SYSTEM OF DIGGING FORCE MONITORING AND BACKHOE TIP LOCALIZATION FOR MEDIUM - SIZED HYDRAULIC EXCAVATOR

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SUMMARY

In this paper system of measuring and registration of digging force or working reaction was described.It consists of three angle transducers mounted in joints (bucket-arm,arm-boom and boom-body), 2 sensors of digging force,electric connections and computer based data processing system.The conversion algorithm of input to output data was formulated,as well as a method of the potential digging force prediction (by means of hodographs).The principles of system assembling and final mounting were described with some facts about measurement's range and accuracy.

1.INTRODUCTION

Single-bucket hydraulic excavators made by Polish industry,at present belong to traditional and poor-equipped machines.The introduction to them the automation elements and optimization of work is difficult,because of hydraulic systems application,in which the gear pumps are central elements,working in relative low pressures and at constant delivery of pump.

The high-pressure,variable displacement axial piston pumps are not made in country and this restricts the possibility of electronic control introduction to hydraulic system of excavator.In spite of the bad condition of domestic hydraulics,the modernization of excavators can be carried by development operator's assisted systems during his work,i.e.systems assuring safe using of machines,allowing on higher precision of works and on continuous supervision over work of basic sets and equipment.

Thus the activity aiming to approaching of Polish excavators quality to world standard should be carried to three directions:

-general introduction of modern hydraulics suitable for digital control;
-outfitting of power unit of excavator with automatic system remaining of optimal parameters of its operation;
-introduction of modern systems for making operation easier.

Works on above mentioned problems started in 1986,among others within the framework of CPBP 02.13."Systems with artificial intelligence for working machines and vehicles".This theme was coordinated by Institut of Fundamental Technologic Researches of Polish Academy of Science [1].

Problems concerned with introduction of hydraulics suitable for digital control were investigated by means of the testing stand equipped among others with attachment of Warynski K-111 excavator and computer IBM PC/AT.This stand was utilized for simulation of machine operation with the mathematical models describing the mechanical part

machine.Modern hydraulic units were used,such as:proportional control valves,pumping sets with variable delivery and others.In the field of interest there were also works concerned with mechanics of the earthmoving processes ([2]).

In the framework of complex problem there was separate theme "Automation of excavator work".This theme included the introduction of the modern,energy - saving systems.

The purpose of theme was providing of excavator with:

-warning - diagnostic system;

-automatized engine operation system;

-bucket position and shearing force value monitoring system.

In the framework of first task the model of new automatic warning - monitoring system for "Warynski 611" excavator was elaborated and also a new system,informing the operator about parameters of operation and about technical condition of working elements ([3]).

Above system is composed of 41 sensors,located in the most important units of machine.Total amount of continuously supervised diagnostic parameters is 51.

Automatized engine operation system of excavator was elaborated at Poznan Technical University ([4]). The engine operation parameters are adjusted by means of the mechanism for change the value fuel dose and by the mechanism for change of fuel injection advance angle . The characteristics,which are the results of stand measurements,together with selected guidelines of injection advance angle and fuel dose regulation,were stored in computer memory together with response value,for instance - settings of valves controlling advance angle.

Below authors present in detail system mentioned in the title.

2.THE STRUCTURE OF THE SYSTEM OF DIGGING FORCE MONITORING AND BACKHOE TIP LOCALIZATION

The systems,which assisted the operator during excavator work,were the purpose of group of researchers from Institute of Cranes and Heavy Machinery Engineering of Warsaw University of Technology ([5]) closely collaborated with researchers from Lodz Technical University [6], and also with group from Wroclaw Technical University([7]).The system for recognition and recording of attachment's position in operating space,measurement and recording of shearing forces (shearing resistance),occuring in work cycle of excavator and also in evaluation system of excavator ability for execution of presently required work,were the purpose of above mentioned groups working at the excavator outfit. The arrangement of force sensors and the sensors of relative attachment's elements rotation angle as well as computational and informing electronics elements are presented on fig.1.

