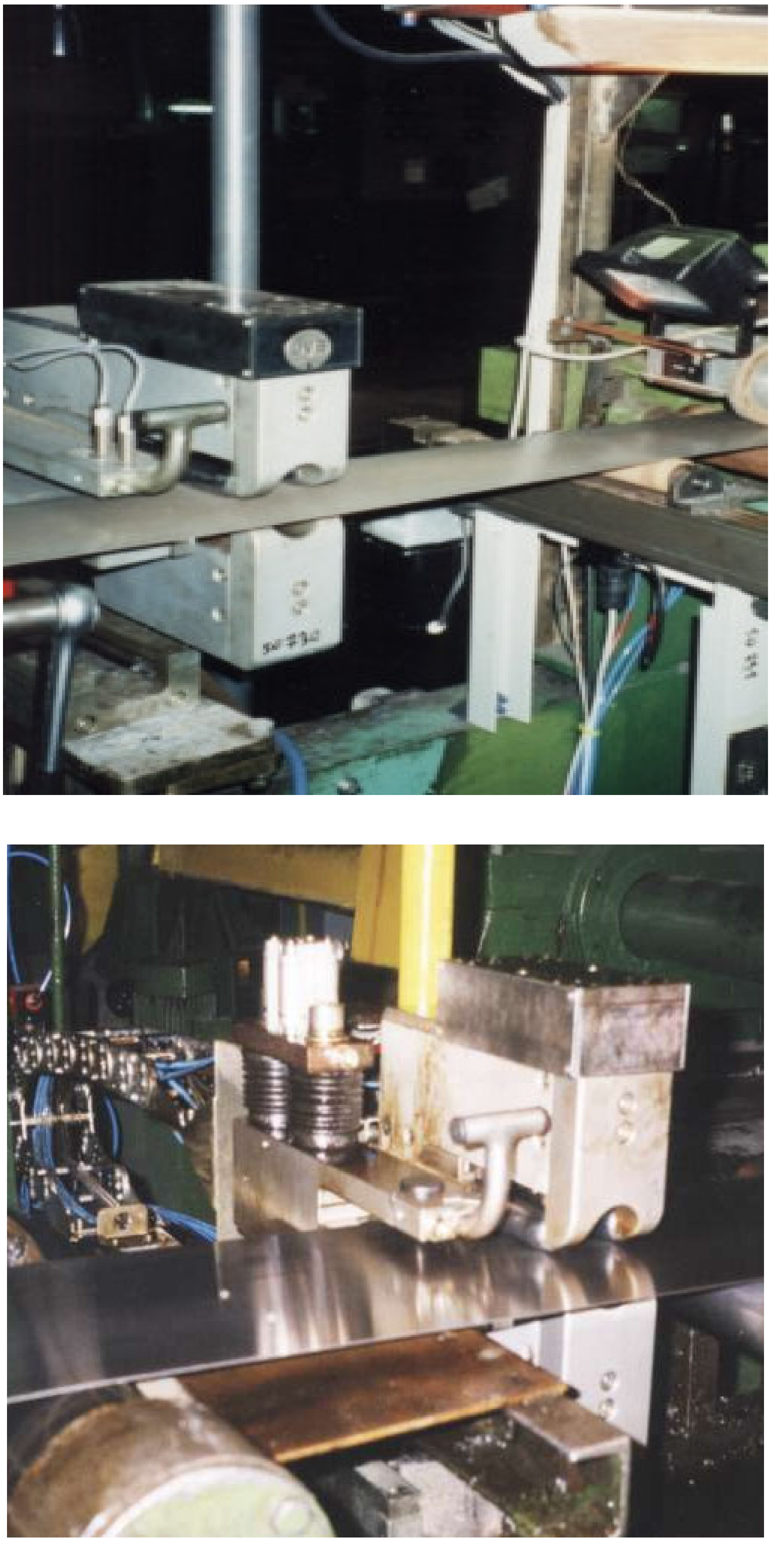


Fig. 2.4 Modern thickness measuring machine, at different working position

CHAPTER III

DESIGN AND CONSTRUCTION OF THE MEASUREMENT SYSTEM

3.1 Design and Construction of the Thickness Measuring Machine

The aim of this section is to obtain measurement data which can be used to verify the new model. To define the thickness of a plate, three parameters must be taken into account:

1. the distance between the coil and the work-piece,
2. the electrical resistance, and
3. the thickness of the metal plate, strip or bar.

When thickness measuring machine is applied to this type of measurement, one of the parameters must be kept constant. A design that would maintain the distance between the coil and the workpiece is one possibility.

Contact type thickness measuring machine is a device measuring the thickness of the cold rolling sheet metal. Primary considerations in the proper instrument selection process include the calibrated range(s) required to obtain the classification (accuracy) required.

The transducer is mounted on a base of size support. The rollers are manufactured from C1040 carbon steel. To reduce the vibration effect on the thickness measurement, C8640 carbon steel springs are used on the main frame feet. The main frame is mounted on the base frame through two sliders. These sliders move the main frame back and front. This makes easier the measurement of 200 mm wider sheet.

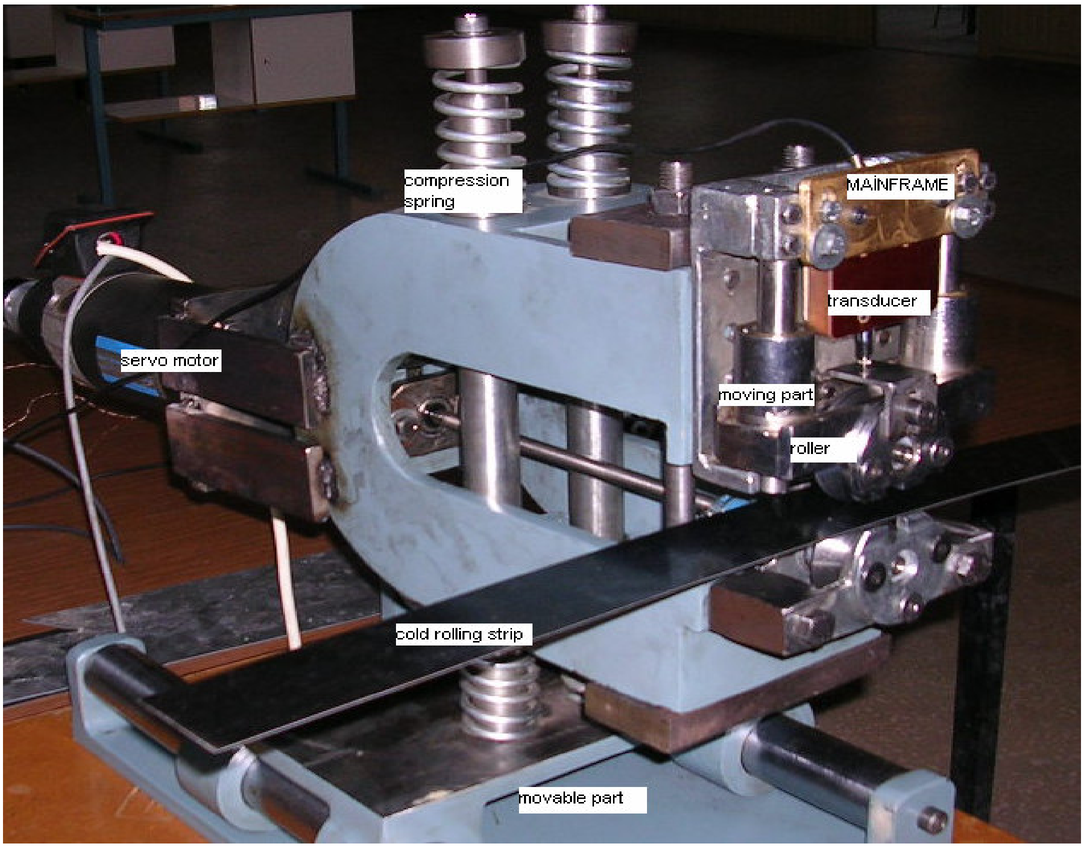


Fig. 3.1 Thickness measuring machine

Photography of the unit is given in Fig. 3.1. Movable measuring points with two traversing measuring heads are followed by the strip edge. One measuring head is fixed over the strip centre line. Movable measurement points are with either a fixed or a carrying two fixed measuring heads.

The technical drawing in Fig. 3.2 illustrates a thickness measuring machine of the automatic type and it will be seen that the flat anvils of precision LVDT are replaced by two steel rollers. With this unit, continuous measurements are made, any deviation of the thickness from the required set value causing the upper roller to move vertically relative to the lower one, this movement, which is measured by reference to the amount of disturbance of a move transducer with magnetic field, being recorded, after a considerable magnification, on the meter scale standing to the right.

