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Effect of Radiation on the Mechanical Properties of Materials

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Abstract - Property means the quality that defines a specific characteristic of a material. The properties of a material provide a basic for predicting its behavior under various conditions. In selecting a particular material for engineering applications properties such as machinability, mechanical stability, chemical durability, electrical resistivity, thermal conductivity etc play an important role.

In present work we have studied the mechanical properties such as percentage elongation, ductility, Young's modulus, hardness, strain energy and creep. The samples were irradiated by 6 MeV electron beam (Race Track microtron of Pune University). The mechanical properties were measured using the tension test (before and after irradiation). It was found that the percentage elongation or ductility has been increased after irradiation. Also there is a significant change in Young's modulus and strain energy per unit volume after irradiation.

Keywords - 1. Mechanical properties; 2.Irradiation; 3.Race Track Microtron; 4.Tension test.

I. INTRODUCTION

Every Engineer is vitally concerned with the materials and their properties. Whether he has to manufacture a bridge, a machine or an automobile part, he must have an intimate knowledge to select suitable material for his products according to the requirements.

In selecting a particular material, properties such as machinability, mechanical stability, chemical durability, electrical resistivity and thermal conductivity as well as cost of the material should be considered.

II. PROPERTIES OF MATERIALS

Property defines specific characteristics of material. The properties of material provide a basic for predicating its behavior under various conditions. Mechanical properties like tensile strength, percentage elongation, ductility, Young's modulus, hardness and creep (before and after irradiation) were investigated. For irradiation Race Track Microtron of Pune University was used for irradiation with operating beam energy 6-8 MeV. The material was irradiated by 6 MeV electron beam[1]. The mechanical properties were tested with the help of tension test.

Hardness, strength and brittleness are not the same things, however when it comes to metals at least, these three qualities often go hand in hand. Cast iron is a typical example of this combination. When properly designed for a structural application, most cast iron materials are exceptionally strong and able to carry massive loads, whilst retaining an elegant and light quality that was almost impossible to achieve using building materials such as stone.

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Cast iron is also hard with a typical hardness range of BHN 150-250, compared to low carbon steels which are generally fall between BHN 150-200. Unlike mild steels though, many cast iron materials are prone to fracture especially under shock loading (sharp impact), or focused heating (when welding for example). Hard materials are often difficult to form into shapes by common fabrication techniques; instead many hard materials are cast into moulds instead. Hard materials are also useful for cutting purposes, although as we have seen cutting tools may function better in use when tempered[4,5,6]. Keeping this in mind the above material was used in the present investigation.

III. EXPERIMENTAL PROCEDURE

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality for use in design and construction[2,3]. If a material is to be used as part of an engineering structure which is to be subjected to a load, it is important to know that the material is strong and rigid to withstand the loads that it will experience in service. As a result engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading. The most common type of test used to measure the mechanical properties of a material is the Tension Test.

Tension test is widely used to provide basic design information on the strength of materials and is an accepted test for the specification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are the tensile strength (UTS), yield strength or yield point (σy), elastic modulus (E), percent elongation ($\Delta L\%$) and the reduction in area (RA%). Toughness can also be found by the use of this testing technique.

IV. TESTING SYSTEM

The testing system consists of a tensile testing machine, a load cell, a power supply and an X-Y recorder. Testing Machine is of hydraulic type (Alşa Universal Testing Machine). It is a load-controlled machine. Load Cell provides an electrical circuit for measuring the instantaneous load along the loading axis. Power Supply is connected to load cell. It feeds the load cell, amplifies the output signal and displays the load. Recorder plots the variation of load against time.

V. STEPWISE PROCEDURE

1. Measure the diameter of the specimen at three different sections. Calculate the original diameter by taking average of three readings. The minimum overall length of the specimen shall be 20 times diameter plus 200 mm.

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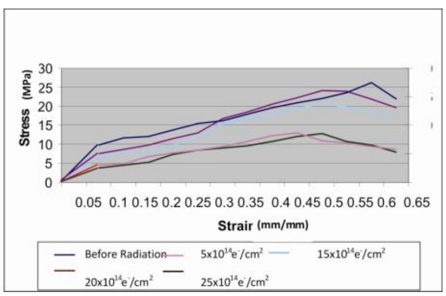
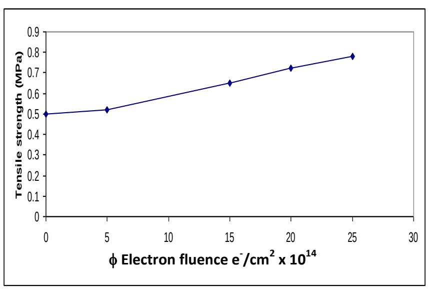
2. Mark the points over the grip length, with the punch such that the distance between two consecutive points is half the gauge length.
3. Select a suitable loading range depending on the diameter of specimen. Start the UTM and adjust the dead weight of movable heads and then set the load pointer to zero.
4. Fix the specimen bar between the grips of top and middle cross heads of loading frame.
5. Attach the extensometer on the bar at the central portion of the bar. The distance between upper and lower pivots of extensometer shall be equal to gauge length.
6. Switch on the machine and open the control valve so that the load is increased gradually and at the required rate.
7. Record the load at suitable interval from the digital display unit or the load dial.
8. Corresponding to loads, note the readings of extensometer.
9. For initial few observations, load and extension are in pace with each other. Record the yield point load by observing the hesitation of load pointer. The extension readings are faster at this moment.
10. Remove the extensometer; hence measure extension by divider or suitable scale.
11. Record the maximum load. Observe the decrease in load and neck formation on the specimen.
12. Record the load at fracture and put off the machine.
13. Remove the specimen. Observe the cup and cone formation at the fracture point. Rejoin the two pieces, measure the final gauge length and the reduced diameter.

