NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Effect of Drill Bit Sizes and Workpiece Material on Vibrations in a Drilling Machine

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Article Info

Keywords:
Vibration chatter, vibration model, drilling operation, material removal

Received 08 February 2022
Revised 03 March 2022
Accepted 05 March 2022
Available online 13 March 2022

https://doi.org/10.37933/nipes/4.1.2022.22

https://nipesjournals.org.ng

Abstract

Vibrations are known to negatively affect drilling operations which is a widely used machining process for creating holes. In this work, different materials were drilled using varied drill bit sizes while simultaneously measuring the vibrations at different parts of the machine. ANOVA (two steps without replication) was used to analyze data, and then regression models were developed. Higher amplitudes observed at the electric motor indicated that it is the major source of the vibrations. The vibrations in all the parts of the machine investigated were found to vary significantly with different sizes of drill bits and material of the workpiece. Also, the variations in vibration parameters showed a good fit with regression models of power 3, having R-values of 1. Conclusively, vibration during drilling operation can be affected by a number of factors, the electric motor being the most contributing factor.

1. Introduction

Drilling, a typical material removal process used to create holes in a workpiece, is often associated with vibrations that are known to cause poor surface finish, tool wear and reduction of machine lifespan. Faulty parts, poor designs, and unbalance forces have been identified as different sources of these vibrations [1]. The vibration could be of any type, namely, forced vibration, damped, non-linear or self-excited. Still, chatter, a form of self-excited vibration, is the most significant of all types in machining operations, including drilling [2, 3]. Investigations regarding vibrations in drilling are well-dated [4]. So far, several efforts to study the vibrations in drilling operations have been reported.

Some previous studies focused on investigating the reduction of vibrations during drilling operations. One common way is the use of a vibration absorber [5]. It has the advantage of providing a cheap and easy-to-maintain solution for suppressing vibration in vibrating systems with harmonic excitation [6] is the reason for its popularity. In the work of [7], an installed dynamic absorber was reported to reduce the vibrations in drilling operations for different sizes of drill bits that were studied. Additionally, [8] reported that values of measured amplitude for vibration chatter were suppressed when a tuned mass damper was installed in a drilling machine. Besides the use of various dampers, other methods involve the integration of certain devices such as balls packing for improving damping capability [9], as well as Micro Electronic Discharge machine (micro-EDM) to improve machine effectiveness [10].

Additionally, there are some works that tend to model such vibrations. One of such models is the improved Finite Element Model based on theory and experiment developed by [11]. Also, evaluation of the natural frequencies alongside modal analysis of the vibrations in drilling machines has been carried out using Finite Element Analysis [12]. Furthermore, [3] developed a set of delay differential equations validated against experiments that can be used to simulate chatter vibrations during drilling.

However, some reports focus on vibrations affected by certain variables during drilling operations**.** Based on experimental studies using twist drills, the geometry of the drill bits has been reported to affect the lateral vibrations of a drilling machine [13]. Also, spindle speed has been found to affect vibrations during drilling [14] significantly. More so, in a recent study, the land width of twist drills was found to have more influence on machine lateral vibrations when compared to other factors like feed rate, cutting speed, cooling lubricant pressure, a pre-hole diameter which also had contributive effects. Another factor earlier reported is the density of the material. It has been shown that vibrations assessed using a piezoelectric device were higher in denser materials like steel than that of wood that was far less in density [15]. However, only a few materials were reportedly studied. Also, there is a dearth of information on the variation of these vibrations with drill sizes and different positions in the body of the drilling machine. This study aims to investigate how the vibrations during a drilling operation may vary with the sizes of drill bits and material type and assess the vibrations in different parts of the machine at no-load and load conditions.

2.0. Materials and Method

A single-phase B24H excel H/D pillar drilling machine was used in experimental analysis. Four sizes of drill bits were randomly chosen. The drill bits were of sizes 4 mm, 6 mm, 14 mm and 16 mm, and were all carbon-steel-black-oxide coated twist drill bits because of their suitability for work on a wide range of materials. Besides, black oxide bits are often more durable than HSS bits.Four materials were selected for the investigation: plywood, carbon steel, chrysotile asbestos, and polycarbonate plastic. Each of the test specimens was designed with specifications: length 79mm, breadth 64 mm and thickness 5mm. A Benetech GM63B vibration meter was used to take vibration readings from the drilling machine during the experiment.

