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THE WORK OF THE SEMINAR ON PRECISION MECHANICS AND CALCULATING TECHNIQUES, CONDUCTED BY ACADEMICIAN M. O. BRUTSKUS

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The Seminar at the Department of Precision Mechanics of the Institute of Machine Science, USSR Academy of Sciences, has been working since January 1946. In the course of 1946 the Seminar has met 37 times and in the first half of 1947 it met 24 times.

The Seminar is working with the Dept of Approximate Calculations of the Mathematics Institute, USSR Academy of Sciences, and with the Laboratories of Electrical Modeling of the Power Institute imeni G. M. Krzhizhanovskiy, USSR Academy of Sciences. Workers from the USSR Academy of Sciences and from various research and project organizations studying calculating-solving constructions are taking part in the Seminar. The Seminar discusses problems connected with the theories, constructions, accuracy, practical application, and development of various calculating-solving machines. Various methods of solving mathematical problems are surveyed. The work done in 1945 in the Seminar was described in the journal "Izvestiya OTN AN SSSR" (No 8 for 1946 and No 5 for 1947). A short list of the works of the Seminar in 1947 is given below.

O. P. Kramer lectured on the calculation of ballistic trajectories that required the integration of second-order differential equations, which was carried out by the Adams-Stormer method. Since in certain cases this method required many and extremely difficult calculations, he substituted a more rational method proposed by S. A. Kazakov, a professor at the Moscow State University. The lecturer described in detail the schemes of the solution when both methods were employed and graphically illustrated the advantage of Kazakov's method. O. P. Kramer's lecture was published in No 5 of "Izvestiya OTN AN SSSR" for 1947.

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L. I. Gutenmakher reported on existing methods of measuring various phenomena found in electrical modeling. Such phenomena can be developed into three groups: not varying in time, periodically depending upon time, varying in time according to any law. Relative to measurements of phenomena in the first group the lecturer described the most applicable method of measurement -- compensation -- with a discussion of its practical accomplishment in the form of a transformer scheme. Such a method permits one to obtain the result of measurement in three significant figures. Later L. I. Gutenmakher described the method, often applied in practice, of finding isolines (lines of equal potential).

L. I. Gutenmakher reported on several existing methods of measuring phenomena of the second group, the main one of which reduces to rectifying an alternating current and measuring it by a "zero apparatus" -- a magnetoelectrical apparatus, which is sufficiently accurate. The Laboratories of Electrical Modeling worked out a special rectifying apparatus based upon the use of electron tubes which permits one to measure very accurately a rectified current.

In order to get rid of the defects inherent in this method -- rectification of harmonics of high orders and distortions by these of the main result -- various special methods and additional apparatus are employed. Besides the described methods for measuring periodic alternating current, the lecturer named several more apparatus: a magnetodynamic vectormeter of original design, a wattmeter, and others giving a great selection of measuring means depending upon the concrete conditions of measurement.

For the measurement of quantities varying in time according to any law, there exists the method -- of universal application but seldom used for mass measurements -- of measuring by means of the oscillograph. Besides this method there is a more frequently used and more applicable method of measuring voltage according to accuracy, as explained in the following: the measuring apparatus is switched in momentarily and the average value of the

reading is taken; the momentary switching in of the apparatus is effected by a mechanical or electrical arrangement.

Besides the report on the methods of measuring electrical quantities, L. I. Gutenmakher lectured on the introduction of nonlinearity into electrical models with electronic amplifiers, which presents additional possibilities in the solution of mathematical problems by electrical modeling.

A series of lectures were delivered by F. V. Mayorov, a worker from the Moscow Power Institute imeni Molotov. He lectured on the calculating-solving machines worked out at the Power Institute imeni Molotov. The peculiarity of these machines, as described by Mayorov, is the employment in them of one of the basic elements of the tachogenerator -- namely the D.C. dynamo with a shunt winding for excitation.

Formerly tachogenerators were employed as tachometers, but their application in the circuits of calculating-solving machines opened great possibilities. The voltage of the tachogenerator representing (voltage) functions of several quantities can be utilized as the product of four "co-multiples."

Another peculiarity of the calculating-solving machines prepared at MEI is the employment of profile potentiometers -- namely, ordinary linear potentiometers but "profiled off" by connection of the various parts of the shunting resistances.

Auxiliary elements of the calculating-solving machines described by Mayorov are the electronic regulator of speed and the electronic amplifier.

