Observation of Stress-Strain Relationship of Structural Steel in Universal Testing Machine

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Abstract -- This paper is about practical tensile testing of structural steel S355. There are many European grades of structural steel such as; S195, S235, S275, S355, S420, S460 etc. The maximum chemical composition of structural steelS355 is 0.23 C, 1.6 Mn, 0.05 P, 0.05 S and 0.05 Si. Mechanical properties of structural steel S355 are yield stress of 355 MPa and ultimate stress of 470 to 630MPa according to European Committee for Iron and Steel Standardization. There are many types of material testing such as tensile test, compression test and other test etc. Material testing is of extreme importance that the user of materials be able to obtain reliable information on the properties of materials. Material testing is one of the helping functions of engineering fields. It is really necessary and important for a country in order to become more developed. Without it, all engineers are faced the problem. The yield point, and ultimate strength of structural steel S355were determined in uniaxial tension. The specimen geometry was used with the region of minimum cross section having the dimensions: diameter is 6 mm and gauge length is 10 mm. Three fundamental mechanical properties of metals are modulus of elasticity (E), yield stress (σ_y), and ultimate stress (σ_u). The lower limit of yield point was determined to be 374.882 MPa. The upper limit of the yield point was determined to be385.094 MPa. The ultimate stress was determined to be 628.278 MPa.

Indexed Terms: modulus of elasticity, tensile testing, ultimate strength, yield point

I. INTRODUCTION

Testing is applied to materials components, and assemblies. It consists of measurement of fundamental properties or measurement of responses to particular influences such as load, temperature, and cormorants. Inspection is closely related to testing and it is applied to materials, components, and assemblies. Inspection is concerned with the geometry of objects, detection of internal defects, and examinations for performance, color and general appearance. Tests and inspection methods may not be destructive of the object being examined, and hence, testing is commonly subdivided into two major areas: destructive and nondestructive testing. Tests are also classified as physical, chemical or mechanical tests. Physical tests include measurement of such quantities as specific gravity, and electric, magnetic, thermal, and optical properties. These are usually performed in scientific laboratories, rather than engineering laboratories, and are not further mentioned here. Chemical tests, by which chemical properties are determined, are generally in the realm of the scientist rather than the engineer and, with the exception of corrosion testing are not discussed in this text. Mechanical tests are most often performed in engineering laboratories. These include measurements of properties such as hardness, strength, and toughness. These tests require special equipment and techniques.

Testing is an essential part of any engineering activity. Inspection and testing must take place at many stages in the complex process of producing engineering materials; during the forming of these materials into components and assembling the components to create an engineering product of satisfy some specific requirement. The requirement for testing does not automatically case when the product has been manufactured. The type of test used can be broadly classified into two categories:

a) Tests to establish the properties of the material, and
b) Tests to determine the integrity of the material or component.

There are six commercial testing of materials. They are-

1. Tensile Test
2. Bending Test
3. Impact Test
   (i) Izod Test
   (ii) Charpy Test
4. Hardness Test
   (i) Brinell Test
   (ii) (ii)Vickers Diamond Test

(iii) Rockwell Test
5. Ductility Test
6. Fatigue Test

II. DESCRIPTION OF TESTING EQUIPMENT

The tensile test is one of the most widely used of the mechanical tests. There are many variations of this test, specified in detail by the ASTM (American Society for Testing and Materials), to accommodate the widely differing character of materials such as metals, elastomers, plastics and glass. The tensile testing of metals is described below.

The common metallic tensile specimen is machined from a 12 mm round. It has a central reduced section of 6 mm diameter and length of 30 mm as shown in Fig.1. The specimen is gripped in a machine which can apply measured the loads along the axis of the specimen.

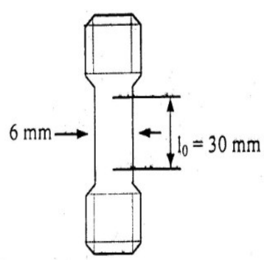

Fig. 1: Standard Round Tensile Specimen

If necessary, the displacement sensor (potentiometer) for measuring changes in length can be attached to the machine. As the specimen is slowly elongated, simultaneous measurements of applied load versus length and stress versus strain are recorded automatically. Stress-strain relationships determined in this way can be applied to specimens and structural members whose dimensions differ from those of the test specimen. The test is completed when the specimen finally breaks. The basic unit essentially consists of the following elements,