Each of the test pieces was set on the drilling machine, and the varied sizes and types of drill bits were used to drill the samples while taking measurements of acceleration, velocity and displacement. Three (3) readings were taken at different sections of the machine: swivel, chuck, motor, and handwheel, each at intervals of 45 seconds, starting from 45 seconds after turning on the machine. The procedure was repeated for the different materials with varied bit sizes. The average of the three readings were calculated and summarized using bar charts and line graphs on Microsoft Excel. Then, using the Two-way ANOVA, the variability for bit sizes, the material used and the position where the measurement was taken were analyzed. This was followed by the determination of the correlation between the different parts where the measurements were taken using the Pearson correlation coefficient. Finally, effect of drill bit sizes on vibration responses was modelled using regression curve and their effectiveness investigated using R-square value.

3. Results and Discussion

The average values of amplitude, velocity and acceleration at different points of the machine at no load differ, as shown in Figures 1, 2 and 3 respectively. Expectedly, the motor vibrations were observably the highest since it is the driver of the machine. Values of displacement at no load were between 0.02 mm and 0.2 mm, while those of velocity and acceleration were 1.1-11.8 m/s and 0.2-1.2 $m/s^{2,}$ respectively.

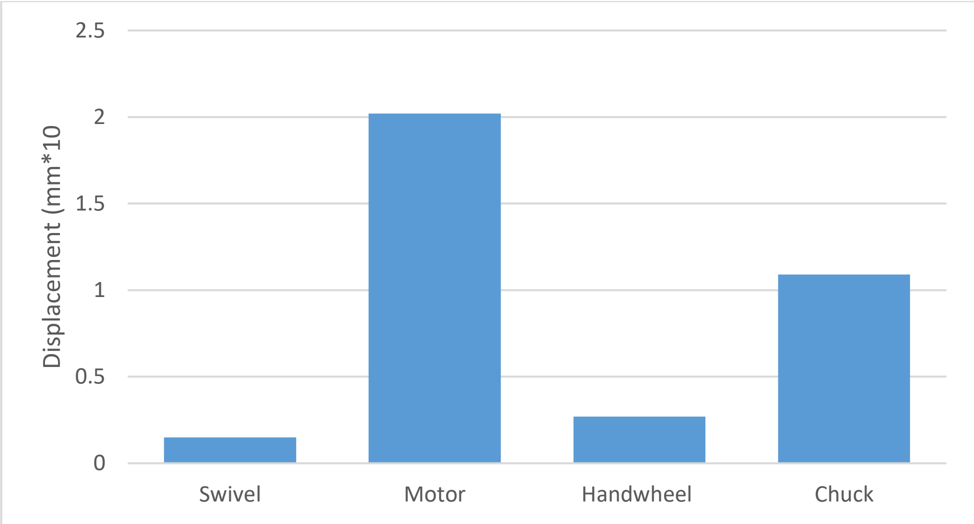

Figure 1: Measured values of amplitudes at different points in the drilling machine at no-load condition

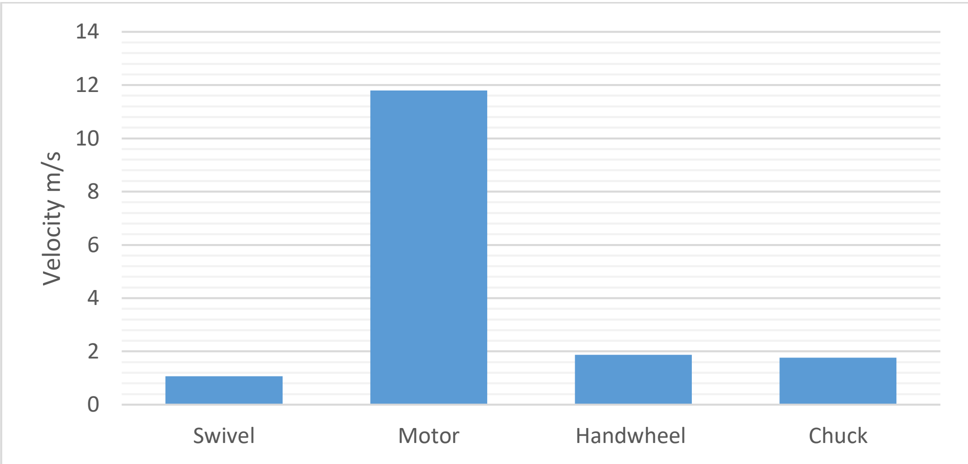

Figure 2: Measured values of velocities at different points in the drilling machine at no-load condition

