Heat treatment of steel parts in different media

Suresh C. MAIDARGI and Veena RANI*

Department of Chemical Engineering, Dayananda Sagar Institutions, Shavige Malleshwara Hills, Kumaraswamy Layout, Bangalore - 560 078, Karnataka, India

Abstract

This study reports an investigation of the effect of different media (oil and polymer) on the properties of different grade steel parts. Steel parts after manufacture, will not have the desired properties like wear resistance, tensile strength, surface and core hardness. To attain these, heat treatment processes like Case Hardening (CH) or Through Hardening (TH) were carried out in sealed quench furnace and rotary furnace. The microstructure of the steel part influences the hardness of the same. The required microstructure is Fine Tempered Martensite (FTM) and the Quench media has a very important role in achieving this. Using different grades of steels, the trials were carried out in SAVSOL Q OO1 oil and POLYQUENCH-GN polymer. Finally comparative trials were also carried out in order to determine the suitability of new quench media. Polymer quench was found to be better quench media in terms of time and energy savings to get the required microstructure – FTM, which gave the improved desired properties.

Keywords : Carburizing, Hardening, Quenching, Tempering, Metallography.

Introduction

Heat treatment can be defined as "*a process in which steels or alloys acted upon thermally, so as to change their structures and properties in the desired direction*". There are variety of surface heat treatments like annealing, normalizing, softening, case hardening, through hardening to convert surface materials chemically and physically, ranging in thickness from few microns to substantial depths in order to impart enhanced hardness and wear resistance properties. Steel is our most important engineering material and respond well to heat treatments. Fundamentally, all steels are primarily mixtures, or more properly, alloys of iron and carbon. Iron is the primary metal used to make a variety of steels and carbon is the principal ingredient in most of the steels.(1)

In this work, trials on Case hardening (process of hardening the surface of low-carbon steel, 900°C~1000°C for 2~6 hours) and Through hardening (process that is achieved by austenising and quenching with a carbon neutral atmosphere, 830°C~870°C for 2~3hrs) processes were carried out in different media (oil and polymer) and comparative studies were also carried out on different types of steel parts with the aim of determining the better quench media and improving the metallurgical properties of a steel.(2)

Heat treatment process, irrespective of technique (Case Hardening or through hardening) involves: Heating, Quenching, and Tempering. Heating is a process in which the steel part is heated to a temperature at which it changes from ferrite crystal structure to austenite. Simultaneously carburizing is done to impart carbon content, as it enhances the hardness, wear and tear properties. It is carried out by exposing the parts to a carbon rich atmospheres which is created by passing the carbonaceous gases like methanol, LPG, etc. During carburizing, various chemical reactions occur in the furnace. Methanol on the hot surfaces breaks into carbon monoxide plus hydrogen, the formed carbon monoxide decomposes to nascent carbon, while LPG changes to low quality hydrocarbons and to nascent carbon. At the end, methane formation occurs and finally it also decomposes to nascent carbon.(3) This process is followed by carbon diffusion and it depends on the Fick's law of diffusion.(4) Quenching is a process of rapidly cooling of steel parts in oil or polymer from austenising temperature.(5) The quenchants used in this work are oil (Savsol Q001) and polymer quenchant (PolyQuench-GN). Tempering is a process in which the quenched steel part is heated below the critical temperature (150°C~500°C) for specified time to impart toughness.

Heat treatment, it is mainly dependent on transformation of microstructure (Figure 1). The

*Corresponding author E-mail : veena.gvt@gmail.com

primary elements of steel are iron and carbon, when it is heated or austenized, it converts into austenite and when it is rapidly cooled, it turns into supersaturated solution called martensite. Finally it converts into fine tempered martensite, when it is tempered below critical temperature.

