ABSTRACTS

DEPARTMENT OF ELECTRICAL COMMUNICATION ENGINEERING

1. AN IMPROVED METHOD OF DEMODULATION OF WIDTH-MODULATED PULSES. V. Narayana Rao, *Electrotechnics*, March 1951, No. 23, 75–84.

The paper gives an account of the theoretical and experimental investigations carried out by the author regarding the demodulation of width-modulated pulses. A brief account is given of the spectrum of width modulated pulses and of the edge noise accompanying such pulses. It is shown that an improvement in signal to noise ratio is obtained if signal power can be extracted from the sidebands accompanying each of the pulse repetition frequency harmonics. The experimental set-up to check this theoretical improvement is also described.

2. A METHOD OF GENERATING WIDTH-MODULATED PULSES. V. Narayana Rao, *Electrotechnics*, March 1951, No. 23, 85–92.

The paper describes a new method of producing width-modulated pulses employing square waves. The modulation characteristics for a typical tube and circuit arrangements are shown. A step by step circuit analysis is also given. Also the harmonic distortion inherent in this system is theoretically examined and curves are drawn of the second and third harmonic distortions as functions of the circuit parameters and percentage modulation.

3. EQUIVALENT Π AND T NETWORKS FOR ALL FREQUENCIES. B. S. Ramakrishna, *Electrotechnics*, 1950, No. 22, 121.

The T and π networks constructed as equivalent to each other at any definite frequency in the usual manner do not preserve their equivalence as the frequency is changed, unless the networks happen to be constructed entirely of a single kind of element, *i.e.*, either entirely resistive, inductive, or capacitive. In this article, a method of obtaining T and π networks equivalent to each other at all frequencies is developed for the case in which the original network whose equivalent is desired, contains more than a single kind of element. This is done by keeping the frequency as an explicit variable in the relationships determining the impedances of the equivalent network sought for. Such networks would be equivalent to each other not only for steady state signals of any frequency, but also for transient signals. The general possibility of representing a given four-terminal network by means of a T network-equivalent for all frequencies is also indicated.

4. A CASE OF COMBINED RADIAL and AXIAL HEAT FLOW IN COMPOSITE CYLINDERS. V. R. Thiruvenkatachar and B. S. Ramakrishna, *Quart. Jour. of Applied Math.*, October 1952, **10**, No. 3.

Although several problems of heat flow in composite cylinders have been studied, all the cases considered treat the heat flow in the radial direction only. The case of combined radial and axial heat flow in composite cylinders presents an interesting boundary value problem which has also considerable significance in the theory of vibrations and propagation of electromagnetic waves. In this paper, a case of combined radial and axial heat flow in the unsteady state in finite cylinders composed of two coaxial parts of different materials is considered. The temperature distribution in the cylinder at any instant under the assumed boundary and initial conditions has been obtained by the use of the Laplace transformation. The procedure is illustrated by a numerical calculation in a particular case.

5. A TRIGONOMETRIC SERIES USED IN PHYSICAL PROBLEMS. S. K. Lakshmana Rao and B. S. Ramakrishna, *Nature*, Feb. 14, 1953, **171**, 308.

In connection with a certain boundary value problem in room acoustics, the trigonometric series mentioned below has been encountered. As it happened that certain other trigonometric series met with in some other physical situations can be obtained as special cases of this series, the summations have been carried on in closed form.

The series concerned were

$$\sum_{n=1}^{\infty} \frac{\sin (n+0)\, x}{n+0} \; \frac{\sin (n+\psi)\, n}{n+\psi}, \quad 0 < x < \pi)$$

and the corresponding series in cosines.

6. CERTAIN TRIGONOMETRIC SUMMATIONS. S. K. Lakshmana Rao and B. S. Ramakrishna, *Proc. Ind. Acad. Sci.*, 1952, **36**.

The details of the calculations of the above series are given in this paper.