Recognition and recording system of attachment position in operating space is composed of:3 resolver sensors of relative rotation angle of backhoe attachment elements,connected with computational unit (self - made microcomputer),installed in operator's cabin and equipped with reading system of position's coordinates of shearing edge (fig.2).Angle resolver sensors - screwed in pins connecting the attachment elements - were equipped with semiconductor temperature meters for compensation of thermal deviations.The conception of measuring of relative angle of attachment elements rotation,for example - bucket in relation to arm (fig.3) - is based on fixing of sensor holder in relation to one of these elements and on connection its central rotating part by dog

determination of all linear and angular dimensions was made (in symmetry plane of boom),which are the input data for computer calculation of X - Y coordinates of bucket's teeth points.These dimensions were determined by geodesic methods and storing into memory.The computational procedure allows on position determination of shearing edge (teeth points of bucket) in relation to rotation point of boom (versus chassis) in whole operation field of machine.The current values of X - Y coordinates are presented in operator's cabin on display of the modulus MPS.

The system of measuring and recording of shearing forces occuring in work cycle of hydraulic excavator,consists of force converters placing in piston rod of arm's cylinder (fig.4) and in piston rods of two boom's cylinders.

The new measuring method for forces,which reacting on cylinder in direction of their procracting was introduced.It is based on direct recording of tensile forces (compressive) on cylinder's piston rod.This method substitutes old but still often apllied procedure - encumbered with significant error,and which was based on pressure measurement in cylinders or by method with utilization of measurement pins.The application of latter method in excavator "Warynski 611" was impossible from constructional reasons - two boom's cylinders on single pin.

Electronic system of force measurement (fig.5) consists of strain gauge, at object electronics (amplifier, filters, balancing system),voltage - frequency converter and computer - display block.This system allows on determination of vertical and horizontal components of force,loading the teeth points of bucket,which is treated as external one.This force is calculated as function of : attachment's configuration,the weight of its elements and recorded by above mentioned strain gauges in boom's cylinders (2 forces) and in arm's cylinder.

The system of excavator ability evaluation for present work execution,utilizes previously discussed elements of systems , i.e. position and force measurement.The force value of shearing edge loading is compared with potential force,which may load excavator.

The computational program of such force for whole field of excavator operation was based on algorithm,in which hodographs method was applied.This algorithm gives the possibility for accurate illustration of position place of excavator's bucket shearing edge in connection with whole machine,determines direction and sense of a reaction force arising during active or passive digging and calculates relation of force occuring at present machine loading to potential force,without disturbance of work safety.

The values of both forces:real and potential,are transferred to operator by special constructed monitor (modulus MPS - fig.6).In this way the operator is informed about instantaneous possibility of machine loading or about necessity of its unloading.

3.THE INITIAL RESULTS

The systems described in chapter 2 were calibrated and prepared for operating testing.

The initial verification of the method was carried out on the scale model (1:5) of excavator's attachment . The precise calibration of resolver's system was done by means of geodesic method of spatial intersection,and then checked using measuring method of diagonal surveying of section between point of boom's rotation and teeths of the bucket respectively.The goodness - of - fit was high and relative error didn't exceed 3,5%.

The calibration of the shearing force system was carried out by means of special

elements.Theirs own masses were taken into account.The relative error varied between 2 and 5%,and should be decreased by way of specifying of the excavator parameters.At present fields tests are starting.

Simultaneously excavator parameters identification is running as well as the works connected with automation and optimization of machines working processes : loosening of compact soil,reloading of loose materials,etc.

4.REFERENCES

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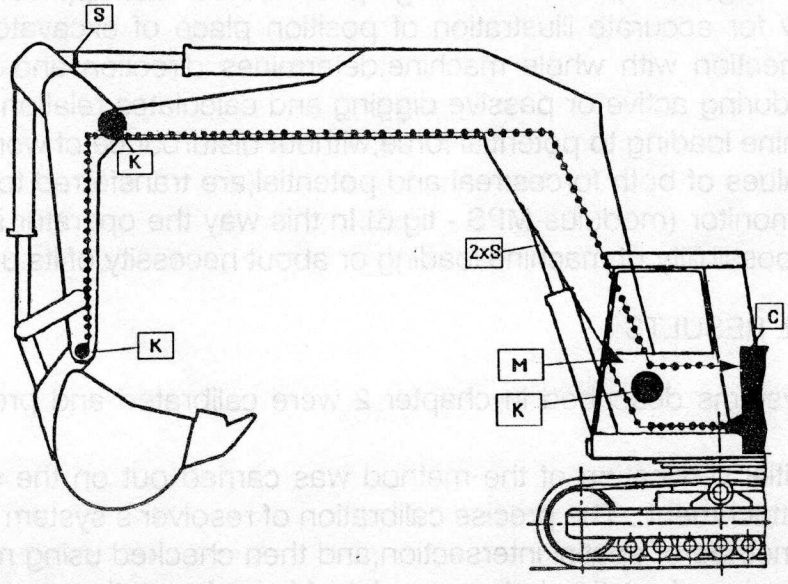