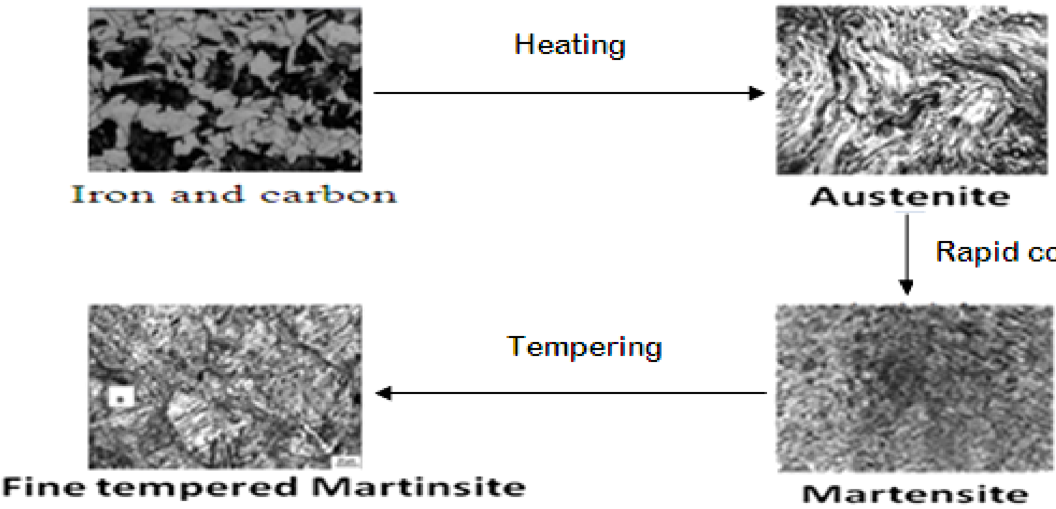

Figure 1. Transformation of microstructure

Materials and Experimantal Procedures

Some of the properties of oil and polymer solution were checked, more importantly the cooling characteristics of Savsol Q001 was determined by ivf smart quench method (Figure 3). The other properties like concentration by refractometer, specific gravity by hydrometer and pH by pH strips were maintained around 10%, 1.05~1.07 and 9.9 respectively for polymer solution.(6) Before comparative analysis, few trials were carried out on CH and TH processes in both the oil and polymer quenchants to know about the features of the media. All the oil quench trials were carried out in sealed quench furnace and polymer quench trials in rotary furnace.

Using oil, the first CH trial was carried out on 32 teeth Gear (20MnCr5). The process cycle is as shown below (Figure 2) and the tempering cycle was carried at 150°C for 90 minutes.(7)

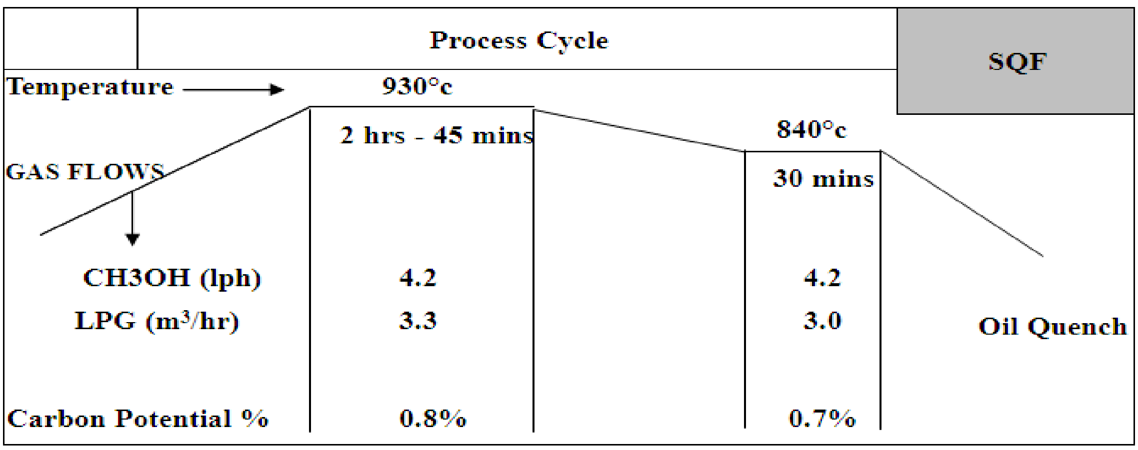

Figure 2. Schematic representation of CH PROCESS CYCLE on 32 teeth Gear (20MnCr5)

The last step of the process is metallography[8] ; it involves cutting the heat treated steel part into small piece, moulding, grinding, polishing and etching. The same piece was checked or microstructure and case depth under metallurgical microscope and hardness under Rockwell machine. By referring conversion chart, tensile strength was also noted. The third trial of the three trials was succeeded in attaining the requirements. Similarly, TH trials were carried out on 1541 shaft propeller; temperature maintained in the process cycle was 850°C for 90mins and 450°C for 90 minutes in tempering cycle. The third trial got succeeded.

