

Improvement of Hardness of low carbon steel used for clamp sleeve spare part for crimping machine by heat treatment process

Md. Arefin Kowser & Muhammad Hurmutul Islam

Abstract— It is important to improve materials property for the application in engineering fields. In pharmaceutical industries, there are different materials used for different purposes collected from foreign countries whereas the factory uses machine in Bangladesh. In pharmaceutical industries, crimping machine is used at Metered Dose Inhaler (MDI) plant to crimp body and head part of the aluminium can. For this, Clamp Sleeve is used as the part of crimping mechanism which was purchased from foreign countries. Due to the continuous action of the clamp sleeve to the crimping tong the inner surface of the clamp sleeve get corroded and also due to surface roughness the pressure of the clamp sleeve to the crimping tong is not uniform, for which it is unable to provide desire shape crimping quality. The clamp sleeve is replaced frequently whenever the crimping appearance fails to meet compliance. Clamp Sleeve Spare parts has been arranged or purchased from the foreign countries like Switzerland which can be matter of receipt the object a certain time, huge price and also need to dedicate people to follow up and maintain the sufficient stock. To minimize the time interval of availability of the clamp sleeve with reasonable price, the clamp sleeve spare parts of the crimping machine has been developed using the local shaped low carbon steel material.

Keywords— *Clamp sleeve, Pack carburizing, Quenching, Tempering, Rockwell Hardness test*

Introduction

The reduction of material cost is a method for improving material economy. The use of low carbon steel is one of the solution for reducing cost in industrial applications, requires specific focus on manufacturing cost.

Carburizing is one of the important heat treatment process. Carburizing is the addition of carbon to the surface of low-carbon steels at temperatures within the austenitic region of the steel concern, which generally is between 850°C and 950°C. Within this temperature range austenite, which has high solubility for carbon, is the stable crystal structure. Hardening is accomplished when the subsequent high-carbon surface layer is quenched to form martensite so that a high-carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low-carbon steel core [1]. Carbon diffusivity in austenite varies both with carbon concentration and carburizing temperature [2-5]. Considering that carbon concentration depends on its activity in austenite and that the finite repulsive interactions exist between neighboring carbon atoms in octahedral sites, Babu and Bhadeshia [6] modeled carbon diffusivity in accordance with kinetic and thermodynamic behavior of carbon in austenite. The study of process parameters in metals during heat treatment has been of considerable interest for some years [7-11] but there has been

relatively little work on process variables during the surface hardening process [12] since controlling parameters in carburization is a complex problem. The major influencing parameters in carburization are the holding time, carburizing temperature, carbon potential and the quench time in oil [13]. The aim of project work is to improve the mechanical properties of low carbon steel applicable for pharmaceuticals industries. In Metered Dose Inhaler (MDI) plant, there is a crimping machine which purpose is to crimp the body of the aluminium can with head. The major part of the crimping machine is the crimping head. Inside crimping head, there are clamp sleeve and crimping tong. The up& down movement of the piston shaft by air pressure with the application of pneumatic control valves, the clamp sleeve press the crimping tong to crimp the aluminium can and the crimping tong application for crimping & releasing the aluminium can after smooth crimping is controlled through the up & down movement of the main piston shaft by air pressure with the application of pneumatic control valves. Low carbon steel is locally available which has less hardness. So, the purpose of the project is to improve hardness (clamp sleeve which has been shaped using the locally available low carbon steel material) through the heat treatment process and to implement it to the machine functional area to meet the same purpose as it done earlier using the foreign clamp sleeve part. The crimping machine is shown in fig.1 and the clamp sleeve part as shown in Fig.2