Fig. 1
K - SENSOR OF RELATIVE REVOLUTION ANGLE
S - SENSOR OF FORCE, M - DISPLAY, C - COMPUTER

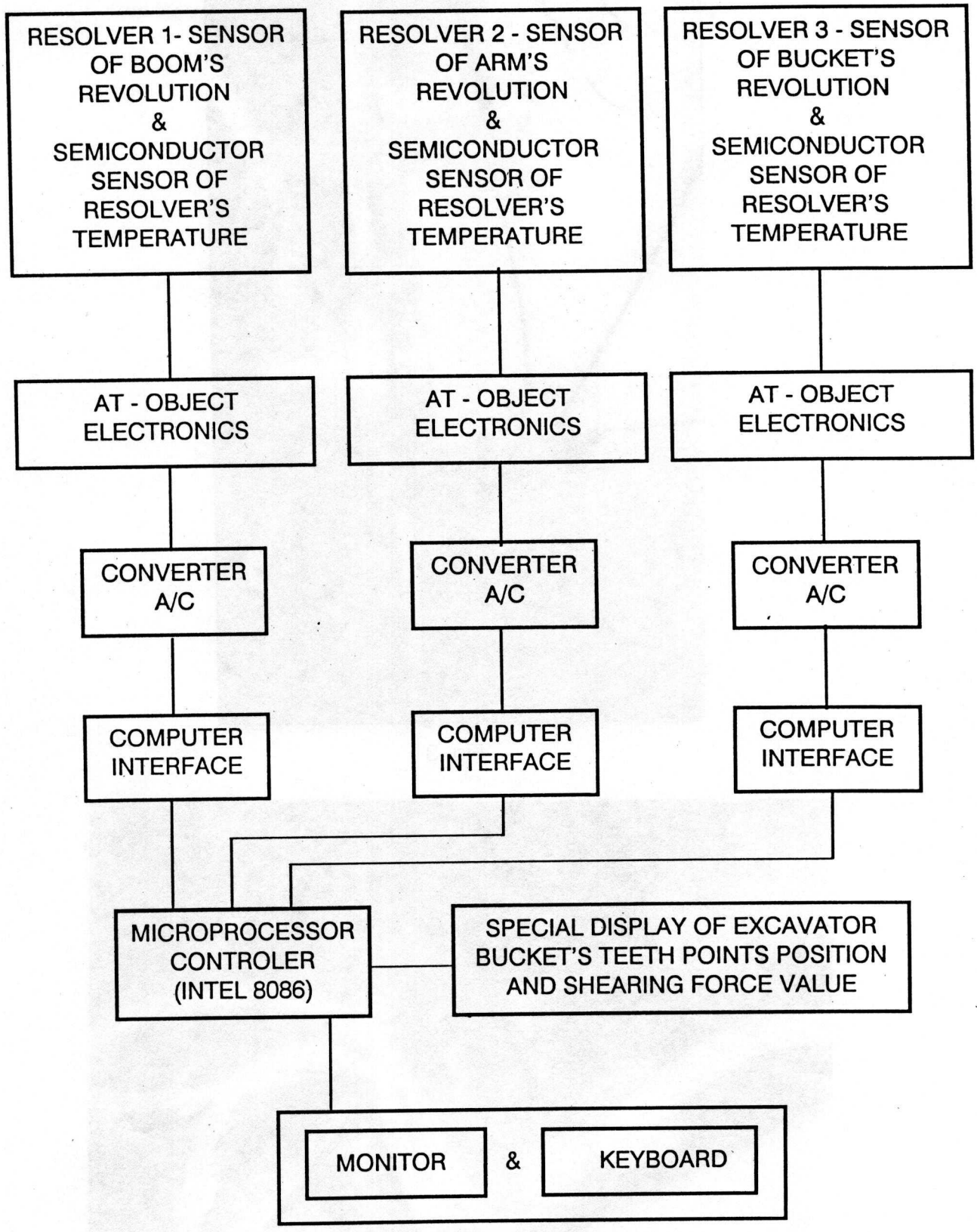
RESOLVER 1- SENSOR OF BOOM'S REVOLUTION & SEMICONDUCTOR SENSOR OF RESOLVER'S TEMPERATURE
RESOLVER 2 - SENSOR OF ARM'S REVOLUTION & SEMICONDUCTOR SENSOR OF RESOLVER'S TEMPERATURE
RESOLVER 3 - SENSOR OF BUCKET'S REVOLUTION & SEMICONDUCTOR SENSOR OF RESOLVER'S TEMPERATURE
AT - OBJECT ELECTRONICS
AT - OBJECT ELECTRONICS
AT - OBJECT ELECTRONICS
CONVERTER A/C
CONVERTER A/C
CONVERTER A/C
COMPUTER INTERFACE
COMPUTER INTERFACE
COMPUTER INTERFACE
MICROPROCESSOR CONTROLER (INTEL 8086)
SPECIAL DISPLAY OF EXCAVATOR BUCKET'S TEETH POINTS POSITION AND SHEARING FORCE VALUE
MONITOR
&
KEYBOARD