Using polymer, the first CH trial was carried out on AISI 1018 Bearing cup, the temperature in the process cycle was 930°C for 150 minutes and in the tempering cycle, it was 150°C for 90 minutes. The last trial of the five trials got succeeded. Similarly, TH trials were carried out on shaft propellor, the temperature maintained in the process cycle was 850°C for 90 minutes and in tempering cycle it was 600°C for 90 minutes. The second trial of the two trials got succeeded.

Comparative studies on CH process were carried out by varying the time and maintaining constant gas flow rates and temperature (930°C in process cycle and 150°C in tempering cycle). The component studied includes 32 teeth Gear (20MnCr5), En353 Drive shaft, En36Rollers, MS Bolts, AISI 1018 Washers and AISI 1018 Bearing cups.

Comparative studies on TH process were carried out by varying time and maintaining constant gas flow rates and temperature (850°C in process cycle and 450°C in tempering cycle). The components studied include 1541 Shaft propellor, 15B25 Screws, C-48 Break pin, En-48 Clips and En-31 Piston pins. In the first trial, even though the temperature maintained was constant, the hardness obtained in polymer quench was higher than in oil quench. So, in the other four trials the temperature was decreased by 10°C and checked for the properties.

Results and Discussion

The cooling curve of the Savsol Q001 oil and their properties are as shown in the below (Figure 3). The graph explains about three stages of quenching which includes Film phase, Boiling phase and Convective phase.[9] The maximum cooling rate was found to be 113°C/s and the temperature at maximum cooling rate was 624°C.

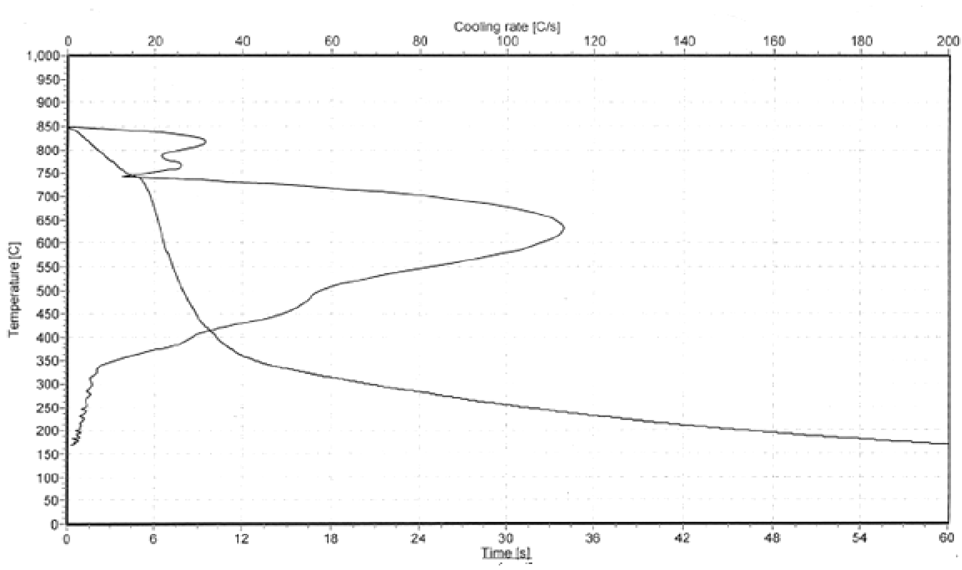

Figure 3. ivf Smart Quench Report of Savsol Q001oil

In oil quench, the three trials of the CH process on 32 teeth Gear explains that the case depth increases with the increasing carburizing time. The optimum temperature required was found to be 930°C and the carburizing time 195mins, as shown in the below (Figure 4) and the FTM structure of the successful trial is as shown below (Figure 5).