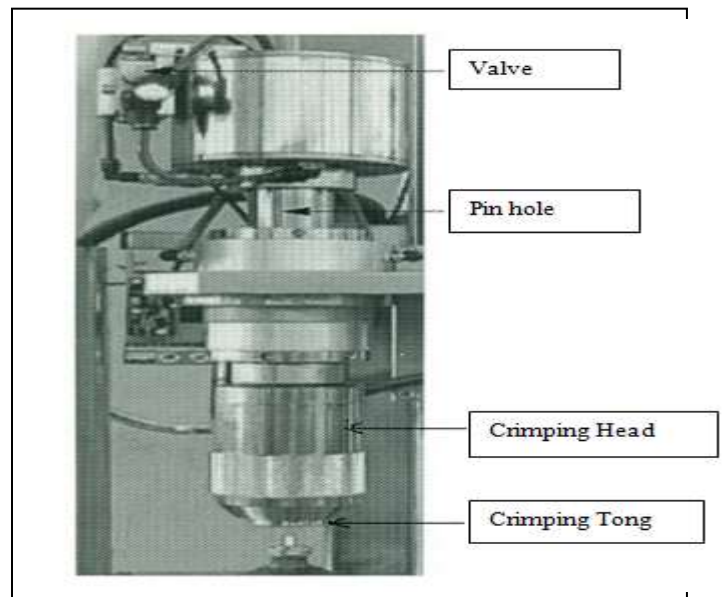


Fig.1: Crimping Machine



Fig.2: Clamp Sleeve which is located inside the crimping head and outside the inside the crimping head and outside the crimping tong

Author's information

Md. Arefin Kowser

Associate Professor, Department of Mechanical Engineering, Dhaka University of Engineering & Technology, Gazipur, Country: Bangladesh

Muhammad Hurmutul Islam

Post-Graduate student, Department of Mechanical Engineering, Dhaka University of Engineering & Technology, Gazipur Country: Bangladesh

Experimental Procedure

The followed experimental procedure for the project work can be listed as:

- 1) Specimen preparation
- 2) Heat treatment of materials
- 3) Test Parameter
- 4) Material Composition study
- 5) Mechanical property study

1) Specimen Preparation:

The first and foremost job for the experiment is the specimen preparation. The specimen size should be compatible to the machine specifications. Low carbon steel solid round shaped bar is first purchased from a reliable local source and then the material is shaped and finished as per sample. The Specimen for impact test is shown in Fig.3, hardness test as in Fig.4 and the compression test in Fig.5.

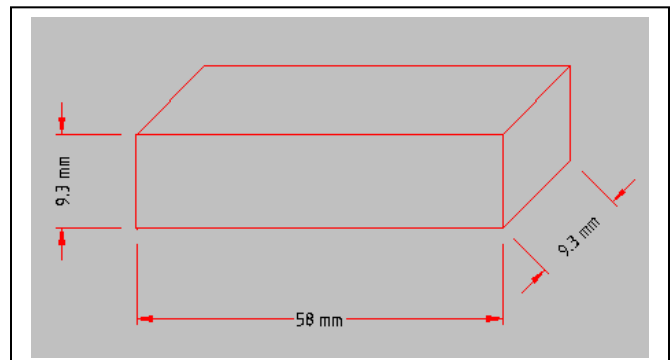
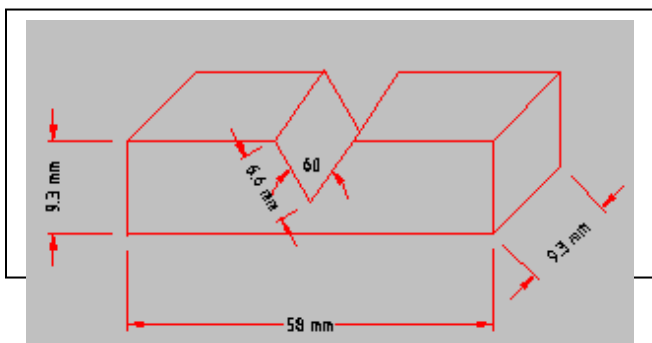