1) Machine base
2) Hand grips
3) Support with cross-head
4) Upper-member
5) Lower cross-member
6) Hydraulic system consisting of a main cylinder
7) Hand wheel
8) Forced display
9) Elongation display via a dial gauge
10) Gripping heads
11) Sample

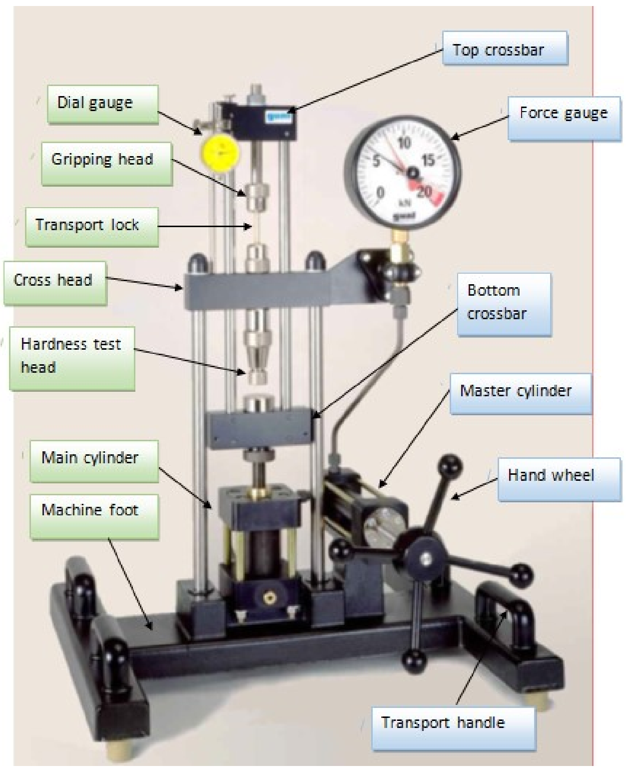

Fig. 2: WP 300 Universal Material Tester (20kN)

Fig. 3: Data Acquisition System

This data acquisition is an additional feature for the material tester WP 300. It supports tensile tests, compressive tests, hardness tests according to Brinell, shear tests and the determination or the modulus of elasticity of a bending specimen. The measuring system consists of a pressure sensor for force measurement, a linear potentiometer to measure the displacement and a measuring amplifier including a

USB interface for connection to a PC. Measured values are evaluated in the user-friendly software: diagrams can be recorded, saved and printed on a printer. Additionally, it is possible to print a complete test log in accordance with DIN for tensile and compressive tests. Up to ten load extension curves can be displayed simultaneously. Load-extension diagrams are displayed in real-time. The system follows the following sequence of operation.

1) Automatically transferring test results from their testing machines into host computer system or database, to eliminate data entry errors.
2) Automatically calculating test results, to reduce test times.
3) Verifying test results to ensure there were no calculation errors.
4) Verifying that a test was performed according to specification to ensure the loading rates or rates of travel were correct.
5) Easily comparing old test results to more recent results, simplifying test procedures to reduce test times and improving the accuracy and reliability of their testing machine.

III. OVERVIEW OF STRESS-STRAIN DIAGRAM

A. Proportional Limit:

As the stress and strain increase in a tensile test, eventually a point is reached at which stress and strain are no longer directly proportional to one another. The lowest stress at which stress and strain are no longer proportional is known as the proportional limit.

B. Elastic Limit:

Beyond the proportional limit, strain increases faster than does stress, and eventually the material are permanently deformed. Response of this kind is known as inelastic action, and the stress which causes it is known as the elastic limit strains below the elastic limit are known as elastic strains: elastically strained objects recover their original dimensions upon removal of a load.

C. Yield Point and Yield Stress:

In mild steels, with increasing strain, a point is reached at which strain increases without further increases in stress. This stress is known as the yield point. The yield point is much more readily determined than is the proportional limit or the elastic limit. It is taken as a practical measure of the limit elastic action, i.e., the stress above which the material is permanently deformed. The practical limit of elastic action is extremely important in manufacturing operations such as rolling drawing and deep drawing spinning, etc., for it shows what stresses must be exceeded if permanent deformation is to be achieved.