MECHANICAL ENGINEERING SECTION

1. THE EFFICIENCY OF HEAT TRANSFER IN EXTENDED SURFACES OF TRIANGULAR PROFILE BY AN ANALOGIC METHOD. Nigamananda Das and A. Ramachandran, *Electrotechnics*, 1952, No. 24, 127.

Generalised equations for heat transfer in various forms of extended surfaces have been developed on mathematical basis by previous investigators for undisturbed temperature conditions. The geometrical type of electrical analogger provides a ready analysis of heat transfer in extended surfaces under various boundary conditions. In this paper the above method has been made use of in studying the heat flow in a straight triangular fin under a particular boundary condition, and "Comparative Efficiency" data have been given for different height-width values of the fin. The 'Economy' of fin dimensions has also been discussed which indicates the maximum length of straight fin for any value of width of the base. As shown in the paper, the results agree qualitatively with those obtained from generalised mathematical equations.

DEPARTMENT OF AERONAUTICAL ENGINEERING

1. METHOD OF USING EXPERIMENTALLY GIVEN FUNCTIONS AS APPLIED FOR DERIVING THE MAXIMUM EFFICIENCY OF SHIP PROPELLERS. O. G. Tietjens, *Mechanical Engineer*, October 1950.

It quite often happens that the functional relations between physical quantities in research problems are far too complicated to be dealt with in an analytical manner. Even in purely theoretical problems it often so happens that an integral cannot be integrated and recourse has to be taken to a graphical or numerical solution of the integral. In the further course of the investigation, whenever the solution of this integral is being made use of, not an analytical expression but only a set of graphs is available.

Or in other cases, parts of a research investigation are not yet sufficiently advanced in theory and one has to rely on relations between physical quantities obtained by experiments. Also here instead of a mathematical expression only a set of curves representing the experimental data are available. There is, however, an essential difference in the two sets of curves mentioned. In the first set the accuracy can be improved to any desired degree, whereas this is not true, as a rule, for experimentally given curves.

In the paper it has been shown in what manner functional relations, obtained either by graphical integration or by experiments, can be worked with and that far-reaching results can be obtained in this way which otherwise to obtain would be quite impossible. The method is applied to the problem of propeller design of highest efficiency taking into account all possible losses, that is to say not only losses which could not be avoided when neglecting the viscosity of the fluid but also the losses due to viscosity.

The fundamental data to be given for the design of a propeller are: the thrust, the forward speed, the angular velocity (rpm) and, of course, the density of the fluid. The data which should be furnished by the theory are: (i) the most favourable diameter and, hence, the best speed ratio and the best specific loading, (ii) the profile, (iii) the chord, (iv) the effective angle of incidence of the various blade elements and (v) the highest possible efficiency. The outline of the theory is given in case of a 2-bladed propeller. The theory is based on the distribution of the circulation as given by S. Goldstein.

Since experimental data as to the performance of a sufficiently large variety of profiles in air are not yet available, particularly, for Mach Number close to 1 or even beyond 1, the theory has been applied only for waterscrews so far. For waterscrews the required variety of profiles is considerably less (sickle profiles) and sufficient data are available including those for very small coefficients of cavitation ($\sigma = 0 \cdot 1$).

It is the first time that, besides the induced drag of the blade elements also the profile drag has been taken into account for calculating the highest possible efficiency of a propeller with finite number of blades.

2. THE WIND TUNNEL, THE BASIC RESEARCH EQUIPMENT IN AERONAUTICAL ENGINEERING. O. G. Tietjens, *Mechanical Engineer*, Dec. 1951.

After having pointed out the enormous power required for modern wind tunnels the performance of the two types of wind tunnels is explained, *viz.*, the open-circuit and the closed circuit wind tunnel. Contrary to the prevailing opinion that the closed circuit type is more efficient, *i.e.*, requires less power for a given area of test section and for a given air velocity since it is always the same air which only needs to be circulated, it is shown that the open-circuit type is the more efficient one.

