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A study on improving torsional power of carbon steel St.37 with 800 ºC heating and fresh water quick cooling

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Abstract

The steel St.37 is often used as a machine component or as a shaft material, because it is relatively inexpensive and easily heat treated. Heat treatment of steel St.37 is used to get the desired strength change. It means, before being used in construction techniques, the resistance of steel to external loads as a technical material is very important to know. Due to the resistance of external loads, for example in the form of twisting on the shaft or engine components in appropriate technology is very common. The change of steel strength by the external load is carried out by heat treatment, which through the heating process to a certain temperature and the cooling process using certain media and with a certain cooling speed as well. This study examines how much the standard steel torsion strength (St.37) is increases compared to the same type of steel after going through the 800 ºC heat treatment process with rapid cooling using fresh water. The testing of this study is carried out on the Torsion Measuring Testing Machine Model N-50, together with the fourth semester students, in the material and metrology testing laboratory of the Bali State Polytechnic Mechanical Engineering Department. As a result, steel St.37 hardening through 800◦C heating and cooled quickly using fresh water, compared with standard steel (St. 37), it seen from the test results, namely: Maximum steel twist stress St.37 Standard: 503.7021855 N.mm^{-2} at the maximum torsional moment is 24.6 Nm, whereas, the maximum torsional stress of St.37hardening steel: 697.8735409 N.mm^{-2} at a maximum torsional moment of 35.4 Nm. The elasticity modulus (G) of each specimen after being calculated using relevant formulas, is obtained: G (St.37 standard) = 4205.500677 (N.mm^{-2}) G (St.37 hardening) = 1335.750379 (N.mm^{-2}).

Keywords: Steel; heat treatment; twist stress; twisting resistance; and hardening

1. Introduction

The Department of Mechanical Engineering, Bali State Polytechnic (PNB) directs students to design appropriate technology tools or machines before completing their study at PNB. The results of student design are expected to be more reliable and able to meet the needs of the community. Reliable machines or equipment are machines or tools in their working processes that are safe for operators and their environment, and guaranteed sustainability in their maintenance and repair, also are able to produce competitive products [1].

The choice of material to be used as a component of a machine or tool must be in accordance with the designation and mechanical properties in order to meet the criteria and the burden that occurs on it. Mechanical properties of materials or steel can be known through several testing processes in material testing laboratories. Steel is a technical material that results from advanced processing of crude iron through a smelting process in the converter consisting of the main elements metal or Ferro, carbon, manganese, phosphorus and Sulphur [2]. Heat treatment of steel is intended to obtain the desired mechanical properties, namely heating process with a certain temperature in a heating kitchen and cooled by using certain media as well [3].

This study examines the increase in St.37 steel torsional resistance which gets warmed to 800 ºC and cooled rapidly using fresh water. The choice of steel as mentioned above (St.37) is because the material is widely used and generally available on the market and meets the requirements as a raw material for tool components or machinery of appropriate technology. The hardness testing process is carried out on a specially designed machine that can provide information on the torsional strength of the test object, [4]. This research is a study to determine the extent of the increase in standard St.37 steel torsional strength compared to St.37 steel which is hardened or heat treated based on the theories of materials testing technology especially steel [2].

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Nomenclature

τp	Torsional tension ($N.mm^{-2}$)	θ	Twisting angle (º)
Mp	Twisting moment (N.mm)	ϕ	Specific twisting angle ($^{o}.mm^{-1}$)
Wp	Moments of detention (mm^3)	l	Work piece length (mm)

The objectives of this study include: (i) To obtain torsional moment data that occurs on St.37 pavement / hardening steel; (ii) To obtain data on the value of steel torsional strength St, 37 with heat treatment; (iii) To compare the changes of the standard St.37 steel torsional angle with St.37 pavement; (iv) To know the elasticity modulus of St.37 pavement steel. The results of this study are expected to provide benefits. This research is very useful for researchers and students to develop and deepen their knowledge in the field of material technology, as well as to increase skills in the implementation and operation of materials testing tools. For Bali State Polytechnic institutions, this research is useful to introduce to the parties so that it can be used as a source and comparison of relevant research results. For the community especially those who are dealing with the design and selection of steel materials, the results of this study can be used as a guide in the removal of technical materials in the form of metals and non-metals in general and steel particularly in St.37.