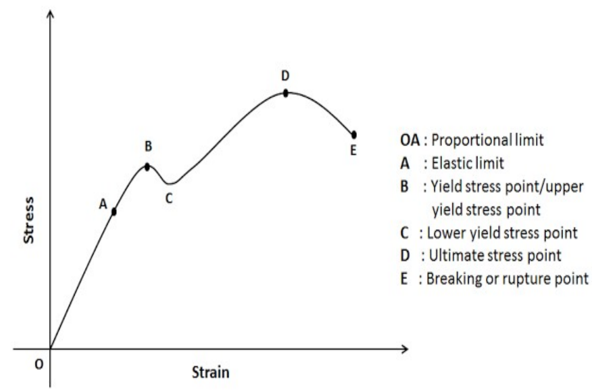

Fig. 4: Stress-Strain Relationship

D. Ultimate Stress or Tensile Stress:

The maximum ordinate to the curve is known either as the ultimate stress or tensile stress of the material.

E. Percentage Elongation:

Beyond the limit of elastic action, the tensile specimen at first elongates quite uniformly along its length. Eventually the elongation tends to become concentrated in one region and since the volume of the material does not change, this results in development of a constriction. This is called necking down. The change in length divided by the original gage length is expressed as a percentage of elongation.

F. Percent Reduction of Area:

The percentage reduction of area is often quoted for round-bar specimens instead of a percentage elongation value. There is certain merit in this as the reduction of area value is largely independent if specimen dimensions and gauge length. It is the difference in area between the cross-sectional area of the test-piece at the point of fracture and the original cross-sectional area.

IV. TENSILE TEST RESULTS

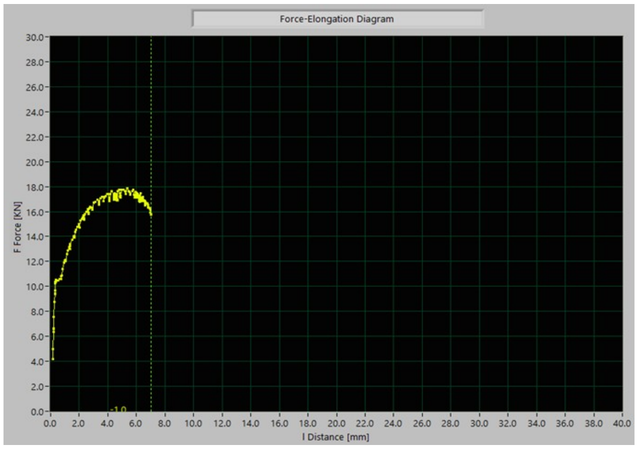

Fig. 5: Force as a Function of Displacement for Structural Steel S355 Tested in Tension

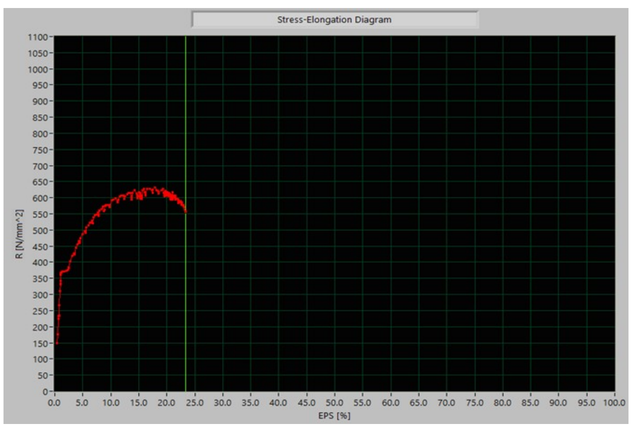

Fig. 6: Stress-Strain Plot for Structural Steel S355 Tested in Tension

The force-displacement graph examined for the structural steel S355 is shown in Fig.5. The data shown in Fig.5 were converted automatically to a corresponding stress-strain graph as shown in Fig.6.