A comparison is carried out in detail as to the power requirements of the two types, based on the same size of structural parts, *viz.*, settling chamber, test section and diffusor. It is shown that on this basis, the power requirement of a closed circuit type is about 45 per cent. larger than that of an open-circuit type. Besides this, there are other advantages in favour of the open-circuit type: no need of guide vanes and of the four " corners " of the closed type, no cooling tower or air exchanger is required with the open-circuit type since always fresh air of constant temperature is sucked in and accelerated. But more important is the fact that the turbulence level can be made considerably smaller with an open-circuit wind tunnel than with the closed type. All the disturbances and turbulence created by the propeller, the guide vanes, etc., which reach the test section in the case of a closed circuit wind tunnel, are discharged at the outlet of an open-circuit wind tunnel.

The second part of the paper deals with the problem of how far model tests can be applied to full size airplanes. The relative importance of the Reynolds Number and of the Mach Number is discussed to some extent and it is pointed out that the general trend in modern wind tunnel testing goes rather in the direction of investigating the principles of the flow phenomena in different wind tunnels specifically built for various purposes. The technical impossibilities, for the time being, to build the power units required for wind tunnels of ever-increasing sizes and velocities represent, on the one hand, a barrier for further investigation; on the other hand, however, it also suggests a more sound way of investigating the problems, namely, by studying the fundamentals and the underlying theories rather than by obtaining the integrated effect of the flow by means of model tests at equal Mach Numbers and similar Reynolds Numbers as for the full size airplanes.

3. ON THE PHYSICAL SIGNIFICANCE OF SOME DIMENSIONLESS GROUPS IN THE THEORY OF HEAT TRANSFER. P. Srinivasa Row, *Mechanical Engineer*, December 1951.

Any formulation which expresses a relation between several physical quantities is in essence an algebraic equation in which the measurements or numbers—denoted by letters—imply but do not disclose the units in which each one of the several entities have been measured. Corresponding to this we have a dimensional equation which tells us how the dimensions of these units are combined in each term of the algebraic equation. It is obvious that the physical equation should necessarily be dimensionally homogeneous. In brief, dimensional analysis is a search for a correct dimensional form for an unknown equation.

Buckingham's π theorem is first presented in the paper as a preliminary to the study of dimensional analysis. The demonstration of this theorem is on the lines suggested recently by Stanley Corrsin in his paper on "A Simple Geometrical Proof of Buckingham Theorem" (*American Journal of Physics*, March 1951, **19**, No. 3, 180).

In the study of heat transfer, the analysis becomes extremely simple by forming dimensionless groups of the several physical quantities involved. We thus get for example the Nusselt Number $N_{NU} = \frac{hD}{k}$, where h is the film coefficient or the heat transfer from a fluid flowing in a smooth pipe, D the diameter of the pipe and V the velocity of flow. Indicating the density by ρ and the viscosity by μ we have the Reynolds Number $N_{Re} = \frac{VD}{\mu}$, and the Prandtl Number $N_{Pr} = \frac{c\mu}{k}$, where c is the specific heat and k the coefficient of thermal conductivity. Several other combinations yielding dimensionless groups are indicated by other names such as Peclet Number N_{Pe}, Grashof Number N_{Gr}, etc., and these have considerably helped in solving the complex problems of heat transfer.

It has been possible to dive a little deeper and see that these different numbers have definite physical significance. The Nusselt Number, for instance, can be shown to represent the ratio of turbulent heat transfer to molecular heat transfer. The Reynolds Number can be regarded as a measure of the ratio of the turbulent momentum exchange and an effective molecular momentum exchange. Further, these different numbers are interrelated as, for example, the product of the Reynolds Number with the Prandtl Number gives us the Peclet Number. The interrelation between the different numbers are exhibited on a diagram in accordance with the scheme of Van Driest.

Similarity relations are then discussed and the part played by the different dimensionless groups is discussed in detail. Each fixed pair of values, N_{Gr} and N_{Pr} can be shown to determine a series of similar cases all of which have the same Nusselt Number. All possible cases, which may be thought of as points in a quadrant of a plane with co-ordinates $N_{Gr} > 0$ and $N_{Pr} > 0$ determine one unique surface in the space with positive values of N_{Nu}' as the third co-ordinate.