Fig. 2

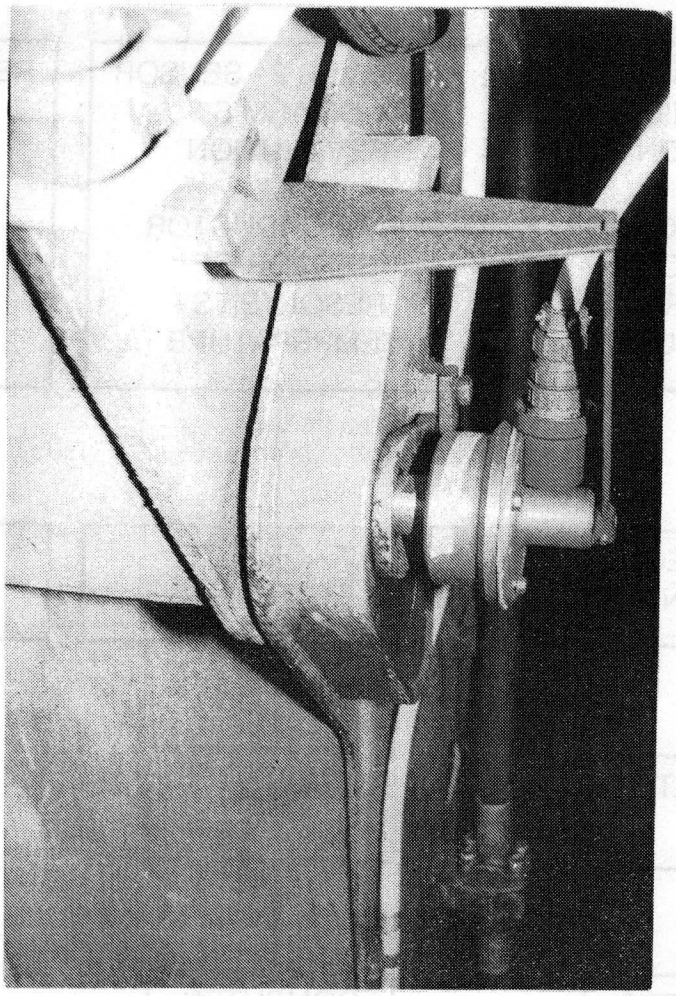

Fig. 3

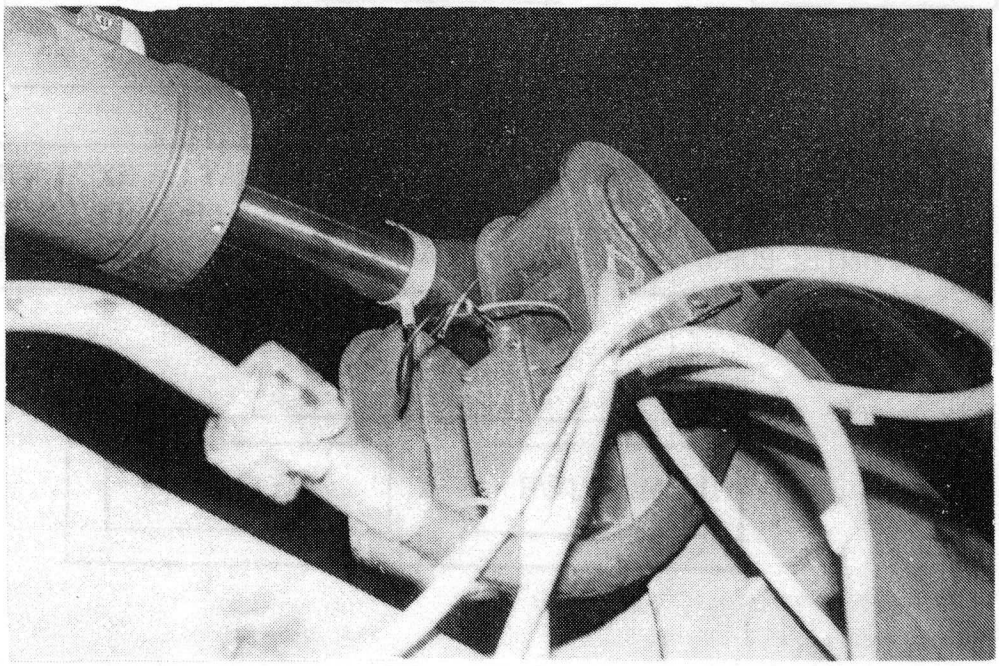

Fig. 4

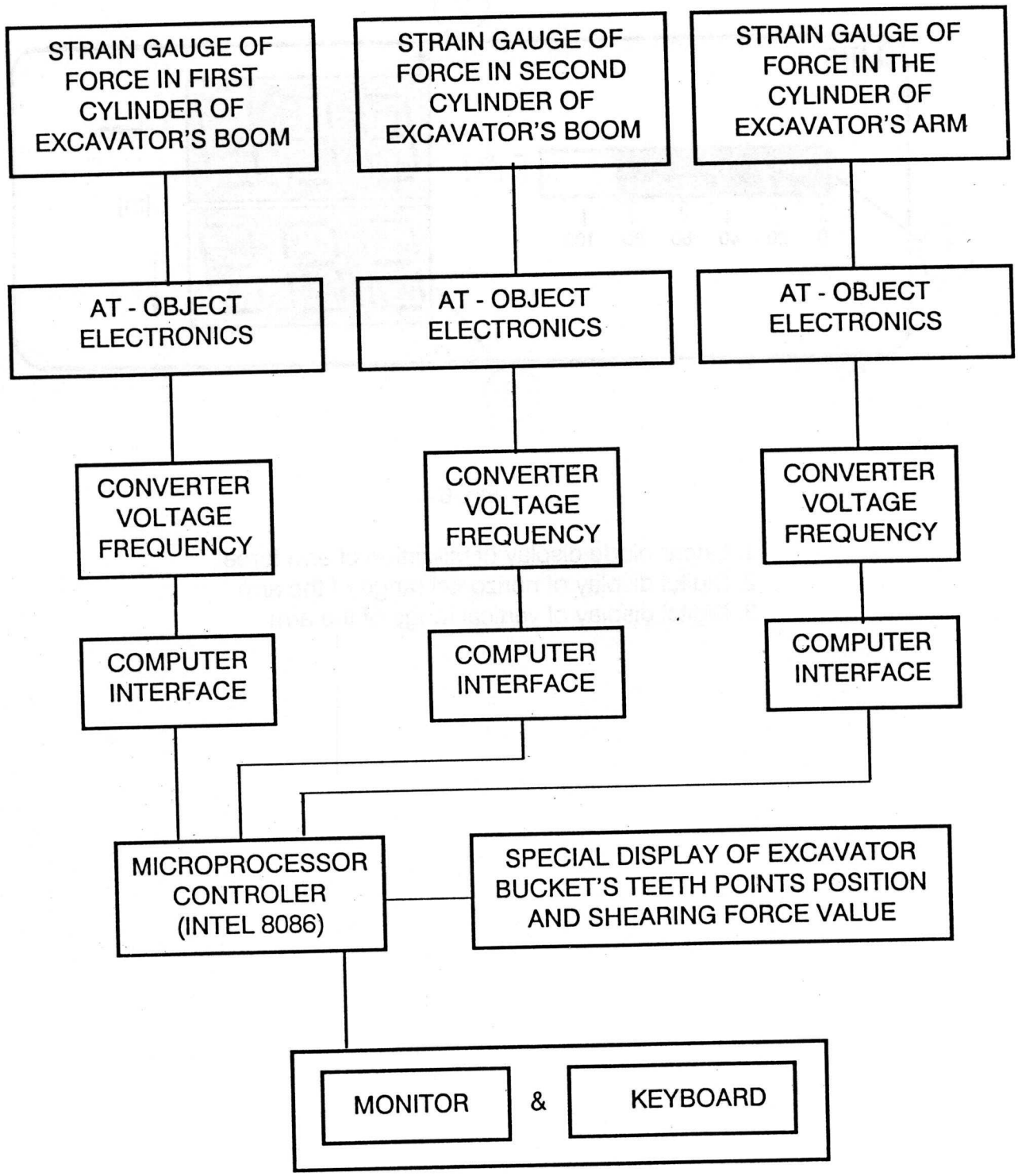
STRAIN GAUGE OF FORCE IN FIRST CYLINDER OF EXCAVATOR'S BOOM
STRAIN GAUGE OF FORCE IN SECOND CYLINDER OF EXCAVATOR'S BOOM
STRAIN GAUGE OF FORCE IN THE CYLINDER OF EXCAVATOR'S ARM
AT - OBJECT ELECTRONICS
AT - OBJECT ELECTRONICS
AT - OBJECT ELECTRONICS
CONVERTER VOLTAGE FREQUENCY
CONVERTER VOLTAGE FREQUENCY
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Fig. 5

