DU MONT

VOL. 4, NO. 12
VOL. 5, NO. 1

APRIL-MAY, 1941

OSCILLOGRAPHER

DYNAMIC BALANCING OF SMALL ROTORS BY MEANS OF THE CATHODE-RAY OSCILLOGRAPH

by

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As is well known, the elimination of bearing vibration in a rotating mass possessing length in the direction of the axis of rotation requires more than simple static balance. Static balance will have been achieved when the rotating mass or rotor, freely supported on a horizontal axis, shows no tendency to come to rest with a particular heaviest point downward. Mathematically this condition is expressed as that in which the center of gravity of the rotor lies on the axis of rotation.

But what is required at high speeds is dynamic balance. This will have been achieved when, if the rotor is flipped out of its bearings into free space while spinning, it will continue without wobble to spin about its original axis. Mathematically this condition is expressed as that in which the products of inertia of the rotor about its axis of rotation are equal to zero.

It can be demonstrated mathematically that a rotor can be brought to perfect balance by two weight adjustments made at any radial distance in any two non-coincident planes which are perpendicular to the axis of rotation. When convenient circles have been chosen as the correction loci, the practical problem remaining is to determine the amount and location around the periphery, of the masses which must be added or subtracted. In order to achieve a balance with a minimum change of mass, it is customary in the case of rigid rotors to choose the correction planes to be near opposite ends of the rotation axis and to choose the correction radii as large as possible.

The method of balancing described in this paper is not claimed to be entirely new in principle, but is a development of Akimoff's procedure. The rotor to be balanced is mounted in cantilever bearings and rotated at controlled speeds. In the figure a small armature to be balanced is mounted in its own bearings, together with field pieces and brushes, so that it can be electrically driven. Other small rotors may be driven by belts or by air jets. The cantilevers should be sufficiently stiff so that the associated natural frequencies lie within the range of the cathode-ray oscillograph amplifier. The needle of a rochelle salt phonograph pickup ("P" in the figure) engages the side of each bearing cantilever ("C"), so that the bending of each cantilever generates a corresponding voltage. (This type of pickup has advantages over the magnetic type, in that its response to amplitude is independent of frequency and its peak instantaneous voltage occurs at peak displacement).

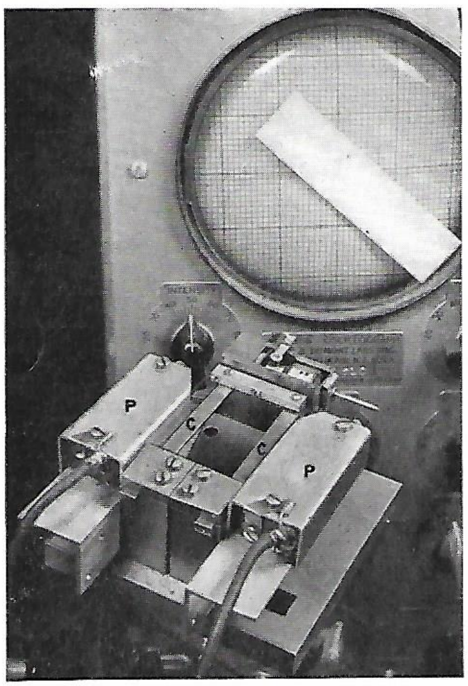

Figure 1: Arrangement of cantilevers and pickups for the balancing of small rotors.

A rotor mounted in the described manner will have two modes of vibration. In the first of these the two bearing cantilevers will bend in phase, i.e., will move up and down together. In the second mode the cantilevers will move out of phase, so that the rotor executes a torsional motion about an axis parallel to the cantilevers. In the more usually shaped rotors, where the radius of gyration about the rotor axis is not too large compared to the inter-bearing distance, the resonant frequency of in-phase motion will be considerably below that for out-of-phase motion. The subject method of balancing utilizes this fact and also the fact that static unbalance tends to cause in-phase motion, whereas the dynamic unbalance remaining in a statically balanced rotor tends to cause out-of-phase motion.

The procedure to balance a rotor is to connect the phonograph pickups respectively to the horizontal and to the vertical deflection amplifiers of a cathode-ray oscillograph. When the rotor is turned at a speed *below* the out-of-phase resonant frequency and *above* the in-phase frequency, the in-phase motion of the bearings resulting from static unbalance will appear on the screen as a narrow loop whose slope to the left or to the right can be checked as corresponding to in-phase bearing motion. Now, the amplitude of motion resulting from a mass unbalance is independent of frequency for frequencies well above resonance. Hence the deflection of the cathode-ray beam will be constant and proportional to unbalance over a range of speeds and the speed adjustment is not critical.