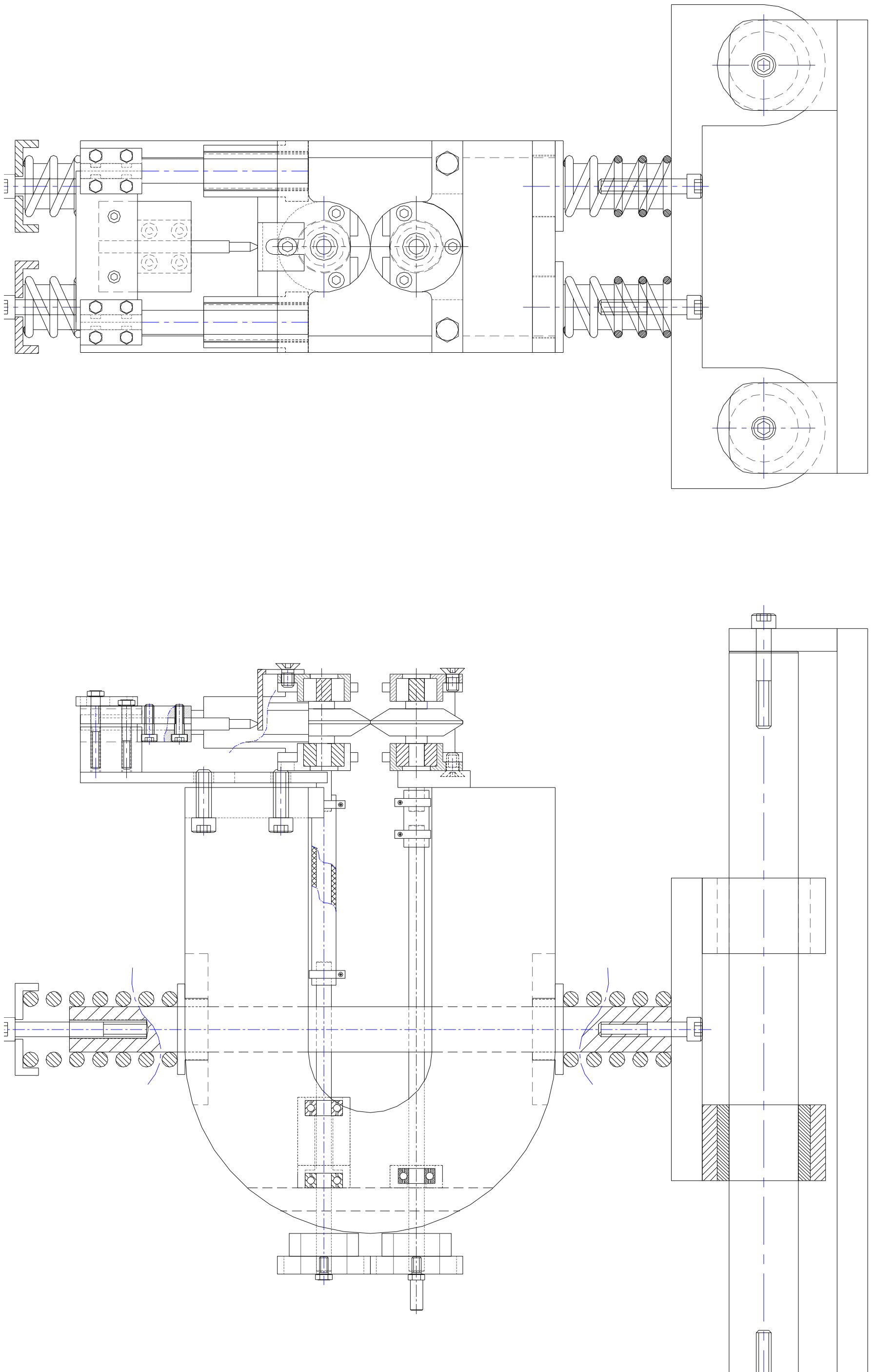


Fig. 3.2 Technical drawing of thickness measuring machine

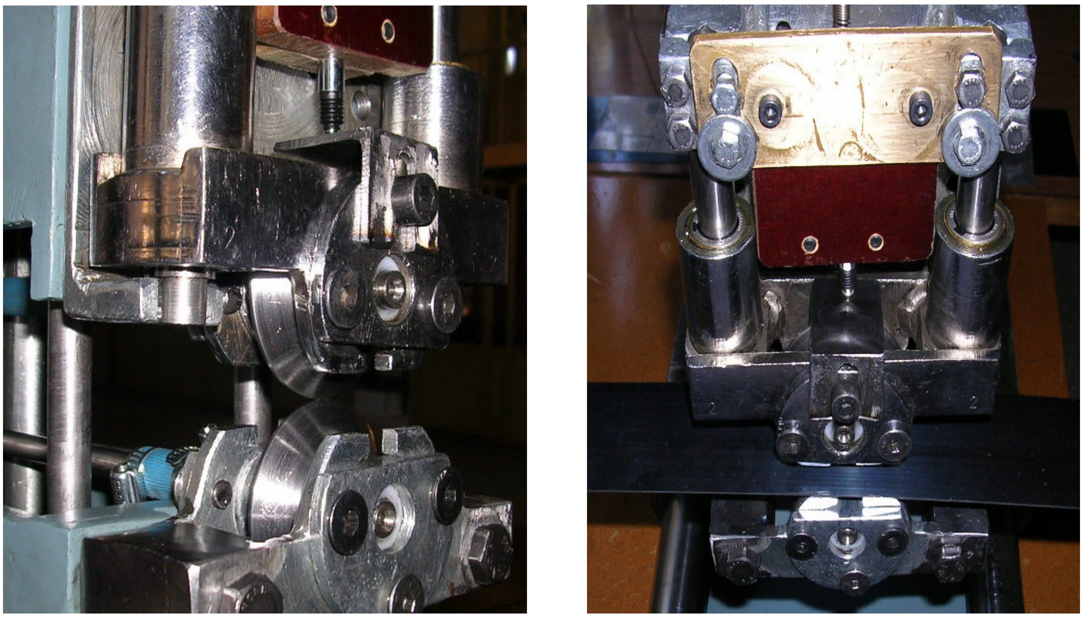


Fig. 3.3 The moving part

The photography of the moving part is shown in Fig. 3.3. The LVDT transducer is connected to the upper roller. This transducer is mounted with fiber material. The transducer has a free ends. This free end is on the ground and the polished surface. This surface is parallel to the upper roller axis. The transducer is used for converting displacement into electrical signals (Ampere, output signal, is linearly proportional to its displacement.)

A transducer is a device that converts physical phenomena such as distance, stress, or temperature, into equivalent electrical output signal. The electrical signal is usually an analog signal, a continuously variable voltage directly proportional to the magnitude of the phenomena. Some transducers are self-generating like thermocouples, piezoelectric transducers. The transducers that used in this thesis, LVDT for distance measurement. The connection of these transducers with mainframe and communication with PLC (Programmable Logic Controller) will be explained after this section.

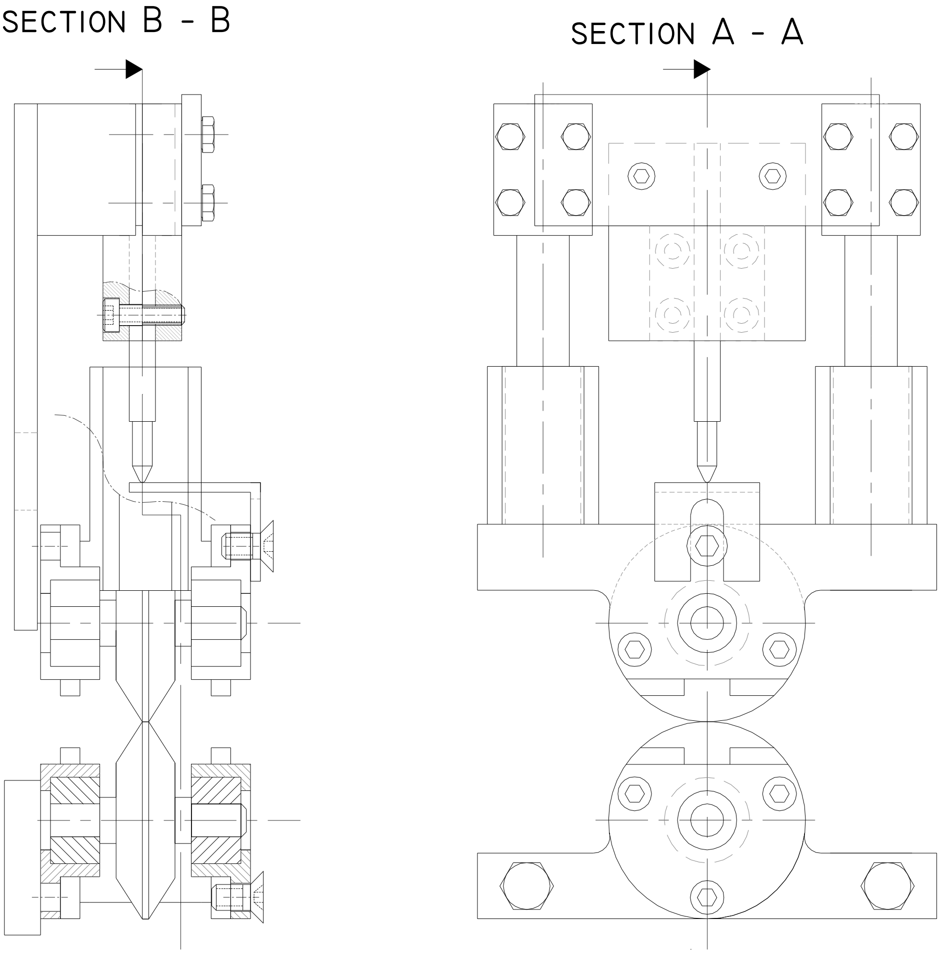
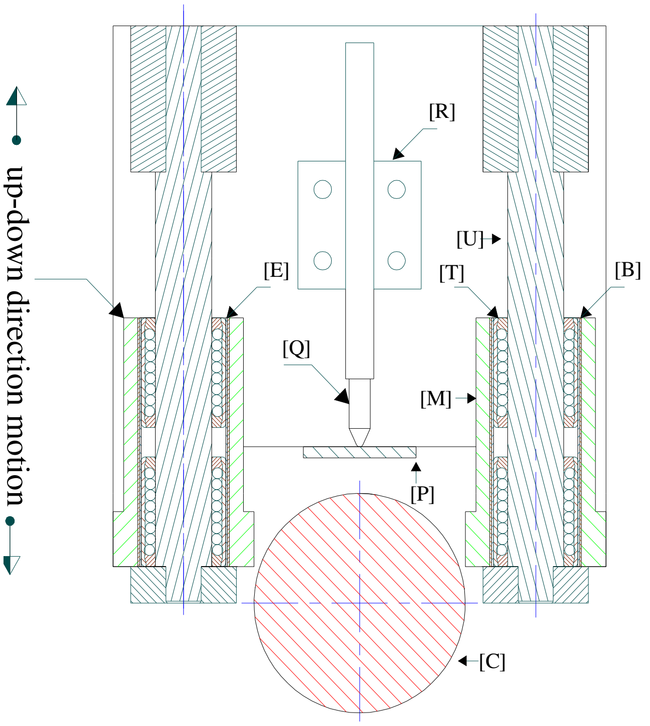


Fig. 3.4 The horizontal mechanism

Fig. 3.4 shows, the horizontal mechanism of the thickness measuring machine. As section views by use of a weight mechanism loaded arm, a limited amount of vertical float of the unit as a whole is possible and, because of these compound movements. However, if material of bad shape passes through the rollers, or if the strip oscillates above, or below the pass line, erroneous readings may be recorded. The technical drawing (B-B, A-A section view) in Fig. 3.4 illustrates a sliding mechanism by weight of mainframe.

The parallelism between two pair bearings are assured, while the bearing assembly is made. The bearing is merged in the brass shell, to do this. This brass shell is glued on the base metal with by 502 type adhisive.



THICKNESS MEASURE MACHINE ASSEMBLY

PART	DESCRIPTON
[M]	LINEER BEARING HOUSE
[Q]	LVDT TRANSDUCER
[P]	GRINDING SURFACE
[U]	GRINDING BEARING SHAFT
[E]	BRASS SHEEL
[R]	TRANSDUCER CONNECT PART
[C]	ROLLER
[B]	502 GUIDE
[T]	LINEER BEARING

Fig. 3.5 Detailed drawing of the moving part

Fig. 3.5 shows, all of the parts in detailed of the main frame. The relation between the sheet thickness variation and the upper roller movements is adjusted by two linear bearings which are mounted parallel with respect to each other. These two parallel linear bearings are mounted on the machine to measure the thickness variations precisely.

The supports have linear bearings that have been fitted. These linear bearings make easy to move the weight on it. This bearing has a coefficient of friction of 0.001 to 0.005. This support starts roll and slip over precision-grounded shaft together with different thickness of sheet metal. To achieve smooth movement, two pairs, two linear bearings per support are used. At the same time, this prevents the deflection on the shaft. The parallelism of the thickness measuring machine shaft and mainframe shaft is checked out by means of a 0.01 accuracy dial indicator mounted on the main frame.

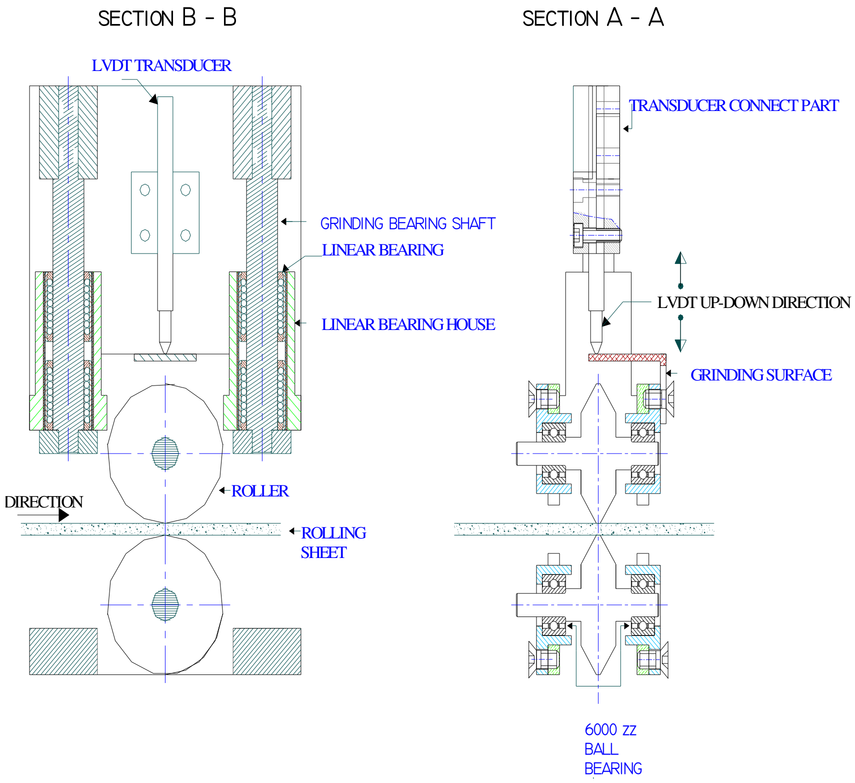


Fig. 3.6 Section view of main frame

Transducer is positioned in the path of the measuring bundle, i.e. above the measured strip. The accuracy can be controlled occasionally by putting a strip of known thickness in the field of the measuring beam. Fig. 3.6 shows section view of main frame.

The used transducer in this machine to measure the thickness is the contact type transducer (LVDT). This transducer measures the sheet thickness between the two parallel rollers. The lower roller is rigid and the upper roller is moved up and down directions. As a result of the upper roller movement, the transducer connected to the upper roller, measures the thickness variations along the sheet feed direction. Specification of LVDT are include in APPENDIX-A-2

Thickness measuring machine consists of the transducer, a rolling sheet, a flexible connection part and the mainframe. Fig. 3.7 shows detailed drawing of the horizontal mechanism with sheet moving position.

