ANALYTICAL DESIGN OF REED

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Abstract

Frequency is an important electrical quantity which is present in only Alternating Current (AC) circuits. Frequency measurement is very important in various AC applications, especially in AC power systems designed to run efficiently at one frequency only. When AC is being generated by an electro-mechanical alternator, frequency will be directly proportional to speed of the machine shaft and it could be measured by measuring the shaft speed. To measure the frequency at some distance other means of measurement will be necessary. One simple method of frequency measurement in power systems utilizes the principle of mechanical resonance. As every physical object possessing the property of elasticity has an inherent frequency at which it will prefer to vibrate. Various researchers focused on its construction manipulation to achieve reduced calibration time but rare focus on reed.

Keywords: *Alternating current, Natural Frequency, Reed, Resonance, Reed Type Frequency Meter, Vibration*

Reed type frequency meter is device which indicates the measurement of frequency. The instrument is consist of multiple reed in which each reed has a different natural frequency and is marked accordingly. Using number of reeds makes it possible to cover a wide frequency range. The instrument can also be used to measure electrical frequency of AC signal in a range of 45-55 Hz, 47-53 Hz, 55-65 Hz, and 57-63 Hz which is available in 0.5, 1, and 1.5 accuracy class when connected across input of 110,220,380,440 volts. Reed type frequency meter works on the phenomenon of resonance hence it is also called as mechanical resonance type frequency meter. The natural frequency of reed designed should be equal to twice of the frequency of AC current because force of attraction between electromagnet and reed is twice in a pulse. The instrument when mounted on the vibrating body, the reed whose natural frequency is nearest to unknown frequency of the body vibrates with larger amplitude.

Why Reed Design is Important?

Reed is key component of the vibrating reed frequency meter which is responsible for indicating the AC frequency. In traditional method, design of reed is based on space availability of housing as per Indian standard 2419 (IS 2419) for instruments. The reed undergoes annealing process to soften the material of reed followed by bending free end. The important of reed design is calibration of its frequency. Highest frequency provided by instrument manufacturers in range of 55-65 Hz is of 65 Hz. In tradition design the calibration for 65Hz reed should be performed by adding minimum weight. In order to bring down the natural frequency of reed to its indicating frequency, mass in the form of solder metal is added behind the bend portion of reed, as frequency is inversely proportional to mass. It means that amount of mass to be added increases when desired natural frequency of reed decreases. This process of calibration is tedious and time consuming. Hence need is arises to find a suitable method for all mentioned ranges of frequency meter which overcomes the existing problems in mass production.

How to find Natural Frequency of Reed

Calculation of natural frequency when a cantilever beam is subjected to compound loading is not a regular engineering practice. In this case of reed type frequency meter the reed is subjected to uniformly distributed load and a point load at. The load is uniformly distributed load throughout effective length of reed due to its own weight. Concentrated mass at the free end of the reed as point load because of bend. This unusual problem is solved by Dunkerly's method. This method enables the frequency of an oscillation to be deduced when it is due to two or more masses. For example a cantilever oscillates because of its distributed mass and because of any point load on it. Any engineering professional know how to work these out separately but together the formula will be different. Suppose a beam oscillates a frequency f1 due to one load, f2 due to another load. When all loads vibrate together, the resulting frequency f is found using the reciprocal rule below.

………. (a)

Hence by applying Dunkerly's formula for the frequencies obtained from above two different type of loading natural frequency of the reed can be calculated. Dunkerley's method gives lower bound approximation which makes the design usable. Any error in approximation will increase the practical natural frequency which can be reduced by adding some weight at the tip of the reed.

Analytical Design

Every physical body has an infinite number of resonant or natural frequencies. The body will vibrate with a different vibration envelope for each of these resonant frequencies. Vibration envelope referred as the mode of vibration, hence the resonant frequencies referred as modal frequencies. Vibration envelope of a stick can be observed by holding it horizontally by its end and moving it rapidly up and down. The first mode will look like a wedge with the apex at hand. When the meter stick reaches the edge of the vibration envelope, it must come to a stop so it can reverse its direction. Eyes can see the stick when it briefly stops moving, but when it passes through the midpoint it is going very fast and appears as a blur. If the stick shaken even faster second vibration mode will be observed. No one has been able to shake it fast enough to see the third mode. The first three vibration modes of a cantilever beam are shown in Figure 1. The Reed of the reed type frequency meter vibrates with first mode of vibration.

