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Correlation between Mechanical and Magnetic Properties of Structural Steel Bar due to Variable Loading Conditions

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Abstract: ***The aim of our research is to analyse the change in magnetic flux due to strain produced in a steel bar while loading condition is varied. The bars were placed in a universal testing machine and load was applied in real time. With the help of a copper coil of specific inductance the change in magnetic flux was observed due to the strain produced while elongating the bar placed in universal testing machine. Due to change in magnetic flux the inductance of the coil with the core of steel bar also changed which was compared with the Hooke's law i. e., the stress-strain graph. A corelation is to be obtained between strain and the magnetic field. This can be further used to develop a soft sensor to measure strain or loading conditions on a structure.***

Keywords: Magnetic properties, stress, strain, Hooke's law, Real time load, structural steel

1. Introduction

Non-destructive testing equipment are used in the Construction industry to obtain structural health monitoring parameters without disturbing the homogeneity of existing structure. Due to certain discrepancy in the results of NDT equipment it is better to rely on multiple sources to have less possibility of error in the results thus obtained. There is a significant change in the magnetic properties of a material due to lattice deformation when stress is applied on it. This change can also be seen in the form of strain produced in the object. These two changes due to a certain stress have some corelation, which if established will be helpful to give some predictions in the stress condition of an object.

2. Literature survey

There have been some research in this direction which directed the result towards having a significance corelation between magnetic properties and mechanical properties of a material. It was found that due to change in Lattice at atomic level the magnetic properties of that material were changing. The change was obtained in the form of eddy's current induced in the material. A thin plate was used to have effective plastic stress measurement. But the elastic forces and their pattern was not ensured. Further, the plate used in the experiment was of that to obtain effective stress and observation in the eddy's current. The magnetic properties also include change in magnetic flux density. Eddy's current can be easily detected on the surface but if induced at a depth it will be hard to measure. So, we determined to use the change in magnetic flux density and change in current due to changing permeability of the core due to strain in steel bar.

1) Robert Laue, Frank Wendler, Sebastian H€artel, OlfaKanoun, Birgit Awiszus, Analysis of stress: It Discussed about the effect of stress over a plate. Change in the magnetic properties was observed with a probe which measured the eddy's current. Eddy's current can be determined at the surface. The Structural Steel/ Rebars are out of scope for probes using eddy's current.
2) By Charles W. Burrows, CORRELATION OF THE MAGNETIC AND MECHANICAL PROPERTIES OF STEEL influence and plastic strain on magnetic properties during the forming process, S2666912921000234: This Paper in depth discusses the effect of temperature and various experiments conducted in this field. The effect of stress over magnetic properties is also demonstrated upto some extent. The Rebars are made in different conditions and they also exhibit other properties from normal steel rods.

3. Problem Definition

When any structure goes under cyclic loading there are places at which it gets deformed earlier than others due to change in loading patterns. These specific problems are dealt in the software like SAP2000, ETABS etc. But there are no devices available in the market to monitor the real time load of a structure and maintain a database so as to verify the studies and make a further improvement in the structural analysis. This research was an attempt to obtain a relation between the two fields. Such that the properties can be corelated and their relation can be used to make a device

which can monitor the load of a building or structure in real time.

4. Motivation

In seismic zones, industrial buildings, commercial buildings, etc. certain loading conditions have a pattern and they influence the structural health. To obtain that loading pattern there should be a device to monitor the loads in real time such that it can be maintained on a database and with accuracy we can predict the life of a building which is very important to obtain the economic feasibility of the building. This can also help us to come to a conclusion of whether to use the structure further or not after a serious damage to the structure. After seismic activity or any structural failure in the building it is often renovated. But after that renovation also to monitor the health of a particular member can be done using a device which can monitor the loading condition in real time.

5. Objective

Objective of this research is to use the findings of experiment to set a relation between magnetic and mechanical properties of a material.

6. Methodology/Approach

A coil or a solenoid has got an inductance which changes according to the core of the material used inside the coil. That material can be air or anything as per requirement. When the core of the material changes its inductance also changes due to which there is a change in current of circuit. The change is significant and of the order of 0.1 mili-amperes. This value also depends on the inductance of the coil, type of material used, etc. When a tensile load is applied on the object placed at the core of the coil there is a longitudinal strain produced which changes the cross-section area and internal properties of the material. This change in the properties changes the inductance of the coil which is noted with the help of an ammeter placed in the circuit. This change in current is observed and noted at the particular amount of load applied. In this research we tried to derive a relation empirically between strain and change in the current. This change in the current if detected efficiently can conversely give us the value of the load applied. The initial confirmatory experiment for our future work was performed to obtain the following data in the form of Table. Other values like inductance, magnetic flux, etc. can be obtained on the basis of standard formula.

Stress (KN)	Strain (mm)	Current (A)
0	0	0.1491
25	7	0.1475
50	11	0.1465
75	15	0.1468
85	18	0.1475

A 16mm Rebar was placed in the air core coil with an inductance of 2.69mH. Then a Universal Testing Machine with a capacity of 400KN was used to give tensile force on the rebar. At different forces the strain and current was measured using an inbuilt strain gauge and a multi-meter. The Data observed confirmed a pattern in the variation of the current observed.

7. Results and Discussion

The variation had a pattern. When initially the force was applied due to change in its magnetic permeability the inductance of the coil got changed resulting in the declination of the value of current through the coil. But as we proceed further till the rupture limit of the Rebar specimen the volumetric strain was enough to allow magnetic flux leakage and increase in the value of current. So, after a point of time the volumetric strain superseded the change in magnetic permeability. Which can be used as an indication of failure of rebar in any device made on this principle.

8. Conclusion

The future work of this project is to obtain the graphs between stress, strain and the current in the circuit with the same setup. Then the setup can be changed to get the values for a new inductance. The same amount of material will be required to reconduct the experiment for a new coil. The obtained values can then be analysed to come to a conclusion to make a device which is compatible to fit in the structural components like beam, slabs etc.

9. Future Scope of the work

The presented work demonstrates the relation between magnetic properties and the mechanical properties of a material due a stress applied. The work is further applicable to make a device which can monitor the load over a structural member. Looking at the importance of the structural load monitoring systems and their future scope, this research has its significance as a part to contribute in the future work.

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