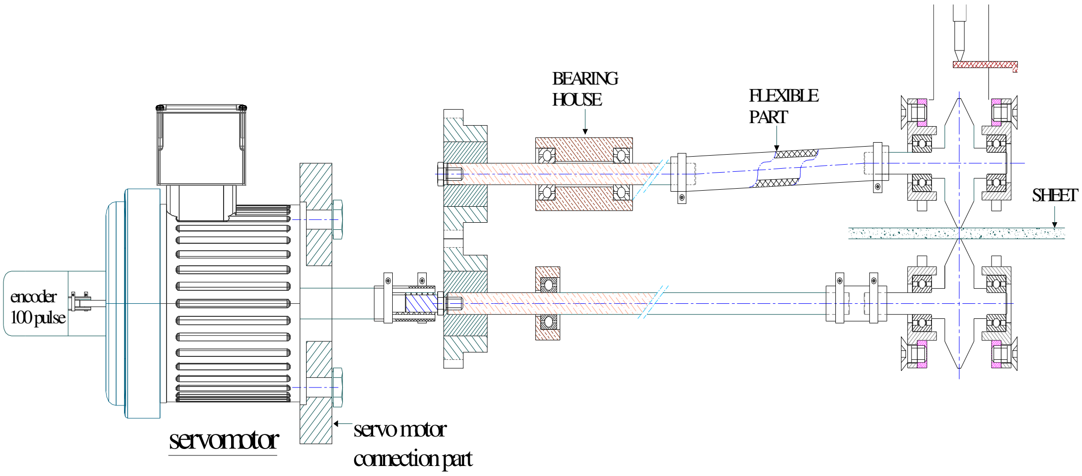


Fig. 3.7 Horizontal mechanism with sheet moving position

The thickness measuring machine is designed for measuring real-time thickness variation by accurately measuring the variation of the cold rolling. The measurement range of the designed thickness measuring machine between -350 and +2280 micron. Thickness measuring machine is required by measurement standards where the measured position of the machine head is an inaccurate reflection of actual measure in the cold rolling process. The strip enters and leaves the mill over pass-line rollers, and usually through guides (for lateral control) and upper and lower pads. The controlled pass-line allows the strip gauge to be more conveniently measured continuously by a strip thickness measuring machine.

3.2 Driver Unit of Machine

Speed and acceleration of the servomotor was controlled by DC power supply with changing the armature voltage. Normally, the servo driver has a digital control unit; it can be programmed by PLC, RS-232 or RS-485 serial communication. Direct DC power supply is used for the set-up.

Fig. 3.8 is shows the servomotor assembly. Bracket is used to hold the servomotor rigid on mainframe and to mesh the gear with each other correctly. Servomotor connection part welded on the main frame connection part welded on the mainframe.

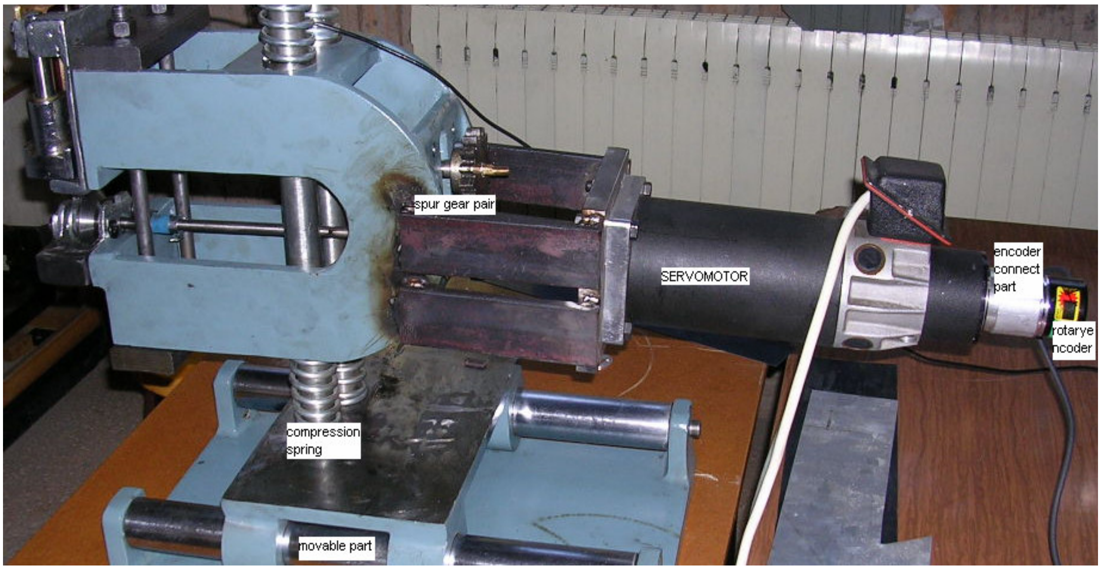
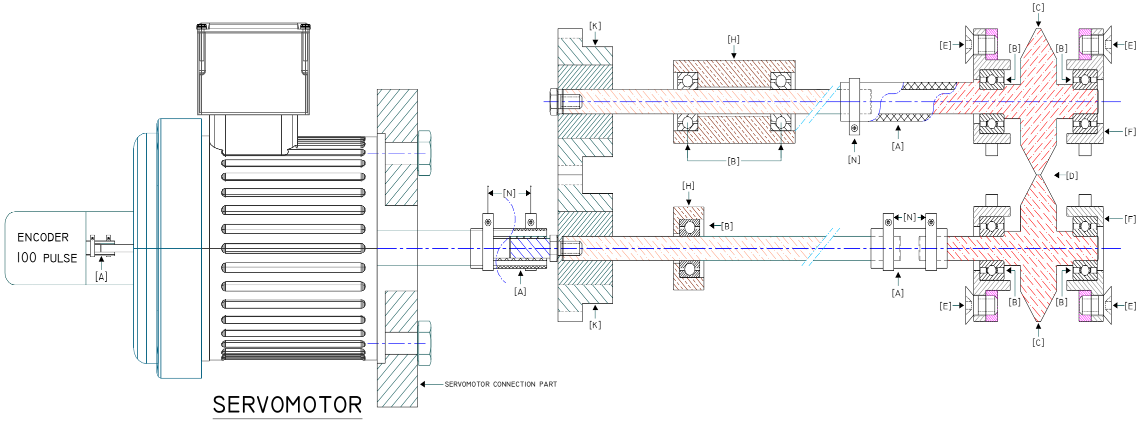


Fig. 3.8 Servomotor assembly

The rollers run synchronously. This synchronization is obtained by a gear pair. Same module of the gear pairs of that is the same as the roller diameter to adjust the parallelism between the gears shaft centers, in Fig. 3.8. In the construction of the upper roller as a bearing material, two polyamides are used.

Two ball bearings are used in the upper gear to facilitate the up-down movement. The upper gear is connected to the upper roller with flexible coupling. The aim of the flexible coupling is to eliminate the eccentricity problems.

The lower gear is driven by the servomotor. All system is run by the lower gear. All of driver parts are mountain on the main frame with a bracket. Fig.3.9 shows a detailed assembly drawing of the measuring machine. It consists of a servomotor connection part, a flexible coupling with driver unit and incremental encoder with flexible coupling. Flexible coupling used to conduct motion between moving parts for non-affected to the eccentricity.



THICKNESS MEASURE MACHINE ASSEMBLY

PART	DESCRIPTON
[N]	PIPE CLIP
[K]	MODUL 4 GEAR
[H]	GEAR PAIR BEARING HOUSE
[F]	BEARING HOUSE
[E]	M8x10 BOLT
[D]	ROLLER CONTACT POZITION
[C]	ROLLER
[B]	6000 zz BALL BEARING
[A]	FLEXIBLE CONNETION PART

Fig. 3.9 Driver unit of the machine

Thickness measuring is operated by touch rollers with cold rolling motion driver gear-pair for synchronization motion, shows in Fig. 3.10. A servomotor was mounted to the mechanical gear-pair of the thickness measuring machine, but actual run can not use servo motor driver.

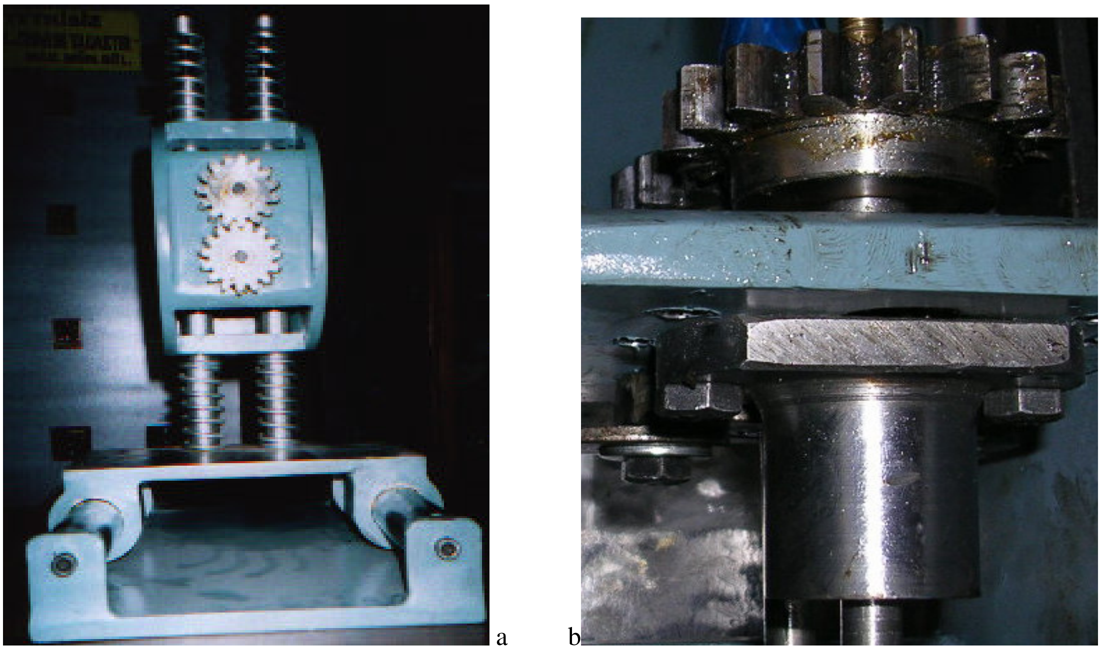


Fig. 3.10 Spur gear pair a) mesh position b) with bearing house

CHAPTER IV

CONTROL OF THE EXPERIMENTAL SYSTEM

4.1 Introduction

Measurement starts with the acquisition of quantitative data, perform data transformation and/or data reduction, and turn the data into results, which is interpretation. Data reduction is important in most measurements because the world is so complex, that the models which are simple to understand and useful are needed. It is interesting to see that although starting with the quantitative data, the interpretation is quite subjective.

This software is designed to enable the users with little or no computing knowledge to utilize the PLC program. The acquired data is analyzed by PLC program and displayed on PC screen. Driver PLC program is the layer of PLC that directly programs the registers of the data acquisition hardware. It manages operation with the computer and its integration with the PLC resources.

In former times, thickness measuring machine were purely analogue instruments, where the entire set-up was performed manually, and data were acquired and processed in the assigned analogue devices. Thickness measuring machine is a part of an integrated system consisting of PLC, PC and the application software. All these operations and processes are controlled from the PC via application software. In order to ensure applicability to the wide range of applications appearing thickness measure research, the thickness measuring machines and PLC system must be highly flexible. Application of PLC is also integrated by the instrument control (HE 10 port and fast counter part) with data acquisition.

4.2 Data Acquisition

4.2.1 Analog to Digital Converter

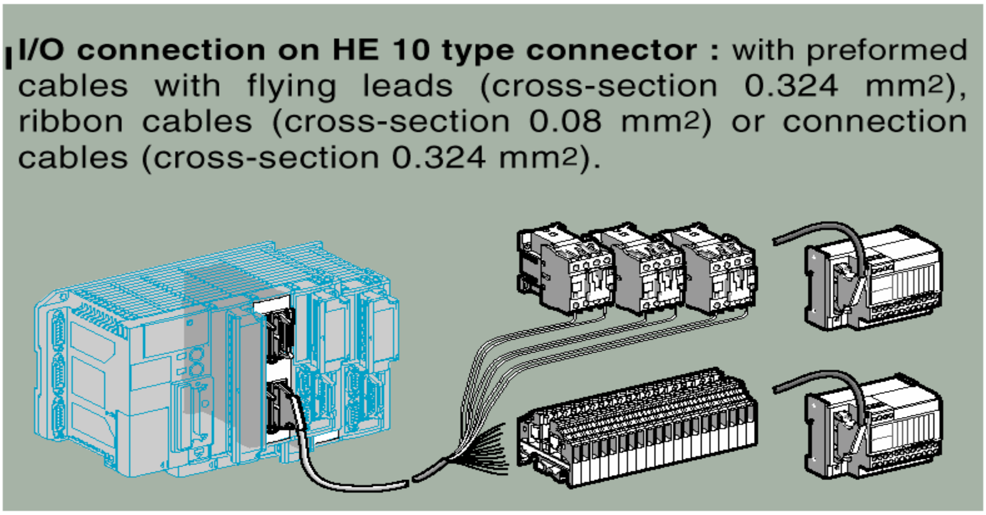
A/D converter often is shared among multiplexed output signals. Standard analog output ranges are essentially the same as analog inputs: ±5 V dc, ±10 V dc, 0-10 V dc, and 4-20 mA dc. Essentially, the logic circuitry for an analog voltage output uses a digital word or series of bits, to drop in (or drop out, depending on whether the bit is 1 or 0) a series of resistors from a circuit driven by a reference voltage. Many data acquisition functions return the actual voltage values returned by the A/D converter.