Fig. 4: Specimen for Hardness Test

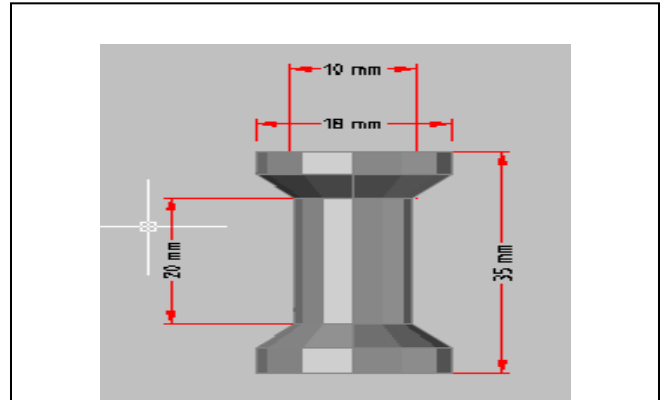


Fig.5: Specimen for Compression Test

Physical Dimension of different test Specimen is shown as follows in Table 1.

Table 1: Physical Dimension of different test Specimen

Sl. No.	Test Specimen	Dimension of the Specimen
01.	Hardness test	Length-58 mm, Width- 9.3 mm ,Thickness- 9.3 mm.
02.	Impact test	Length-58 mm, Width- 9.3 mm,Thickness- 9.3 mm, V Notch depth -6.6 mm, Included Angle of V-notch is 60°
03.	compression test	Grip distance- 35 mm,Grip Dia-18 mm,Gauge Length- 20 mm, Gauge Dia-10 mm.

2) Heat Treatment

Low Carbon Steel is primarily heat treated to create matrix microstructures and associated mechanical properties not readily obtained in the as-cast condition. As cast matrix microstructures usually consist of ferrite or pearlite or combinations of both, depending on cast section size and/or alloy composition. The principle objective of the project is to carry out the heat treatment of Low carbon steel material and then to compare the mechanical properties before heat treatment & After the heat treatment of the locally purchased low carbon steel material. There are various types of heat treatment processes are adopted.

a) Pack Carburizing :

1. In Pack carburizing, the specimen was heated to a temperature of 900°C. At 900°C the specimen was held for 4 hours.
2. Then the furnace was switched off so that the specimen temperature will decrease with the same rate as that of the furnace

The objective of keeping the specimen at 900°C for 4 hrs is to homogenize the specimen. So that the specimen at that temperature get sufficient time for properly homogenized .The specimen was taken out of the furnace after 48 hours when the



Fig. 6: Pack carburizing Box inserted to the Furnace

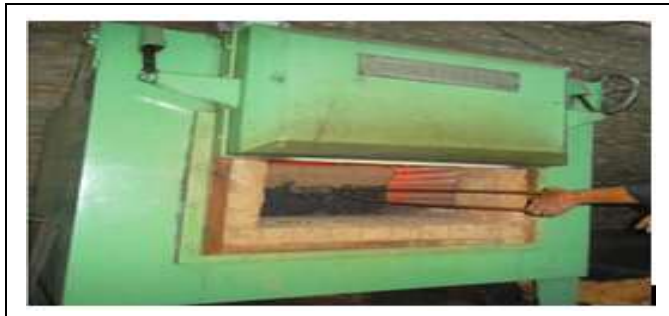


Fig.7: Sample taken out from the Furnace after pack carburizing after pack carburizing

b) Quenching:

- 1) The specimen was heated to the temperature of 850°C and were allowed to homogenize at that temp for 15 minutes.
- 2) After 15 minutes, the specimen was taken out of the furnace and directly quenched for rapid cooling using the quenching medium as water solution of 10 percent sodium chloride (brine Solution).

c) Tempering:

- 1) The specimen were heated to 150°Celsius for 1 hour to reduce the tendency for internal stress formation. After the heat treatment specimens were air cooled. Time VS Tempering Temperature for hardness HRC-51 are shown in Fig. 8.