The dimensionless analysis of convection is considered next and in the course of the discussion of more complex cases of similarity we come across the Stanton Number. This is identical with von Karman's Heat Convection Number.

4. A NOTE ON THE DESIGN OF COLUMNS STRESSED BEYOND THE YIELD POINT. C. L. Amba Rao, *Mechanical Engineer*, December 1951.

For materials like wood, annealed copper, aluminium and brass alloys which have fairly low elastic limits and have no well-defined yield point, to be useful, it necessitates the working of the material in the plastic range. A number of empirical relations have been advanced by different workers in the field. In this short note an attempt is made to discuss the applicability of each. Column failures can be broadly classified into two groups: general instability failure or primary failure and local instability failure or secondary failure. Each of these can be further subdivided into elastic instability failure and inelastic instability failure. The offset method of obtaining yield point is discussed. The various modulii of elasticity put forward by Engesser, Considere, Karman and Osgood for the plastic range are discussed in detail. Detailed working of Johnson's parabolic equation in the short column range and Euler's in the long column range is also given.

In the plastic range in Euler's equation if the double or reduced modulus $\bar{E}$ or the tangent modulus E_t is substituted instead of E, stresses in the plastic range are obtained. For ordinary purposes E_t is easier to evaluate and gives lower values while the calculation of $\bar{E}$ for some out-of-the-way sections is complicated and the stress obtained thereby is higher too. For columns with ordinary workmanship the experimental points in the short column ange fall generally below the reduced modulus curve. For these reasons the use of E_t gives better agreement with the experimental results. At very high stresses E_t is small compared to Young's modulus E, which is constant for a given material. Hence E_t is the main criterion influencing the main value of E. In the plastic range there are no wide variations in E_t with respect to grain direction and stress relieving. This works favourably in anisotropic materials.

5. REDUNDANCY OF A STRUCTURE. P. Narasimhamurthy, *Mechanical Engineer*, December 1951.

Redundancy of a structure can be defined as the degree of static indeterminateness of a structure. A classified list of redundant structures of ordinary occurrence is given. In the solution of redundant structures the additional conditions are provided by the elastic behaviour of the structure under load. Before proceeding to analyse a structure it is always helpful to determine the nature of redundancy and the degree of redundancy. The nature of redundancy of a structure may be with respect to its internal or external forces. A study of the nature of supports provides information regarding the nature or redundancy. Three kinds of supports in structural work are discussed. Internal redundancy and external redundancy in a structure are defined and discussed with examples. The degree of redundancy is also explained and examples have been worked out to predict the degree of redundancy in plane frames as well as space frames. Some special types of statically indeterminate stresses have also been dealt with. The significance of zero load test is also given.

6. BUCKLING OF AN N-SECTION COLUMN. G. Sri Ram and G. V. R. Rao, *Jour. of the Aeronautical Sci.*, Jan. 1952, **19**, No. 1.

Consider a column built in at one end and free at the other, subject to an axial load P. The failure of the column is assumed to take place due to lateral instability rather than by direct compression. When the column is made up of N sections along its length an analytical solution for the critical load can be obtained. Let L be the total length of the column and $l_i = L_i - L_{i-1}$ = the length of the i-th section of the column. With the moment of inertia I_i this section can be characterised by $k_l l_i$, where $k_i^2 = \frac{P}{EI_i}$ and E is the Young's Modulus for the material of the entire column. Assuming that δ is the deflection at the free end, one can set up the differential equation for the i-th section as

$$EI_i \left(\frac{d^2 y_i}{dx^2}\right) = P(\delta - y_i).$$

The solution can be obtained in the form of

$$y_i = \delta + A_i \cos k_i x + B_i \sin k_i x.$$

The 2N + 1 constants A_i, B_i and δ can be solved with the help of 2N + 1 known boundary conditions of the column. If these coefficients have non-zero values one must satisfy a determinantal equation. The expansion of the determinant leads to a transcendental equation, the solution of which gives the critical load of the column.