It is next necessary to determine the angular position at which the mass should be applied to achieve static balance. The rotor should be marked with numbers around its circumference. Mask off the cathode-ray screen so that only the extreme deflection appears. Turn up the brightness control and bring the rotating rotor close to the screen in a darkened room. For best results the screen of the cathode-ray tube should be at least 5 inches or larger in diameter. The number which is "stopped" at the top of the rotor marks the point at which weight must be added or subtracted. If there is any overall phase shift, the proper point for mass correction may be slightly to either side of the top number on the rotor. Such phase shift can be separately determined by adding a relatively large mass next to a particular number on the rotor and by noting where this number is stopped. Similarly, the direction of the correction can be determined and the needed mass change estimated by adding a small known weight at the stroboscopically determined point. Then by successive, approximating changes of mass, a minimum cathode-ray deflection, indicating static balance, will be obtained.

Dynamic balance is achieved by increasing the rotor speed to above the out-of-phase resonant frequency. The slope of the deflection line on the oscillograph will reverse in sign, showing the change of relative phase for the bearings. If the static balancing has been properly carried out, the screen pattern will be a very narrow rather than a wide loop.

The mass adjustment for dynamic balance is accomplished as for the static case except that mass must be added or subtracted at two diagonally opposite points in the stroboscopically determined plane thru the rotor axis. Mass adjustment is carried out until the voltage output of both pickups is a minimum.

Actually, after a little skill is gained, it is not necessary to make the static and dynamic corrections separately. In the presence of combined static and dynamic unbalance, at speeds above the out-of-phase frequency an open loop will be observed on the cathode-ray tube. With equal horizontal and vertical amplification, one pickup will be seen to generate the larger signal. The gain of the other amplifier should be reduced to zero, and the rotor stroboscopically stopped by properly masking the remaining horizontal or vertical deflection line. The weight correction should be made on the rotor end generating the larger voltage. By successive repetition of the procedure, the Lissajous loop can be closed and reduced to zero simultaneously.

MEZGER CALLED TO ACTIVE DUTY IN U. S. NAVY

Many of our readers have been calling on G. Robt. Mezger during the past years for information relative to the application of Du Mont Cathode-Ray Tubes and Oscillographs. Mr. Mezger was recently called to active duty by the Navy Department and we are sure our readers will feel the loss of this source of information on Cathode-Ray Oscillography as much as we do at Du Mont. However, our Mr. L. F. Cramer, who previously handled this position, has again taken over the direction of this department. We are sure your inquiries addressed to Mr. Cramer will receive the prompt attention to which Du Mont customers have become accustomed.

SPECIAL NOTICE

Due to the U. S. Governments restrictions on the use of certain materials, it has become necessary to employ substitutes wherever possible. Although these substitute materials are being used in our instruments, the performance specifications of the latter are in no way affected. It is necessary, in accepting orders during the present crisis, that we reserve the right to make any necessary substitutions of materials in the manufacture of our equipment.

CATHODE-RAY SYMPOSIUM AND PRIZE CONTEST EXTENDED

Due to the great and rapidly growing importance of the cathode-ray tube in National Defense activities, the DuMont prize essay contest has had to be extended for another three months in order to provide a still greater fund of practical information. However, no further extension will be granted, and all essays must be in by September 1st, 1941.

The Cathode-Ray Symposium and Prize Essay Contest remains open to everyone regardless of position, title, academic and engineering qualifications. Contestants may submit any number of papers, but only papers dealing with actual applications of cathode-ray tubes, oscillographs or other cathode-ray equipment, are eligible. Theoretical discussions, contemplated projects or mere suggestions cannot be considered. The application, however, may be in any field. Subject matter only is considered, and contestants may express themselves as best they can. Photographs, drawings and sketches will count heavily but are not essential if text is sufficiently explicit. Outstanding authorities in the cathode-ray field will act as judges, and their decisions will be final. All papers become the property of Allen B. DuMont Laboratories, Inc., of Passaic, N. J., and none can be returned. Papers accepted for publication in the "DuMont Oscillographer" will receive an honorarium of $20. In addition, there will be awarded three grand prizes of $100, $50 and $25 for the three best papers submitted during the Symposium.

ALLEN B. DU MONT LABORATORIES, INC.
2 MAIN AVE., PASSAIC, NEW JERSEY

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