Automation and Robotics in Construction XII
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CAT - Computer Aided Testing in Automation of Stability Tests of Mobile Building Construction and Earth-moving Machinery

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ABSTRACT

This paper describes methods of testing of stability of building construction machinery and equipment using an automatized data acquiring and processing system.

This method allows to determine on-line the machine stability with respect to a choosen tipping edge (line) and in accordance to corresponding standards.

1. INTRODUCTION

The abbreviations of CAD and CAM are well known. Continousely the computer applications are broadened in more and more fields giving help to engineers and technicians dealing also with testing in building construction and earth-moving machinery.

Those new applications are especially usful where on-line measurements are bound with calculations and immidiate results are expected .

A very important feature of safety in the exploatation of mobile machinery is to fulfill the conditions of stability. In the wide range of construction and earth-moving machinery such as tower cranes, autocranes, excavators, access platforms and many others, the safety certification demands results of their stability test. It is typical for this equipment, that the working load is acting outside the area defined by the points of support. The safety of the machine, of the operator and the workers and other people in the vincinity of the machine is strictly connected with the stability. There are several standards (national and international) precisely specifying the conditions of stability with defined factors of safety. In most cases there is a demand to define reaction forces in all supports of machine, taking into account diverse positions (and directions) of working load. On this basis, the in- stanteneus position of the center of gravity can be calculated .

The metod introduced in the Research Institute for Building Construction Mechanization and Mineral Mining in Warsaw joints the fluent strain measurement of four (sometimes three) support forces e.g. forces between wheels or crawlers and the ground, with the computer aided system of aquiring measured data and their processing.

During taking the measurements, the tested machine is executing its working movements with suitable loads. These movements and loads are programmed according to the stability safety test; and it is mostly turning round of the body with e.g. maximal and minimal reach with corresponding loads.

Measurements carried out in such a way define stability conditions towards any tipping line and also the instanteneus position of the center of gravity, more precisely: by the positioning of its vertical projection on horizontal plane (plane of the ground).

2. MEASURING SYSTEM

The measuring system consists of four (or three) load sensors with strain gauges and strain measurement bridge imbedded in the laptop.

The load sensors are originally designed spring rings with fixed strain gauges in a special housing .(Fig.1).

