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Experimental Study of Static Deflection and Natural Frequency Of Cu-Al Combined Rods

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Abstract

In this research, the static deflection and the natural frequency of the aluminium-copper combined rods with a fixed length of 60 cm and with different lengths of its parts were studied experimentally. Six rods were used, each divided into the following parts: (60 cm copper), (12cm aluminium– 48cm copper), (24cm aluminium–36cm copper), (36cm aluminium–24cm copper), (48cm aluminium–12cm copper), (60cm aluminium). The rods were fixed by simple support at each end. The static deflection was measured by moving the digital dial gauge along with the rods divisions while fixing the load value each once. The natural frequencies of each rod were measured by an oscillator device. The results showed that the static deflection of the parts made of aluminium is greater than that made of copper While the natural frequency of the rods increases with the increase in the aluminium proportion compared with copper in each rod.

Key words: static deflection, copper, Aluminium, natural frequency

1. Introduction

Rotating shafts are used in many electrical machines and important mechanical applications in various modern industries. Rotating shafts are usually made of common metals such as iron, aluminum, copper and other metals. In the recent century, the production of rotary columns of different diameters may be graduated or plucked, and each has its own application [1-3].

In some cases some the companies also produced rotating shafts made of polymeric composite materials, glass fibers, carbon or other types of fibers to achieve high specific modulus which is represent the ratio of young modulus to the density and specific strength which is equal to ultimate strength to the density of shaft. [4-6] Some researchers have tended to study new types of rotating shafts that consist of two or more materials welded together or linked by one of the mechanical bonding methods such as the threading method as used in this work , the Coplin method, and other methods.[7,8]

The most important mechanical properties that need to be studied for rotating shafts are tensile, fatigue, hardness and impact properties in addition to some other loading conditions such as bending with different fixing methods such as rotating shafts with two fixed ends and rotating shafts fixed from one end, which leads to static deviation under constant and variable loads. [9, 10]

The studies of natural frequencies are of paramount importance to avoid cases of approaching the natural frequency that cause some cases of mechanical failure when it reaches to the resonance phenomena. Some researchers have been interested in the study of static deflection; the author studied the theory of static deflection in loose-ended rotating rods. He studied the behavior of these rods in several ways, including the classic Rayleigh method, modified Rayleigh, and modeling

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by the ANSYS soft wear program. Through his study, he changed the position of the force from the fixed end to the free end he was found that the static deviation increases as the distance of the force from the fixed end towards the free end increases [11]. The author studied the static deflection of rods of stepped diameters in an experimental and theoretical simulation they found that the static deviation increases with the decrease in the diameter of the rotating rods significantly the experimental results [12]. Some researchers conducted a study on steel rotating shafts and found that the increase in torque increases the angular deflection, which corresponds to the static deflection in linear deflection studied the vibration and deflection of a naturally vibrating metal wire. They also used the virtual artificial network by predicting the natural frequency and static deviation. The results showed that there is a great matching between the experimental results and the results of artificial virtual network. [13]

When using a rotating shaft made of two or more different materials, the challenge appears here of calculating the equivalent young modulus of the rotating shaft, and it can be calculated through the supper position method according to the length of each material of which the rotating shaft is made. When using a rotating shaft of different diameters or stepped or a variable tapered cross-sectional area , here appears the challenge of calculating the equivalent moment of inertia for the rotating shaft in all the cases mentioned above in this case the trigonometry techniques and mathematics relations can be used mathematically integrals to calculate it**.**

In this work the static deflection and natural frequencies of combined rods made from copper and aluminum materials would be calculated experimentally. The combined rods would divided to five segments each of them has 12cm length represent variation in materials.

2. Experimental Work

2.1 Materials Used

Aluminum and copper metals were used as the shaft materials table (1) presents the mechanical properties of these metals. The combined rods with a diameter of 8 mm are made from aluminum and copper connected together by make external threads in one shaft against the internal threads in the other shaft. Different lengths for each rod were used with keep the total length of rod with constant value of 60 cm. The dimensions of rods considered to suitable static deflection and natural frequency devices. The static deflection of pure aluminium and pure copper rods were studied while the combined rods were partition to four nodded with five elements each of them. The first rod was made from pure AL only the second rod were consist of 48 cm of AL 12cm of copper coded as (48AL-12Cu) the recent rods were coded as the following (36AL-24Cu), (24AL-36Cu) and (12AL-48Cu) the last rod were made from copper. The static deflections of combined rod were studied at four nodes of each 12 cm of length of shaft Figure (2) show the schematic of combined rods.