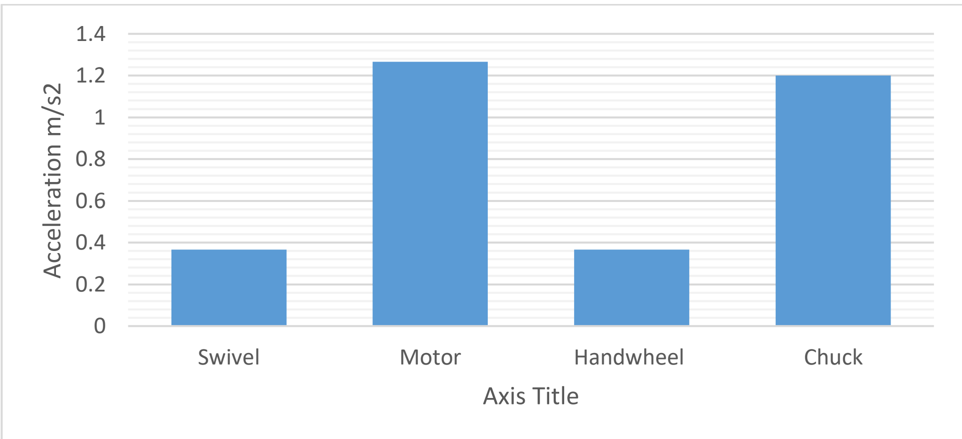

Figure 1: Measured values of acceleration at different points in the drilling machine at no-load condition

Other parts of the machine show varied values of vibration variables. Also, these values vary significantly, as the P-values obtained via analysis of the variance (Table 1) for displacements, velocity and acceleration are far less than 0.05. The variations in vibration may be ascribed to the shape, dimension, motion and different materials of construction for the different parts. However, estimated values of the correlation coefficient were very close to 1, as can be seen in Tables 2 and 3. It is an indication that there is a strong correlation between the vibrations at different points of measurement. It can, thus, be acceptable to say that vibrations in other parts were majorly due to vibrations from the driving part (electric motor), and other causes of vibrations such as misalignment, loosened nuts, and degeneration can be considered minimal.

As the machine was used on the workpiece of different materials, values of vibration variables were observed, and their average values are shown in Figures 4, 5 and 6. Regardless of the workpiece material, the values of vibrations on the motor and other parts of the machine were slightly higher than the values at no-load conditions (Figures 1, 2 and 3). This may be due to resistance offered by the material being drilled, which in a way increases the maximum driving force. Notwithstanding, the vibrations measured at different parts do not show any significant variations for the different workpiece materials, having P-values greater than 0.05 (see Table 1). So, for this case, the vibrations in the machine can be considered not to be affected reasonably by the type of material being drilled; this is contrary to the observations by [15]. Therefore, there may be other factors that influence the effect of materials on the vibrations in a drilling machine. There were, however, strong correlations between vibrations variables measured at various parts of the machine, having large values of the correlation coefficient as shown in Table 3. It can thus be deduced that most of the vibrations in the different parts of the machine had the same sources.

Table 1: P-values for ANOVA analysis

	Displacement	Velocity	Acceleration
Parts of machine measured	2.87E-02	9.80E-13	2.12E-08
Material being drilled	2.44E-01	3.78E-01	5.11E-01
Size of drill bit	1.00E-02	8.36E-03	8.10E-08

Table 2: Correlation analysis result under no-load condition

	Swivel	Motor	Handwheel	Chuck
Swivel	1.0000			
Motor	0.9576	1.0000		
Handwheel	0.9849	0.9930	1.0000	
Chuck	0.9971	0.9767	0.9952	1.0000

Table 3: Correlation analysis for different workpiece and bits sizes

	Swivel	Motor	Handwheel
Swivel	1.00000		
Motor	0.52153	1.00000	
Handwheel	0.09836	0.58914	1.00000