Table 1: Result Table for Yield Stress

t [h:min:s]	l [mm]	F [KN]	EPS [%]	R [N/mm^2]	TEST []
5:10:11.1 P	0.613	10.581	2.042	374.243	1.000
5:10:12.1 P	0.711	10.600	2.369	374.882	1.000
5:10:14.1 P	0.748	10.798	2.492	381.903	1.000
5:10:13.1 P	0.760	10.888	2.533	385.094	1.000
5:10:15.1 P	0.833	11.376	2.778	402.328	1.000
5:10:16.1 P	0.944	11.893	3.145	420.625	1.000
5:10:17.1 P	1.005	12.055	3.350	426.369	1.000
5:10:18.1 P	1.042	12.115	3.472	428.497	1.000
5:10:19.1 P	1.054	12.001	3.513	424.455	1.000
5:10:20.1 P	1.140	12.591	3.799	445.305	1.000
5:10:21.1 P	1.201	12.855	4.003	454.666	1.000
5:10:22.1 P	1.275	13.168	4.248	465.730	1.000
5:10:23.1 P	1.336	13.198	4.453	466.794	1.000
5:10:24.1 P	1.336	13.018	4.453	460.411	1.000
5:10:25.1 P	1.373	13.385	4.575	473.389	1.000
5:10:26.1 P	1.483	13.746	4.943	486.155	1.000
5:10:27.1 P	1.605	14.022	5.351	495.942	1.000
5:10:28.1 P	1.642	14.052	5.474	497.006	1.000
5:10:29.1 P	1.654	13.914	5.515	492.112	1.000
5:10:30.1 P	1.691	14.383	5.637	508.707	1.000
5:10:31.1 P	1.789	14.534	5.964	514.026	1.000
5:10:32.1 P	1.875	14.756	6.250	521.898	1.000
5:10:33.1 P	1.985	14.979	6.618	529.770	1.000
5:10:34.1 P	1.998	14.792	6.658	523.175	1.000
5:10:35.1 P	2.022	14.696	6.740	519.771	1.000
5:10:36.1 P	2.059	15.262	6.863	539.770	1.000
5:10:37.1 P	2.169	15.406	7.230	544.876	1.000
5:10:38.1 P	2.218	15.520	7.394	548.919	1.000
5:10:39.1 P	2.304	15.689	7.680	554.876	1.000

Table 2: Result Table for Ultimate Stress

t [h:min:s]	l [mm]	F [KN]	EPS [%]	R [N/mm^2]	TEST []
5:12:06.1 P	5.208	17.656	17.361	624.448	1.000
5:12:07.1 P	5.233	17.409	17.443	615.725	1.000
5:12:08.1 P	5.233	17.662	17.443	624.661	1.000
5:12:09.1 P	5.368	17.854	17.892	631.469	1.000
5:12:10.1 P	5.453	17.638	18.178	623.810	1.000
5:12:11.1 P	5.527	17.590	18.423	622.108	1.000
5:12:12.1 P	5.564	17.361	18.546	614.023	1.000
5:12:13.1 P	5.564	17.463	18.546	617.640	1.000
5:12:14.1 P	5.699	17.650	18.995	624.236	1.000
5:12:15.1 P	5.784	17.764	19.281	628.278	1.000
5:12:16.1 P	5.846	17.367	19.485	614.236	1.000
5:12:17.1 P	5.858	17.229	19.526	609.342	1.000
5:12:18.1 P	5.870	17.175	19.567	607.428	1.000
5:12:19.1 P	5.870	17.151	19.567	606.577	1.000
5:12:20.1 P	5.882	17.120	19.608	605.513	1.000
5:12:21.1 P	5.882	17.102	19.608	604.874	1.000
5:12:24.1 P	5.895	17.241	19.649	609.768	1.000
5:12:22.1 P	5.907	17.560	19.690	621.044	1.000
5:12:23.1 P	5.919	17.313	19.730	612.321	1.000
5:12:25.1 P	5.931	17.193	19.771	608.066	1.000
5:12:26.1 P	5.931	17.169	19.771	607.215	1.000
5:12:30.1 P	5.931	17.217	19.771	608.917	1.000
5:12:27.1 P	5.956	17.524	19.853	619.768	1.000
5:12:29.1 P	5.956	17.259	19.853	610.406	1.000
5:12:28.1 P	5.968	17.337	19.894	613.172	1.000
5:12:31.1 P	5.993	17.187	19.975	607.853	1.000
5:12:32.1 P	6.005	17.457	20.016	617.427	1.000
5:12:34.1 P	6.005	17.229	20.016	609.342	1.000
5:12:36.1 P	6.005	17.151	20.016	606.577	1.000

V. CONCLUSION

From an experimental result, the yield stress of structural steel is greater than the European standard. This shows that the specimen is pure steel and some errors were avoided during experiment. The computer software and control system has achieved the desired results. Studies of material behavior under mechanical tensile have been widely performed using universal tensile testing machines. Specimens can potentially be different types of materials including metallic and non-metallic materials.

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