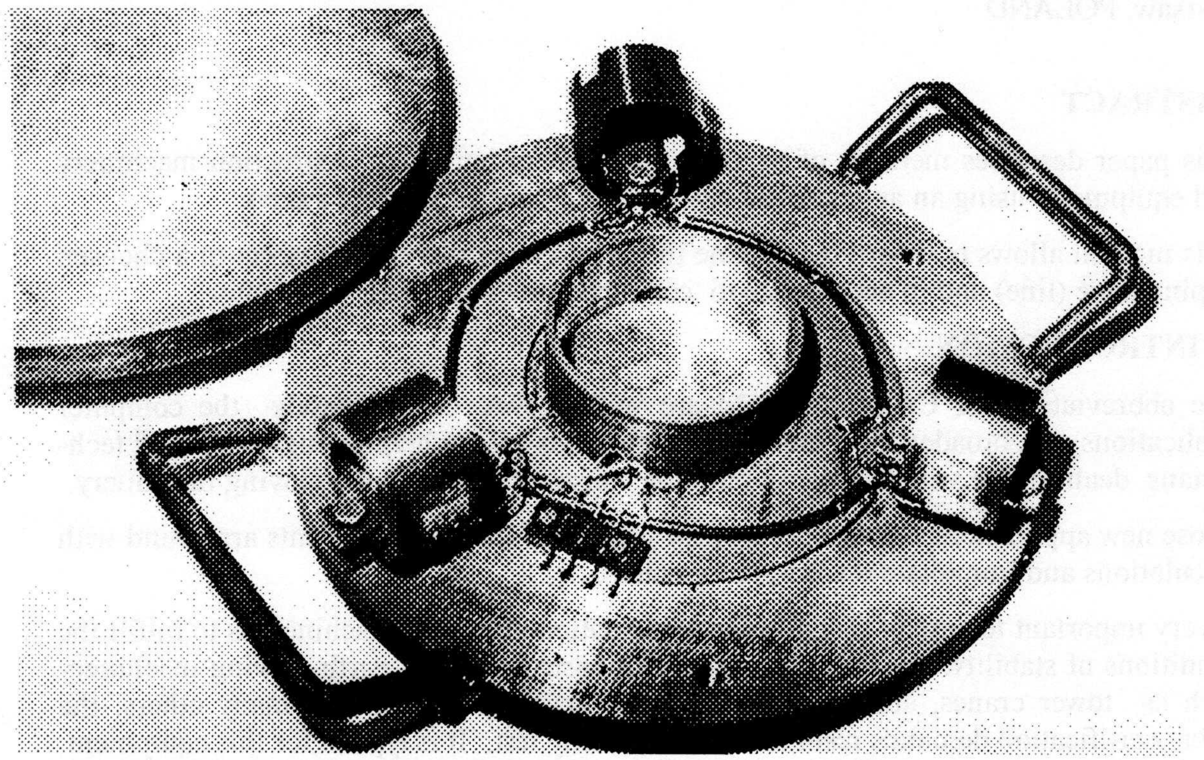


Fig. 1

Those sensors are previously calibrated using a precise load testing machine - giving the possibility of defining of accuracy of this measuring system.

During the measurements the load sensors were put under the wheels or under the crawlers in such a way, that the vertical axis of the each sensor should cross the axis of the corresponding wheel or crawler drum.

There are many different strain measurement bridges. In this case the Vishay multichannel bridge was used.

3. COMPUTER AIDED DATA ACQUIRING AND PROCESSING SYSTEM

To obtain the complete information about the changing position of machine's center of gravity it is necessary to collect a great number of measurement results and calculate from those results the center gravity coordinates . Therefore the only practicable method is to employ a computer i.e. introduce computer aided data acquiring and processing system.

The system should be programmed in such a way, that in very short intervals the measurement signals should be taken from all load sensors and any changes in resistance values of strain gauges should be transformed into voltage signals, digitalized and collected in time of measurment. The next step is to calculate corresponding load values (knowing the load-strain characteristics of the load sensors). The stability conditions can be finally asessed using the calculated center gravity coordinates.

During whole measurement - on line - there should be the possibility to show load curves of all sensors as a function of time, or/and a chart of the way of the center of gravity (practically its vertical projects on the horizontal plane) showing also how far it goes against the lines of tipping.

The previousely mentioned strain measurement bridge Vishay 2100 and laptop with built in ESAM system for acquiring and processing data can be uswed fot this purpose.

