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An Investigation of the Effect of Grain Size on the Mechanical Properties of 0.2% Carbon Structural Steel

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ABSTRACT : Industrial application felt the dominance of structural steel as a principal raw material. In designing and fabrication of heavy to light engineering machineries the mechanical properties like Tensile strength, Yield Strength, Elongation, Toughness and Hardness plays very important role. These properties are the important engineering criterion in today's world. These properties deepened on number of factors. An important factor is grain size of the material. Tensile strength is higher when the grain size is smaller and vice versa. Grain size affects many properties of the polycrystalline materials like strength, Ductility, hardness & Toughness etc. Grain size of metal can be changed to attain desired properties with suitable heat treatment.

In the present work structural steel has been taken and investigation carried out to develop a relation between Tensile strength, Toughness, Hardness and grain size of the metal. The grain size has been measured very accurately on computer aided image analyzer. Rests of the mechanical properties are tested on the testing machines.

Verification of results has been done by determining the grain size and yields stress of the same metal with different methods used and with the hall- Fetch equation, which gives the relation between grain size and yield strength.

Keyword : Grain Size, Structural Steel, Mechanical properties.

I. INTRODUCTION

Industrial application felt the dominance of structural steel as a principal raw material. In designing & fabrication of heavy to light engineering machinery's the mechanical properties like Tensile strength, Yield Strength, Elongation, Toughness and Hardness plays very important role. These properties are the important engineering criterion in today's world. These properties deepened on number of factors. An important factor is grain size of the material. Grain size of metal can be changed to attain desired properties with suitable heat treatment.

Structure steels are most commonly used material by the engineering industries. This is because of its application and economic availability. The applications of this material are widespread hence from the technical point of view therefore the properties of this material are very important. Structural steels are available in market in various forms like Plates, Angles, Channels, and Rods etc. Hence looking at the vide spread application of this material this study has been undertaken.

II. OBJECTIVE

The objective of this study is to study of grain size on mechanical properties of structural steel without changing the chemical composition. This is the material most widely used in engineering application. Hence for certain application the enhanced properties are required without changing the chemistry of the material. To attain this objective a material is selected in as rolled condition and the grain size is varied by suitable heat treatment and then the properties are measured to see its effect [1-2]. From the experimentation carried out it was observed that there is a tremendous change in the mechanical properties with the change in grain size that can be utilized in practical applications.

III. EXPERIMENTAL WORK

Structural steels are available in market in various forms like Plates, Angles, Channels, and Rods etc. This material is manufactured in accordance with the IS: 2062 [3]. To study the existing problem a plate of 12 mm thick is selected which is cut into smaller pieces. These pieces are then subjected to the annealing treatment to change the grain size. The treatment is given in such a way to gat the minimum to maximum grain size so that properties can be studied in a most effective manner over a range of grain diameters (4-5) To change the existing grain the annealing was carried out at different temperatures, viz., 900, 950, 1000, 1050 and 1100?C so as to get define change in the grain size. After the heat treatment all samples were first studied under microscope to see the change in the grain size. After ensuring the definite change in the grain size of all the samples the standard samples were prepared for the mechanical testing.

Specimen Preparation

After heat treatment the standard specimens were prepared for the mechanical testing like tensile test and Impact test. The standard specimen for tension tests were

prepared as per IS: 1608 [6] which specifies the dimension for the tension test for steel plates of various thickness. Also the standard specimen for impact test were also prepared as per IS: 1157 [7].

The hardness specimens were taken out from the tensile specimen.

IV. SPECIMEN FOR GRAIN SIZE MEASUREMENT

The most important part of metallography deals with the microscopic examination of prepared metal specimen, if the specimen is properly prepared then only it is easy to investigate the structural characteristics as grain size, the shape the distribution of secondary phases and nonmetallic inclusions, segregation and other heterogeneous conditions, all of which profoundly influence the mechanical properties and behavior and characteristics of metal. When these and other constitutional features are determined by the microscopic examination and the extent to which they exist in the microstructure is known, it is then possible to predict with considerable accuracy the expected behavior of the metal when used for a specific purpose [8].

