Performance Monitoring System
For
Electromagnetic Vibrating Feeders
Of
Coal Handling Plant

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1.0 Abstract: -

The handling as well as the processing tasks has shaped the character of the coal handling plant. The use of dozers and mobile equipments are done for feeding purpose. The efficient and economical storage, movement and control of large tonnage coal handling installations, coal car unloading, storage, reclaim system depend on the proper application of feeders. The feeder is one of the key machines in Coal Handling Plant. If the feeder is damaged or not available for use the whole process can be stopped and expensive downtime and repair costs can result. There are various types of feeders. Vibrating Feeders provide the most efficient and economical method of conveying coal. It is the simplest and easiest means of controlling the rate of flow or feed. In this paper a simple system, which easily monitor feeding rate to help operator to control plant, is discussed. Many times operator cannot judge performance of feeder. This system is very useful to judge the performance. A mathematical relation is shown in paper for feeding rate.

2.0 Introduction: -

Vibrating Feeders are of a simple design and robust construction to ensure long, trouble-free operation. The intensity of vibration is variable over a wide range through a suitable controller, which ensures a steady uninterrupted flow of material under varying conditions. They protect the belt conveyors from damage by feeding the material onto the belt conveyors from storage hoppers, silos, and surge hoppers at a controlled rate. Low amplitude of Vibrations (generally 1 to 3 mm) and high vibrations (table stroke) frequency (up to 3000 per minute) are typical of the vibratory feeder. The absence of the any major moving parts such as bearings, eccentrics, belts, motors etc. is another major advantage and consequently only minimum preventive maintenance is required.

3.0 Operating principles: -

Vibrating Feeders consist of Vibrating Tray fitted to a power unit of considerable weight. The Electromagnetic unit is mounted inside the heavy power unit. The power unit also houses the spring bars, which consist of a number of leaf springs clamped at the two ends of the power unit. A heavy fabricated centerpiece carries the magnet armature at one end and the Vibrating Feeder Tray at the other end. The centerpiece is tightly clamped around the middle of the spring system. The feed tray is of heavy welded construction with stiffeners and gussets to provide rigidity.

The absence of wearing mechanical parts, such as gears, cams, belts, bearings, eccentrics or motors make Vibrating Feeders the most economical equipment. See Figure No 1. The machine is a spring connected two mass vibrating systems with electromagnet providing the exciting force. The springs are so chosen that the natural frequency of the machine correspond approximately to the frequency of the pulsating power supply. These feeders are supported in position by means of suspension rods by floor mountings and in each case adequate vibration absorbers are incorporated. With single vibrator feeders a combination of suspension and floor mounting is permissible, but it is not recommended for multi vibrator machines.

Employing pulsating current operates vibrating feeders. This current when passed through stator creates a series of interrupted pulls on the armature. The resultant is vibrations. On the powered part of the cycle, i.e., when current is allowed to flow, magnetic attraction takes place between the core of the electromagnet and the armature. The trough and the vibrator unit are therefore drawn towards each other, and at the same time the spring system is deflected. The resulting restoring force built up in the deflected spring causes the return stroke to be completed during the non-powered part of the cycle, and the trough and vibrator unit therefore more away from each other. Varying the power input to the vibrator coils by means of an electronic controller control the amplitude of vibration.

3.1 <u>Performance</u>: -

The current consumption is a minimum for a given intensity of vibration when the natural frequency of the machine is the same as the power supply frequency. In practice the natural frequency is made slightly higher than the supply frequency to ensure stable operation and to reduce damping effect of load. By means of the sprigs selected the feeder can be made to vibrate at or near the supply frequency. The final tuning or synchronization is done either by tightening or slackening the springs with no load on the feeder trough so that the effect can be readily observed. With correct springs and coil(s) fitted and when correctly tuned the feeder will have maximum amplitude of vibration. It is necessary to maintain the stroke of feeder as per given value by equipment manufacturer. This stoke must be adjusted by using core clamping bolts. Adjusting the springs should not carry it out, as it will change the stiffness. The performance of the feeder is mainly depending upon the tuning. See Figure No 2.

