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STEEL TWIST (St. 42) STRENGTH CHANGES ANALYSIS WITH QUICK HEATING AND COOLING USING PLAIN WATER AT 800"C TEMPERATURE

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Abstract. *: Steel twist is often happened on machine component that is the axis that its main function to continue power and circle. So, the choosing of axis substance that will be used is very important to know the strength of its twist, so it is safe to be used. This research is the research continuation that is has ever done before. Steel as technical material is often used as machine components, the strength to the external load is very needed to be known before it is used. The external load that is often happened to the machine component is twist load, pull load, bend load, and pound load. This research analyze the standard steel twist St.42 after it is heated at 800'C temperature with quick cooling, using plain water that is done in material test laboratory, majors in Machine Technical, Bali State Polytechnic. The research is aimed to get how big is the St.42 steel strength changes and its twist angle changes after being heated until 800'C and being quick cooled by using plain water, infact it becomes more tough and becomes more twist endure compared to standard St.42 steel. Its strength changes shows there is twist strength improvement until 38, 549%, that is from 503,7021855 (N/mm2) becomes 697,8735409(N/mm2), thus the steel angle arises, even the specific twist angle arises from 0,959385993 ('/mm) becomes 9.403372244('/mm)..*

Keywords : St.42 Steel, heat treating, twist strength.

1. INTRODUCTION

1.1 Background

Mechanical Engineering Department, Bali State Polytechnic is a vocation education institution that educate its alumnus to be a ready working manpower. Until the last project subject, which is the main subject and come close to the end of education, its subject matter sub part makes machine building stake or efficient technology tool. Efficient technology machine is hoped to be able to support the need of tourism sector which is Bali's excellence, [1]. The main component of efficient technology is axis. The axis is generally made of steel, a technical material. The axis material steel that is found in the market, based on its pull strength, there are some kinds such as St.42, St.60 and others. Steel, in other to be used as a machine component to continue its power and twist strength circle is very important to be known. Therefore, research to know steel twist strength is very important to be done, and this research is using twist test machine.[2].

Steel twist strength can be changed by doing heating or *heat treatment* to the steel suitable as the standard. The heat treatment can be done by heating the steel in the heater furnace with a certain temperature and it is quick cooled or it is hardened as the clear procedure operational standard. The twist test machine and the heater furnace is available in testing laboratory in machine technical in Bali State Polytechnic. That is why, this research is done with the practical work students at material testing laboratory and metrology majors in machine technical in Bali State Polytechnic. To do the previous practical work twist testing has got the subject about material technology knowledge and well trained. At the testing time the researcher must pay attention and obey the rules at metrology and material test laboratory beside safety and salvation factors which is conditioned on each testing tool, in this case using Twist Testing Machine testing tool and some others equipment. Steel or material twist strength is the ability of a material or steel to put up with a twist burden on its surface wide. Material twist strength include the

hardness from a material or steel which is most of them are influenced by its fusion elements. Carbon in the iron or in steel definitely influence the quality of steel pull strength or steel hardness.[1].

Experiment result data is input into table format which is used as twist testing primary data. Furthermore testing result primary data is processed by using or input relevant formulas suitable as this research needs. Steel twist strength is a mechanical nature from the most of steels, is influenced by carbon elements and its fusion. Steel mechanical nature is very important to be known in other that at the time of using, is able to put up with the burden and is safe to be used, so that the steel purposes effectively. Carbon element in steel definitely influences steel quality and strength which is needed and can be reached is by heat treatment, [3].

This testing is done to determine the twist strength of a material/steel, of course through testing or twist experiment suitable as mutual procedure operational standard. Steel strength testing in mechanical technique Bali State Polytechnic laboratory can give information about maximum specific twist angle, twist moment, and maximum steel twist tension, [4].

1.2 Problem Formula

Based on the background of problem above, then, the problem formula in this research are;

a. Does the twist testing that is done produce twist strength change on steel St.42 suitable as heat treatment theory?
b. How much is the twist strength changes and the specific twist angle happened on St.42 which is got heat treatment?

1.3 Aim and Objective

The aim of the research such as;

a. To know the twist strength changes that is happened on steel St.42 which is got heat treatment at 800'C temperature and it is cooled by fresh water quickly.
b. To know definitely the changes of St,42 steel twist angle with heat treatment at 800'C.
c. To know definitely the changes of St,42 steel specific twist angle strength with heat treatment at 800'C temperature.

