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LETTERS TO THE EDITOR

AN ELECTRICAL IMPULSE LOADING DEVICE FOR THE DYNAMIC ANALYSIS OF STRUCTURES

An electrical impulse loading device based on capacitor discharge has been developed and tested.

1. INTRODUCTION

In linear systems analysis, it is considered that an impulse whose duration is less than one cycle of the highest natural frequency of the system is a good approximation to an ideal impulse function, whose spectrum contains equal amplitudes of all frequencies. With such an excitation all of the natural frequencies of the system are excited simultaneously [1]. The impulse technique is quite convenient and accurate for measuring the natural frequencies of vibration of the system.

The time period of the highest natural frequency of vibration of many types of structures is of the order of milliseconds. In order to make a good approximation to an ideal impulse function, the duration of the impulse should be about one-tenth of the above time: i.e., of the order of microseconds. Mechanical mechanisms will fail to produce an impulse of this duration due to the inertia inherent in them.

In view of the ferromagnetic nature of most structures, an electromagnetic impulse loading device is of interest and an account is given here of the development and testing of such a device [2].

2. DEVELOPMENT OF THE DEVICE

It is known that pulses associated with very high accelerations can be produced electrically. An electromagnet is used to convert this electrical pulse into a mechanical impulse.

If F is the force exerted by an electromagnet, then [3, 4]

$$F = K \frac{(NI)^2}{L^2} A, \tag{1}$$

where N is the number of turns of the coil, I the current through the coil, A the area of the core, L the length of the air gap and K a constant of proportionality. The main problem in connection with an electromagnet is that it does not allow a sharp rise or fall of current flowing through the coil due to its inductance effect. This effect can be reduced by using an air core copper coil (see Figure 1 and Plate 1) having 4 turns. To allow high currents to flow, the coil (1) is made of $\frac{3}{8}$ in diam. copper rod. The inductance of the coil is 2 microhenries at 10 kHz.

The capacitor discharge system is chosen to produce an electrical impulse of very short duration. Commercially available (32 + 32) microfarads electrolytic capacitors rated at 400 working volts are used to make the capacitor bank. With sixteen such capacitors, the total capacitance of the bank (2) is 1024 microfarads.

A bridge rectifier (3), rated at 230 working r.m.s. a.c. volts and 800 milliamperes is used to charge the capacitor bank.

A charging resistor is necessary to limit the peak charging current within the current rating of the rectifier. A coiled coil filament type 60 watt electric lamp (4) is used to limit the peak charging current. The advantage of using an electric lamp as a charging resistor is that its resistance decreases directly with the decreasing current through it. Thus the electric lamp

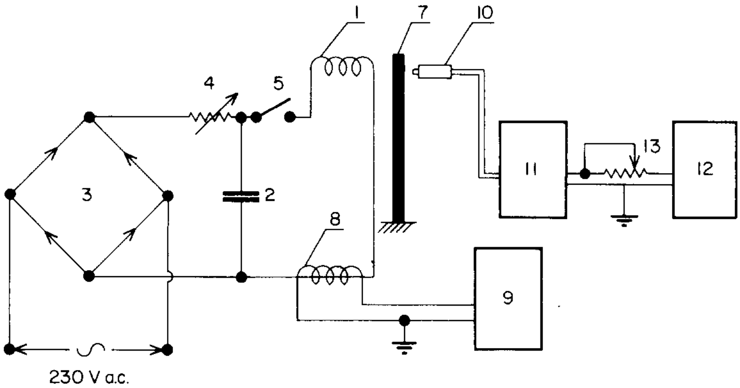

Figure 1. Schematic diagram of impulse loading apparatus. (1) Copper coil, ⅜ in diam. wire, 4 turns; (2) capacitor bank, 1024 μF, 400 V; (3) bridge rectifier, 230 V, 800 mA; (4) charging resistor, 60 W electric lamp; (5) 60 A mains switch; (6) stiff steel base (shown in Plate 1 only); (7) thin M.S. strip model, 3·18 × 10 × 300 mm; (8) current pulse sensing coil; (9) cathode ray oscilloscope, Model VP-516 A, Matsushita, Japan; (10) electromagnetic vibration pick-up, velocity type, PR 9262/02 Philips; (11) amplifier in the vacuum tube voltmeter, model, NP-955 C, Matsushita, Japan; (12) UV Recorder, S.E.2100, SE Labs (Engg.) Ltd., U.K.; (13) variable resistor.

acts as a positive current coefficient resistor and is ideally suited for the purpose. This enables quicker charging than with a fixed resistor and also serves as a visual display during charging.