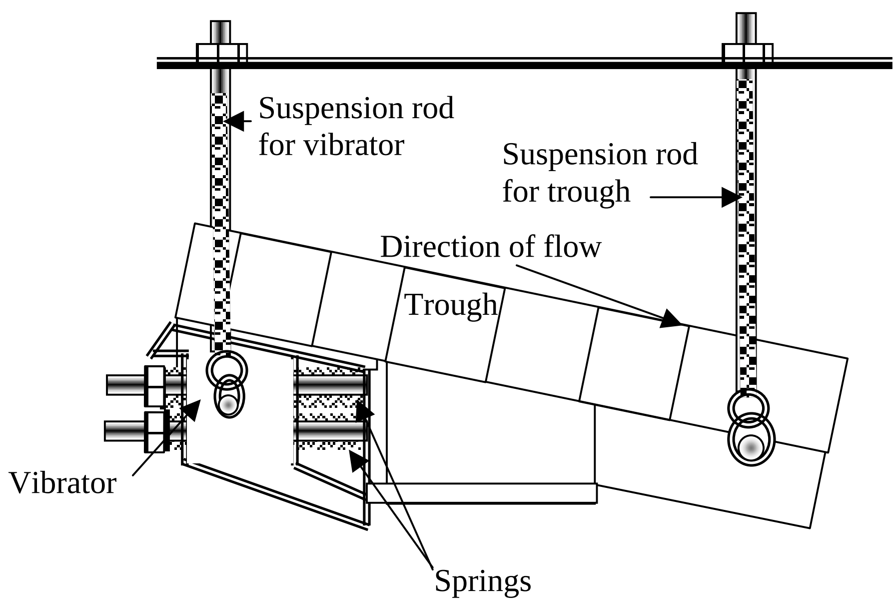


Figure No 1

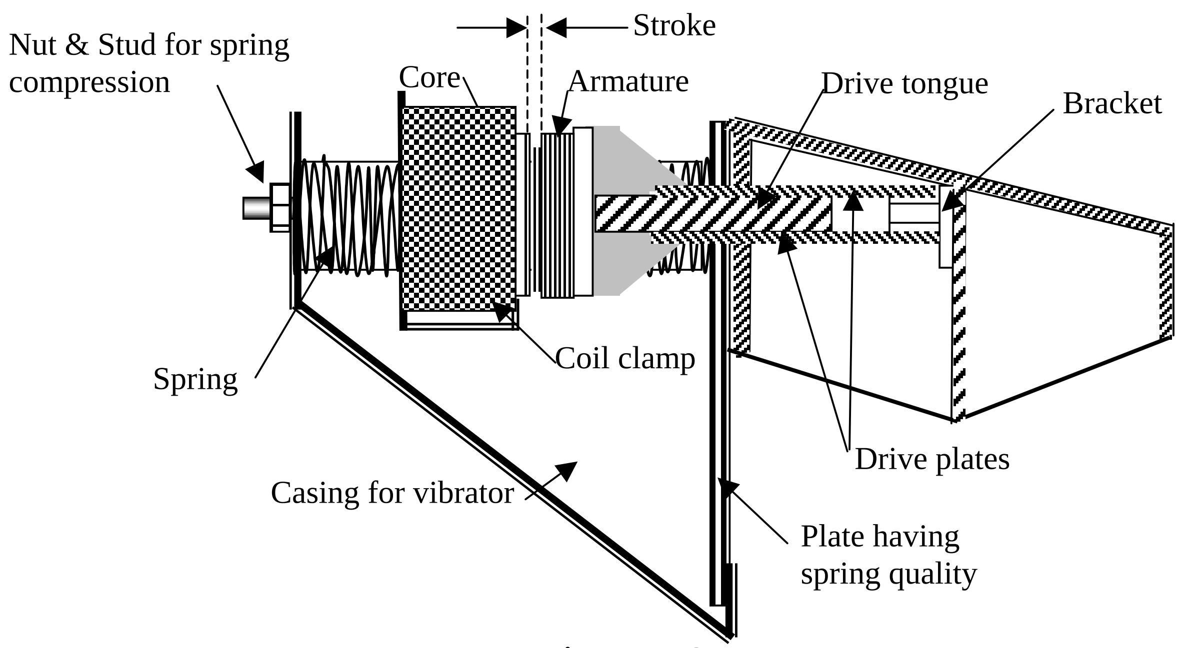


Figure No 2

4.0 Mathematical Relation Of Flow Rate To Operating Current -

The vibrating feeder forms a spring connected mass vibrating system with electromagnet providing the exciting force. See Figure No 3.System is introduced to make relation of mass flow with current flow to coil.

The natural frequency of the vibrating feeder is depends upon the coal flow.

M_{feeder}= Mass of empty feeder

M_{coal}= Mass of coal in the tray at the incidence

$M= M_{feeder}+ M_{coal}$

K= Spring constant