DAQ board has 12-bit resolution; this means that the board has 4096 codes. The range of the A/D converter for the DAQ product is either -5 to +5 V, or 0 to 10 V, depending on the polarity setting. Notice that each range is 10 V in size. So, each of the 4096 codes is distributed over a 10 V range in either case. However, the pre-conversion gain is still needed, which effectively changes the range over which the codes are distributed. So, gain of 10 is applied, the effective range of the A/D converter in LVDT transducer is -1.5 to +5 V, and the codes are distributed over a 6.5 V range. Thus, each code is worth 6.5/10th as much voltage, resulting in higher accuracy.

The operation of thickness measuring machine has traditionally been considered as a time-consuming task. It includes set-up and optimization of a large number of parameters. In recent years, computer-controlled thickness measuring machines have become available that allow the automatic set-up and calibration. The availability of fast, high resolution analogue-to-digital (A/D) converters has made digital data acquisition and data reduction the most common way to deal with the analogue output from the transducers. Computer-controlled thickness measuring machines therefore support data acquisition by means of A/D boards connected to the PLC. The accuracy of the thickness measuring machine depends on the choice of A/D board.

4.2.2 Transmitting thickness value in PLC

The indicator is used according to the demand in one of the following transmission standards HE 10 connector. A HE 10 connector serial standard is used to cost-effective connection where a 24 V solution is required (mixed I/O modules with HE type 10 connectors for direct connection) for PLC. The connection to the screw terminal block on the front panel of mixed I/O modules is shown in Fig. 4.1. The memory switch is connected with HE 10 serial cable [20].



I/O connection on HE 10 type connector : with preformed cables with flying leads (cross-section 0.324 mm^2), ribbon cables (cross-section 0.08 mm^2) or connection cables (cross-section 0.324 mm^2).

Fig. 4.1 HE 10 type connector

4.2.3 The Network

The data consists of 8 bytes. The number of communication bits sent per second is called as baud rate. The allowable baud rate values for PC indicator are: 1200, 2400, 4800, and 9600. The indicator communicates with PLC at 9600 bps (bytes per second). All remote modules are connected to the network system, PLC, share the same RS-485 network These RS 485 type non-isolated links use Uni-telway, Master/slave, Modbus slave or character string. It can detect the baud rate and the data format automatically and control the direction of the RS-485 network precisely. This method greatly reduces system cost and increases reliability. The photograph of the experimental system is given in Fig. 4.2

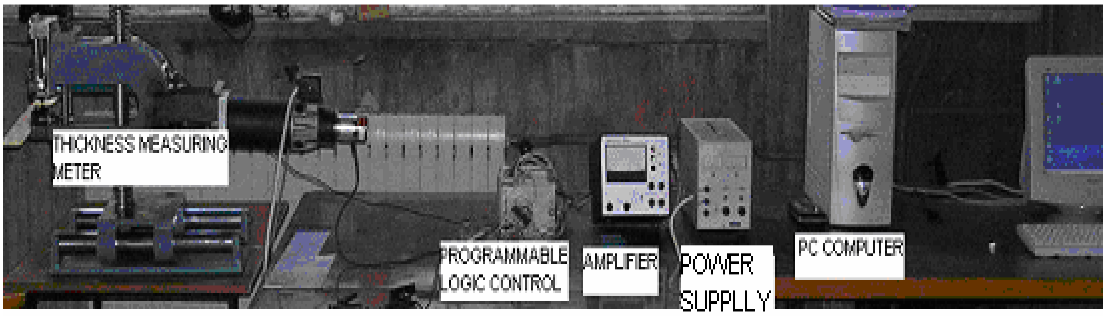


Fig. 4.2 The computerized systems

Since the signals of the thickness control system had to be taken from the 'heart' of the electronic circuits, it was necessary to minimise the risk of disturbance during the measurement procedure, much care was applied for the layout of wiring, shielding and grounding. Further, it was decided, that the usual data acquisition systems, consisting of a PC with analogue I/O boards, would not be sure enough for a stable, disturbance-free operationner over a longer time. For monitoring, a standard PLC (programmable logic controller) was used to collect the essential sensor signals. The signals were fed into analog input modules and processed by the data logging software, via a RS-485 serial interface, the recorded data were sent to a PC. Fig 4.3 shows, the photograph of the logging equipment.

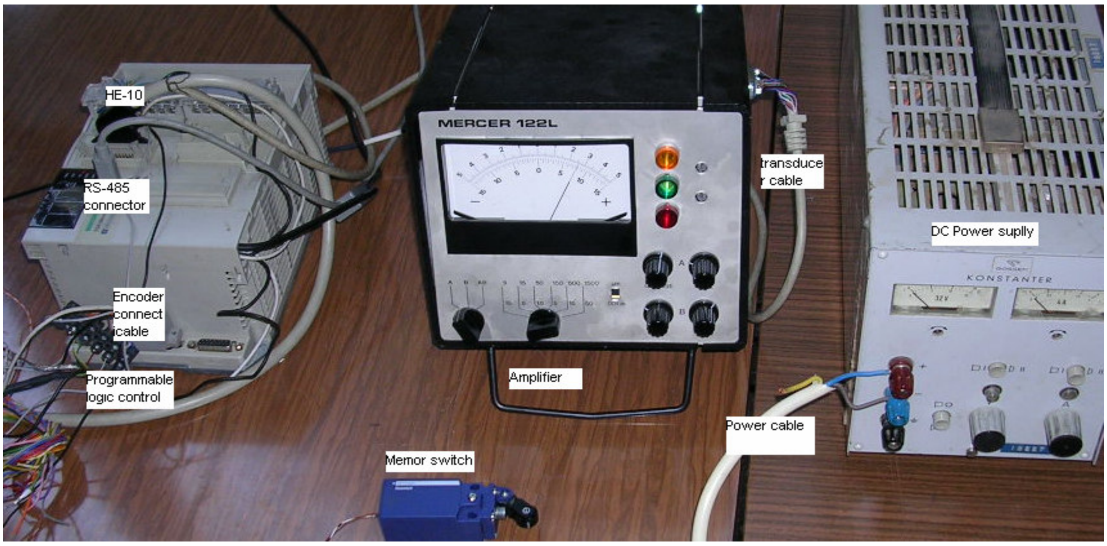


Fig. 4.3 Data logging equipment for the thickness measuring machine

The following signals have been wired to PLC for recording: the roller position by an incremental encoder, the thickness gauge by a transducer, the memory data by a switch. A data-logging system based on industrial PLC components was developedand installed at a thickness measuring machine. Fig.4.4 shows the configuration of system and connection of cable position with connection of electronics part.

The operation of the system can be given as the following principle; the host PC sends out commands via the COM 1, RS-485 network receives this command. Then, the module begins extracting the destination address field and compares it to its local module address. The module whose matched address continues to execute this host PC command, while other modules will bypass it if there is other modules. After executing the PC command, the destination module sends the result back into RS-485 network. The specification of RS-485 serial port are include in APPENDIX-A-1

For this thickness measurement PL7 program, we used LD (ladder) type languages. These languages can be mixed within the same application. One section of program can be written in ladder, another in text. These languages are set up: Pre-defined function blocks (Timing, counters…), application specific functions (analogue, communication, counting…), specific functions (time management, character strings…)

Counter modules Micro PLC counting, using 500 Hz discrete inputs (2 up/down counter channels with up-counting, down-counting or up/down counting functions, with or without detection of direction of operation) 10 khz fast counter channels integrated into bases. Fast counter channels are used, with 0 channels having for up/down counting function. The specifications of TSX 3722 MICRO PLC are include in APPENDIX-A-4

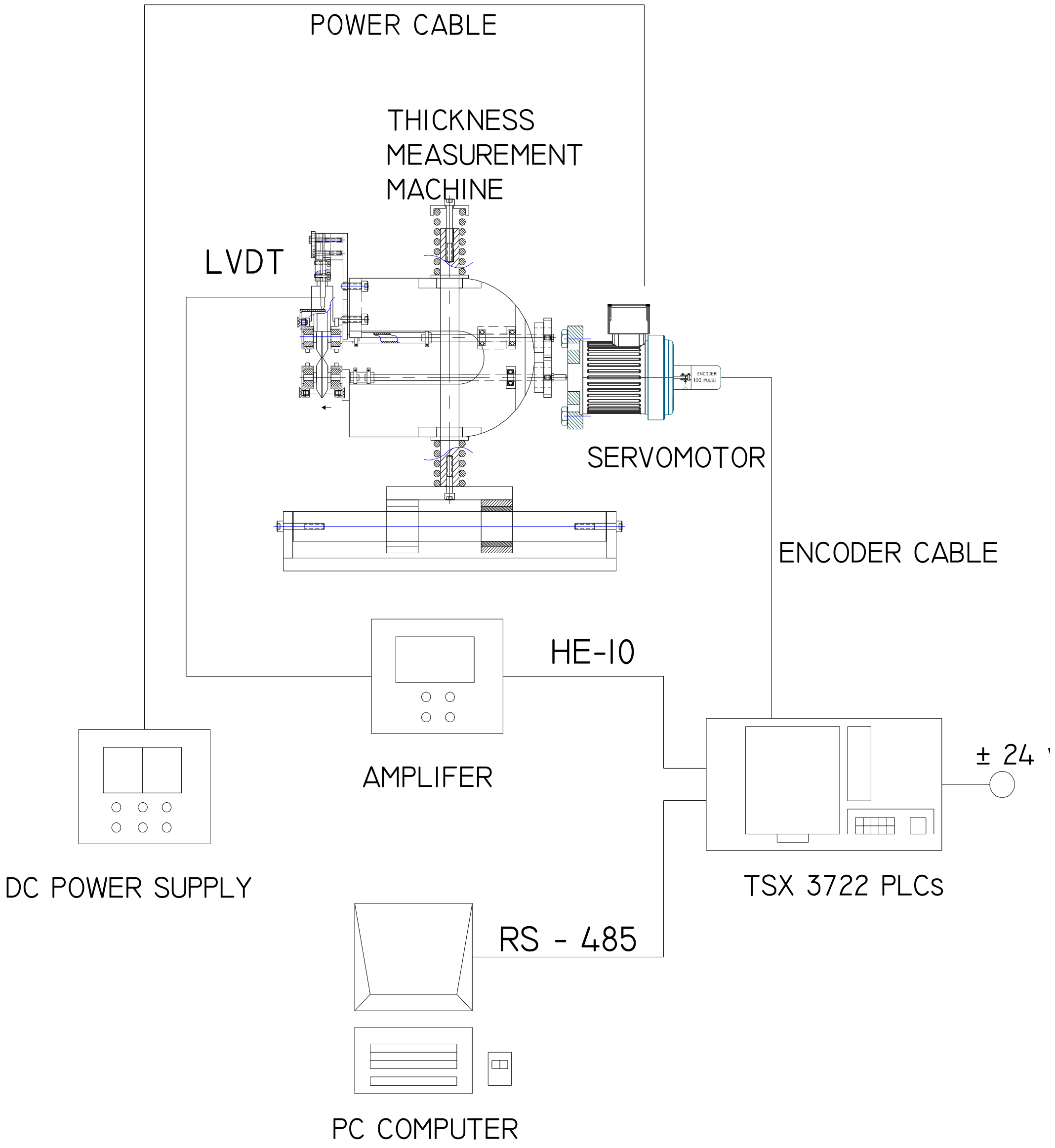
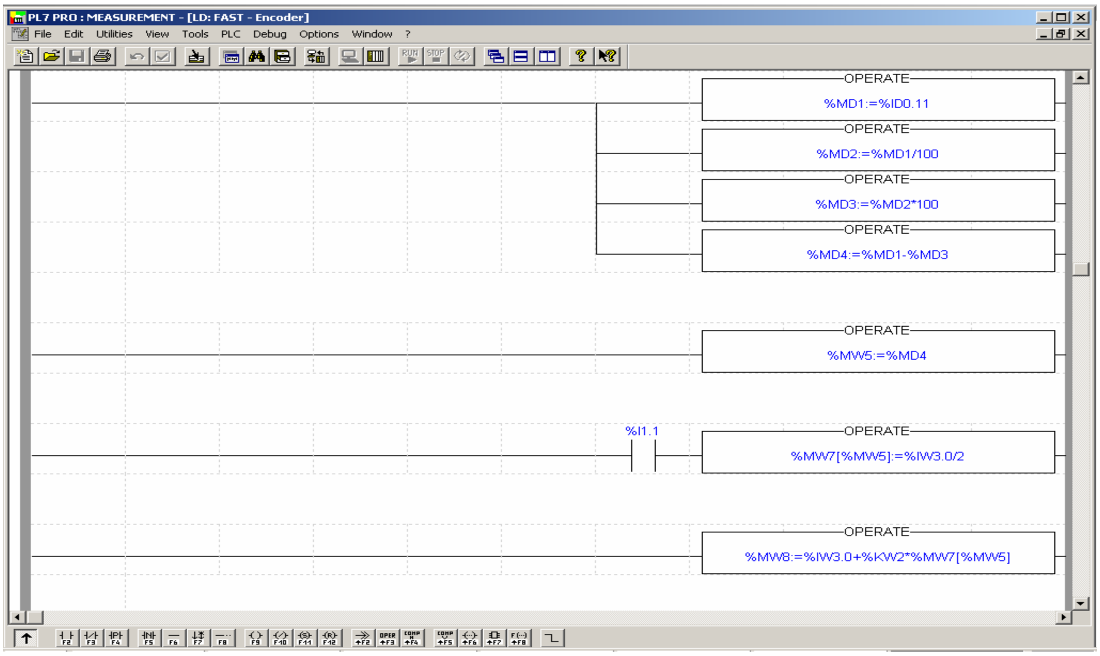


