4X3U

DEPARTMENT OF MECHANICAL ENGINEERING

MATERIALS SCIENCE

INDENTATION OF METAL BY A BALL

OBJECT

To examine the deformation of a metal specimen when a hardened steel ball is pressed into it under different normal loads and to determine how such indentations should be used to give an indication of the properties of the specimen.

INTRODUCTION

One often wants to obtain some indication of the mechanical properties of a piece of metal, but cannot perform a compression or tension test. This may arise because:-

(a) The piece of metal is so small that it is impossible to machine a tensile or compressive specimen from it. Or,

(b) You cannot afford to destroy the piece of metal or machine part, because you want to use it for its proper pump purpose afterwards. Or,

(c) You have not had time to prepare and test a tensile or compression specimen.

There is therefore a need for a simple, quick and non-destructive, test that will tell us something about the properties of the material, although it is unlikely that it will tell us as much as a tensile test. This experiment is concerned with establishing the basis for such a test.

Let us suppose that we apply a normal load on a hardened fig. 1, and let us suppose that the load is great enough to cause plastic flow of the specimen. When we remove the load and the ball, an indentation:

Can we use the size of this indentation as some measure of the mechanical properties of the specimen? This is the question to which this experiment is directed.

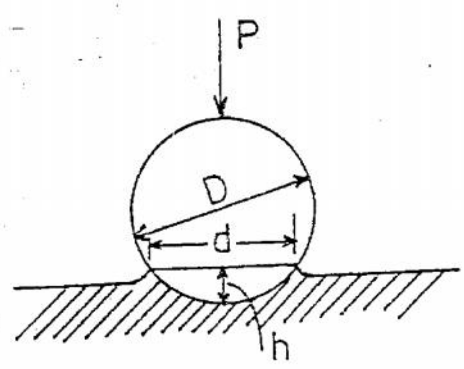

fig1.

The first step is to use different loads P and To examine how the indentation varies in size. If the curved surface area of the indentation It is found that the points lie on an approximate Straight line through the origin, although there is no obvious reason why this should be so. if the experiment is performed on another material a straight line of a different gradient is obtained.

This result gave Brinnell the idea that the gradient of this graph represented a property of the material and he suggested that this property should c called 'hardness'. The connection between hardness and other mechanical properties, such as yield stress, was not understood at that time.

However, it would be tedious in real life to perform a number of tests to obtain the gradient of this graph. It would be much more convenient if a reliable measure could be obtained from just one indentation, but care must be taken that the load used is not too large or too small as the graph tends to depart from a straight line at these values of load. Supposing that we take that care, the Brinnell hardness Number is defined as:

$$\text{B.H.N.} = \frac{\text{load}}{\text{Curved surface area of impression}} = \frac{P}{\pi Dh}$$

$$= \frac{2P}{\pi D\,(D-\sqrt{D^2-d^2})}\ \text{Kg/mm}^2$$

By convention the load P is measured in Kg and linear dimension is mm, so that the units of B.H.N. are Kg/sq.mm, but the units are not normally stated.

GUIDANCE ON PRECEDURE

1. Apply a series of loads to two metal specimens via a 10mm diameter ball:
   a) Use loads 250, 500, 1000, 1500, 2000, 2500, 3000 Kg.
   b) Do not place impressions closer together than 2½ times the diameter of the impressions, otherwise the indentations affect each other. Do not place them within two impressions diameter of the edge of the specimen. Also for reliable results the depth of the specimen should be at least 10 times the depth of the impression.
   c) Apply each load for 30 secs before you release it.

2. Measure the diameter of the impressions with a microscope.

COMPUTATION AND GRAPHS

1. Plot load against curved surface area of the impression and derive the gradients of the graphs.

2. Examine your results more closely of impression

   a) B.H.N. against diameter of impression
   b) B.H.N. against applied load

The experimental points on these two graphs are likely to show considerable scatter. Think carefully about the likely experimental error before you attempt to draw curves through the experimental points and draw conclusions from the graphs. You may assume that the error on applied load will be within 1% or 2% of full load for the machine for each intended load. You may draw your own conclusions concerning the accuracy of the diameter measurement from the microscope.

DISCUSSION

1. From your graphs deduce what range of diameter of impression compared with the diameter of the ball would be acceptable for a single indentation test.

2. From your graphs deduce what range of loads would be acceptable for each of your specimen materials for a single indentation test.

3. In practice when you have to make a hardness test you can by simple inspection tell whether the specimen is steel, aluminium, or copper etc. You must then decide upon the indenting load which you will use. As a guide a standard procedure is laid down as follows:

For steels, and cast iron $\frac{P}{D^2} = 30$

For copper and aluminium alloys $\frac{P}{D^2} = 10$

For copper and aluminium $\frac{P}{D^2} = 5$

For lead, tin and their alloys $\frac{P}{D^2} = 1$

Where P is the load in Kg and D is ball diameter in mm. Compare this guidance with your deductions under 2 above.