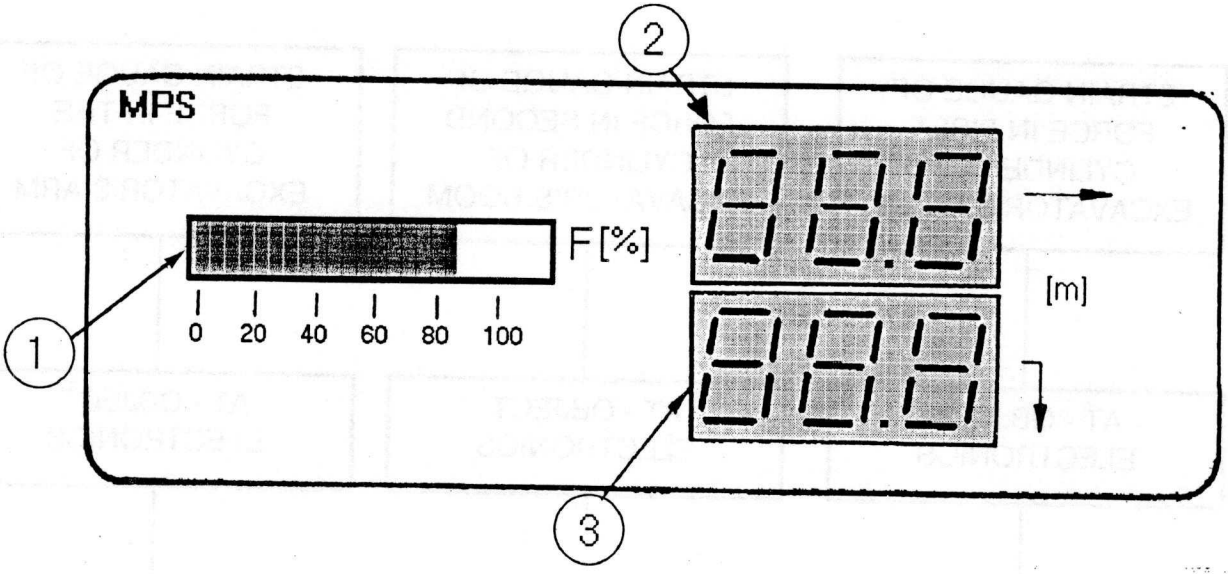

Fig. 6

1. Linear diode display of utilization of arm force
2. Digital display of horizontal range of the arm
3. Digital display of vertical range of the arm