Different operations that were used for preparation of specimen are listed below:

1. First different specimens were cut into proper size approximately about 5mm.
2. Any one surface of the specimen made plane with the help of surface grinder.
3. Different specimen has been mounted in the Bakelite with the help of mounting press.
4. Marking has been done on the different specimens.
5. Polishing was done one by one with rough emery papers, fine emery papers and finely with polishing cloth.

After above operation specimens were ready for microscopic examination.

V. RESULTS AND DISCUSSION

Different specimens were tested on Universal tensile testing machine 60-ton capacity; to find out the tensile Strength, yield strength, percent elongation of the material. Impact testing machine was used to analyze the impact strength. Hardness testing are done on the Brinell hardness tester. After testing the different samples are prepared for microscopic examination [9-10]. One by one each sample was taken to the computer aided image analyzer to analyze the actual grain size so that the properties can be compared with the grain diameter. A set of grain sizes were obtained for each sample on image analyzer out of which few repeated reading ars selected as actual grain size for comparison purpose.

The Chemical Composition of Material

% Carbon Max.	% Manganese Max.	% Sulphur Max.	% Phosphorous Max.	% Silicon Max.
0.21	1.3	0.042	0.041	0.3

Mechanical Properties

Simple No.	***Tensile Strength***	***yield Strength***	***Elongation (%)***	***Hardness (BHN)***	***Impact Strength (J)***
1. As rolled	595	421.78	24	250	27
2. Annealed at 900°C	525.12	352.94	28.4	195	30
3. Annealed at 950°C	490.19	325.5	30.03	160	33
4. Annealed at 1000°C	425.58	275.18	32.21	140	36
5. Annealed at 1050°C	401.96	250.19	32.25	131	39
6. Annealed at 1100°C	386.45	230.56	39.18	120	42

Grain size (mm) Measurement

Simple no.	*Equivalent Dia.*	*Average Dia.*	*Area*	*Average Area*	*Parameter*	*Average Parameter*
	3.568		10		22	
	3.192		8		18	
1.	2.985		7		16	
As rolled	2.764	3.1465	6	7.833	14	
17.666						
	3.385		9		20	
	2.985		7		16	
	4.918		19		28	
	3.909		12		25	
2.	5.046		20		26	
Annealed	4.652	4.984	17	19.833	26	31
At 900³C	5.971		28		43	
	5.412		23		38	
	6.284		31		24	
	5.293		22		23	
	5.171		21		22	
3.	5.863	5.802	27	21.666	23	23
Annealed	5.528		24		21	
At 950°C	6.676		35		25	
	10.012		73		43	
	11.056		96		64	
4.	12.134		138		59	
Annealed	11.284	11.04	102	101.5	68	55
At 1000°C	10.232		81		43	
	11.523		119		53	
	13.493		143		77	
	14.184		158		81	
5.	13.159		136		72	
Annealed	15.676	14.895	193	175.666	117	
96.333						
At 1050°C	16.507		214		100	
	16.352		210		131	
	19.771		307		197	
	16.584		216		73	
6.	16.963		226		187	
Annealed	14.582	18.856	167	278	159	
180.666						
At 1100°C	20.212		351		218	
	25.024		401		250	

Comparison of Grain Size with Mechanical properties

Simple No.	*Average Grain Dia.*	*Tensile Strength*	*Yield Strength*	*% Elongation*	*Impact Strength*	*Hardness*
1.	3.1465	595	421.78	24	27	250
2.	4.984	525.12	352.94	28.4	30	195
3.	11.04	490.19	325.5	30.03	33	156
4.	14.895	425.58	275.5	32.21	35	140
5.	14.895	401.96	250.19	35.25	39	131
6.	18.856	386.45	230.56	39.18	42	120

VI. CONCLUSION

1. There is a linear relationship found between grain size and tensile, yield strength of a structural steel. Which indicates that tensile strength; yield strength and elongation are directly proportional to the grain size of a structural steel?
2. Without changing the chemistry of a material the toughness of material can be increased with slight modification in manufacturing process.
3. With the method of grain size measurement tensile and yield strength of a material can be found out.
4. For actual component that is installed at site with this technique a replica of a material can be taken out to measure the grain size. This is very useful for residual life estimation.
5. Grain size measurement with image analyzer is very accurate and fast as compared to other techniques.

Results of these investigation may be used to determine the mechanical properties of a material if grain size is known and vice-versa.

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