Fig. 4.4 The configuration of system

The faster task represents the program, used for the thickness measurement program. There are two types of measurement programs. These programs run with different LD languages. Fig. 4.5 and Fig. 4.6 nearly show that, PL7 program for the thickness measurement. For this project, nearly twenty PL7 program were made. Specifications of the different measurement PL7 programs are included in APPENDIX-A-5.



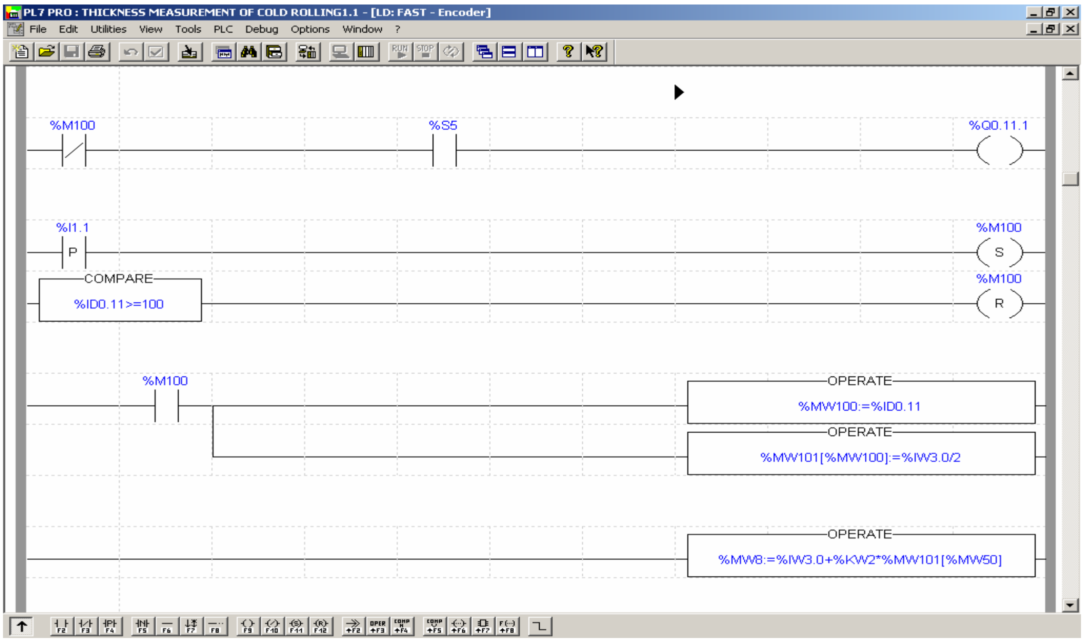
```
OPERATE  %MD1:=%ID0.11
OPERATE  %MD2:=%MD1/100
OPERATE  %MD3:=%MD2*100
OPERATE  %MD4:=%MD1-%MD3

OPERATE  %MW5:=%MD4

%I1.1    OPERATE  %MW7[%MW5]:=%IW3.0/2

OPERATE  %MW8:=%IW3.0+%KW2*%MW7[%MW5]
```

Fig. 4.5 The thickness measurement program LD language, first



```
%M100    %S5    %Q0.11.1

%I1.1 P    %M100 S
COMPARE  %ID0.11>=100    %M100 R

%M100    OPERATE  %MW100:=%ID0.11
         OPERATE  %MW101[%MW100]:=%IW3.0/2

OPERATE  %MW8:=%IW3.0+%KW2*%MW101[%MW50]
```

Fig. 4.6 The thickness measurement program LD language, second

For incremental encoder used %Q0.11, %I1.1 used for the memory switch, and %IW3.0 used for the transducer, in LD language. Program runs briefly as the following, PLC reads the encoder output signal, so the position control can be performed. The memory switch is used for selecting the zero point by incremental encoder (the resolution of encoder 100 pulses at 100 ppr), and so, the roller error values are obtained in PLC memory (%MW7) with by transducer. Fig. 4.5 Thickness measurement program, and can be explained briefly;

%Q0.11: Acknowledge of encoder

%Q0.11.1: Reset command of encoder in PL7 programmer

%MD1:=%ID0.11:PLC read encoder value and known rollers position with A/D

%MD2:=%MD1/100, %MD3:=%MD2*100, %MD4:= %MD1-%MD3 calculation For example:

%MD1=1254. %MD2=12.54 (PLC can not define the latter comma), so %MD2=12

%MD3=1200, %MD4=54 %MW5:=% MD4 : value assignment in %MW5, so %MW5=54 (rollers position)

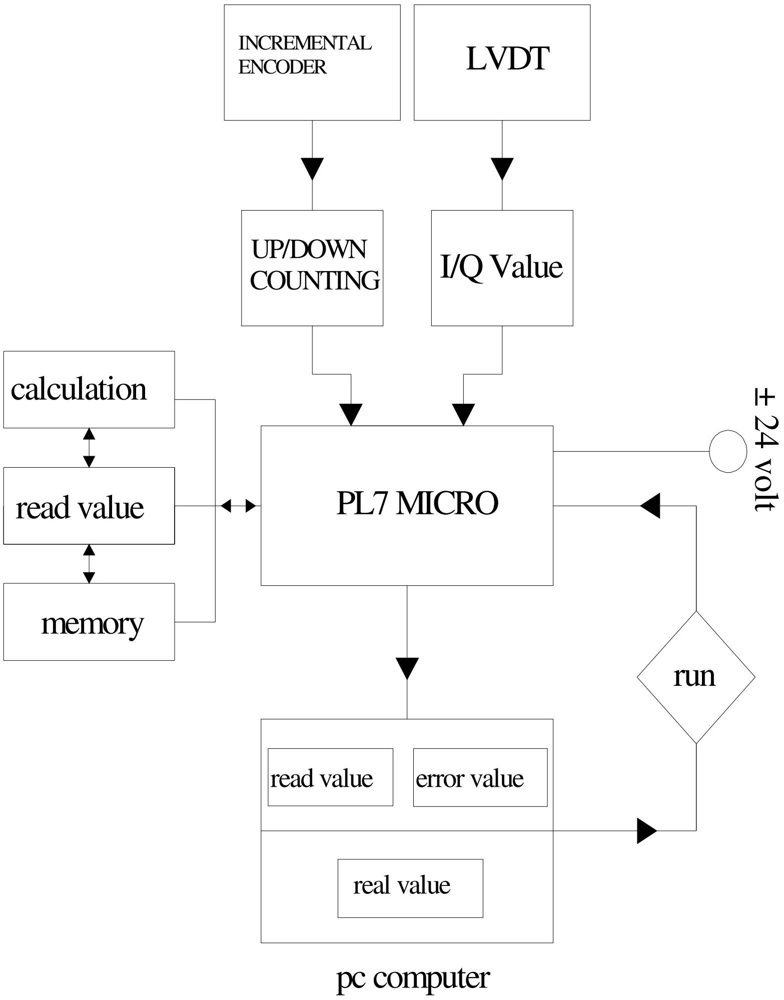


Fig. 4.7 Flowchart of the program

If the sheet is moved between the rollers, PLC reads the transducer value and the subtracted error value of the rollers. Fig. 4.7 shows the flowchart of the program

PLC program at performs position based calculations, reads I/Q value, and counts the position. The counting parameter is adjusted during PLC run mode, in Fig. 4.8. The specifications of the incremental encoder are include APPENDIX-A-3

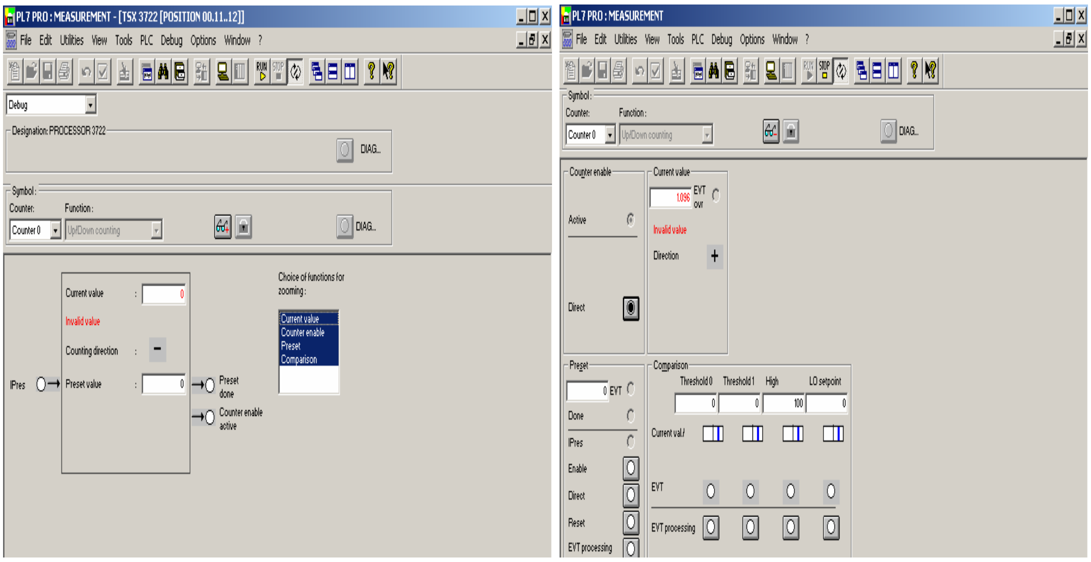


Fig. 4.8 Counter parameter at run mode

Thickness measuring machine improves measurement resolution, control and is selected to match the sheet metal thickness and the error result. When PLC is run, there are two families in the run-time screen, which have the input data (value), and the graphic tabs (Fig. 4.9). These tab tables control PLC.