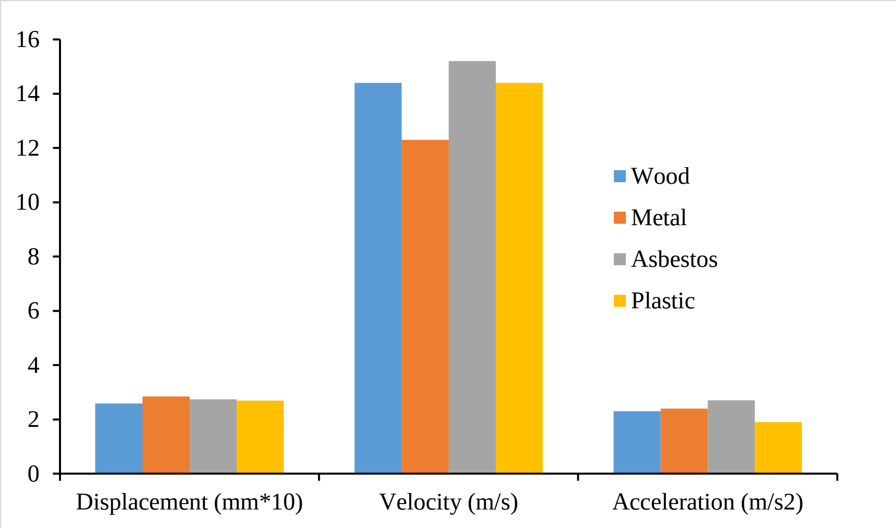

Figure 2: Measured vibrations on the electric motor for various materials

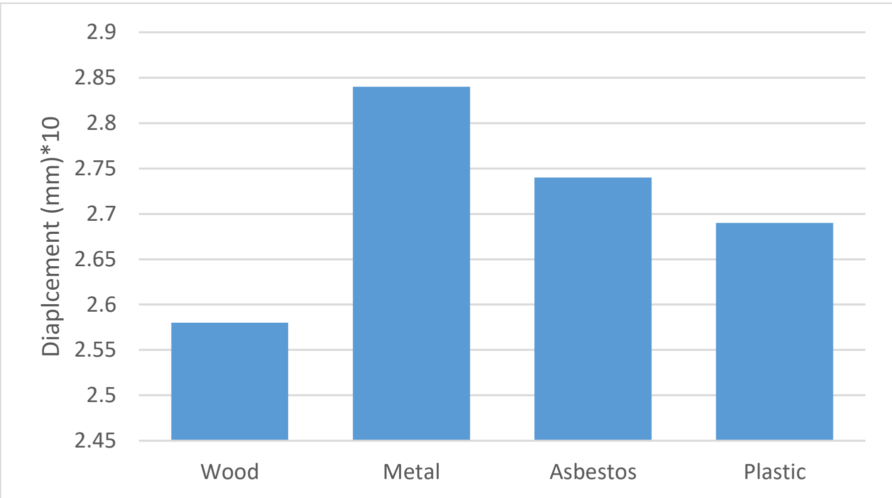

Figure 4: Measured amplitudes on the electric motor for various materials

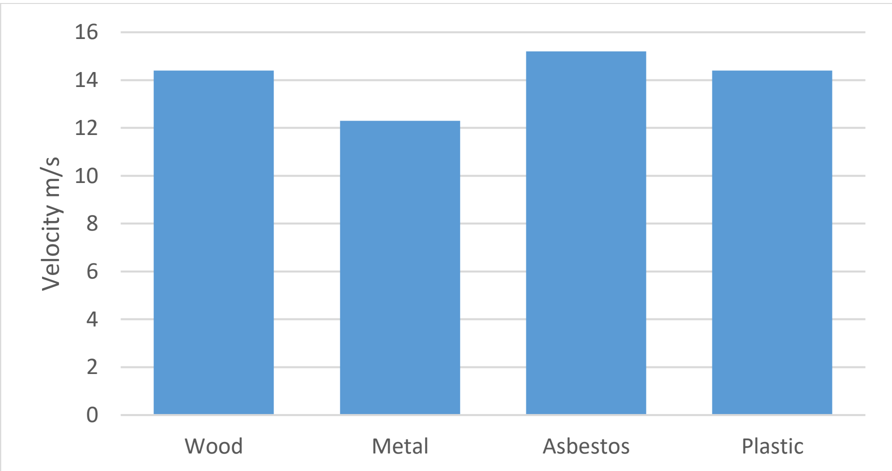

Figure 2: Measured velocities on the electric motor for various materials

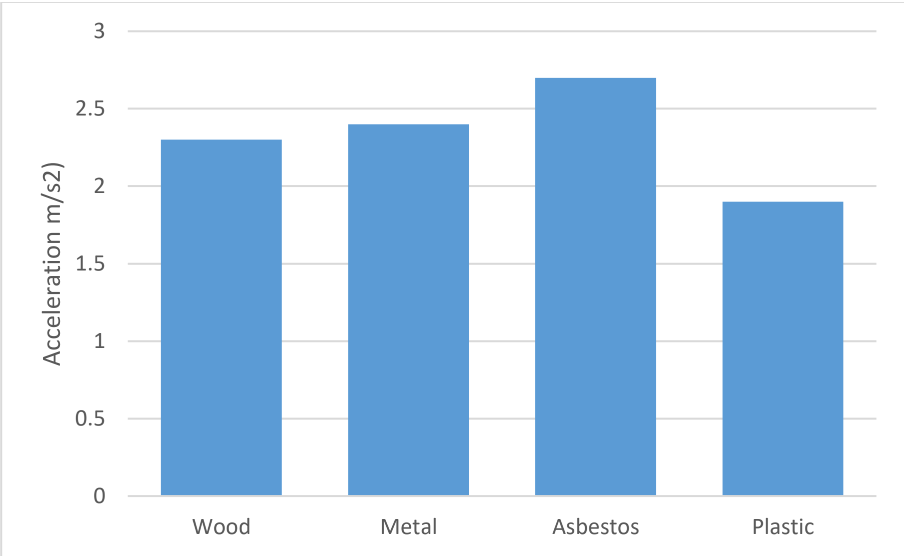

Figure 2: Measured accelerations on the electric motor for various materials

The vibrations of the machine were strongly affected by the size of drill bits, with estimated p-values that were less than 0.5, as shown in Table 1. The curves of displacements, velocities and accelerations for various drill bit sizes are shown in Figures 7, 8 and 9, respectively. The vibration variables on the machine do not necessarily increase with the size of drill bits. As shown by the trend line in each of the plots, their patterns can be adequately modelled using a polynomial curve of the third order, with R-values equal to 1 for the different cases. The metallic material seems to have the most extreme values suggesting that it has the capabilities to effect the most changes in vibration variables of the machine.

