SCHOOL OF ENGINEERING
TAYLOR'S UNIVERSITY

ENG 60503
PROPERTIES AND APPLICATIONS OF MATERIALS

Brinell Hardness Test

Lab Tutor: Ms. Norhabibah binti Mohamad

NAME	ID	SIGNATURE
Hong Jian Hua	0330534	
Lim Min Yee	0330907	
Yap Jin Teck	0326788	
Tan Jia Hao	0330881	

Due Date:
Date of Submission:

Return of student marked assessment tasks. Please check (√) the necessary column.

/	Electronically to the individual student via the University learning management system
	Collect during class, only by the student
	Collection from the school or a staff member upon presentation of their student ID card
	Collection from module coordinator, lecturer or tutor by prior arrangement

* For online assessment such as forum, quiz, test, survey and etc., return of students marked assessment tasks are published in TIMES.

Table of Contents

Date of Experiment:	
Report due date:	
Report submission date:	
Checked by:	
Item/marks	
Format/10	
Abstract and Introduction/10	
Figures and Diagrams/15	
Materials and Method/10	
Results Discussions/45	
References/10	
Total	

Abstract

The objective of this experiment was to study the hardness of different materials and compare the data collected from the experiment with the theoretical values. The experiment was conducted using the gunt universal testing machine WP300 where a specimen will is placed between the lower cross member and crosshead of the device. In this experiment, 4 pieces materials were tested which are aluminium, brass, copper and mild steel. Each specimen will be subjected with the same amount of force and the dent formed will be measured in order to determine the hardness of the materials.

To begin the experiment, a point was marked on the surface of the aluminium. The crosshead is then lowered until it is in contact with the point marked on the surface of the aluminium specimen and the hand wheel was turned to subject 10kN force on the specimen. After 15 seconds, the crosshead was lifted and a dent was formed on the surface of the aluminium specimen. The diameter of the dent formed was the measured by three different persons using an electronic vernier caliper and the data was recorded. The same steps were repeated on the other specimens. With the data collected, the Brinell hardness number formula was then used to determine the hardness of the specimens.

Based on the data collected, we can conclude that mild steel has the highest hardness in comparison to the other specimens, followed by brass, copper and lastly aluminium. The difference between mild steel and the other specimens is the presence of iron. The strength of pure iron is greatly increase when alloyed with carbon. Copper and aluminium are non-ferrous metals, wherein the main constituent of these specimens are not iron. Brass is alloy of zinc and copper which make it a non-ferrous alloy metal. Mild steel is an alloy ferrous metal which composed of iron and up to 0.3% of carbon[4].

When the experimental data is compared with the theoretical data, the errors are minimal which suggest that the experiment was a success.

1.0 Introduction

Brinell hardness testing is to determine the hardness of a material based of the indentation of formed on a material when a large force is apply. The hardness of a material is determine using the widely and standardized Brinell hardness test method which was created by a Swedish engineer.

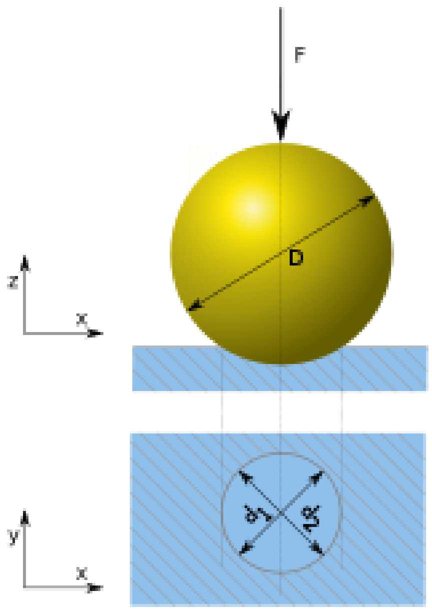


Figure 1. Force diagram

A dent is formed on the material after testing which will be used to determine using the Brinell hardness number formula

$$HB = \frac{0.102F}{2\pi D(D - \sqrt{D^2 - d^2})}$$

Where D = diameter of indenter

d = diameter of the indentation

F = force applied

The hardness of a material depends on various factors, such as the composition of the metal and atomic structure of the molecule. Metals can be separated into ferrous and non-ferrous metal. Ferrous metal are metals that consist of iron whereas non-ferrous metal does not. Iron, when alloyed with carbon, has a much higher strength compared to pure iron. However, non-ferrous metals are usually lighter and does not have magnetic properties compared to ferrous metals hence making it desirable for certain structural applications[4].