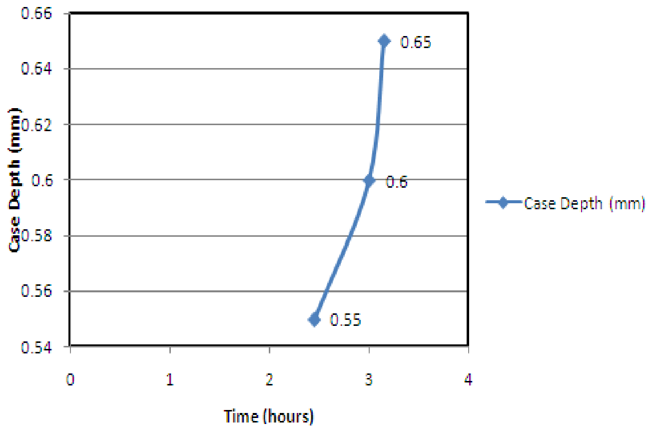

Figure 4. Effect of carburizing time on case depth-CH on gear teeth

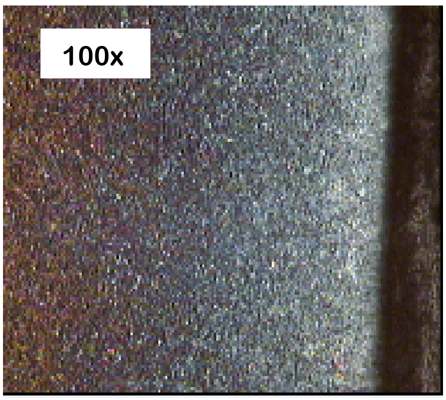

Figure 5. FTM of third trial with Case depth-0.65 mm

On the other hand, the three trials of the TH process on shaft propellorexplains that tempering temperature is indirectly proportional to hardness. The optimum tempering temperature was found to be500°C as shown in the below (Figure 6). The FTM of the successful trial is as shown in the below (Figure 7).

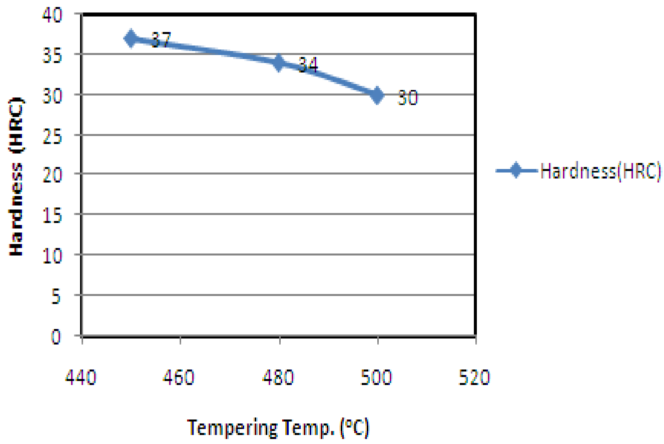

Figure 6. Effect of tempering temperature on hardness-TH on shaft propellor

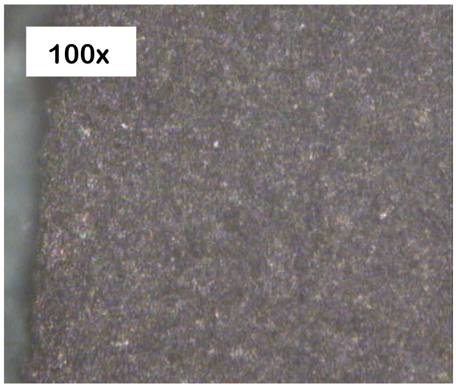

Figure 7. FTM of third trial with hardness-30HRC

In polymer quench, the five trials of the CH process on bearing cup explains that CH process is mainly about carburizing time and case depth is directly proportional to carburizing time. The optimum temperature was found to be 930°C and carburizing time 210 minutes, as shown in the below (Figure 8). The FTM structure of the successful trial is as shown below (Figure 9).