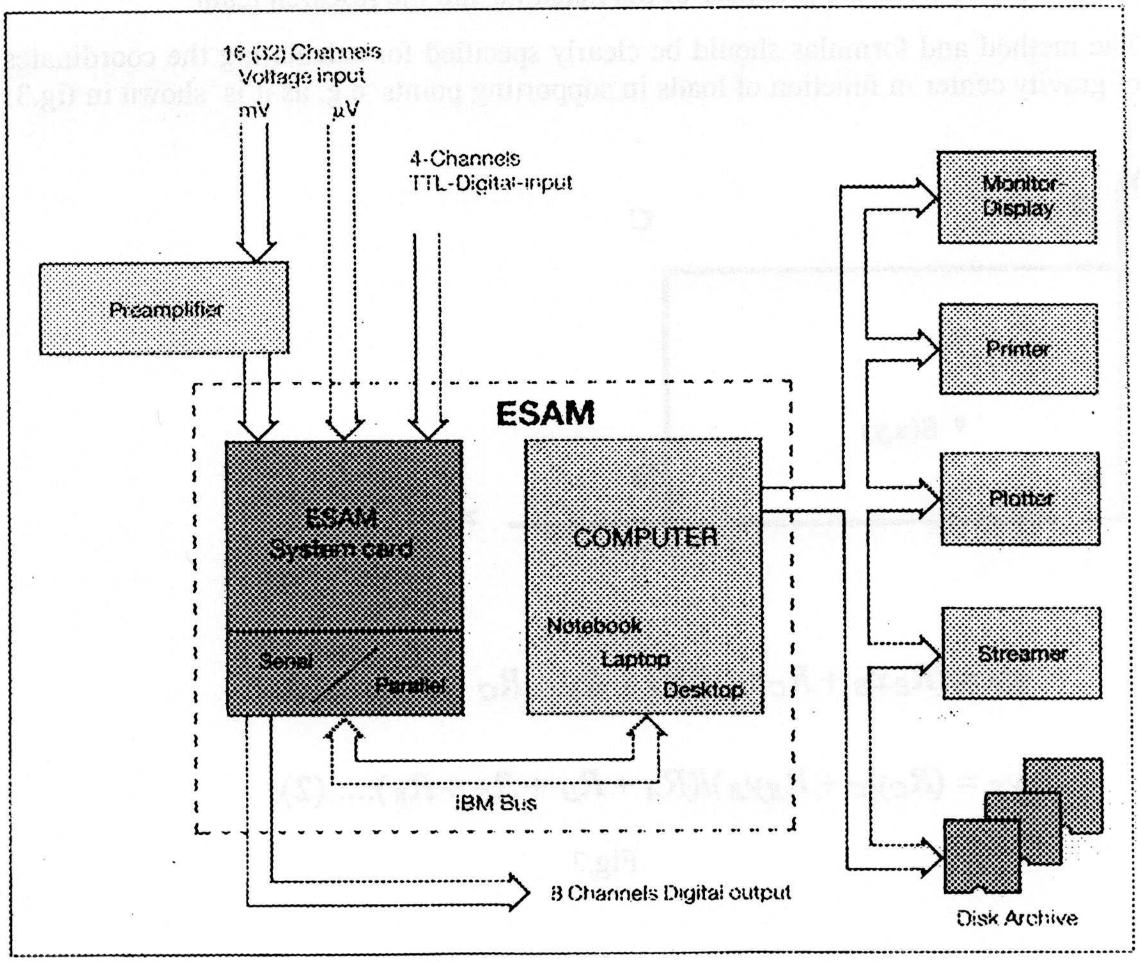


Fig.2

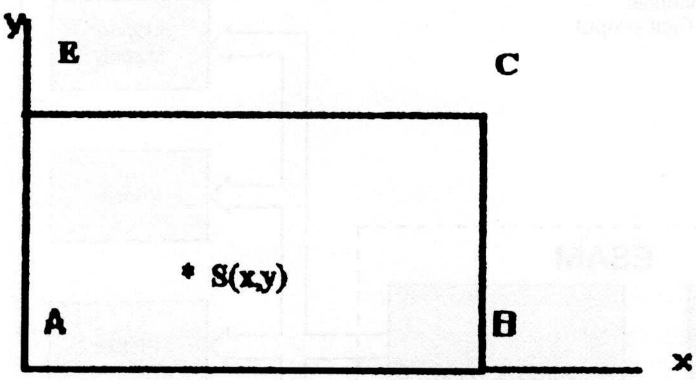
The Electronic Signal Acquisition Modul (ESAM) is an application oriented, versatile system based on an IBM-compatible LAP TOP Computer with a complex software package. It has 16 analog plus 4 digital input channels.

The ESAM I/O card is mounted in the computer (laptop) itself, and the BNC connectors taking the signal inputs are fixed to the computer housing. The input channels accept voltage ranges from + 1.25 V till +10 V. The sampling frequency can be choosen up to 150.000 samples per second. ESAM can be both: battery and mains operated. The general system chain of ESAM is shown on fig. 2.

4. COURSE OF MEASUREMENTS

Before beginning the measurements the following preparatory work should be carried out and documented in written form:

1. The load sensors should be initially calibrated on the load strenght machine.
2. The precised measurement programme should be prepared including all working loads and corresponding working movements of the machine elements. The sampling frequency should be choosen between 100 and 1000 Hz depending on dynamic characteristics of the machine
3. The stability criteria (e.g. corresponding standards) should be agreed as according to (2) between the producer of the machine and the research team
4. The method and formulas should be clearly specified for calculating the coordinates of gravity center in function of loads in supporting points e.g. as it is shown in fig.3.



$$x_s = (R_B x_B + R_C x_C)/(R_A + R_B + R_C + R_E).....(1)$$

$$y_S = (R_C y_C + R_E y_E)/(R_A + R_B + R_C + R_E).....(2)$$

Fig.3

5. The testing field should be prepared according to the safety regulations
6. The load sensors shoud be positioned with vertical axes forming exactly the vertexes of a rectangle and the distances between them should be precisely measured.