2. Method

This study was carried out by collaboration of fourth semester students who conducted material test practical activities at the Material and Metrology Test Laboratory, Mechanical Engineering Department, Bali State Polytechnic. The process of this research is carried out through two stages, namely: the first stage of the formation of dimensions, by smoothing the surface and the length of the test object, including heating of the specimen in the heating kitchen until it reaches a temperature of 800 ºC, then cooled quickly using fresh water.

The second stage is the data collection on the torsion testing machine, namely; Torsion Measuring Testing Machine Model N-50. This study tested the twisting of the specimen regularly and gradually measured until the test object broken. Therefore, testing specimens directly against standard or hardened test objects [5]. Test specimens were tested for each of the five sticks on the hardness testing machine. The testing process starts from installing the test object on the stand with the torsion angle 00 and adjusting the load by twisting the work-piece through the load input by turning the hand-wheel. The reading of the torsional moment data starts from a multiple of twisting 100 until the test object breaks, and the twisting moment returns to zero. Thus the testing process is carried out by each test object five times carefully until completion [6].

Tests using the Torsion Measuring Testing Machine Model N-50 obtain primary data in the form of the magnitude of torsional angle readings and twisting moments that occur based on the research requirements. Other data needed are calculated using relevant formulas, namely:

a. The voltage drop (τp) is calculated by the formula:

$$\tau p = \frac{Mp}{Wp} \left(\frac{N}{mm}\right) \quad (1)$$

Wherein:
Mp = Moments of twisting that occur (N.mm)
Wp = Torsion resistance that occurs (mm^3)

For solid and round sections:

$$Wp = \frac{\pi d^3}{16} \; . \quad ..(2)$$

Wherein:
d = diameter of the test object (mm).

b. The twist angle is divided by the length of the work piece (l), then a specific twisting angle is obtained:

$$\theta = \frac{\phi}{l} \; (^{\circ}.mm^{-1}) \quad (3)$$

Furthermore, the torsional moment-twist angle diagram and the specific torsional stress angle diagram (*shearing stress-specific angle of the twist diagram*) can be described based on the data obtained directly from the torsion testing machine and data calculated based on the formulas [7].

c. In the same situation, the moment of polar inertia can be calculated or worked through the shear or twist torsion modulus. By giving a torsional moment a shear stiffness modulus (G) is obtained or also called a shear modulus. Within the proportional limit, the following formula can be calculated as follows.

$$\phi = \frac{Mp.l}{G.Ip} \; (radian) \quad (4)$$

$$= \frac{Mp.l}{Gp.Ip} \, \frac{360^{\circ}}{2\pi} \; (\,^{\circ}\,) \quad (5)$$

Wherein:
ϕ = twisting angle (°)
Mp = the twisting moment happened (N.mm)
l = work piece length (mm)
Ip = moment of polar inertia (mm^4)
G = tension or shear modulus ($N.mm^{-2}$)

For solid and round sections:

$$Ip = \frac{\pi \; r^2}{2} \quad \text{or} \quad \frac{\pi \quad d^4}{32} \quad (6)$$

3. Results and Discussion

3.1 Test Results

This research has been carried out with students of the Mechanical Engineering Department, Bali State Polytechnic, batch 2011/2012, it was carried out meticulously and systematically under the supervision of researchers, starting from testing St.37 standard specimens and St.37 hardening. The test results carried out by each type of test object as much fifteen times, noted and processed with the appropriate formulas and then entered into Table 1 which shown Test I (St.37 Standard) of diameter x Length: 6.29 mm x 31.27 mm and Table 2 shows Test II (St..37 Hardening) diameter x length: 6.37 mm x 30.48 mm.