This research result is hoped to give benefit to;

a. For researcher himself, this research is very useful to develop and deepen knowledge in material technology field, and also adds skill in application and operating the material testing equipment.
b. For Bali State Polytechnic Institution, this research is useful to introduce to the parties in order to be used as resource in choosing an appropriate material especially steel St.42.
c. For the society especially who are wrestling with designing and choosing the steel material, this research result can be used as a catalog in choosing technical material or especially steel St,42.

2. METHOD

2.1 Research Location and Process

Research data, is taken from research which is done by researcher and corporate with the students in fourth semester who is doing material testing practical work in Metrology and Material Testing Laboratory, Machine Technical Department, Bali State Polytechnic. This research process is done through two phase, they are: the first phase, dimension forming that is diameter and the length of homogeneous testing material, includes heating toward testing thing on heater furnace until reach 800'C temperature, and then it is cooled quickly by using fresh water, while the second phase is data taking on twist testing machine. This research is testing by damaging the testing thing through twisting or testing the testing thing directly toward standard testing thing and which is hardened, [5]. Testing thing consist of ten sticks of each to be processed on twist testing machine. Twist testing is done by using twist testing machine Model N-50 (*Torsion Measuring Testing Machine Model N-50*), [1].

Testing process starts from measuring and recording testing thing dimension that is the length and diameter, furthermore it is paired or set on twist testing machine by handling on each of both ends on *gearbox unit* and *digital torque meter*. Load input together with twisting angle is given through *hand wheel* on gearbox unit. That loading is continued by testing thing twist to *digital torque meter* which can give twist moment data that is happened at every twist degree that is done. Thus, the testing process is done toward every testing thing carefully until finished if testing thing is cut until its twist moment signal back to zero, [6].

This research process is done through two phases, they are: the first phase of the testing thing preparation include heat treating toward testing thing and the second phase, that is data taking on hardness testing machine. The preparation work is aimed to get the smooth and flat of the testing thing surface. While heat treatment toward testing thing at heater furnace is aimed to harden and or mellow the material thing compared to standard testing thing, [7].

Research location; This research is done corporate with the students who do material testing practical work program in the fourth semester at Metrology and Material Testing Laboratory, Machine Technical Department, Bali State Polytechnic. The students divided into six groups and each group consists of four to five students. Every group is given three kinds of testing thing that is testing thing standard, hardening and mellowing, one for each. Testing result data of each group is smoothed down suitable as testing thing that its data taken as data that is put into this research.

2.2 The Observed Parameter

The Testing is using *Torsion Measuring Testing Machine Model N-50,* gets the primary data in the form of the level of twist moment and angle reading which is happened as research needs. Another data that is needed is counted by using the relevant formulas such as the previous research (below), [6]

a. Twist tension (tp) is counted with the formulas :

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

In which:

Mp = The occuring torque (N.mm)

Wp = The occuring twist resistance (mm^3) ,for solid and round cross section: $Wp = \frac{\pi d^3}{16}$ ....(2)

b. If the twist angle is divided with the length of working thing (1), so it is got the specific twist angle.

$$\theta = \frac{\phi}{l} \left(°/mm\right) \text{ ……..(3)}$$

In which:

The Testing is using *Torsion Measuring Testing Machine Model N-50* gets the primary data in the form of the level of twist moment and angle reading which is happened as research needs. Another data that is needed is counted by using the relevant formulas such as the previous research (below), [6]

c. Shearing stress (τp) is calculated by using formula:

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

In which:

Mp= The occurring torque (N.mm)

Wp= The occurring torsion (mm^3)

For solid and round cross section: $Wp = \frac{\pi d^3}{16}$ ....(2)

Thus,

d. If the torsion angle is divided by the length of the work piece (1), then it is obtained a specific angle:

$$\theta = \frac{\phi}{l} \left(°/mm\right) \text{ ……..(3)}$$

Further, the torque - twist angle and shearing stress - specific twist angle diagrams can be drawn according to data obtained directly from the torque test machine and data calculated on the basis of formulas, [10].

Furthermore, shearing stress-specific angle of the twist diagram can be described as data that is got directly from torsion testing machine as well as data that is counted based on formulas, [10].

e. At the same situation, the moment of polar inertia can be calculated or worked through the formula of shear stiffness modulus. By giving the torque, it is obtained the modulus of shear stiffness (G) or shear modulus. Within the proportional limit, the following formula can be used:

$$\phi = \frac{Mp.l}{G.lp} \left(radian\right) \text{ …….. (4)}$$

$$= \frac{Mp.l}{Gp.Ip} \frac{360^{\circ}}{2\pi} \left(^{\circ}\right) \text{ …….. (5)}$$

In which :

ϕ = twist angle (°)

Mp = the occurring torque (N.mm)

l = length of the work piece (mm)

Ip = moment of polar inertia (mm^4)

G = stiffness/ shear modulus (N/mm^2)

For solid and round cross section :

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

Further, the torque – twist angle and torque-specific angle of the twist diagrams can be illustrated if necessary, in accordance with the data obtained directly from the torque test machine and data calculated on the basis of formulas , [8].