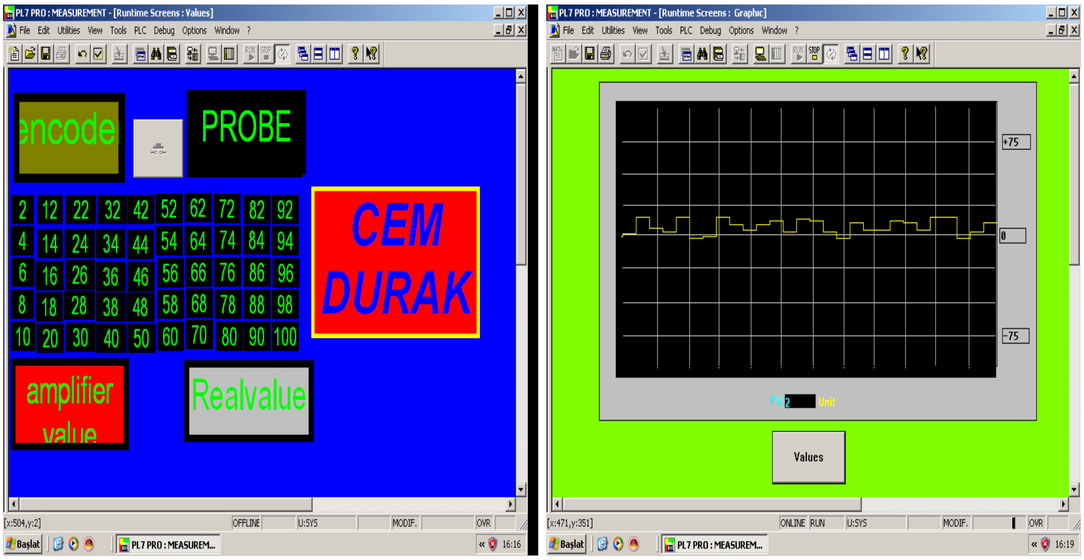


Fig. 4.9 Value and graphic family (run-time screen)

Results

Thickness variation-rolling cycle diagram is plotted on the screen. The thickness of the sheet metals is measured with both computerized system and hand operated micrometer. The operator faults like reading and manual operation errors are eliminated with the computerized system in cold rolling industries.

The experimental thickness measuring machine measures different thickness of sheets with the ranges between -350 and +2280 micron. Thickness variation-rolling cycle diagram values are affected by the cycle time of graph and the rolling speed. Measurements are made at different speeds and periodic time of graph.

The operator can see the actual thickness and the error rolling value of thickness, but also manoeuvre the gauge and get all interesting information about the actual measuring situation.

The input data tab button is used for finding serial ports on PLC and for setting the found serial port parameters used in PL7 program with hardware. Fig. 4.10 shows that, PLC running mode thickness variation-rolling cycle diagram, at periodically increasing with speed.

Measured data is sent to a PC by PLC, where it can be displayed on-screen in the form of trend graphs utilizing thickness measuring machine software for a confirmation of variations in thickness.

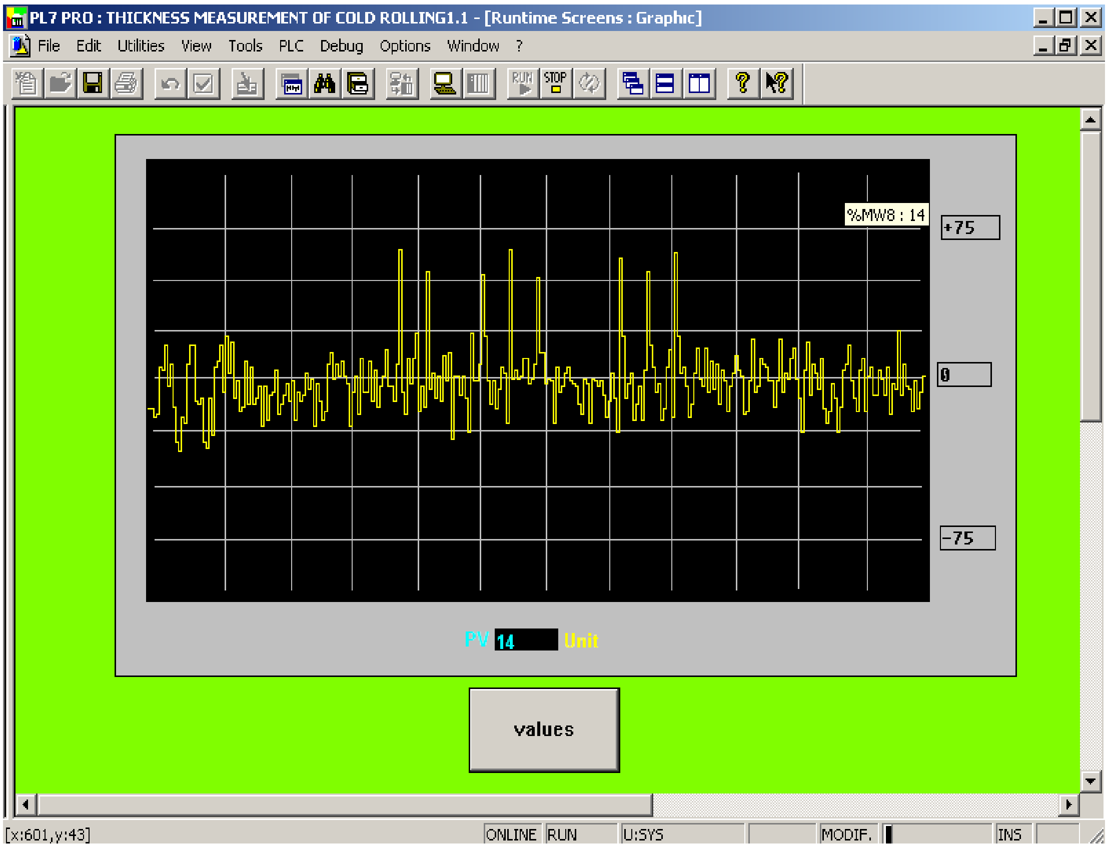


Fig. 4.10 Thickness variation-rolling cycle diagram (speed continuously increases)

CHAPTER V

DISCUSSION AND CONCLUSION

6.1 Discussion

In this study, the on-line thickness measurement of the sheet metal is controlled automatically. A contact type sheet metal thickness measuring machine is designed and constructed for cold rolling process. Thickness is measured between two point contact rollers which are designed and constructed with the roller motion is adjusted by using a servo motor with directly connected DC power supply by chance its armature voltage. On-line report of the measurement data is shown on the monitor color print-out as value list and as graphics immediately after the thickness measurement of sheet is completed.

If the displacement is changed very rapidly, use of the manual-operated thickness measurement recorder is become impractical. Thickness measuring machine is facilitated to data acquisition of displacement accurately.

The solution for the thickness measurement control is an on-line method, which allows a computational efficient implementation even on a PLC (programmable logic controller).

Contact type thickness measuring machine is a part of an integrated system consisting of the PLC, PC and the application software. All these operations and processes are controlled by PC via the application software. In order to ensure applicability to the wide range of applications appearing thickness measuring research, the thickness measuring machines and PLC system must be highly flexible. The measuring chain consisting: Thickness measuring machine, PLC, LVDT and data acquisition.

A computerized, PLC operated, thickness measuring machine with dedicated accessories facilitates automatic set-up, calibration, data acquisition, data conversion and fundamental data reduction. The hardware set-up sets the characteristic automatically to cover all applications and provides signal filtering and amplification for measurement of displacement.

The maximum and minimum thickness values obtained are filtered during measurement by averaging of 1 to 100 values with the period of 1 cycle of rollers at different speed.

Diamond transducers are used for measuring the thickness of the sheet. However, this type of transducers operating at very high speeds makes jumping and straching on the material surface. So, presented precision measurement can not be performed. In this thesis, design and construction of a new thickness measuring machine is presented. The measurement is focused on laboratory cold rolling of strips. Measurement stroke is 210 mm, with the between -350 and +2280 micron is obtained, thickness measuring machine. During the operation of the measurement system, there is no need to mechanical adjustment of the measuring head. Obtained values are not depending on the type of the measured sheet material. The influence of the operator on the accuracy of measurement is eliminated. There is only simple digital calibration.

6.3 Recommendations for the Future Work

The following recommendations may be given to improve the set-up and the dedicated software.

a) New accessories (already high precision rolling (0.001 mm), laser transducer, absolute encoder …) can be added of for high speed thickness measurement.

b) The capacity of the thickness measuring machine can be increased for high sensitive applications at high speed rolling, for example 500 rpm.

c) The set-up is developed for the thickness measurement. New thickness measuring machine can be improved for other measurement methods, for example profile gauge, tin strip gauge, no dependence on different type of measured sheet material.

d) The system is driven by a servomotor. This servomotor is driven by DC power supply. The variable speed control of the servomotor can be done by computer serial port, or potentiometer.

e) Contact instruments (rollers), based on pneumatic devices, can also be used for pre-loading. They can be replaced on the system.

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18. UVB TECHNIK s.r.o. Ostravska 79A, 748 01 Hlucin, Czech Republic tel.:+420-595 044 444, fax:+420-595 044 700,

19. www.metronix.com

20. www.schnider-electric.com.

21. Friedrich Vollmer Feinmessgeraetebau GmbH D-58093 Hagen- M Berchum VerbandsstraBe Phone: +49 (0)2334 507-Fax: +49 (0)2334 507199

APPENDIX-A- 1 RS-485 CONNECTION

A.1.1 RS-485 CONNECTION

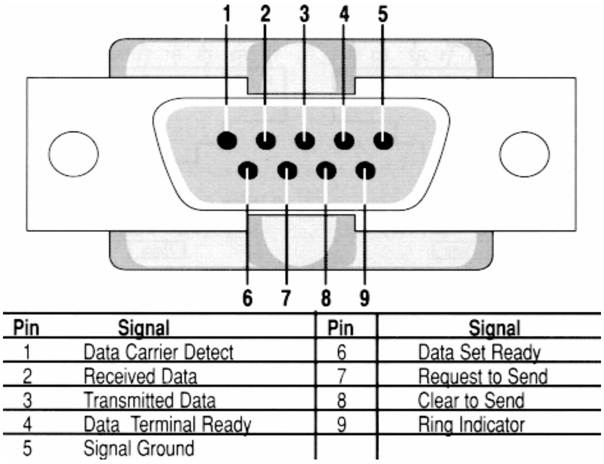
Most RS 485 systems use Master/Slave architecture, where each slave unit has its unique address and responds only to packets addressed to this unit. This article will mainly cover the Master/Slave architecture because it is sufficient for 95% of applications. This system is ideal for devices, which need to immediately transfer some very important and up-to-date data.

The communication device uses a 10-bit format. Some conventional PLC use 11-bit data format and some weight scale equipment uses 12-bit. If the host-PC has to send command to remote modules, PLC equipment, one possibility is to use three independent two-wire RS-485 networks. All these modules must communicate at the same baud rate in a conventional system. Only one speed is valid in the RS-485 network, the high-speed modules should be forced to communicate at a low speed baud rate. In other words, the performance of the whole system should be decreased.

USB to Serial Bridge Cable unique cable allows you to use bridge/connectivity between the Universal Serial Bus (USB) and Serial Port interface. The USB to Serial Bridge Cable is your fast solutions to utilize the peripheral with serial port in an easy-to-use environment such as plug-n-play and hot swap function. This cable provides ideal connections to Modems, PDA, or ISDN terminal adapters with over 1 Mbps data transfer rate. The USB to Serial Bridge Cable provides the following features: Support the RS-485 Serial interface, Over 1 Mbps data transfer rate, Windows 95 OSR2, Windows 98, Windows 2000 Supported, Single chip (ASIC) USB to Serial communication.

A.1.2 ADB9 Connector

The 25-pin connector is the standard for RS-485 connections but as electronic equipment becomes smaller, there is a need for smaller connector. For this purpose most PCs now use a reduced function 9-pin D-type connector (Fig. A.1)



Pin	Signal	Pin	Signal
1	Data Carrier Detect	6	Data Set Ready
2	Received Data	7	Request to Send
3	Transmitted Data	8	Clear to Send
4	Data Terminal Ready	9	Ring Indicator
5	Signal Ground		

Fig. A.1 9-Pin signal description

APPENDIX-A-2 L V D T

Linear ball bearing with 1 micron interference fit for radial forces, hardened steel body with TIN coating.The excitation is applied to the primary winding of the position sensor by the oscillator circuit. The excitation is normally a sinusoidal voltage signal, of 0.5V to 5V amplitude and 1 kHz to 30 kHz frequency.

In addition, this instrumentation is available direct analog signal for PLC connection, higher solution display (Mercer 122L) or RS-485 serial communications to feed directly into a PC or data acquisition system. Mercer 122L analogue display gauge unit. Up to 6 Metric and Inch measuring ranges ,tolerance light indicators, 2 probe input, Polarity switch +A-A/+B-B, Course and fine Zero control

APPENDIX-A-3 INCREMENTAL ENCODER

An incremental encoder is a device which provides a series of periodic signals due to mechanical motion. The number of successive cycles corresponds to the resolvable mechanical increments of motion. Rotary encoder photo sensor that converts mechanical chancing among to electrical signal (pulse).These are used in controlling of speed, position and angle.The 4...20 mA circuit is intrinsically safe and has channels A and B. Each channel is powered by the current loop system of the 4...20mA circuits. So channel A has +A and -A, channel B has +B and -B. They hook up as follows: + loop to 24V on the PLC and the - loop to one of the inputs on the PLC [19]. Fig A.2 shows connection shape and size e.g. of encoder.