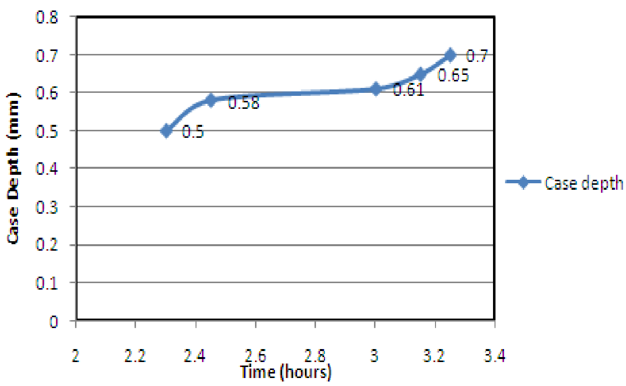

Figure 8. Effect of carburizing time on case depth-CH on Bearing cup

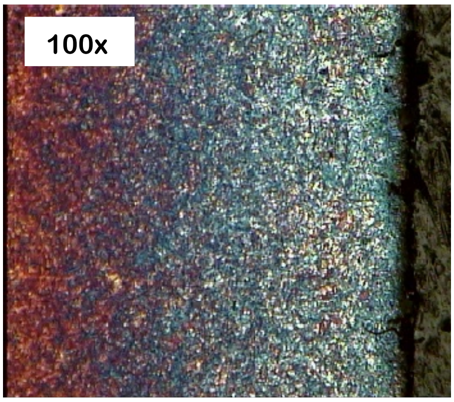

Figure 9. FTM of fifth trial with case depth-0.77mm

Similarly, the two trials of the TH process on Shaft propellor explains that the hardness increases as the tempering temperature decreases and the optimum temperature was found to be 550°C.

Comparative studies were carried out to determine the effect of quench media on the properties of a steel part. The result of the CH process on 32 teeth gear and drive shaft showed that the time requirement is lesser in polymer quench when compare to oil quench because of its severity of quench. But observed some distortions on gear teeth in polymer quench because of the repeating retort movements on gear teeth and some cracks on drive shaft because high severity of polymer quench, as these shafts are long, slender and thin walled components. The CH trials on Rollers, Bolts, Washers and Bearing cups explains that polymer quench is better in terms of time and energy i.e., time requirement is lesser in polymer quench than in oil quench because of its high quench severity as shown in the below (Figure 10).