After the preparations - the results of calibration (1) should be loaded into the computer nd the formulas (4) introduced to the calculating computer-programme.

Then the measurements should follow. For each point of the programme (2) a separate measurement (test) should be performed .

5. MEASUREMENT RESULTS

An example of measurement result are shown in fig.4 and 5.

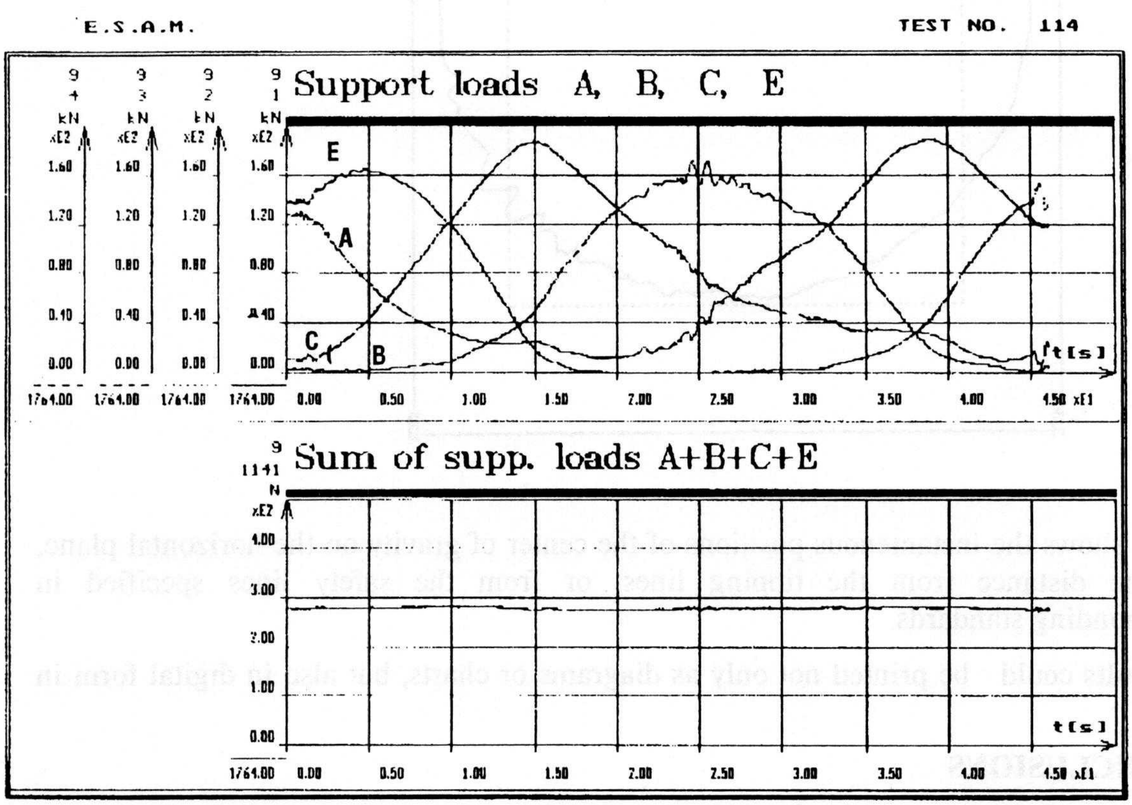


Fig. 4 shows the changes in the support loads during the rotation of the machine's body. The used computer-system allows to conduct a parallel testing if the sum of all support loads remains all time constant. This gives us a additional information about the correctness of the test.