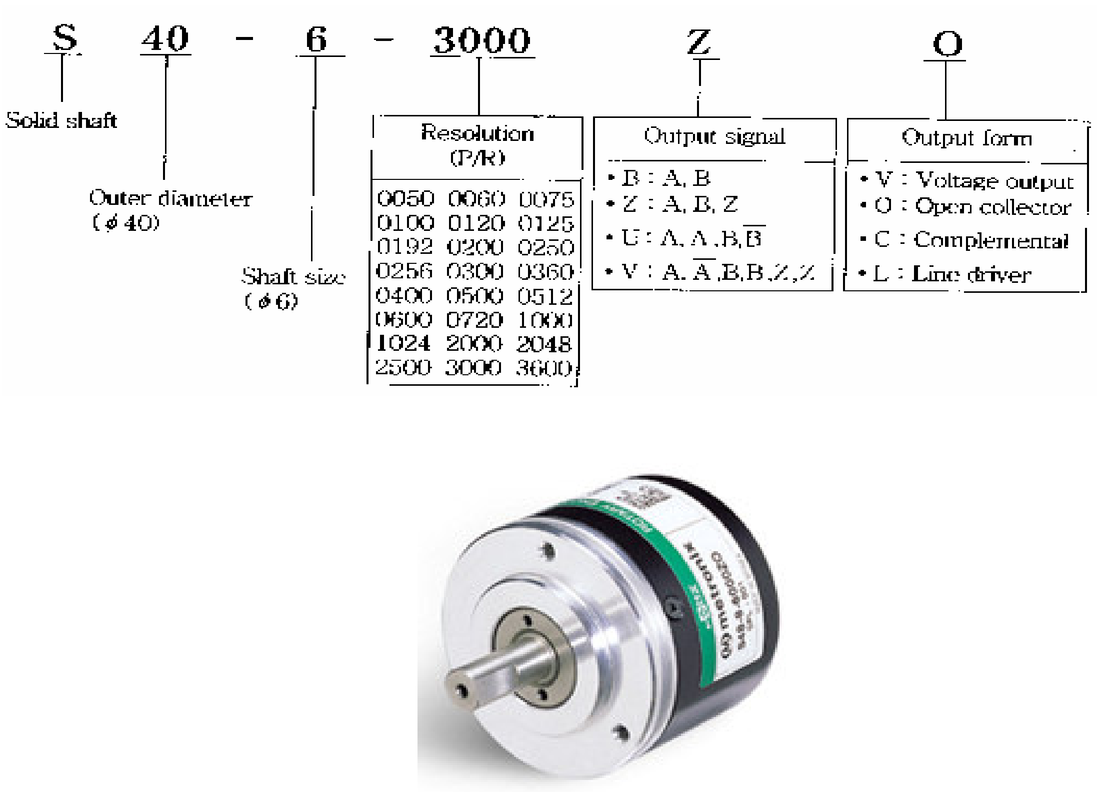


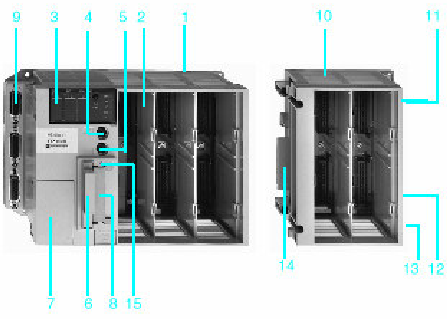
Fig. A.2 Incremental (rotary) encoder

APPENDIX-A-4 TSX 3722 MICRO PLC

The Modicon TSX Micro PLC range offers a selection of PLC base units, either complete with I/O or configurable by the user. Up to 256 I/O can be configured, and with full or half format I/O modules to closer match the application requirements, multi-range 16-bit analogue modules, integrated safety relay module, AS-i master module, multi-protocol communication and modem cards using PCMCIA technology and expandable memory the applications for which this Micro PLC can be used are endless. IEC 1131-3 Windows based programming software enables programming in Ladder Logic (LD), Instruction List (IL) or Sequential Flow Chart (SFC) languages, and when using the Telefast pre-wired cabling system, in place of wiring the PLC to terminals in a control panel, the opportunity exists to save a significant amount of both time and money on the installed cost of the PLC.

Fig. A.3 The Modicon TSX Micro PLC range offers the user a choice of base units. The TSX 3721 PLCs offer the flexibility of full user configuration; have a dual programming port for simultaneous connection of an HMI, and programming equipment, PCMCIA memory expansion and communication ports, and the ability to add an expansion rack. In addition the TSX 3722 also offers 8 analogue inputs, 1 analogue output, and 2 fast counters (10 KHz) as standard [20].

Description



TSX 37-21/22 PLCs and the TSX RKZ 02 mini extension rack comprise:

1 3-slot base rack (positions 1 to 6).
2 Slot reserved for a standard format module.
3 Centralized display block.
4 Terminal port (TER) (Uni-Telway or Modbus Master/Slave protocol).
5 Man-machine interface port labeled AUX.
6 Slot for a memory extension card.
7 Cover for accessing the power supply terminals.
8 Slot for a communication module.
9 On TSX 37-22, connectors for integrated analogue and counter functions.
10 Mini extension rack with 2 available slots (positions 7 to 10).
11 LED showing voltage presence of ⎓ 24 V.
12 Power supply terminals protected by removable cover, to connect an auxiliary ⎓ 24 V power supply if PLCs are supplied with ⎓ 100/240 V.
13 Earth terminal.
14 Connectors to the base PLC.
15 Reset button.

Fig. A.3 TSX 3722 micro PLC

APPENDIX-A-5 PL7 PROGRAMS

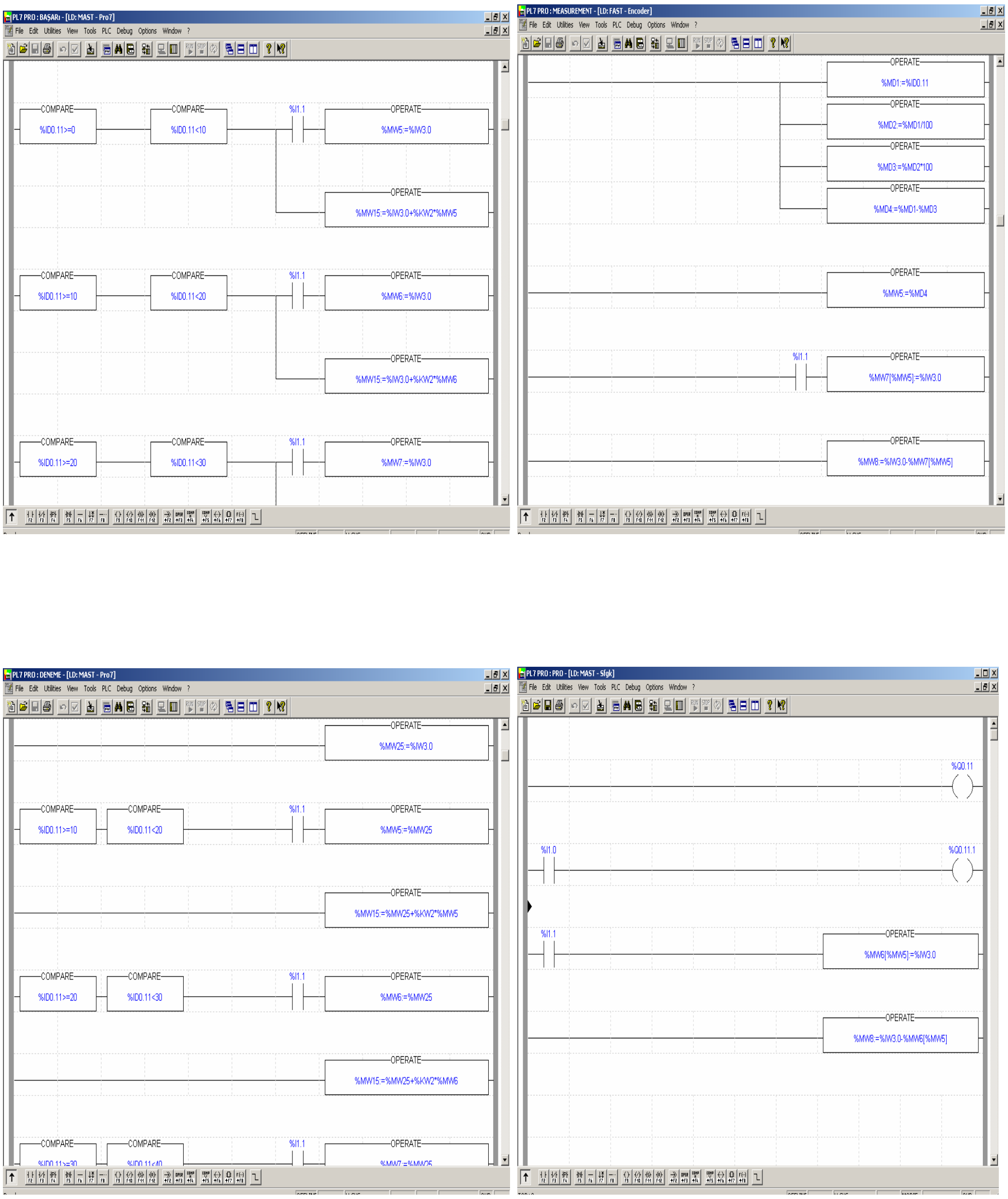


Fig. A.4 Different forms of PL7 program

APPENDIX-A-6 MODERN THICKNESS MEASURING MACHINE

MTUP 301

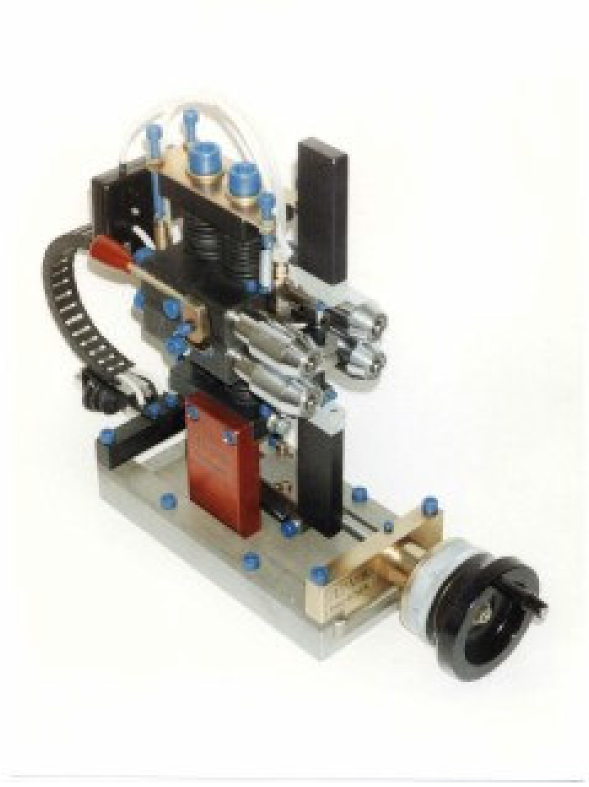


Fig. A.5 Continuous narrow strip thickness gauge by UVB

This Thickness Gauge is determined for exact continuous measurement of narrow metal and non-metallic strip thickness on one surface. Diamond contacts that are in constant touch with the measured strip mediate the transfer of measured value to sensor and to evaluation units. Contacts are designed in such a way, that they do not damage the material and they have long service life even in case of rough handling. Thrust of measuring contacts is adjustable continuously by air pressure. Absolute digital display of the measured thickness, independence of the measured material type, no mechanical adjustment of the gauging head for nominal thickness, easy operation, analogue output module for the control system or recorder 0 – 20 mA.