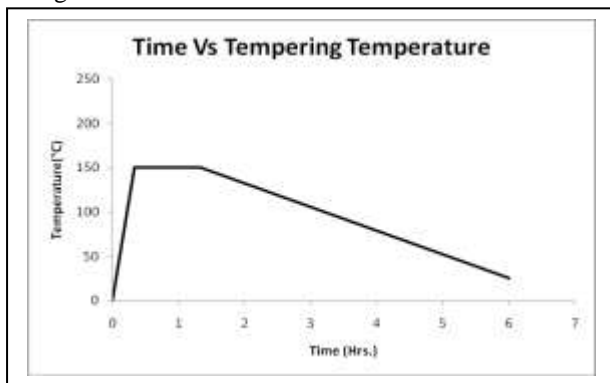


Fig. 8: Time-Temperature curve during Tempering

3) Test Parameter

3.1 Hardness Measurement

Before heat treatment the specimen hardness was measured by means of Brinell hardness tester. The procedure adopted can be as follows:

1. First the ball indenter was inserted in the machine; the load is adjusted to 187.5 kpa.
2. The minor load of a 10 kg was first applied to seat of the specimen.
3. The major load applied and the depth of indentation is automatically recorded on a dial gage in terms of arbitrary hardness numbers. The hardness value thus obtained in BHN values. Then using the conversion table (Ref. ASTM Standard) BHN values was converted into Rockwell hardness HRC values.

The heat treated specimens hardness was measured by means of Rockwell hardness tester shown in Fig. 9. The procedure adopted can be listed as follows:

1. First the brale indenter was inserted in the machine; the load is adjusted to 150 kg.
2. The minor load of a 10 kg was first applied to seat of the specimen.
3. The major load applied and the depth of indentation is automatically recorded on a dial gage in terms of arbitrary hardness numbers. The dial contains 100 divisions. Each division corresponds to a penetration of 0.002 mm. The dial is reversed so that a high hardness, which results in small penetration, results in a high hardness number. The hardness value thus obtained in HRC.

3.2 Impact Measurement

The test is conducted for the three samples carburized under the temperatures of 900 °C. The test consist of measuring the energy absorbed in breaking a V – notched specimen by giving a single blow by swinging hammer. The specimen is simply supported at its ends. As the velocity of striking body is changed, there must occur a transfer of energy; work is done on the parts receiving the blow. The mechanics of impact involves not only the question of stresses induced, but also a consideration of energy transfer and of energy absorption and dissipation. The ability of material to absorbed energy and deform plastically before fracture is called “toughness”. It is usually measured by the energy absorbed in a notched impact test like charpy or izod tests. In present work test of three samples was conducted for 3times and the average of all the samples was taken as the observed values. The specification of charpy machine shown in Fig. 10 used for the Impacts test of present work is as following table 2.

Table 2: Equipment Specification of the Charpy test machine

Parameter	Range
Weight of hammer	10 kg
Striking of hammer	4 cm / s to 5 cm / s
Angle of hammer striking edge	30°
Radius of curvature of striking edge	2 mm
Swing of hammer both ways	0-160°

3.3 Compression Test Measurement

The compressive strength is measured by compressive test which is carried out on a universal testing machine shown in Fig. 11. In present experiment the compressive test was carried out on before heat treated and after heat treated sample. Parameter were setted during compression test is shown as following table 3.

Table 3: Experimental condition during compression test by Universal Testing Machine (UTM).

Parameter	Experimental condition
Cross head speed (mm/min)	0.05
Loading range (KN)	0-50
Humidity (%)	70%
Temperature (°C)	24°C



Fig. 9: Rockwell Hardness Tester



Fig. 10: Charpy impact Tester



Fig. 11: Compression Test by UTM

Before & After Heat treatment of the specimen are compression tested by universal testing Machine shown in Fig. 11. The Stress Vs Strain curve of compression test for before & after heat treated specimen is shown in Fig. 12.