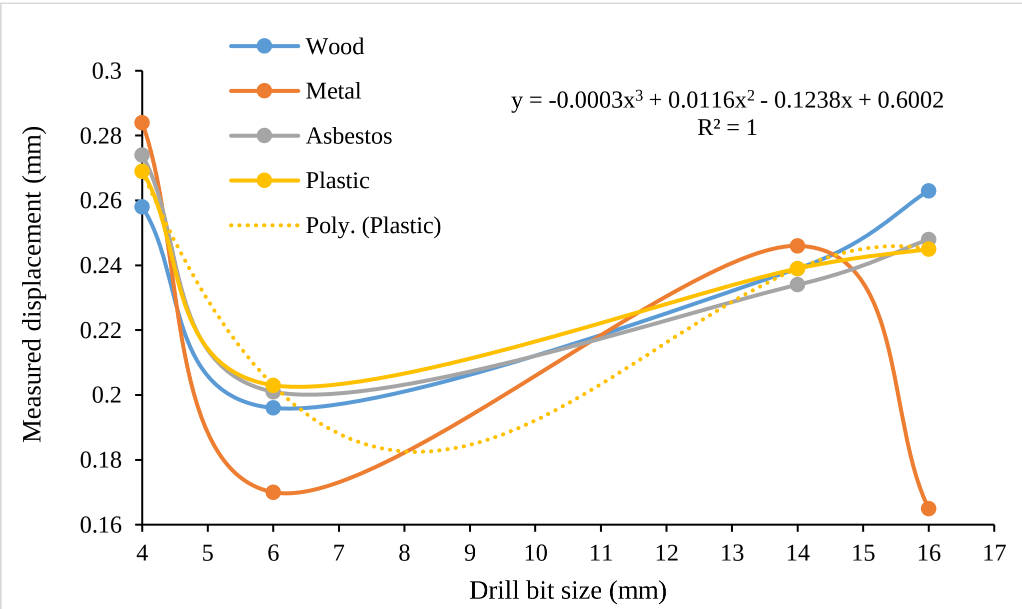

Figure 7: Values of displacement for varied bit size

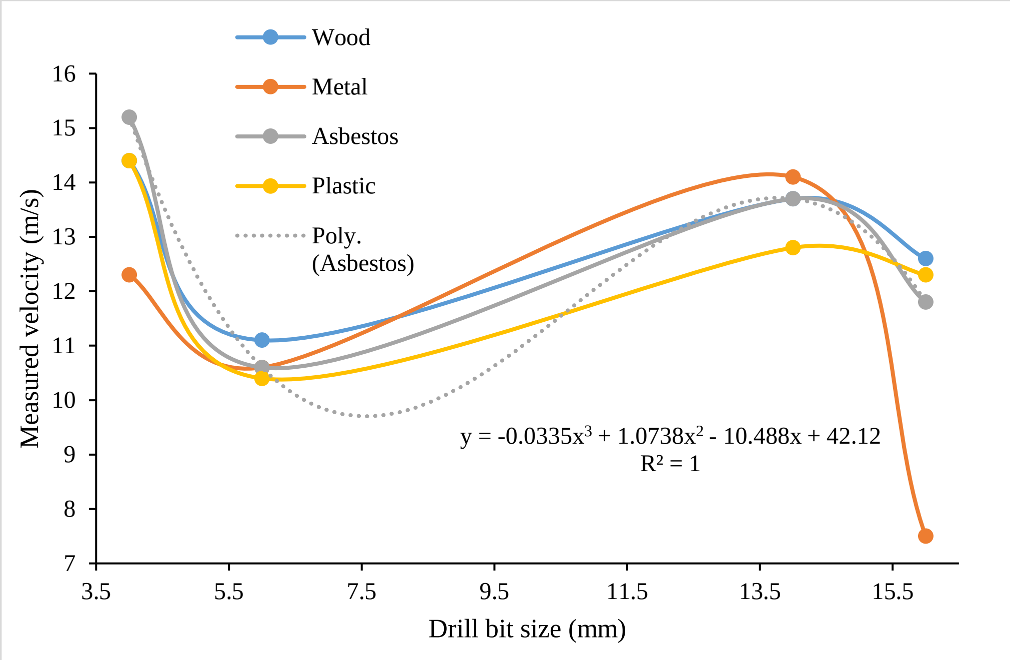

Figure 8: Values of velocity for varied bit size

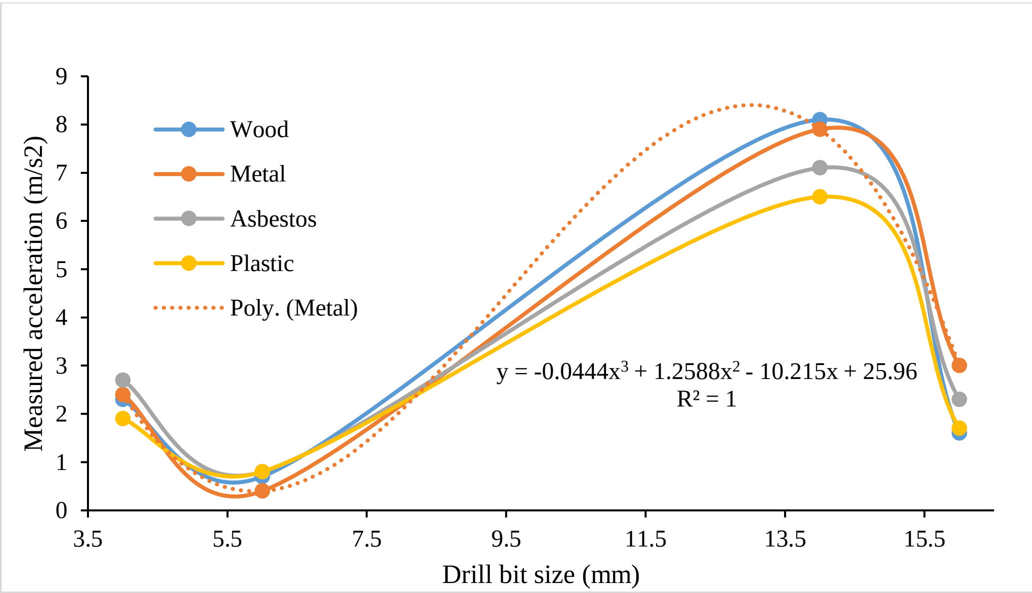

Figure 9: Values of acceleration obtained for varied bit size

4. Conclusion

The vibration on a drilling machine was measured at different parts of the machine for different materials using varied sizes of drill bits. The obtained data were then analyzed statistically. It can be concluded that vibrations varied significantly with the sizes of drill bits and workpiece material. Also, the electric motor was a major source of vibrations, and variations in vibrations properly fit into the 3rd order polynomial regression model.

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