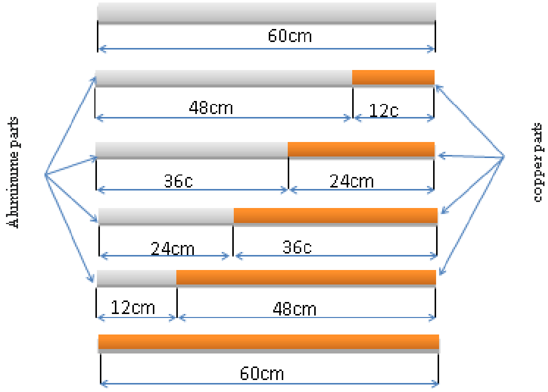

Fig. 1. Schematic of AL-Cu combined rod

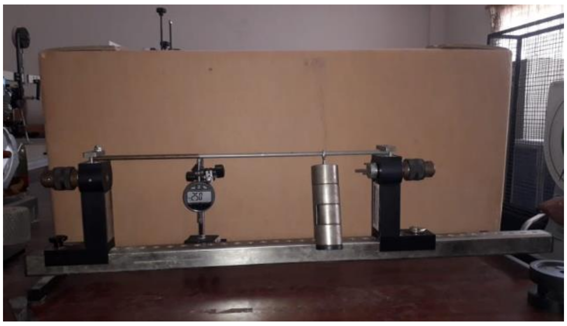

Fig. 3. Static deflection measurement

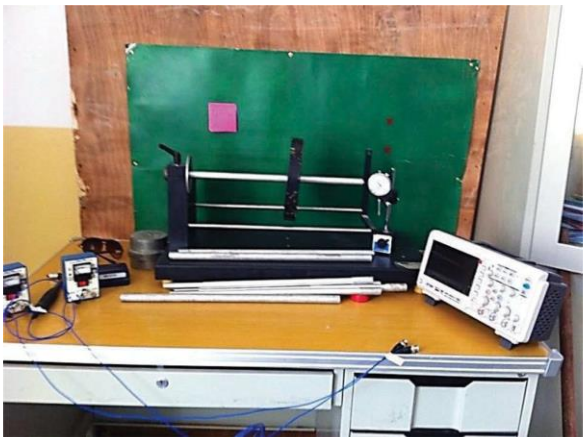

Fig. 4. Natural frequency measurement

2.2 Static Deflection Measurement

Static deflections of combined rods were measured by supported the rod of simply support ends. Each rod divided to 6 nodes – five elements of each 12cm length segments in addition to the centres point. The dial gauge were measured the static deflection when load applied in each nod, there for there are five static deflections of each rod with the zero deflection at ends. Figures (2 and 3) indicate the configuration of applied load and dial gauge position with schematic and measurement of static deflection.

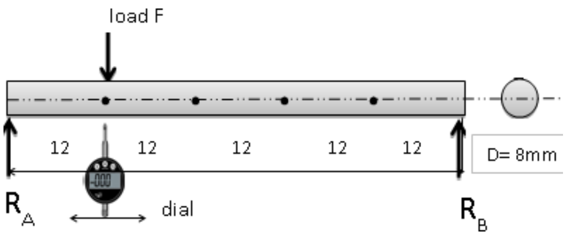

Fig. 2. Schematic of static deflection measurement

2.3 Natural Frequency Measurement

The natural frequencies of combined rods were measured by using oscilloscope-hummer device. The vibration sensor was fixed at the centre of rod when the hummer was attacked at the any point on the rod. The first three natural frequencies were recorded and analysed by fast Fourier transformation soft wear (FFT). Figure 4. indicate the natural frequency measurement of combined rod.

3. Results

3.1 Results of Static Deflection

Figure 5 shows that the static deflection of the 60cm length copper rod is uniform on both simply supported ends. The maximum deflection 0.67mm was occur in the middle point of rod when load position at distance 36cm from the left fixed end. Figure 6 to figure 10 indicates the static deflections of combined rod clear that the deflection of aluminium part of rod is greater than copper part because the stiffness and young modulus of copper is greater than aluminium there for static deflection depending upon the material which made from The maximum were occur at the centres of rod due to the load position is near from it.

