An Applied Mechanics Investigation to experimentally determine the density of plasticine in tribological systems

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***Abstract* - The research paper caters to the identification of the flow behavior of plasticine as a vital component in the physical synthesis of metals, which is associated with the density of plasticine used. Tribological manufacturers implement materials that operate on a mechanism suitable to their respective system thus, accurate measures of density correlate with the optimal functioning of mechanical and thermal devices. A molded, spherical form of plasticine was used in this experiment. It was important to establish the relationship between the mass of the sphere and the diameter of its cube in order to mathematically calculate the density of plasticine through the rate of change of mass with cubic diameter. The experiment was in agreement with theory (within error) and external variables were adequately controlled in an attempt to produce reliable data. The density of plasticine was calculated to be 1.34 g/cm3 with an 8% percentage error associated with it. The experiment was successful in achieving the outcome, although there were certain limitations in the methodology that produced the difference with its literature value.**

***keywords* - Plasticine, Density, Tribology, Vernier Calipers, Proportionality**

INTRODUCTION

This experiment is based on the concept of Measurement and Uncertainty, which serves to apply theoretical formulas of density and volume to a practical investigation related to a Plasticine ball in order to determine a relationship between the mass and cubic diameter of a sphere; this would be used to determine the density of plasticine. Density refers to mass per unit volume and is an essential determinant of the optimal material to be used in tribological systems. In addition, plasticine is a synthetic modelling material made from calcium salts, petroleum jelly, and aliphatic acids.

I. METHODOLGY

The experiment is conducted using the primary equipment of Vernier calipers, plasticine balls, electronic mass balance and the secondary equipment of a calculator. The experiment is set up by procuring different composites of plasticine [1] and rolling them into a spherical shape. The procedure is mapped further as follows:

(1) Measure the diameter of the Plasticine ball for 5 readings using a Vernier Caliper.
(2) Calculate the uncertainty in the measurements in 1 significant figure
(3) Calculate the mean diameter of the plasticine ball.
(4) Measure the mass of the ball using an electronic mass balance
(5) Repeat steps (1) to (4) for 5 different sized plasticine balls, performing the experiment initially with a ball of approximate radius 0.5 cm.

The mathematical derivation to determine the relationship between mass and cube of the diameter of the spherical plasticine balls is as follows [2]:

$$Density = \frac{Mass}{Volume} \quad or \quad p = \frac{M}{V}$$

Volume of a sphere is represented by the following equation:

$$V = \frac{4}{3}\pi r^3$$

Since, radius of a sphere = ½ of the diameter of the sphere, volume of a sphere can be represented by the following equation:

$$\mathrm{V} = \frac{1}{6}\pi d^3$$

Therefore, Density can be represented as:

$$Density\ (p) = \frac{6M}{\pi d^3}$$

Rearranging this, gives:

$$M = \frac{\pi p d^3}{6}$$

Hence, it is mathematically verified that M is directly proportional to d^3 (vice-versa)

Following the methodology, the experiment is conducted for which the data has been represented in Table 1. Since, a weighing machine is a digital instrument with a least count of 0.1 g, the mass of the Plasticine ball has an absolute uncertainty of ± 0.1 g. A Vernier Caliper has the smallest possible measurement or a least count of 0.1 mm, giving it the absolute uncertainty of ± 0.01 cm as it is more accurate compared to a ruler [3].

Table 1: Experimental Data

Trial	**Mass/g (± 0.1 g)**	**Diameter/cm (± 0.01 cm)**					**Mean Diameter/cm (± 0.4 cm)**	**d^3/cm^3 (± 4 cm^3)**
1	4.2	1.88	1.87	1.89	1.88	1.88	1.880	6.64
2	3.4	1.68	1.69	1.68	1.68	1.68	1.682	4.76
3	6.6	2.05	2.04	2.05	2.06	2.05	2.050	8.62
4	1.2	1.15	1.15	1.15	1.16	1.15	1.152	1.53
5	2.4	1.58	1.57	1.58	1.59	1.58	1.580	3.94

Through the theoretical equation, $M \infty d^3$

Thus, $M = kd^3$, where k is the constant of proportionality [4].

In order to verify the constant of proportionality between the mass and cubic diameter of the sphere, consider trials 3 and 4:

According to Trial 3, constant of proportionality = $\frac{M}{D^3} = \frac{6.6}{8.62} = 0.768 \approx 0.8$

According to Trial 4, constant of proportionality = $\frac{M}{D^3} = \frac{1.2}{1.53} = 0.784 \approx 0.8$

Since, the constant of proportionality holds for two different masses, hence, it is verified that there is a direct relationship between mass of a sphere and its cubic diameter.

In order to calculate the Density of the Plasticine ball,

$$M = \frac{\pi p d^3}{6}$$

$$Gradient\ (m) = \frac{\pi p}{6}$$

$$p = \frac{6m}{\pi}$$

$$Gradient = \frac{5.3 - 2}{7.5 - 2.8} = 0.702$$

$$p = \frac{6 \times 0.702}{\pi} = 1.34\ g/cm^3$$

In order to calculate uncertainty in gradient,

$$Gradient_{max} = \frac{5.75 - 3.5}{8 - 5} = 0.750$$

$$Gradient_{min} = \frac{4 - 2.25}{5.9 - 3} = 0.603$$

$$\Delta\ gradient = \frac{0.750 - 0.603}{2} \approx 0.07$$

Since, 6 and π are constants, therefore $\Delta\ p = 0.07\ g/cm^3$

Therefore, the density of the Plasticine ball is: ($\mathbf{1.34 \pm 0.07}$) g/cm^3

$$\%\ uncertainty = \frac{0.07}{1.34} \times 100 \approx\ 5\%$$

$$\% \; error \; in \; final \; calculation = \frac{(1.46 - 1.34)}{1.46} \times 100 \approx 8\,\%$$

II. CONCLUSION

This designed experiment helped obtain a value for the density of the Plasticine ball through a range of calculations. It enabled the application of theoretical mechanics-based knowledge in this practical investigation and was able to fulfill its objectives. The experimental value of the density of Plasticine was of a different magnitude comparative to the standard density of Plasticine. There are various factors that led to this percentage error in calculation which incorporate both random and systematic errors thus, affecting the precision and accuracy of the calculated result. Firstly, there might be a reading error while measuring the diameter of the different massed spheres using Vernier Calipers due to parallax error. Secondly, there might not be sufficient significant figures in the calculated values as a result, subsequent measurements might have been affected thus, impacting the final value of the density of the Plasticine ball. Lastly, enough repeated trials might not have been conducted in order to further, investigate the relationship between the mass of the sphere and the diameter of its cube. In spite of the above improvements, the experiment was deemed successful in helping determine the density of plasticine, which would be helpful for manufacturers in the field of tribology.

III. REFERENCES

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