The principle governing the action of the machines, which were lectured on by Mayorov, is based on the compensation method of measurement. Balanced voltages are feed into the input of the electronic amplifier which plays the role of a speed measurer. From the output of this amplifier the current enters the excitation winding of the driving motor. In this way is the dependence of the motor's speed upon the excitation current attained. One of the advantages of these calculating-solving machines is the independence of the

operation upon the oscillation of voltage in the network, in consequence of which there was no necessity for stabilising arrangements.

The lecturer discussed in detail the principle governing the action of the calculating-solving machine with the tachogenerator, which permits one to perform algebraical operations and differentiation.

The second report of F. V. Mayorov was on the description of the four types of potentiometers employed in electrical calculating-solving machines and on their peculiarities of preparation: 1) linear -- with a runner slide (or cursor) that moves from a cam mechanism according to a definite law; 2) figured or irregularly shaped; 3) with a variable pitch of the coil winding; 4) electrically "off-profiled".

In his third report, Mayorov discussed for a while two cases where electronic amplifiers are employed in calculating-solving machines:

1) the application of electronic amplifiers as zero indicators in bridge schemes;

2) the application of amplifiers as elements in calculating-solving machines.

The lecturer introduced a regulation scheme with an amplidyne-generator (oscillator), where the amplification was effected by the same amplidyne with feedback in the form of a first derivative.

I. A. Vil'ner reported on the nomographing of analytical functions of a complex variable. The lecturer briefly touched upon the method of equilized (compensated) points, widely used in engineering. Next he dwelled in detail upon the nomographing of general systems of various classes and gave the conditions necessary for rectifiability of scales in nomographing.

I. Ya. Akushskiy's lecture was on the process of diagonal summation in a tabulator. He discoursed on the order of inclusion and on the functions executed by the brush blocks which 'discern' the perforations on the punch cards. Diagonal summation discussed by Akushskiy is employed in the numerical integration of differential equations on a mass scale according to the

Adams-Stormer method. The calculation involves a large number of integral curves with various straight portions.

The Seminar heard L. Ya. Meyshuler's lecture on his method of tabulating implicit functions (because of Meyshuler's illness, his lecture was read by A. A. Bunatyan). In the first part of his report the lecturer discussed the tabulation of two functions u and v given in x any y in the form of two systems and two equations with an implicit expression in u and v. An example of such a case is encountered in determining the latitute and longitude of position according to radio direction finding [RDF, called "pelang" in Russian] of radio stations or according to astronomical observations.

This problem of tabulation of implicit functions is solved by creating two tables of corrections (adjustments) for a constant value of one of the given functions and varying values of the other. A suitable interpretation of this method of utilising the tables was used by the lecturer in searching for the point of juncture of the two curves, after which a horizontal line intersecting both curves is drawn, and in solving the obtained triangle whose sides constitute the corrections. In the second part of the report the lecturer discussed the tabulation of one function with four variables.

S. K. Neslukhovskiy reported to the Seminar on one calculating-solving machine designed for solving a constant dependence of a certain form.

In the creation of this machine it was impossible to go according to the method of modeling, since this method cannot give accuracy above three significant figures. A distinguishing peculiarity of the calculating-solving machine is the materialized electrical tables of trigonometric functions executed in form of a perforated, or punched, tape wound on a metal drum from which a brush block "perceives", or takes off, the value of the function with an accuracy of five places after the decimal point. In order to decrease the dimension of the drum, use is made of the principle of the "indexing head," or graduator. A complete rotation of the drum corresponds to a 10° variation

in the argument, after which an axial displacement is carried out. In this manner the whole range in 90° is packed in nine bands, in consequence of which the angles vary smoothly through several minutes.

The values of the trigonometric functions taken up the brushes enter, by means of electromagnets and wire shafts, the keys of a standard calculating-solving machine. The second distinctive feature of the machine is the electromechanical bond between the tables and the problem-solving installation and between the latter and the feeding installation which reproduces the result on the tape. The whole process of the operation is controlled from one distributive regulating installation of the cam type. The processes of setting up the output data and the calculation overlap each other.

I. I. Rapoport reported on differentiating mechanisms [illegible] a complete translation made of one of his articles is available[7]. A simple frictional mechanism used as a tachometer measures the speed as the first derivative of the displacement. In the case where a variable velocity is measured, such a method gives an error in the readings since one differentiates the sum which consists of the fundamental measurement plus certain deviations from this measurement and the problem reduces to differentiating the average value and to excluding secondary (subtle) phenomena in the form of superpositions.