Table 1. Steel St.37 Standard Test Data

Reading angle (°)	Torque (N.m)	Tension Voltage ($N.mm^{-2}$)	Specific Tapping Angle ($°.mm^{-1}$)
10	1.6	32.76111775	0.319795331
20	22.4	458.6556486	0.639590662
30	24.6	503.7021855	0.959385993
40	22.7	464.7983581	1.279181324
50	18.7	382.8955638	1.598976655
60	8.3	169.9482983	1.918771986
70	5.3	108.5212026	2.238567317
80	1.3	26.61840818	2.558362648
90	0.6	12.28541916	2.878157979
100	0.8	16.38055888	3.197953310
110	0.5	10.23784930	3.517748641
120	0.5	10.23784930	3.837543972
130	0.4	8.190279439	4.157339303
140	0.4	8.190279439	4.477134634
150	0.2	4.095139719	4.796929965
160	0.3	6.142709579	5.116725296
170	0	0	5.436520627

Source: Test data St.37 Standards have been processed.

Table 2. Test Steel St.37 Hardening Data

Reading angle (°)	Torque (N.m)	Tension Voltage ($N.mm^{-2}$)	Specific Tapping Angle ($°.mm^{-1}$)
10	0,6	11.82836510	0.324254215
20	12.3	242.4814845	0.648508431
30	20,0	394.2788367	0.972762646
40	22.5	443.5636912	1.297016861
50	24.4	481.0201807	1.621271077
60	25.5	502.7055167	1.945525292
70	26.9	530.3050353	2.269779507
80	28,0	551.9903713	2.594033722
90	28.6	563.8187364	2.918287938
100	29.3	577.6184957	3.242542153
110	30.1	593.3896492	3.566796368
120	30.6	603.2466201	3.891050584
130	31.2	615.0749852	4.215304799
140	31.9	628.8747445	4.539559014
150	32.1	632.8175328	4.863813230
160	32.5	640.7031096	5.188067445
170	33,0	650.5600805	5.512321660
180	33.2	654.5028688	5.836575875
190	33.3	656.4742630	6.160830091
200	33.5	660.4170514	6.485084306
210	33.7	664.3598398	6.809338521
220	34.1	672.2454165	7.133592737
230	34.3	676.1882049	7.457846952
240	34.7	684.0737816	7.782101167
250	34.8	686.0451758	8.106355383
260	35.1	691.9593583	8.430609598
270	35.1	691.9593583	8.754863813
280	35.3	695.9021467	9.079118029
290	35.4	697.8735409	9.403372244
300	20,0	394.2788367	9.727626459
310	1.2	23.65673020	10.05188067

Reading angle (°)	**Torque** (N.m)	Tension Voltage (N.mm⁻²)	Specific Tapping Angle (°.mm⁻¹)
320	1.9	37.45648948	10.37613489
330	0.6	11.82836510	10.70038911
340	0.4	7.885576733	11.02464332
350	0.4	7.885576733	11.34889754
360	0.4	7.885576733	11.67315175
370	0.5	9.856970916	11.99740597
380	0.5	9.856970916	12.32166018
390	0.5	9.856970916	12.64591440
400	0.6	11.82836510	12.97016861
410	0.6	11.82836510	13.29442283
420	0.5	9.856970916	13.61867704
430	0.4	7.885576733	13.94293126
440	0.5	9.856970916	14.26718547
450	0.4	7.885576733	14.59143969
460	0.4	7.885576733	14.91569390
470	0.5	9.856970916	15.23994812
480	0.5	9.856970916	15.56420233
490	0.5	9.856970916	15.88845655
500	0.4	7.885576733	16.21271077
510	0.1	1.971394183	16.53696498
520	0.1	1.971394183	16.86121920
530	0.1	1.971394183	17.18547341
540	0	0	17.50972763
540	0	0	17.50972763