With this arrangement, the capacitor bank also can get charged to the peak value of the voltage, i.e., $\sqrt{2} \times 230 = 325$ volts, without much voltage loss due to the charging resistor. The energy stored is about 54 Joules. Higher voltages are not used so as to reduce arcing of the charge between the contacts of the switch.

A 60 Ampere mains switch (5) is used as the closing switch. Though high currents flow through the coil, the above switch is found suitable, because the duration of the electrical impulse is very short.

A thin mild steel strip (7), in cantilever configuration, is used as the structural model to be excited. The M.S. strip model has a width of 100 mm. The copper coil is made to have a core area of 100 × 100 mm^2 to reduce force concentration per unit area. To properly close the magnetic circuit, the copper coil is gas welded on one side to a stiff steel base (6). The steel base is electrically insulated from the supporting steel rails.

3. RECORDING OF CURRENT PULSE AND IMPULSE RESPONSE

A PVC insulated copper core wire with 4 turns on the high current carrying conductor is used as the current sensing coil (8), whose terminals are connected to a cathode ray oscilloscope (9) with one of the terminals being earthed. By using the built-in internal triggering of the CRO, the current impulse could be observed on the CRO screen in the dark. The current impulse lasted for 38 microseconds and it was the luminous property of the CRO screen that made it possible to see such a short-time pulse. The observed current pulse is shown in Figure 2.

As the force exerted by an electromagnet is proportional to the square of the current, as given in equation (1), it is obvious that the time constant of the force pulse is equal to half the time constant of the current pulse. Thus, as the current pulse falls to almost zero in 34 microseconds, the force pulse falls to almost zero in $38/2 = 19$ microseconds. (More precisely, the current pulse falls to 1·8 % of the peak value in time $t = 4T$, where T is the time constant of the current pulse, and the force pulse falls to 1·8 % of the peak value in $38/2 = 19$ seconds.)

Plate 1. Photograph of the impulse loading apparatus.

Plate 2. Impulse response of the strip model (recording speed: 200 mm/second).

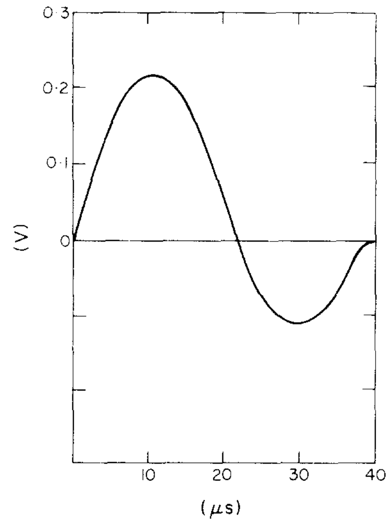

Figure 2. Current pulse (as visually observed on the CRO screen).

An electromagnetic vibration pick-up (10), placed near the free end of the model is used to pick up the impulse response of the model. The signal from the pick-up is amplified by an amplifier (11) and fed to the galvanometer terminals of an ultraviolet light (UV) recorder (12) through a variable resistor (13). The impulse response is recorded on a bromide photographic printing paper loaded in the UV recorder. Copies of the original record are taken by direct contact printing (see Plate 2). The pick-up used is of velocity type, and Plate 2 shows the record of the velocity of the model.

At a point centrally located in the force acting area, the maximum displacement is roughly 1 mm. The static stiffness of the model at that point is found to be 0·275 kg/mm. Thus, the equivalent static force acting on the model will be about $\frac{1}{4}$ kg.

4. CONCLUSIONS

The principle of capacitor discharge can be successfully used to generate an impulse force of microseconds duration. The force magnitude may be increased by increasing the energy storage. The impulse response will be of considerable use in the analysis of vibration behaviour of structures.

Department of Mechanical Engineering,
Regional Engineering College,
Warangal 506004, *India*

V. SIVA PRASAD
R. L. MURTY

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REFERENCES

1. L. J. LEWIS, D. K. REYNOLDS, F. BERGSETH and F. J. ALEXANDRO, JR. 1969 *Linear Systems Analysis*. New York: McGraw-Hill Book Company.
2. V. SIVA PRASAD 1973 *M.Tech. Dissertation. Regional Engineering College, Warangal.* An electrical impulse loading device for the dynamic analysis of structures.
3. G. W. HEUMANN 1961 *Magnetic Control of Industrial Motors, Volume* 3. New York: John Wiley and Sons.
4. R. B. ANGUS 1968 *Electrical Engineering Fundamentals*. Reading, Massachusetts: Addison-Wesley.