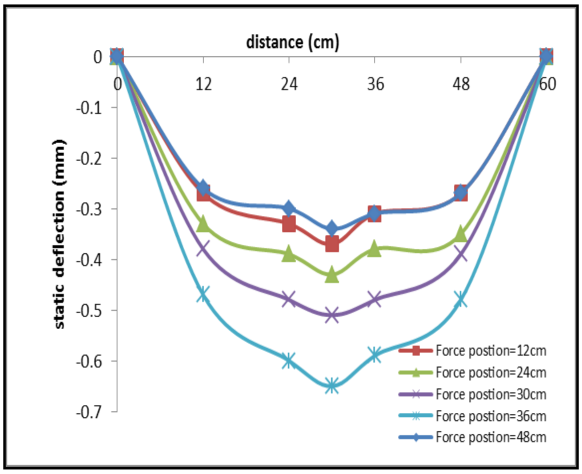

Fig. 5. Static deflections of copper rod

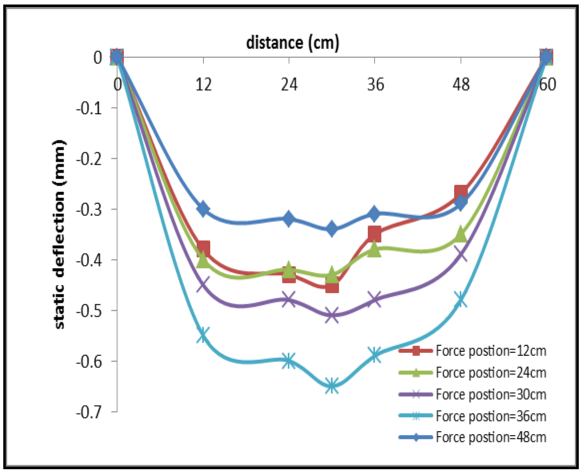

Fig. 6. Static deflections of (12AL-48Cu) rod

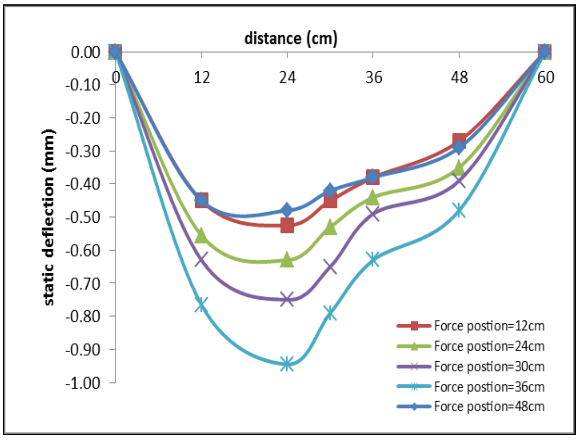

Fig. 7. Static deflections of (24AL-36Cu) rod

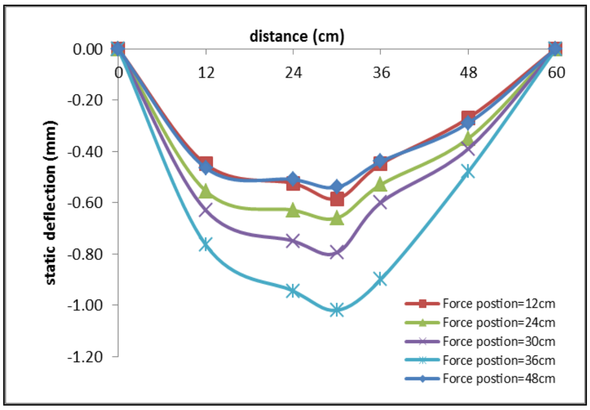

Fig. 8. Static deflections of (36AL-24Cu) rod

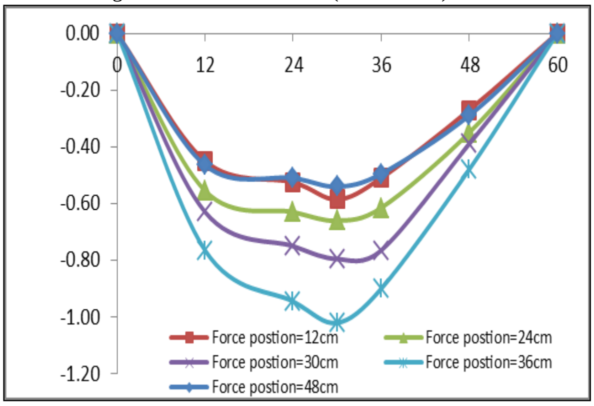

Fig. 9. Static deflections of (48AL-12Cu) rod

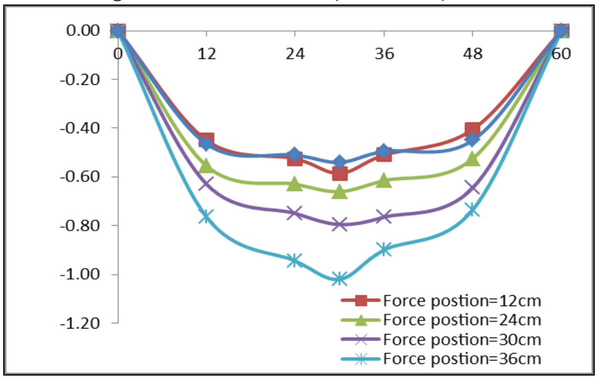

Fig. 10. Static deflections of aluminium rod

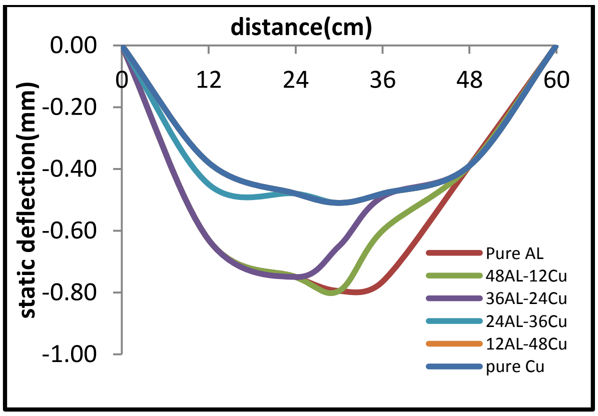

Fig. 11. Static deflections of all rods at mid-point when load distance 30cm

3.2 Natural Frequency Results

Table 1 and Figures 12 to 17 show the values of the natural frequencies of the combined rods used in the work. The table indicates that the highest value of the natural frequency is for the aluminium rod only, which is 105.76 Hz, and then the values decreasing to reach the copper rod, where its value reached 60.434 Hz. This decrease in the natural frequency is due to the high density of copper, which are 8.96 g/cm^3 compared to aluminium, 2.7 g/cm^3 equals under the square root of stiffness/mass.

Table 1. Natural Frequencies of Combined Rods

No.	Types of combined rod	Highest natural frequencies
1	Al only	105.76 HZ
2	48Al -12Cu	102.33 HZ
3	36Al- 24Cu	92.74 HZ
4	24Al- 36Cu	87.219 HZ
5	12Al- 48Cu	70.737 HZ
6	Cu only	60.438 HZ