The main purpose of the testing is to allow an engineer to understand the strength of a material and determine the most suitable materials to be used for a certain purpose. This is crucial when constructing an object as a weak material may lead to the structural failure of the object and cause injury or deaths.

2.0 Experimental Design

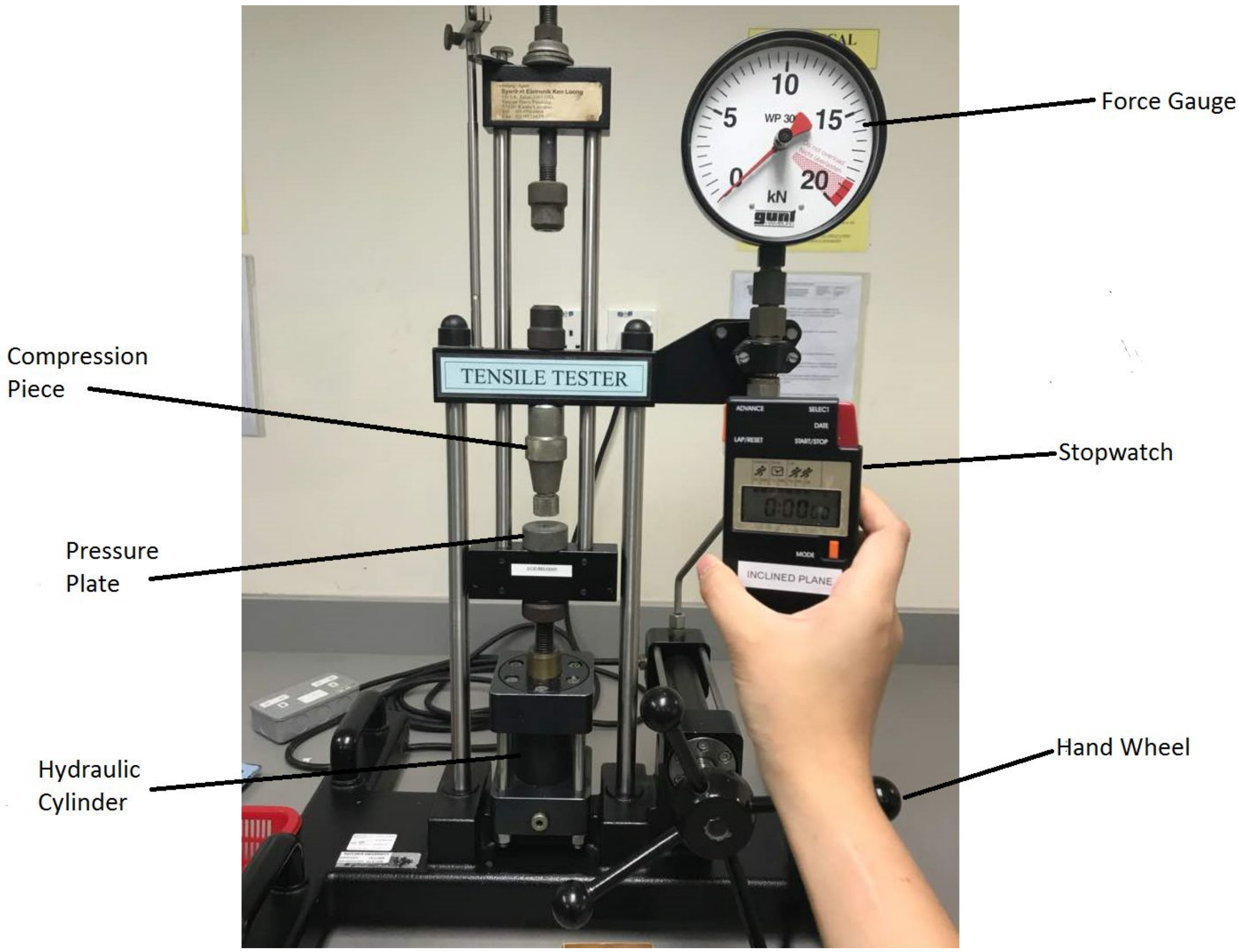


Figure 2. Gunt Universal Testing Machine WP300 used in the experiment.

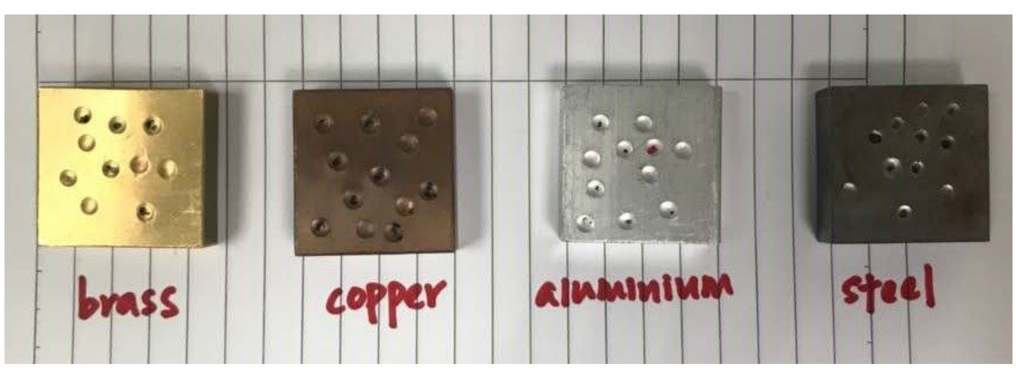


Figure 3. Test specimens for each material used in the experiment.

Figure 4. The force gauge on the Gunt testing machine.

Figure 5. Compression piece and pressure plate of the gunt tester.

2.1 Apparatus

1) Aluminium, Brass, Mild steel and Copper specimens.
2) Digital Vernier Caliper
3) Retort Stand
4) Gunt Universal Testing Machine WP300

2.2 Objectives

1) To determine the Brinell Hardness number of different materials subjected to a 10 kN load.
2) To compare the hardness of different materials with theoretical values.

2.3 Experimental Procedures

1) The Gunt Universal Testing Machine is set up as shown in the experimental design.
2) 4 blocks of specimens of different materials which are aluminium, brass, mild steel, and copper are prepared.
3) The hand wheel is first released to allow the aluminium specimen to fit in.
4) Before applying the load, a stopwatch is prepared at hand, and the point of pressure is first marked using a marker pen for memory.
5) The hand wheel is then turned to apply the load until the force gauge shows 10 kN of force.
6) After applying 10 kN of force, the stopwatch is immediately started to accurately determine 15 seconds of time passing.
7) After 15 seconds, the hand wheel is released and the aluminium specimen is taken out and the dent is measured using a digital vernier caliper.
8) Three group members each measured the diameter of the dent once, and the data was recorded in a table.
9) The average diameter of dent was then calculated and the Brinell Hardness number was found using the formula given.

2.4 Methodology

All the specimen blocks were subjected to a force of 10 kN for 15 seconds from the pressure plate and the compression piece on the apparatus. Specimen blocks of 4 different material were used, namely aluminium, brass, copper, and mild steel. After the force was applied, the diameter of dents on the specimens were recorded by three different members of the group and tabulated. Average diameter of dent was calculated and the Brinell Hardness number was obtained using the formula.

Constant Variable: Force applied and length of time applied on specimens.

Manipulated Variable: Type of material of the specimen block.

Responding Variable: Diameter of dent on specimen block.