I. I. Rapoport analyzed the solution of this problem for various laws governing the measurement of speed and proposed schemes involving auto-friction and differentials which enhance the accuracy of measurement.

In appearances that were held after the lecture it was noted that the lecturer proposes a comparatively slightly convenient method for a tracking (following) system in the form of feedback input proportional to the angle of separation which gives unstable operation for sharp impulses of the differentiated quantity and for small degree of damping. There are more convenient methods of feedback input in the form of derivatives.

Several sessions of the Seminar were devoted to the accuracy of calculating-solving devices. The opening speech was made by N. G. Bruyevich. He noted that the problem of accuracy must be set up so that firstly, there is the possibility of foresight, that is, it should be possible to predict accuracy according to tolerance limits and design; and secondly it should be possible in the completed machine to evaluate the accuracy and compare it with the accuracy of another machine. The concept of accuracy must have definite physical significance and must be convenient to handle in practice.

The most significant value in the problem on accuracy is the error in position of the mechanism. However, the absolute and relative errors cannot be taken beyond the criteria of accuracy.

N. G. Bruyevich proposed to consider criterion of accuracy as the ratio of a) the integral given over practical limits of error with respect to the displacement of a given member to b) the full displacement of the given member. This criterion generally characterizes the quality of the mechanism.

Next, I. S. Gradshteyn evaluated the accuracy of calculating-solving devices by proceeding from the relation of two errors -- namely, the errors of the same device as related to the error due to the discrete assignment of output data. In other cases I. S. Gradshteyn proposed to relate the errors between the input, solving, and the output parts of the entire device. As a result of ensuing discussions it was clarified that in the main this procedure cannot characterize the accuracy of the entire calculating-solving apparatus. The relation among the various errors of the problem-solving device in the optimum case can be referred to the question of the rational or irrational conjunction of comparable parts of the device. The discussion on the problem of criteria of accuracy will be deferred to the end of 1947.

Reports on the accuracy of toothed wheels were made by O. N. Korsakov [author of this article] and N. P. Zakaznov. The former lectured on the errors of cylindrical toothed wheels in the case where they are manufactured according to different systems of tolerances and gave a comparative

evaluation of various departmental norms governing defects of manufacture of toothed wheels.

M. P. Zakasnov reported on existing methods of increasing the accuracy of toothed mechanisms. Present methods of increasing the accuracy of toothed wheels, besides decreasing the limits of tolerance in manufacturing, involve "adjustment", that is, an assembling in such a way that the action of the errors or defects appear a minimum. M. P. Zakasnov talked on various forms of adjustment of toothed wheels having value in most cases and decrease in the action of the most harmful error -- namely, the eccentricity of toothed wheels. By way of illustrating numerical quantities he compared various forms of adjustments.

M. L. Bykhovskiy lectured on his work of clarifying the investigation of accuracy in differential analysers. He reported on his method of setting up the fundamental equations for the determination of the errors, in an analyser, that are in a finite system of ordinary differential equations connecting the primary errors of the mechanism. He also reported on a method of statistical analysis of these equations.

At one of the sessions of the Seminar, M. L. Bykhovskiy gave an informative report on the automatic calculating-analytical machine at Harvard University, which was constructed under the direction of Prof. G. Aiken . The novelty of this machine was the combination of calculation with high accuracy. The machine carries out elementary arithmetical operations and inspection in tables of transcendental functions with 25 significant figures. The machine contains an interpolating block. A tape automatically registers both the solution and the succession of operations performed. The originality of the machine is the testing of results by means of a special counter ~~(calculator~~ after every 20 cycles.

The sessions of the Seminar in the first half of 1947 were concluded by a report by L. V. Kantorovich (Leningrad) on the approximate calculation of the eigen-values of matrices and integral equations, which occur in the

problem of determination of the frequencies of small oscillations in a system with a finite number of degrees of freedom.

In the solution of this problem it is necessary to derive the generating operator by special means.

The originality of L. V. Kantorovich's proposed method of finding the operator involves the employment of iterative methods of successive approximations which gives in comparison with other applications great advantages, especially in mass calculations.

Starting November 1947, the Seminar resumed its work. In the near future the Seminar proposes to take up the study of the following problems:

1) Solution of mathematical problems on punch-card machines

2) The accuracy of several very important mechanisms; for example, toothed mechanisms.

3) Several methods and problems of approximate calculations.

4) Information concerning works on the automaticization of calculations in the USSR and in foreign countries

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