The transcendental equations in the case of 2 sections, 3 sections, 4 sections and N sections are given and simplified form for N-sections is written down.

A symmetrical column with both ends pinned can be reduced to the case treated above by considering only half the length of the column. For an unsymmetrical column pinned at both ends similar formulæ can easily be obtained. A numerical example is carried out applying this method for a column built up in 4 sections. The approximate solution gives the critical load of $P_{cr} = 1\cdot979 \frac{EI_1}{L^2}$. The accurate solution yields $P_{cr} = 2\cdot019 \frac{EI_1}{L^2}$, compared to the strain energy method which gives the critical load $P_{cr} = 2\cdot034 \frac{EI_1}{L^2}$, where I_1 is the section of the column at the built-in end.

7. PLASTIC DEFORMATION IN BEAMS. Y. V. G. Acharya and G. Janaki Ram, *Curr. Sci.*, May 1952.

The plastic behaviour of a material loaded beyond yield may be compared to that of a highly viscous fluid. For equal deformations in the plastic and elastic states, the stress for plastic deformation is much less than that for the elastic state, with the result that the sustained stress in the former state tends to fall. This gives rise to the upper and the lower yield points. In the stress strain diagram these two points are clearly marked for structural steels, whereas in ductile materials the difference between them is not so marked. The corresponding stresses, *i.e.*, the upper and the lower yield stresses, the difference between which may be as high as 25% of the higher stress, are very important and introduce many complications in the theory of elasticity.

If it is considered that the change from the elastic to the plastic region in a material which is in an elasto-plastic state of stress occurs over a layer which is very thin, then the gradient of the stress and hence the instability in this layer would be large. If this layer has a finite thickness, then the stress gradient and consequently the instability would be small. In any case this layer appears to spread fast initially and then slowly till the whole material goes into a plastic state. Hence the criterion for determining the working stresses in a material is the lower yield stress rather than the upper yield stress. This elasto-plastic region has its analogues in hydrodynamics, the methods of which may be applied here also.

If this layer is sufficiently thin to be considered infinitesimal, it may be treated as a shock. If it has an appreciable thickness, it may be considered analogous to a boundary layer which is a region of distributed vorticity and can be laminar or turbulent, and which may " separate " or generate secondary flow. These concepts may be used in an investigation of the elasto-plastic flow.

From an engineering point of view, the moments of rectangular beams under pure bending have been calculated for the following cases: (*a*) within the yield point, (*b*) above the yield point beyond some point for structural steels where the stress falls to the lower yield and (*c*) above the yield point as before for ductile materials where the stress is sustained at the upper yield.

8. PARTIALLY FIXED BEAMS. C. V. Joga Rao and J. V. Rattayya, *Curr. Sci.*, January 1953.

The so-called fixed beams are only partially fixed at their ends. In several cases it might be possible to assume ideal fixity and proceed with the design without making any appreciable error. However, in other cases when the fixities are far from ideal, it is essential to take the partial fixities into account if the accurate analysis and design are needed.

The coefficient of end fixity can be defined as the ratio of actual bending moment at a partially fixed end to the bending moment at the same end in case of ideal fixity of both ends. If K_A and K_B are the partial and fixity coefficients in a fixed beam ($O < K_A \leqslant 1$, $O < K_B \leqslant 1$), it is possible to calculate the bending moment under the load, shear just to the left of the load, shear just to the right of the load and deflection under the load. It is shown that all these are functions of three variables, namely, K_A, K_B and the location of the load, if the load itself is considered as the unit load. Hence nomograms can be constructed with K_A and K_B and the location of the load as independent variables. These nomograms can be used to determine the actual coefficients of end fixity of any given beam.

In practice we can obtain with a given load acting at any point the normal stress under the load by means of electrical strain gauges and this gives us the value of the bending moment under the load. A second equation can be got similarly with the known load at another known point and these two equations can be solved for K_A and K_B. Alternately two deflection experiments or one bending stress measurement and another deflection measurement will give us the required information to solve for K_A and K_B. Once the end fixities are known either the normal procedures or the nomograms can be used for an accurate design.