3.0 Experimental Results and Discussion

3.1 Tabulation of Data

Material	Trial 1 (mm)	Trial 2 (mm)	Trial 3 (mm)	Average diameter (mm)
Aluminium	3.96	3.79	4.01	3.920
Copper	3.62	3.82	3.64	3.693
Brass	3.42	3.45	3.36	3.410
Mild Steel	3.43	3.21	3.17	3.270

Table 1. Raw data from the experiment.

Material	Average Dent Diameter (mm)	Experimental Brinell Hardness (N/mm^2)	Theoretical Brinell Hardness (N/mm^2)	Error (%)
Aluminium	3.920	81.13	78	4.0
Copper	3.693	91.86	95	3.3
Brass	3.410	108.34	100	8.3
Mild steel	3.270	118.12	120	1.6

Table 2. Calculated data from the experiment.

3.2 Sample Calculations

Average Diameter for aluminium = (Trial 1 + Trial 2 + Trial 3)/3

= (3.96 + 3.79 + 4.01)/3

= 3.920 mm

Where F= Force Applied

D= Diameter of the ball

d= Diameter of impression

For Aluminium,

Experimental Brinell Hardness, HB = (102F)/2πD(D- $\sqrt{D^2 - d^2}$

= 81.13N/ mm^2

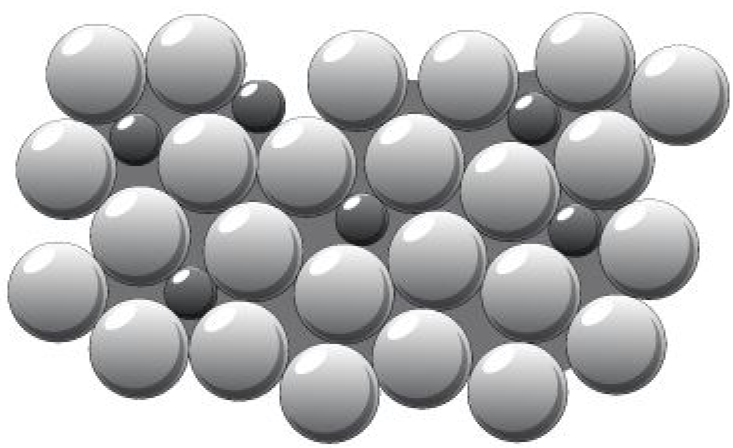
Error % = (Exp HB Value - Theoretical HB Value)/Theoretical HB Value x 100%

For Aluminium, Error % = (81.13-78)/78 x 100%

= 4.0%

3.3 Discussions

Table 1 shows the raw data of the experiment. Using the Brinell Hardness equation, we were able to calculate the hardness of metals based on our experiment. The data caculated is then compared with the theoretical data and the percentage of error is then recoreded in Table 2. Based on the data gathered from the experiment, we can see that mild steel is the hardest material, followed by brass, copper and then aluminium. We can see that the hardest metals in the experiments are metal alloys. This is because metal alloys consists of other elements[1]. A pure metal structure allows for atoms to slip past each atom as the structure of the atom is smooth and uniforms. In the case of mild steel, mild steel consists of atoms such as iron, carbon and manganese [2]. These atoms help to distort the arrangement of the iron metal and allow interlocking of each layer of atom due to the smaller atomic size of carbon. This is also the case for brass metal. Brass consists of a combination of zinc and copper [3] and the ratios are manipulated depending on the type of workload needed.



It is more difficult for layers of atom to slide over each other in alloys [3]

Mild steel is harder than brass because when carbon is mixed with iron when creating steel, the ductility of the metal decreases[4] . This helps with the hardness of the mild steel. Brass on the other hand, is a tensile metal [5]. Varying levels of zinc in brass will affect its strength and ductility.

Copper and aluminium both are pure metals. Copper is stronger than aluminium because copper has larger atomic number compared to aluminium. Although aluminium is able to release more valence electron for metallic bonding, copper's larger atomic number allows the sea of delocalised electrons to have a stronger attraction to the positive cations[6]. Copper and aluminium are one of the softest materials tested in this experiment is due to the smooth atomic structure stated above. Combination of a smooth atomic structure and a weaker electrostatic attraction between aluminium cations and its delocalised sea of valence electrons, we can see that aluminium is the softest materials in this experiment.