f = Frequency of oscillation i.e. natural frequency

ω = Angular frequency of oscillation

$\omega = 2\pi F = (K \div M)^{1/2}$

X_0 = Zero frequency deflection

X_1 = Deflection at frequency f_1

X_2 = Deflection at frequency f_2

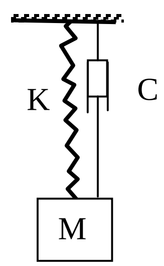


Figure No 3

$f^2 = K \div [4\pi^2 M] = K \div [4\pi^2 (M_{feeder}+ M_{coal})]$

$(M_{feeder}+ M_{coal}) = K \div [4\pi^2 (f^2)]$

$M_{coal} = \{K \div [4\pi^2 (f^2)]\} - M_{feeder}$

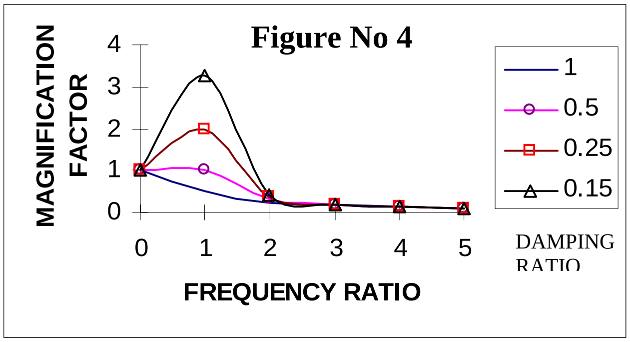
The value K, $4\pi^2$, M_{feeder} are constant for a given geometry and given material. For the same feeder these values are constant.