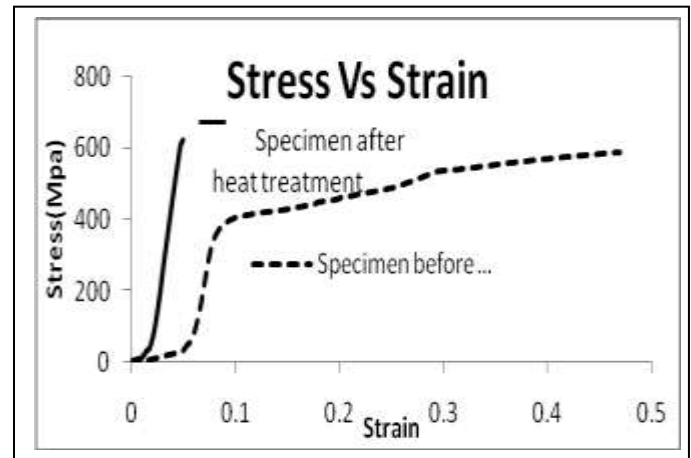


Fig. 12: Stress-Strain diagram of compression before and after heat treated of specimen

From the diagram it can be concluded that after heat treatment of the specimen the ductile property of the material has developed and it will serve the desired purpose .

4) Material Composition Study:

Chemical composition of the locally purchased low carbon steel material is shown as follows in Table 4

Table 4: Chemical Composition of Carbon Steel material.

Sl. No.	Name of the Ingredient	Chemical composition (wt %)
1	Carbon (C)	0.234
2	Silica (Si)	0.435
3	Manganese (Mn)	0.791
4	Sulphur (S)	0.058
5	Phosphorous(P)	0.021
6	Chromium(Cr)	0.166
7	Nickel (Ni)	0.163
8	Molybdenum(Mo)	0.065
9	Cobalt (Co)	0.000
10	Tin (Ti)	0.000
11	Aluminium(Al)	0.000
12	Iron (Fe)	97.068
13	Copper(Cu)	0.138
14	others	0.861

5) Mechanical Property Study:

Test Results:

The test result of mechanical properties of specimen before and after heat treatment is presented in Table 5.

Table 5: Mechanical properties of specimen before and after heat treatment

Sl. No.	Name of Test	Specimen Condition (Before Heat treatment)	Specimen Condition (After Heat treatment)
1	Hardness	BHN 185 in conversion HRC, it was found zero from conversion table. (Reference:ASTM Standard)	HRC-51
2	Impact test	Energy absorbed 15 Nm.	Energy absorbed 35 Nm
3	Compressive Strength	461.5 N (Change of Specimen)	48900 N (No Change of Specimen)

A Comparison of improved local material with foreign material is presented in Table 6.

Table 6: Comparison of improved local material with foreign material

Sl. No.	Key Elements	Clamp Sleeve (Making: Locally)	Clamp Sleeve (Collected from foreign countries)
1	Durability	Durable.	Durable.
2	Quality	Meets requirement.	Meets requirement.
3	Availability	Available whenever require as it is possible to make locally.	Not possible to provide any time as it came from foreign countries.
4	Stock Maintenance	Stock maintenance does not require as it is easily available.	Requires always to keep a lot amount in stock as it came from foreign countries.
5	Price	Price is comparatively less than purchased clamp Sleeve from foreign countries.	Price is comparative higher than the locally.

Conclusion

The experiment for heat treatment of low carbon steel material was carried out in this research for the improvement of mechanical properties of low carbon steel. The specimen was firstly prepared and then heat treatment process of pack carburizing, quenching & tempering has been conducted on the specimen and a mechanical properties has been studied on before heat treated and the heat treated specimen. For this three individual samples has been chosen and the average values of the three specimens for each test has been compiled in the test result of the mechanical properties study. From this experiment it was found that the mechanical properties of hardness, impact or toughness and compressive strength of heat treated specimen has been developed drastically as compared to the before heat treated specimen. The clamp sleeve spare parts has been making using the low carbon steel material as per the dimension of the sample and then heat treatment process of pack carburizing, quenching and tempering has been carried out and then finally checked the hardness and the hardness improved clamp sleeve has been sended to the machine functional area to check the performance of the clamp sleeve and after the consecutive operation of the machine it was found that the hardness improved clamp sleeve meets the user requirement with compliance to the smooth crimping quality. It can be concluded that locally available low carbon steel material can be used for the preparation of clamp sleeve spare parts of

crimping machine in pharmaceutical industry using the proper heat treatment process.

