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MASTER

STUDY OF FREQUENCY RESPONSE
OF SHEFFIELD ELECTROJETS

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Charles H. Jacobson and Robert R. Moore

Abstract. Experiments were undertaken to test the limits of frequency response in a Sheffield Electrojet device. Specific application related to measurement of lathe spindle runout at high speeds (about 2000 revolutions per minute). Findings show the response will be accurate to driving frequencies of 30 cycles per second, as compared to normally used maximums of one cycle per second. Such capability suggests possible applications in other related work efforts.

INTRODUCTION

The Sheffield Electrojet® is a displacement sensing transducer¹ of the linear variable differential-transformer type. Motion of an iron plunger or core in a transformer produces a signal which is detected, amplified, and usually displayed on a panel meter or a strip-chart recorder. The frequency response of these display devices is usually a maximum of about one cycle per second (cps).

Such transducers are widely used at Rocky Flats. The manufacturer specifies the frequency response of the Accutron® amplifier² to be 200 cps, but makes no statement concerning the response of the rest of the system. In general, the electrojet device for Rocky Flats work uses either a panel-meter readout or a strip-chart recorder. The question arose as to what maximum frequency response the Electrojet could achieve. The immediate useful application was the measurement of lathe spindle runout at high speeds.

DISCUSSION

As a first approximation to reality, one may consider the Electrojet as a driven mechanical oscillator with constraints, i.e., the amplitude is strictly limited on one side. Some damping from friction will occur. If the driving frequency stays below the natural frequency of the system determined by the spring and plunger of the Electrojet, resonance effects may be neglected.

The natural frequency, (f_n), of the system in cps is given by Equation 1:

$$f_n = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \quad (1)$$

Where,

k = spring constant in dynes per centimeter
 m = mass of moving plunger, plus $\frac{1}{3}$ the mass of the spring in grams.

The spring constants of the four Electrojets tested are given in Table I.

TABLE I. Electrojet Data.

Electrojet No.	Spring Constant (dynes per centimeter)	Mass of Plunger (plus 1/3 mass of spring) (grams)	*Frequency (cycles per second)
1 - Class X	1.52×10^5	3.07	36
2 - Class X	3.27×10^5	-	52
4221 - Class XX	0.625×10^5	-	23
4335 - Class XX	1.93×10^5	-	40

*NOTE: Data derived from Equation 1:

$$f_n = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

An old jet was disassembled to measure m . It was assumed that the variation in m from jet to jet is small. The spring constant, k , was conveniently measured by a tip-force gauge built by the Research and Development, Mechanical group. The gauge is currently used by the Linear Standards Laboratory.

Experimental: An experiment was devised to measure the sinusoidal frequency response of the movable plunger. A cylinder, rotating about a line slightly displaced from its center line, provides a nearly sinusoidal drive for the Electrojet. The amplitude of the sinusoidal output of the Electrojet is measured on an oscilloscope because most mechanical recorders and meter movements have a limited frequency response (about one or two cps).

The arrangement of the apparatus is shown in Figure 1. At right angles to the Electrojet is a Photocon Research Products Dynagage®, a noncontacting displacement gauge³ with a frequency

¹ Trademark of Bendix Automation Division, Dayton, Ohio.

² *Ibid.*

³ Distributed by The Whittaker Corporation, North Hollywood, California.

response flat to 10 kilocycles per second. This was used for reference purposes. The signal from the Electrojet and the 90-degree out-of-phase signal from the Dynagage are fed to the x- and y-axis of a Tektronix (R)-536 oscilloscope.⁴ If the gains of the two inputs are properly adjusted, the Lissajous pattern on the scope is a circle. If the response of the Electrojet fails, it will show up as a distortion to the circle. If either input to the scope is removed, the other appears as a bar and the amplitude can be easily determined.

Three eccentric cylinders were used to give peak-to-peak displacement amplitudes of approximately 0.006, 0.003, and 0.0015 inches. The cylinders were rotated at various angular velocities by a precision jig borer.

The frequency response data obtained with the four Electrojets are given in Figures 2 and 3. The bars indicate a cumulative maximum error. Over

⁴ Tektronix, Incorporated, Beaverton, Oregon.

the range of displacement used there was no noticeable dependence of frequency response upon the amplitude of sinusoidal input.

The Class-X Electrojets are old and somewhat battered. Their frequency response is *flat* to about 20 cps corresponding to 1250 revolutions per minute (rpm). One showed no noticeable rolloff at 2000 rpm (about 33 cps), the maximum angular speed available from the jig borer.

The Class-XX Electrojets are new and practically unused. In addition the specified radial clearance between plunger and barrel is only 0.0001 inches. Friction would lower the frequency response considerably.

CONCLUSION

It is clear from the experiment that the maximum useful frequency is limited only by mechanical characteristics of a particular Electrojet, if proper recording techniques are used. Selected Electrojets have a good frequency response.

FIGURE 1. Arrangement of Apparatus.

FIGURE 2. Class-X Electrojet, Rolloff at 0.006-Inch Peak to Peak Displacement.

FIGURE 3. Class-XX Electrojet, Rolloff at 0.006-Inch Peak to Peak Displacement.