Let k_1= constant = $K \div 4\pi^2$ and $k_2 = M_{feeder}$

$M_{coal} = \{ k_1 \div (f^2)]\} - k_2$

$[k_1 \div \{M_{coal} + k_2\}]^{1/2} = f$

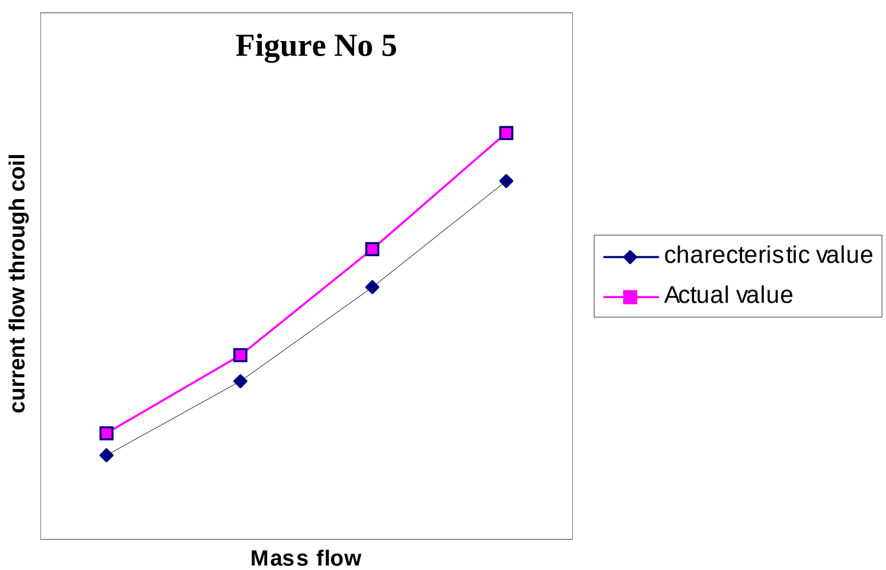
In short increase in mass flow decreases natural frequency of the system.
Critical damping = Cc = $(K \div M)^{1/2}$
Damping = C
Damping Ratio = $\zeta = Cc \div C$
Magnification factor = $X_1 \div X_0 = 1 \div \{[1-(f_1 \div f)^2 + [2(Cc \div C) \times (f_1 \div f)]^2\}^{1/2}$ when it is oscillating at frequency f_1-------- (1)
Magnification factor = $X_2 \div X_0 = 1 \div \{[1-(f_2 \div f)^2 + [2(Cc \div C) \times (f_2 \div f)]^2\}^{1/2}$ when it is oscillating at frequency f_2---------(2)
Dividing 1 by 2
$(X_1 \div X_0) \div (X_2 \div X_0)$
$= \{1 \div \{[1-(f_1 \div f)^2 + [2(Cc \div C) \times (f_1 \div f)]^2\}^{1/2}\} \div \{1 \div \{[1-(f_2 \div f)^2 + [2(Cc \div C) \times (f_2 \div f)]^2\}^{1/2}\}$
$X_1 \div X_2 = \{[1-(f_2 \div f)^2 + [2(Cc \div C) \times (f_2 \div f)]^2\}^{1/2} \div \{[1-(f_1 \div f)^2 + [2(Cc \div C) \times (f_1 \div f)]^2\}^{1/2}$--(3)
See Figure No 4.



Let the f_2 is the natural frequency then $f_2 = f$
Now expression 3 will be
$X_1 \div X_2 = \{2(Cc \div C)\}^{1/2} \div \{[1-(f_1 \div f)^2 + [2(Cc \div C) \times (f_1 \div f)]^2\}^{1/2}$
$X_1 \div X_2 = \{2(\zeta)\}^{1/2} \div \{[1-(f_1 \div f)^2 + [2(\zeta) \times (f_1 \div f)]^2\}^{1/2}$------(4)
For deflection X_1 of force F_1 is required. For deflection X_2 of force F_2 is required.
These forces are depending upon the mass of body.
$F_1 = m \times g$ & $F_2 = m \times g$
Hence $F_1 = F_2$
Now multiplying these forces to deflection. As the value of forces is same the expression 4 will be change as
$(X_1 \times F_1) \div (X_2 \times F_2) = \{2(\zeta)\}^{1/2} \div \{[1-(f_1 \div f)^2 + [2(\zeta) \times (f_1 \div f)]^2\}^{1/2}$------(5)
Now in vibrating period it is required to keep deflection same i.e. $X_1 = X_2$
For this condition the value of force will change. Then $F_1 \neq F_2$
Now expression 5 will be
$F_1 \div F_2 = \{2(\zeta)\}^{1/2} \div \{[1-(f_1 \div f)^2 + [2(\zeta) \times (f_1 \div f)]^2\}^{1/2}$------(6)
The power required to drive the vibrating feeder is depend upon the force.
$F_1 \times X_1 = P_1$
$F_2 \times X_2 = P_2$
As $X_1 = X_2$
Hence $F_1 \div F_2 = P_1 \div P_2$