Reference

- [1] Krauss G. Principles of Heat Treatment of Steel, American Society for Metals, Ohio, 1980, pp. 209-219.
- [2] Goldstein J.I., Moren A.E. Diffusion Modeling of the Carburization Process, Metallurgical and Materials Transactions A, 1978, 9 (11), p. 1515-1525. Parrish G 1999
- [3] Totten G.E., Howes M.A.H., Steel Heat Treatment Handbook, 2nd Edition, Marcell Dekker, Inc., New York, Chapter 7, 1997.
- [4] Agren J., Revised Expression for the Diffusivity of Carbon in Binary Fe-C Austenite, Scripta Metallurgica, 1986, 20(11), p. 1507-1510.
- [5] Asimow R.M. Analysis of the Variation of the Diffusion Constant of Carbon in Austenite with Concentration, Transactions of AIME, 1964, 230(3), p. 611-613.
- [6] Babu S.S., Bhadeshia H.K.D.H. Diffusion of Carbon in Substitutionally Alloyed Austenite,
- [7] Journal of Materials Science Letters, 1995, 14(5), p. 314-316.
- [8] Denis S., Coupled mperature stress, phase transformation calculation model numerical illustration of the internal stresses evolution during cooling of a eutectoid carbon steel cylinder, Metallurgical Transaction A, 1987, 18A, p. 1203-1287.
- [9] Leblond J.B., Mathematical modeling of transformation plasticity in steels I: Case of ideal plastic phases II: Coupling with strain hardening phenomena, International Journal of Plasticity, 1989, 5, p. 551-591. Wang K.F., Chandrasekar S., Yang H.T.Y., Experimental and computational study of the quenching of carbon steel, International Journal of Manufacturing Science and Engineering, 1997, 119, p. 257-265.
- [10] Liu C.C., Xu X.J., Liu Z., A FEM modeling of quenching and tempering and its application in industrial engineering, International Journal of Finite Elements in Analysis and Design, 2003, 39, p. 1053-1070.
- [11] Xu D.-H., Kuang Z.-B., A study on the distribution of residual stress due to surface induction hardening, International Journal of Engineering Materials and Technology, 1996, 118, p. 571-575.
- [12] Shewmon G.P., Diffusion in solids, series in material science and Engineering, Mc Graw Hill, Tokyo, 1963.
- [13] Hochman R., Burson J., The Fundamentals of Metal Dusting, New York: API Division of Refining, 1966, 46, pp. 331.
- [14] Smoljan, B. (1999) The calibration of the heat conductivity coefficient in mathematical Model of steel quenching. Proceedings of MicroCAD '99, Miskolc .
- [15] Smoljan, B. (1995) The calibration of the mathematical model of steel quenching. Proceedings of 5th World Seminar on Heat Treatment and Surface Engineering, Isfahan.
- [16] Patankar, S. (1980) Numerical heat transfer and fluid flow, New York: McGraw Hill Book Company.
- [17] Smoljan, B. (1998) Numerical simulation of as-quenched hardness in a steel specimen of complex form. Communications in Numerical Methods in Engineering, vol. 14, no.1, p. 277-285.

About Author(s) :



Dr. Md. Arefin Kowser is currently an Associate Professor in The Department of Mechanical Engineering Of Dhaka University of Engineering and Technology (DUET), Gazipur, Bangladesh. He has received Ph.D.Degree from Saitama University, Japan in the year 2010. He has also completed his Bachelor degree from DUET and Masters degree from BUET from the Mechanical Engineering Department. His Research works are based on Strength of Materials, Interface Fracture Mechanics, Stability of Structures.



Author is currently working in Nuvista Pharma Ltd., Bangladesh, as Validation Manager and completed his graduation from Rajshahi University of Engineering & Technology (RUET), Bangladesh from 2004 and now taking post graduation in Dhaka University of Engineering & Technology (DUET).