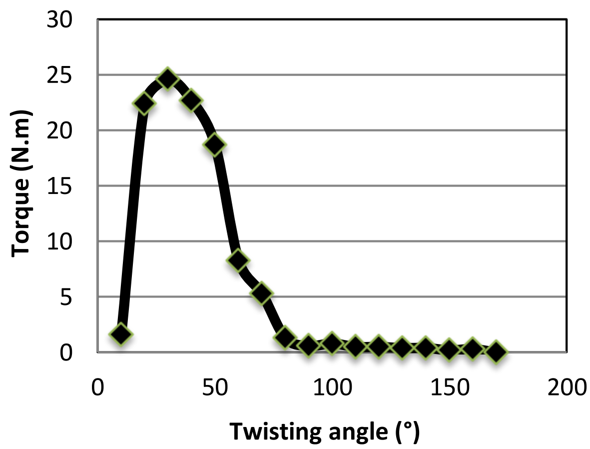


Figure 1. Torque Chart - Twisted Angle St. 37 Standards

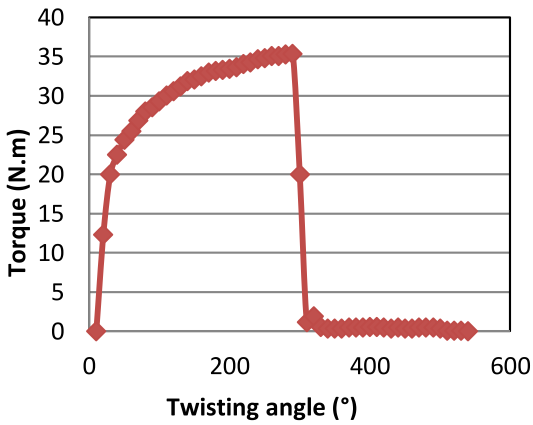


Figure 3. Torque-Twisting Angle St.37 Hardening

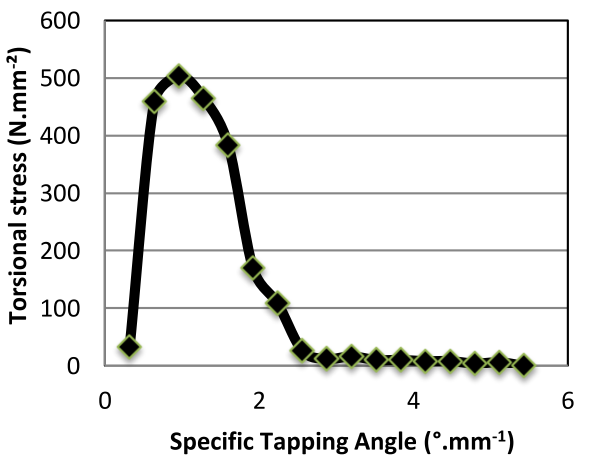


Figure 2. Specific torsional-torsional tension graphs St. 37 Standards

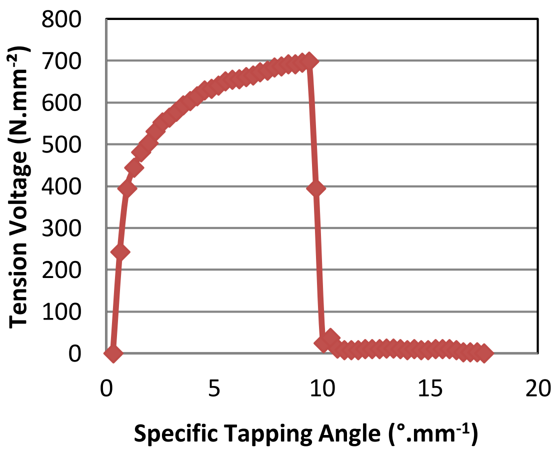
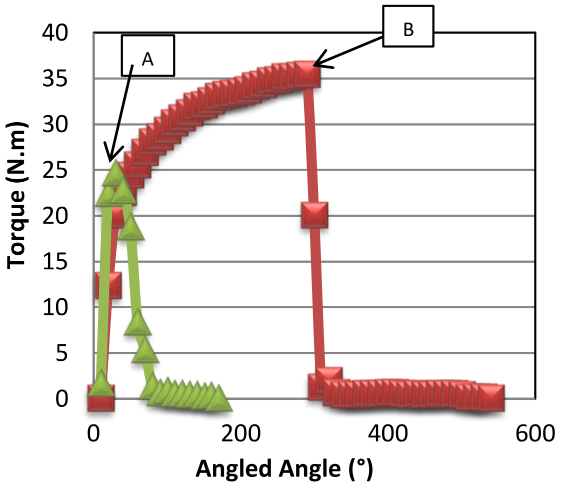
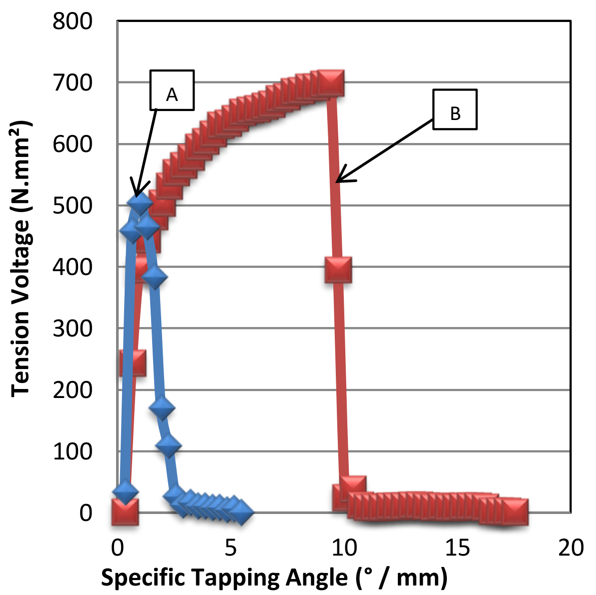


Figure 4. St.37 Hardening specific torsional-torsional tention graph



Description: A = St.37 test sample graphs Standard,
B = Graph St.37Hardening test object.

Figure 5. Torque Charts - Twisting angle of both types of specimens



Description: A = St.37 Standard test sample graphs,
B = Graph St.37Hardening test object

Figure 6. Twisted-torsional graphs of specific twisting angles of both types of specimens

3.2 Discussion

As seen the data in the Table 1 and Table 2 and the graphs for the two types of specimens above, it shows the differences in the mechanical properties of each specimen. It turned out that the specimens that were subjected to heat treatment were hardened by a heating process to 800^{0}C and were cooled quickly using fresh water, their torsional resistance was greater or increased compared to the twisting resistance of the St. 37 standard specimen. The increase in twisting resistance shows in the data above, namely: Maximum steel twist tension St. 37 Standard: 503.7021855 N.mm^{-2} at a maximum torsional moment of 24.6 Nm, whereas, the maximum torsional stress of St.42 Hardening steel: 697.8735409 N.mm^{-2} at a maximum torsional moment of 35.4 Nm. However, the modulus of elasticity (G) of each specimen after calculated using formulas (5) and (6), is obtained: G (St.37 Standard) = 4205.500 (N.mm^{-2}) G (St.37 Hardening) = 1335.750 (N.mm^{-2}).

4. Conclusions

Based on the results of research and data analysis illustrated by graphs, it can be concluded that:

1. Steel St.37 hardening hardened by heating to 800 ºC and chill quickly using fresh water to be more resilient or softer compared to St.37 standard steel. It is evident from the torsional angle St.37 hardening at the proportional boundary equal to 290 degrees, while the torsional angle St.37 The standard at the proportional boundary is 30 degrees. Besides, the torsional moment, twisting tension and the specific torsional angle of the hardened steel have a significant increase. This is shows that there is a significant increase in resistance of twisting.
2. Baja St.37 hardening by heating to 800 ºC and cooled quickly using fresh water, is very useful to obtain shaft material that is more resistant or more resilient to twisting loads when compared to St.37 standard steel

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