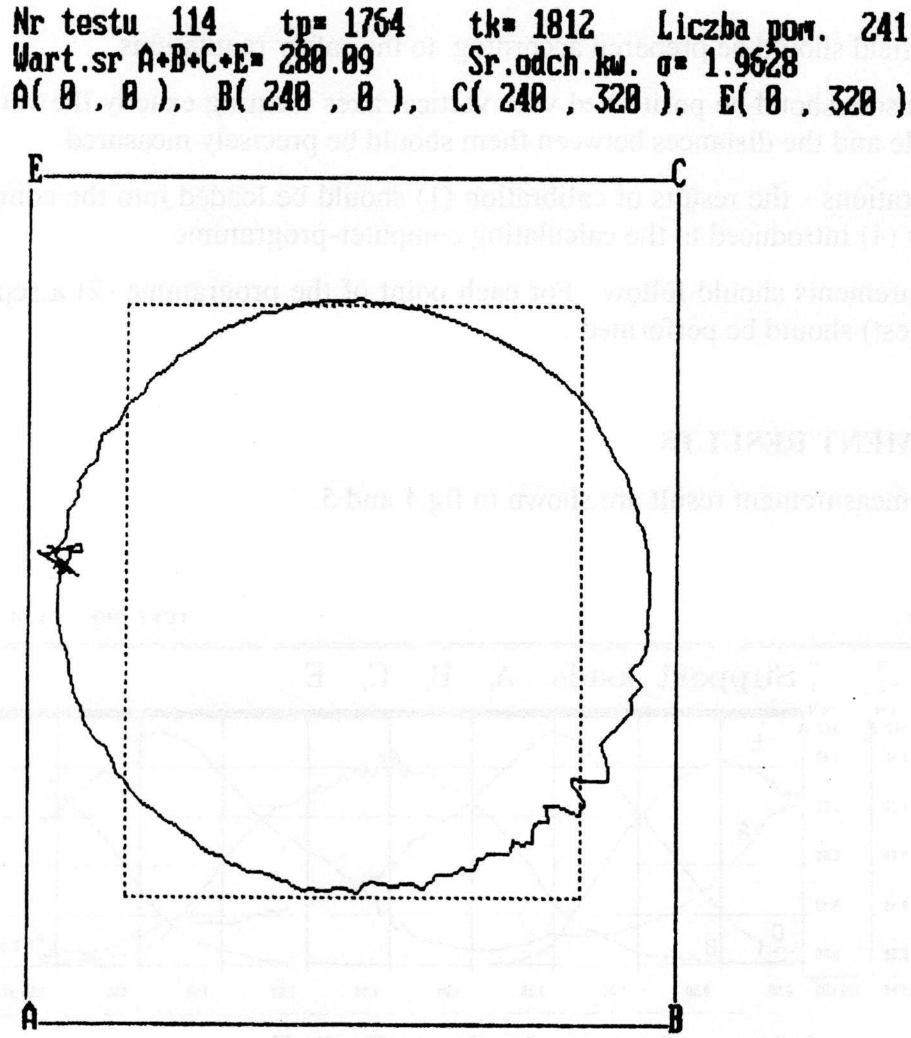


Fig. 5. shows the instantenous positions of the center of gravity on the horizontal plane, and the distance from the tipping lines, or from the safety lines specified in corresponding standards.

All results could be printed not only as diagrams or charts, but also in digital form in tables.

6. CONCLUSIONS

As a result of using the method described in this paper the following adventages have been achieved:

1. diminished measurement error.
2. the possibility of observing in-situ the changes in the support loads and the distance, the center of gravity has travelled and in the practical terms, how far is the machine from tipping over.
3. the time reduction of the measurement cycle.

7. BIBLIOGRAPHY

[1] W.Mijakowski, K.Szymanski - Automatyzacja badan statecznosci maszyn budowlanych IMBiGS, Warsaw, 1994

[2] ISO 4304 Cranes... - General requirements for stability , ISO , Geneve, 1987

[3] NF E 52-610 Élévateurs ... - Régles générales de sécurité part 4. Stabilité, AFNOR, Paris, 1987

ESAM, Electronic signal aquisition module. Producer's description, ESA Messtechnik, Planegg (Germany), 1994