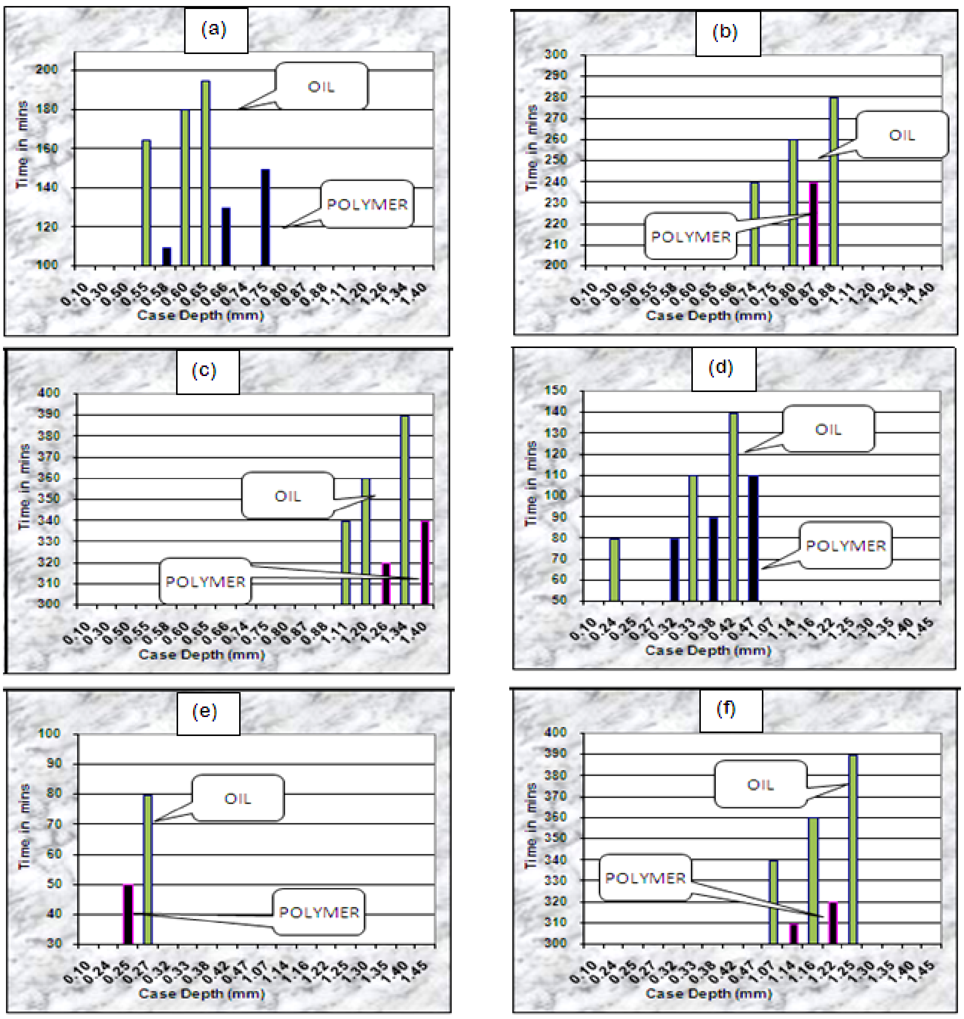

Figure 10. Comparative studies on CH process using (a) 32 teeth gear, (b) Drive shaft, (c) Rollers, (d) Bolts, (e) Washers, (f) Bearing cups.

The first trial of the TH process on Shaft propellor was carried out by maintaining constant temperature 850°C for both the media. Both were succeeded in achieving requirements but the core hardness obtained was less in oil quench compared in polymer quench because of its less severity quench, so the line of oil in the graph is coincided with polymer (Figure 11a). The other trials on screws, brake pins, clips, piston pins were carried out by decreasing the temperature by 10°C in polymer quench. In the maximum cases, even with the lesser temperature, the core hardness obtained was higher in polymer because of its high cooling rate, as shown below (Figure 11).