VI. OBSERVATIONS OF THE TENSILE TEST

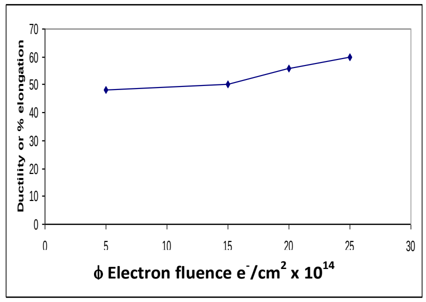
Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. The specimen used is approximately uniform over a gage length.



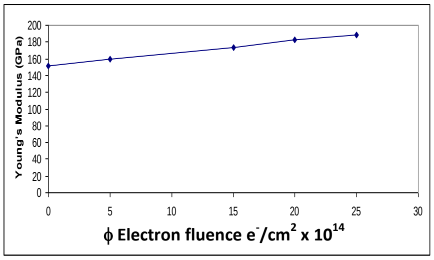
Graph 1: Stress Strain Curves Before and After Electron Irradiation



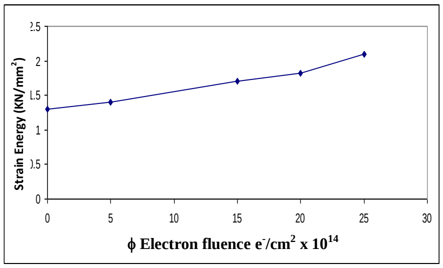
Graph 2: Variation of Tensile strength



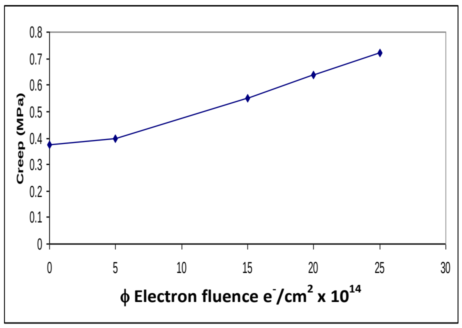
Graph 3: Variation in ductility or % elongation



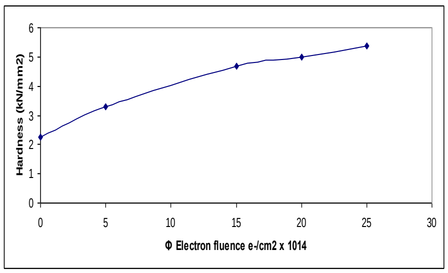
Graph 4: Variation in Young's Modulus



Graph 5: Variation in Strain energy



Graph 6: Variation in Creep



Graph 7: Variation in hardness

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VII. DISCUSSION

- From Graph no. 1, it is observed that stress strain curve becomes successively strong as increase in the electron fluence from 5 x 10^{14} e^-/cm^2 to 25 x 10^{14} e^-/cm^2 and reveals substantial improvement in the mechanical properties
- The graphs 2, 3, 4 & 5 shows that the improvement in the tensile strength, percentage elongation or ductility, Young's modulus and strain energy per unit volume for cast iron.
- Out of these mechanical properties the percentage elongation or ductility is sensitive parameter for evaluating the radiation effect in cast iron so the increasing percentage elongation is observed to be an advantage in this particular case of cast iron where it is increased almost by 12%. This result indicates that the modification in cast iron due to electron irradiation is significant as regards all its mechanical properties such as tensile strength, percentage elongation or ductility, Young's modulus and strain energy per unit volume.
- This particular facts attribute that the finer the grains, the larger the area of grain boundaries that impedes dislocation motion. Grain-size reduction usually improves toughness as well. Usually, the tensile strength, the electron induced defects are responsible for strengthening or improving the properties of cast iron.
- From graph no. 6 & 7, it is observed that creep and hardness also increases with increase in electron fluence. This may be because the imperfection created due to electrons, alters the basic properties of material. Primarily the damages due to point defects irregularities and vacancies created in crystalline structure.

VIII. CONCLUSION

The overall mechanical properties such as tensile strength, percentage elongation or ductility, Young's modulus, strain energy per unit volume, creep and hardness are improved due to 6 MeV electron irradiation.

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