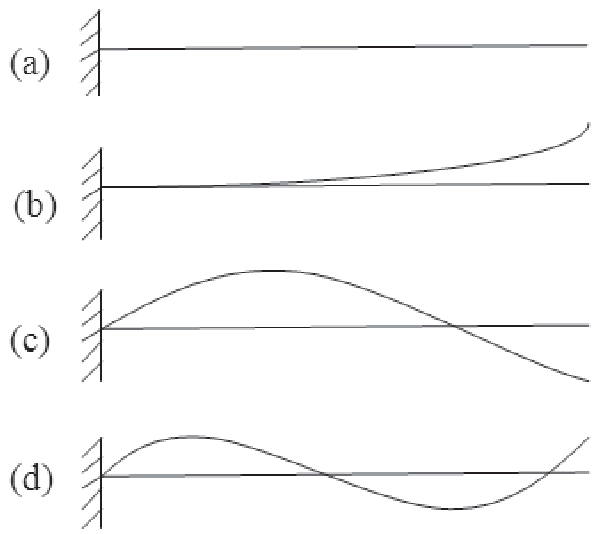

Figure 1a: No vibration.
Figure 1b: First Mode Vibration Envelope.
Figure 1c: Second Mode Vibration Envelope.
Figure 1d: Typical Third Mode Vibration Envelope.

Here the natural frequency is in rad/sec for each mode of vibration is proven and represented by ω.

Natural frequency of first mode:

$\omega_b=(1.875)^2$ rad/sec. ………. (b)

Natural frequency of second mode:

$\omega_c = (4.694)^2$ rad/sec.

Natural frequency of third mode:

$\omega_d = (7.855)^2$ rad/sec.

The natural frequency of a straight reed can be calculated in Hz by the formula:

f = Hz ………. (c)

By putting value of ù equation (b) in equation (c) from above we get,

f = 0.5595Hz ………. (d)

Natural frequency is the frequency at which a system naturally vibrates once it has been set into motion. In other words, natural frequency is the number of times a system will oscillate between its original position and its displaced position, if there is no outside interference. For example, consider a simple beam fixed at one end and having a mass attached to its free end. If the beam tip is pulled downward and released, the beam will oscillate at its natural frequency. Natural frequency because of the length of span and bend length must be taken in account together to calculate resultant natural frequency of reed. Natural frequency because of effective length can be calculated by the equation (d) and natural frequency of beam having mass at its free end can be calculated by the equation shown below.

f = Hz ………. (e)

The deflection of cantilever beam due to end mass is calculated by:

ä = ………... (f)

By putting value of ä from equation (f) in equation (e) the frequency due to mass at free end of the reed can easily calculated,

f = Hz ………. (g)

Result

The table 1 shows the comparison of results obtained from analytically, analysis and practical trials.

Table 1 - Result Comparison of Frequency

Required frequency(Hz)	Analytical Frequency(Hz)	Analysis Frequency(Hz)	Practical Frequency(Hz)
55	54.94	55.02	55.03
56	55.96	56.04	56.06
57	56.94	57	57.03
58	57.98	58.02	58.05
59	58.95	59.05	59.06
60	59.98	60.04	60.07
61	60.92	61.08	61.09
62	62.00	62.01	62.04
63	62.93	63.07	63.09
64	63.95	64.03	64.05
65	64.99	65.02	65.04

Conclusion

The Dunkerly's method gives lower bound approximation. These analytical calculation are useful because the frequency obtained in analysis and practical trails is always greater than analytical results. Hence the frequency can be calibrated by adding weight at free end of the reed. If analytical results are higher than other two method of results its frequency cannot be calibrated.

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