MTP - 1301, MTP - 2001, MTP - 3001

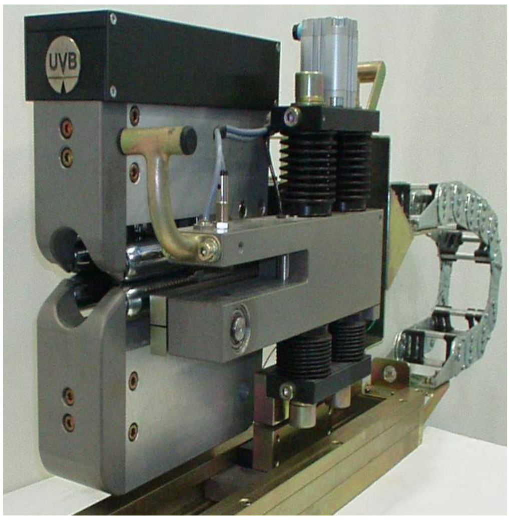
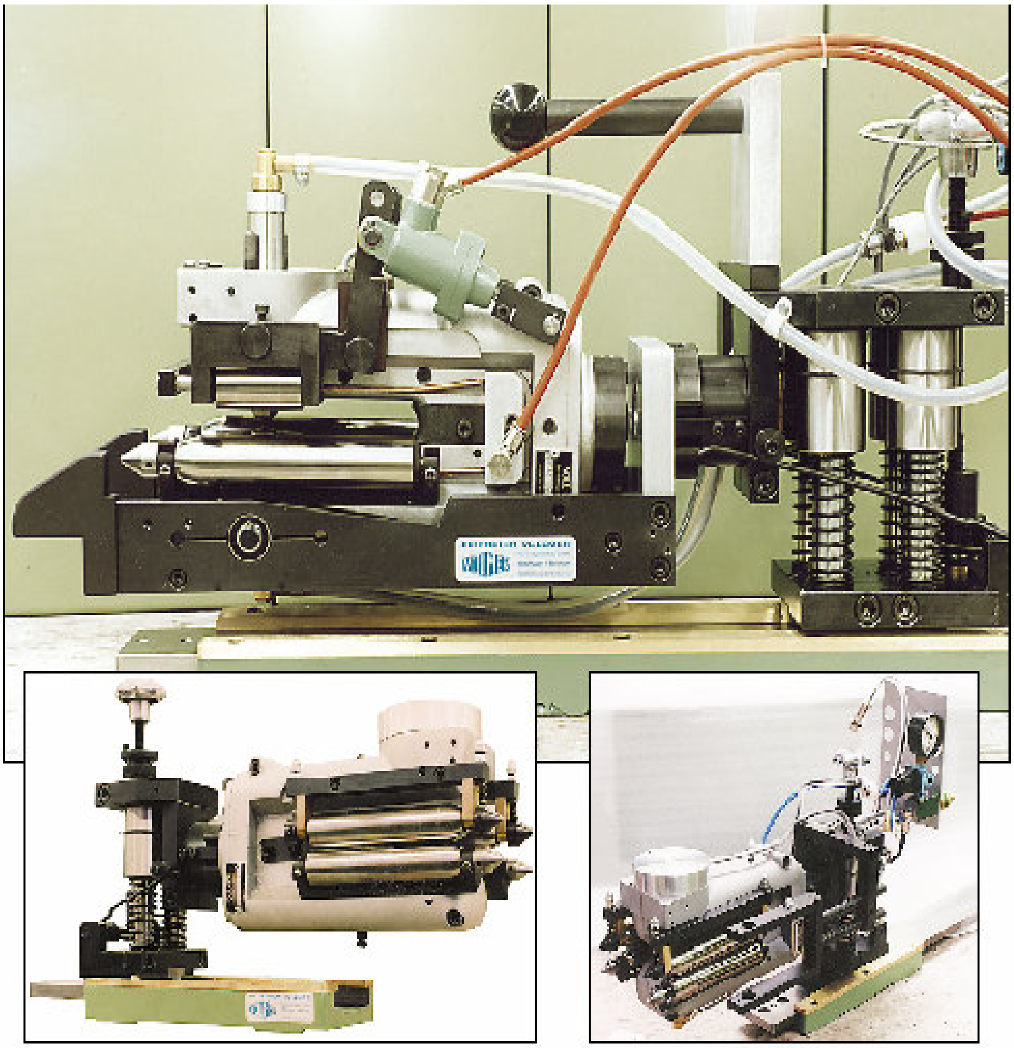


Fig A.6 Continuous strip thickness gauge by UVB

The measuring head is designed in such a way that it copies a strip and thus ensures exact measurement of the thickness even of wavy strip. Diamond contacts that are in constant touch with the measured strip mediate the transfer of measured value to sensor and to evaluation units. Contacts are designed in such a way, that they do not damage the material and they have long service life even in case of rough handling. Thrust of measuring contacts is adjustable continuously by air pressure.

This continuous gauge was developed as an absolute measuring device requiring no mechanical readjustment for the nominal thickness of the measured strip and its absolute measuring capability allows using it also for precision calibration of other (e.g. non-contacts) gauges during the production process. Absolute digital display of the measured thickness, independence of the measured material type, no mechanical adjustment of the gauging head for nominal thickness, digital thickness display, analogue output module for the control system or recorder 0 – 20 mA, ZAP-501 recorder with holder and cover, RS-485(-232) serial data output module automatic guidance of measuring device to the strip

VBM 1063

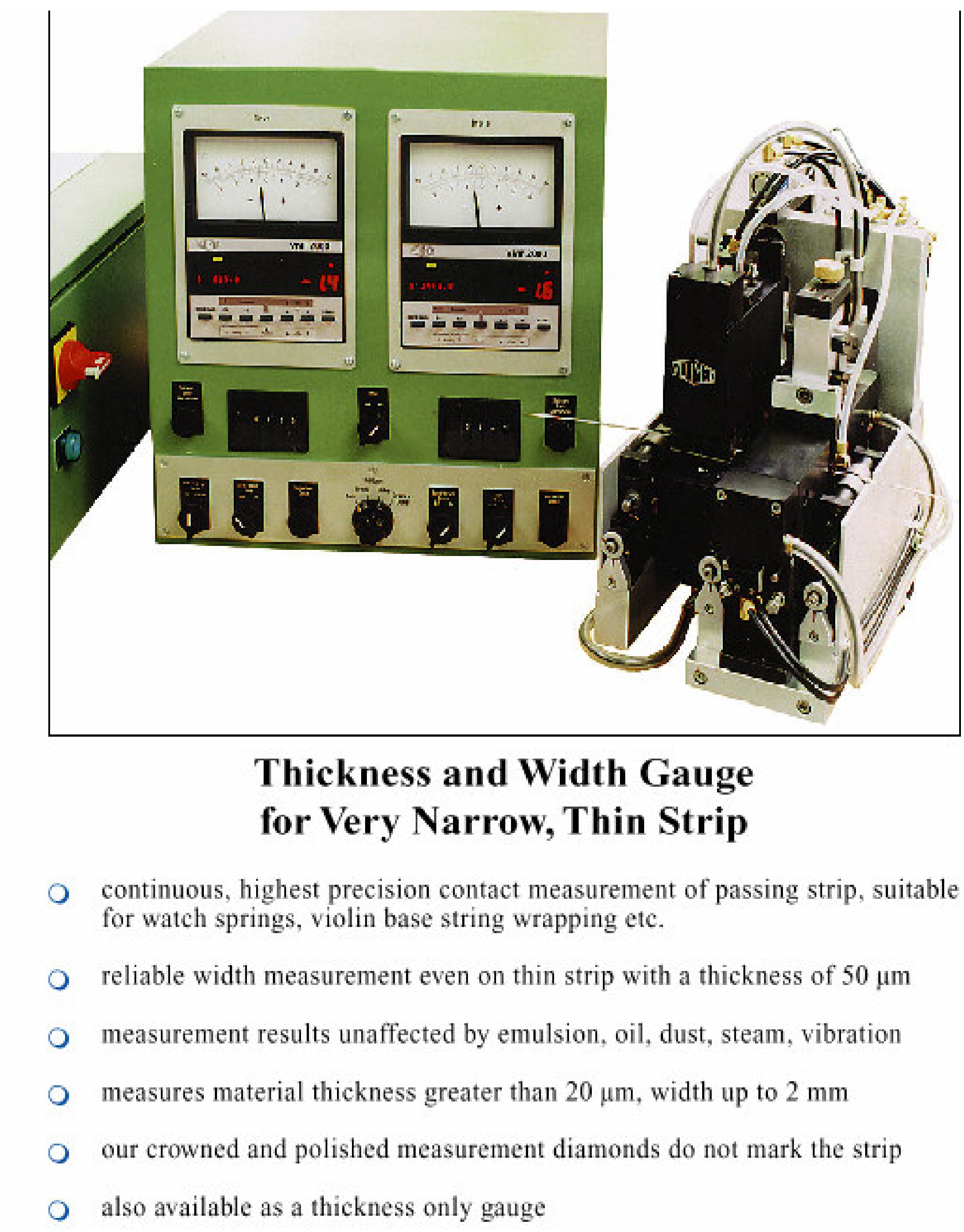


Strip Thickness Gauge

- gauge for continuous thickness measurement of passing strip
- suitable for small mills, slitter lines, press machines and punching machines
- small in size, sturdy design
- large variety of additions available, allows to make this gauge suitable for very many different applications

Fig. A.7 Continuous strip thickness gauge for narrow by VOLLMER

VABL 296/12

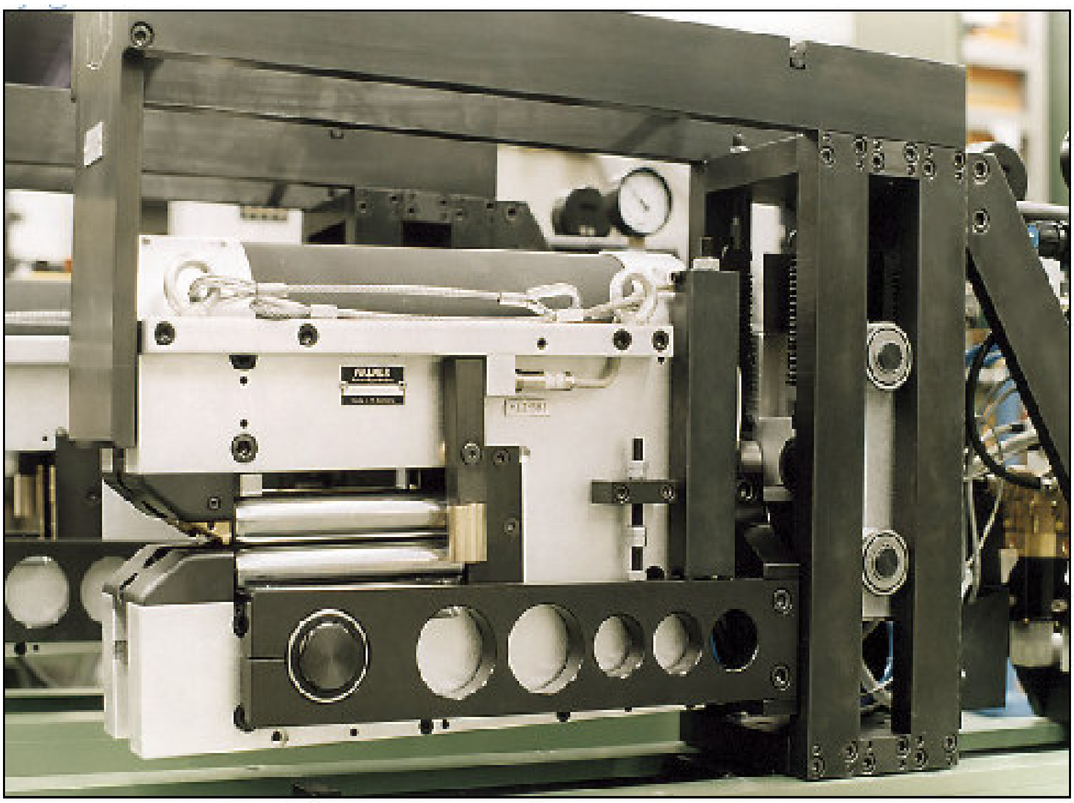


Thickness and Width Gauge for Very Narrow, Thin Strip

- continuous, highest precision contact measurement of passing strip, suitable for watch springs, violin base string wrapping etc.
- reliable width measurement even on thin strip with a thickness of 50 µm
- measurement results unaffected by emulsion, oil, dust, steam, vibration
- measures material thickness greater than 20 µm, width up to 2 mm
- our crowned and polished measurement diamonds do not mark the strip
- also available as a thickness only gauge

Fig. A.8 Continuous strip thickness gauge for very narrow by VOLLMER

VBM 1076/2076



High Performance Strip Thickness Gauge

- gauge for continuous thickness measurement 3,9" / 7,8" (100 or 200mm) off the strip edge
- made for high speed cold rolling mills
- quick change module for reduced downtime e.g. after strip breaking and for economical servicing
- very narrow in size, rugged design
- ideal gauge to be combined with a Vollmer laser strip speed gauge for mass-flow controlling

Fig. A.9 Continuous strip thickness gauge for high performance by VOLLMER