3. RESULT AND DISCUSSION

3.1 Test Result

This research data is obtained from the cooperation with the testing done by the students in the fourth semester of mechanical engineering study program, mechanical engineering department in the laboratory of materials test and metrology of Bali State Polytechnic. Testing is done thoroughly and systematically starting from standard St.42 test object. Furthermore, the test is carried out with the same stages to the test specimens of St.42 that have been heated. The test results performed on each type of specimen as many as ten times, recorded and processed with the appropriate formula, then put in the tables as below.

Test object I (round-shaped) : St.42(Standard)
Length of the test object : 43,4 mm
Diameter of the test object : 9 mm

Tabel 1. Data of St.42 Standard Steel Twist Test

Twist Angle (°)	Torque (N.m)	Shearing stress (N/mm²)	Specific Twist Angle (°/mm)
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

Here is the result of the St. 42 steel which is immediately cooled after the heating.

Test object II (round-shaped) : St.42 (Hardening)
Length of the test object : 43,4 mm
Diameter of the test object : 9 mm

Table 2. Test Data of St.42 (Hardening) Steel Twist

Twist Angle (°)	Torque (N.m)	Shearing Stress (N/mm²)	Specific Twist Angle (°/mm)
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	23.6567302	10.05188067
320	1.9	37.45648948	10.37613489
330	0.6	11.8283651	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

3.2 Discussion

From the data in the table of the two types of St.42 steel test object above, it can be read of the twisted forces shown at the maximum shearing stress of each test object. Table 2.1 shows that: standard St.42 steel is capable of twisting up to 170^0, maximum torque moment 24.6 N.m, specific angle of 5.436520627^0 and most importantly, in this study, the maximum twist strength is 503.7021855 N / mm2. Meanwhile, the test result of the hardened St.42, shown in Figure 2.2 shows that: St.42 (hardening) steel is capable of twisting to 540^0, its maximum torque moment is 35.4 N.m, the specific angle is $17,509,727,63^0$ and most importantly in this study the maximum torque is 697.8735409N / mm^2.

Thus, this study shows that the twist strength of St.42 Standard = 503,7021855 / mm^2, the twisting power of the St.42 (Hardening) is 697,8735409N / mm^2, meaning that there is an increase in torque strength of steel with 800^0C heat treatment with rapid cooling using freshwater by 194, 1713554 N / mm^2. In fact, the twist angle and the specific twist angle rose significantly, each at 370^0 and 12.0732^0.

Furthermore, it can be seen from the test results that the St.42 steel at 800^0C becomes more resilient to twisting, compared to St.42 Standard steel. In fact, there is a slight increase in the angle of twist and a significantly higher increase in specific angle strength in St.42 steel which gets heat treatment and then rapid cooling using fresh water.

4. CONCLUSION AND SUGGESTION

4.1 Conclusion

Based on the research result and data analysis, it can be concluded that:

a. St.42 Hardening steel which is hardened through heating process at 800°C and quick cooling using fresh water has stronger twist than the standard St.42 steel. It is proved from the maximum torque of St.42 Hardening which is 697,8735409N / mm^2, while the maximum torque of St.42 Standard is 503,7921855N / mm2, or up 38.524% of the St.42 standard steel twist strength.

b. The twist angle of the St.42 Hardening Steel which is hardened through heating process at 800°C and is quickly cooled down using fresh water becomes larger than the twist angle of the standard St.42 steel. It is proved from the maximum twist angle of the St.42 Hardening (540^0), while the maximum twist angle of the standard St. .42 is 170^0, or there is a significant increase of 217.647%.

c. The specific twist strength of the St.42 hardening steel which is hardened through heating process at 800°C and is quickly cooled down using fresh water turns out to be larger or stronger than the standard St.42 steel. It is proved by the maximum specific angle of power of St.42 Hardening which is 17, 50972763^0 / mm, while the maximum twist strength of the St.42 standard steel is 5.436520627^0 / mm or increased up to 222.076%.

1.4 Suggestion

a. Further research is needed by conducting research on steel specimens of a kind but different types, on the type of resistance testing against hardness, tensile strength and other strengths.

b. It is necessary to test the same specimen with different heating temperatures and other studies.

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