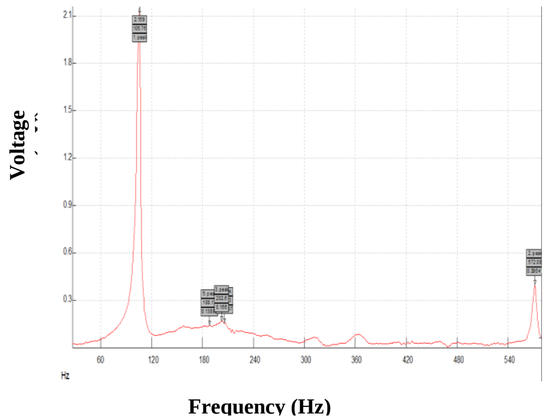

Fig. 12 spectrums of natural frequencies for (Al) rod

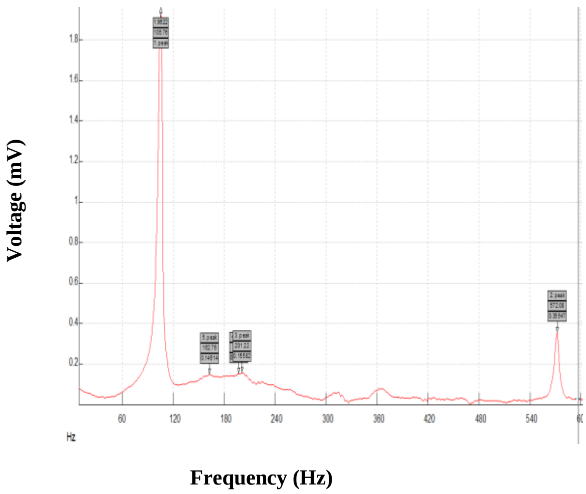

Fig. 13 spectrum of natural frequencies for (48Al -12Cu) rod

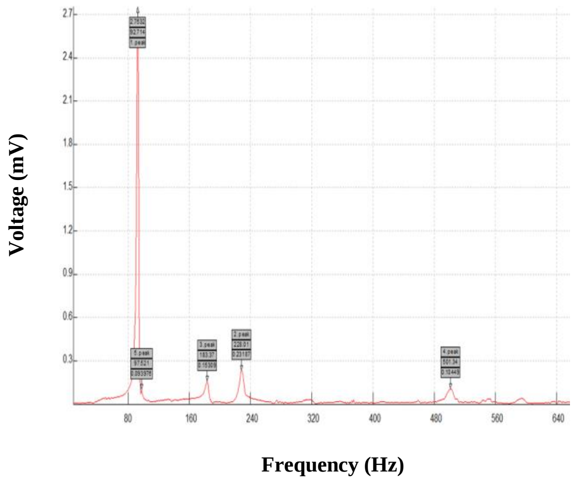

Fig. 14 spectrum of natural frequencies for (36Al -24Cu) rod

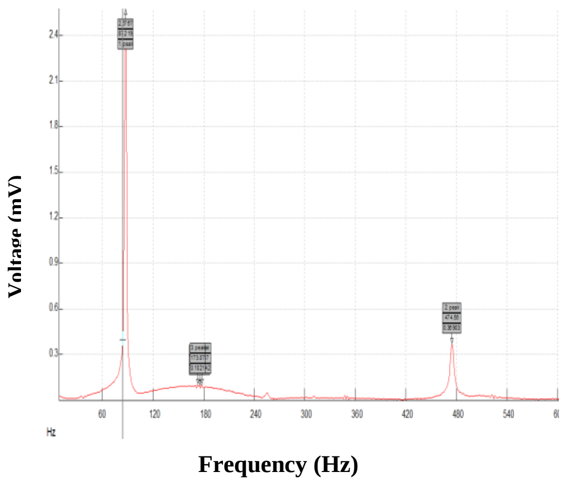

Fig. 15 spectrum of natural frequencies for (24Al -36Cu) rod

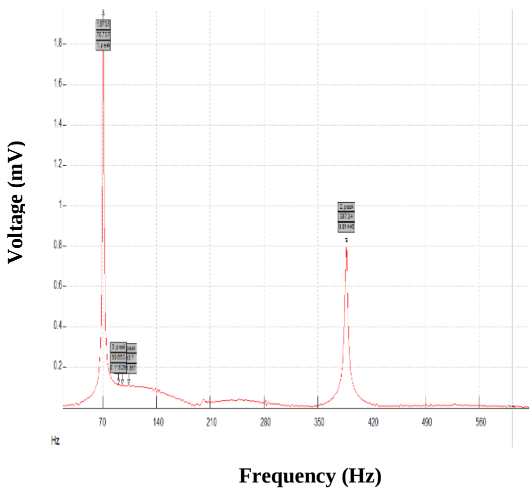

Fig. 16 spectrum of natural frequencies for (48Cu -12Al) rod

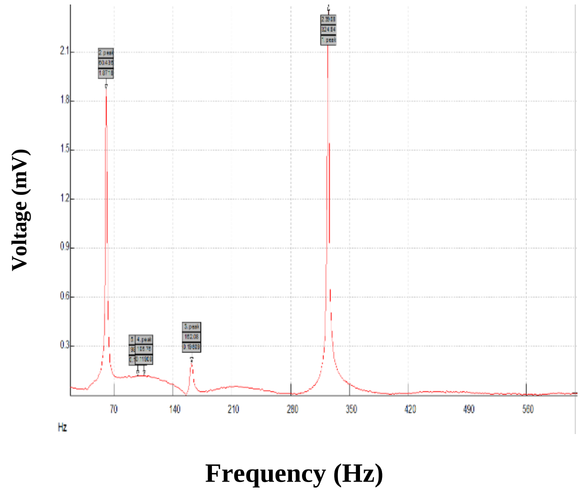

Fig. 17 spectrums of natural frequencies for (Cu) rod

4. Conclusions

From above results the static deflection and the highest natural frequencies of combined rod which made from Copper is less than made from aluminium due to the stiffness and density of copper is higher than aluminium which lead to increase in the static deflection and natural frequencies of aluminium.

Acknowledgments

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