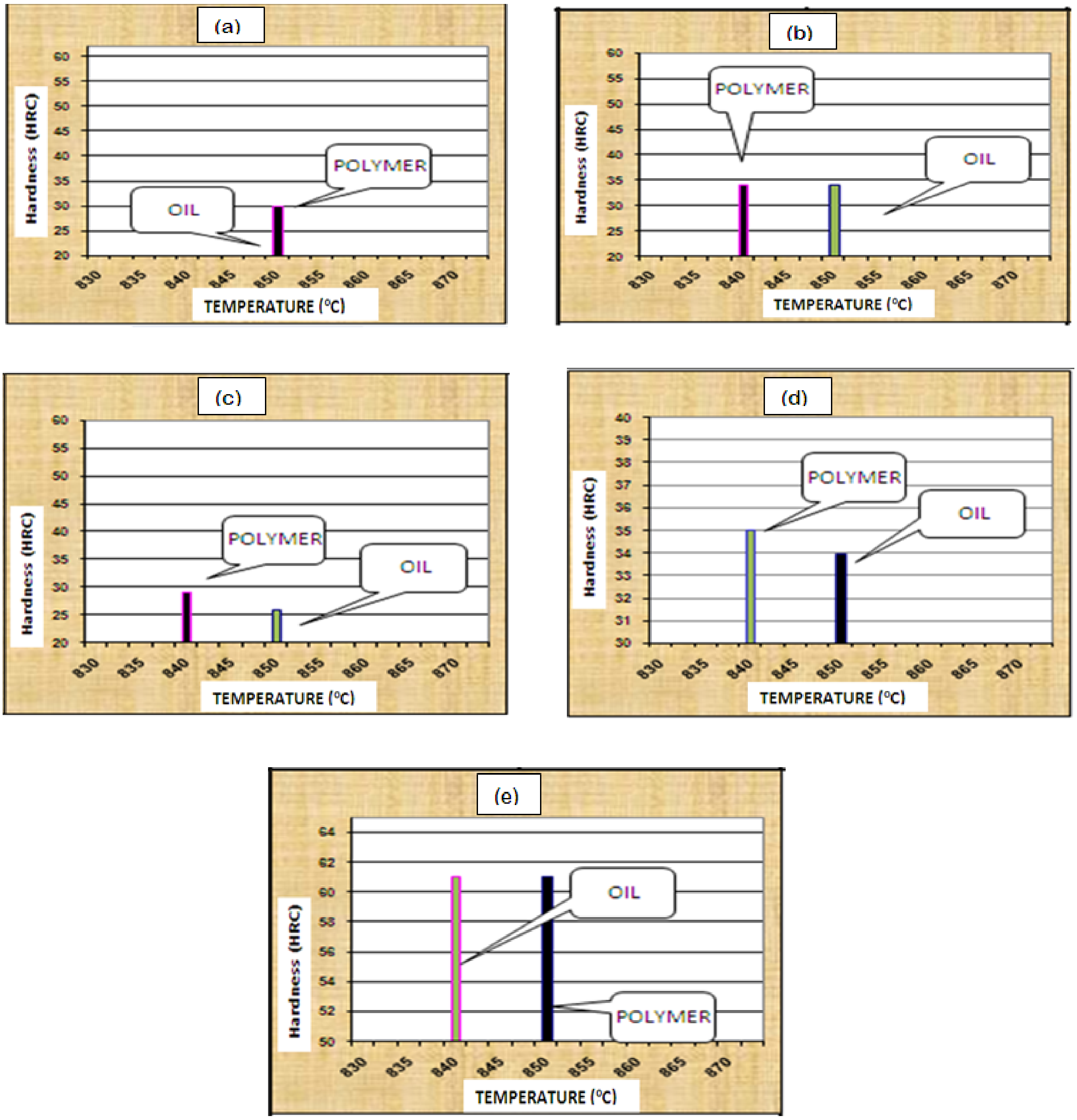

Figure 11. Comparative studies on TH process using (a) Shaft propellor, (b) Screws, (c) Brake pins, (d) Clips, (e) Piston pins.

Conclusions

The following conclusion has been drawn from the experimental result and discussions already made.

1. PolyQuench-GN Quenchant is better in terms of time and energy savings because the cooling rate of polymer solution is higher than oil.

2. For a given temperature, case depth increases with the increasing carburizing time.

3. Increase in the tempering temperature decreases the hardness of the steel parts.

4. In comparative analysis, polymer quenchants were better in attaining required case depth, tensile strength, core hardness within a lesser time compared to oil.

5. Polymer quenchants are not suitable for crack sensitive steels.

6. PolyQuench-GN has no negative impact on environmental conditions especially during disposal activities.

References

1. Unterweiser, P.M. (1989). *Heat Treater's Guide : standards practices and procedures for steel*. 5th edition. Metals Park, Ohio : American Society for Metals.

2. Krauss, G. (1990). *Steels : Heat Treatment and Processing Principles*. in ASM International. Materials Park : Ohio.

3. Collin, R., Gunnarson, S. and Thulin, D. (1972). Mathematical Model For Predicting Carbon Concentration Profiles Of Gas-Carburized Steel. *J. Iron Steel.* **210(10)** : 785-789.

4. Naito, T. (2002). *Gas carburizing and material strengthening methods*. Practical carburizing technology. 2nd edition.

5. *Tool and Manufacturing Engineers Handbook.* (1985). Society of Manufacturing Engineers. 4th edition. 10-25.

6. *Quenchants-Monitoring and Maintenance.* (2011). Fuchs Technical Information. 912 edition. 7-12.

7. Htun, M.S., Kyaw, S.T. and Lwin, K.T. (2008). Effect of Heat Treatment on Microstructures and Mechanical Properties of Spring Steel. *J. Met. Mater.Miner.* **18(2)** : 191-197.

8. Robert, F.M. and Michael B. (1949). *The Principles of Metallographic Laboratory Practice*. 3rd edition.

9. Ivf smart quench manual. (2007). Ver 2.2, 6th edition. 46-54.