4.0 Error Analysis

The error of the experiment is calculated using the difference between the calculated data and theoretical data divided by the thoeretical data which is then multiplied by 100 to obtain the percentage or error. Comparing the data gathered in the experiment with the theoretical results, we can see that the percentage of error from the data gathered is not significant with the highest error data being brass at 8.3% where the lowest error data was mild steel at 1.6%. Multiple factors may have affected the accuracy of the experiment data. One of the possible factor for some accuracy loss may have been due to the equipment used. Due to the machine requiring human power to apply the force, the cranking motion is not smooth nearing the required 10kN of force. The not smooth nature of the apparatus may have caused the force to be applied slightly above or slightly below the 10kN force required. To improve the accuracy of the data. The experiment was repeated for a second time because the data acquired during the first experiment had a higher percentage error record.

Another possible cause of experimental data errors might be due to parallax error. Due to the gage being analog and not digital, the readings might be slightly inaccurate as readings have to be taking perpendicular to the gage. Slight parallax error may have caused the force applied to be slightly over or slightly below the 10kN force. Parallax error might have also occurred when taking readings of the dent on the metal after the experiment. To improve the accuracy of the experiment, multiple students were used to verify the accuracy of the reading gathered from the gage and also the vernier calliper. The data was then combined to find an average reading.

5.0 Conclusion and Recommendations

After performing this experiment, the Brinell's Hardness equation is used to conclude the hardness of the materials. Steel is the hardest among the materials followed by brass then is copper and aluminium is the softest among the four materials. The experimental and the theoretical values are in line hence our method of performing the experiment is precise. The diameter circular that is deformed is measured to determine the strength between the materials.

Based on the table from the above, the experimental values is slightly different compared to the theoretical values. By comparing the brinell hardness values, the percentage error for steel is the lowest among the four materials which is 1.6%. Next, Brass has the highest percentage error which consists of 8.3% followed by aluminium which is 4% and copper which is 3.3 %. Error can be caused by a few factors of parallax error while student is performing the experiment. First of all that could possibly happen during the experiment is when pre-deformation occur on the plane of the material that is caused by turning the hand wheel. This causes an imprecise value for our data results. Next, human reaction time when student stops and starts the stopwatch when the material is supposed to be left for deformation for 15 seconds.

A few recommendation can be made to overcome the error while performing the experiment. Student can prepare a concave mirror and place it right behind the pressure plate in order to reduce parallax error. Sensor could be use to transmit signals to let go of the materials that is placed on the pressure plate so that we can attain an accurate results. Last but not least, the experiment should repeat at least three times to obtain a more precise value.

Reference

[1] *Machinery Handbook*, Industrial Press Inc, New York, Edition 24

[2]"Atomic Structure of Steel", *Sciencing*, 2017. [Online]. Available: https://sciencing.com/atomic-structure-steel-6638014.html. [Accessed: 07- May- 2018].

[3]"BBC - GCSE Bitesize: Alloys", *Bbc.co.uk*, 2014. [Online]. Available: http://www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/rocks_metals/4_metals_alloys2.shtml [Accessed: 07- May- 2018].

[4]*Boeingconsult.com*. [Online]. Available: http://boeingconsult.com/tafe/mat/FerrousNonFerrousMetals.htm. [Accessed: 07- May- 2018].

[5]"Difference Between Steel and Brass | Difference Between", *Differencebetween.net*, 2010. [Online]. Available: http://www.differencebetween.net/object/difference-between-steel-and-brass/. [Accessed: 07- May- 2018].

[6]"Chemistry: What Factors determine Metallic Bond Strength", *Quora*, 2014. [Online]. Available: https://www.quora.com/Chemistry-What-factors-determine-metallic-bond-strength/answers/5683778?share=674b8182&srid=y7Sd. [Accessed: 07- May- 2018].