And $P_1 = V_1 \times I_1$ & $P_2 = V_2 \times I_2$
The supply voltage remains same while operation i.e. $V_1 = V_2$
Now expression 6 will be
$I_1 \div I_2 = \{2(\zeta)\}^{1/2} \div \{[1-(f_1 \div f)^2 + [2(\zeta) \times (f_1 \div f)]^2\}^{1/2}$------(7)
But in the vibrating feeder the feeder is vibrated at the constant frequency f_1 and the stroke of feeder X_1 is constant. The natural frequency f of the vibrating feeder is depends upon the coal flow M_{coal}.
Now expression 7 will be
$I_1 \div I_2 = \{2(\zeta)\}^{1/2} \div \{[1-(f_1 \div [k_1 \div \{M_{coal} + k_2\}] + [2(\zeta) \times (f_1 \div [k_1 \div \{M_{coal} + k_2\}]]\}^{1/2}$
$I_1 \div I_2 = \{2(\zeta)\}^{1/2} \div \{1-[f_1 \times \{M_{coal} + k_2\} \times \{1+2(\zeta)\}] \div k_1\}^{1/2}$
For the same system i.e. for same vibrating feeder the ζ, f_1 remains same.
Let $k_3 = \{2(\zeta)\}^{1/2}$, $k_4 = 1+2(\zeta)$, $[f_1 \times \{1+2(\zeta)\}] \div k_1 = k_5$ as all term becomes constant.
$I_1 \div I_2 = k_3 \div \{1-[k_5 \times (M_{coal} + k_2)]\}^{1/2}$------(8)
The equation No 8 shows the mathematical relation of change in current with mass flow.

5.0 Characteristic Curve -
The current ratio ($I_1 \div I_2$) will be change with change in natural frequency f and this natural frequency f will change with coal flow M_{coal}. Hence current ratio ($I_1 \div I_2$) will be change with change in mass flow M_{coal}. When the feeder runs empty in ideal condition the current is I_2 which known value. Equipment manufacturer gives this value. Then the value of I_1 can be calculated for each coal flow from the following relation.
$I_1 = (I_2 \times k_3) \div \{1-[k_5 \times (M_{coal} + k_2)]\}^{1/2}$
This will show characteristic curve for the equipment. And actual value is to be checked. These values will be slightly differs from the actual values. See Figure No 5



6.0 New Monitoring System-
The coal flow can be measured by down stream conveyor belt scale.The current transformer (step down) is required to fit in system. The feedback from belt scale is taken

in from of current. The difference between both systems is monitored. The variation will show unhealthiness of system. The block diagram shown in Figure No 6 will clear the idea.

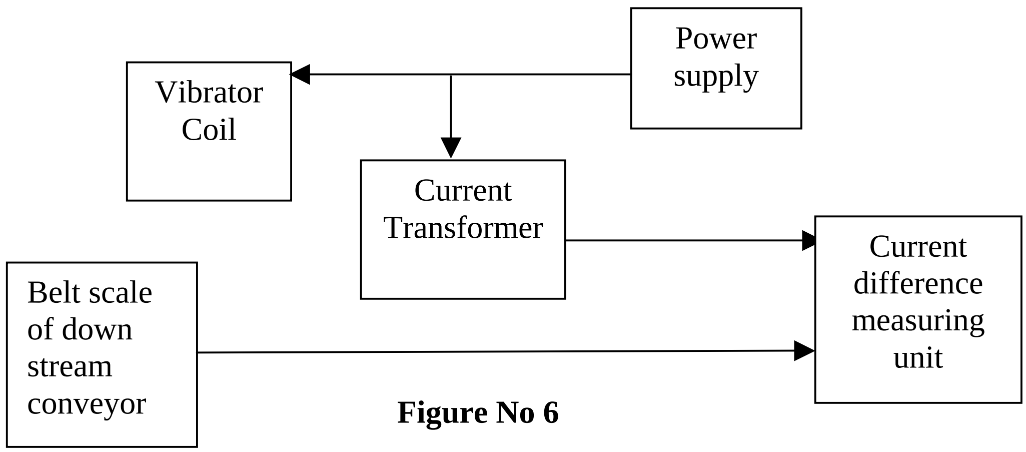


Figure No 6

The characteristic curve and actual value curve after calibration should be checked before system is to be taken in service. Any deviation in system will give alarm. This will alert the operator.

7.0 <u>Conclusion</u> -

This system is very useful for operator to check the performance of feeding units.
The system can easily establish as having very less part to be add in old system. Because of this modification cost is also less.
The system is useful for electromagnetic vibrating feeders only.