New Generation Polymer Quenchant for Heavy Forgings

By

Mr. P.K.Deval

Dy. General Manager – Hardcastle Petrofer Pvt. Ltd

Abstract:
Increasing focus on Infrastructure & Globalisation has led to greater demand for Heavy Engineering Industry. The demand for heavy forgings for various applications like Windmills, Turbines for Power Sector, Forged Rings for slewing rings, large bearings, Pipes, Cylinders, Valves for oil exploration, etc is ever increasing. Traditional approach has been to use large open tanks with suitable quenching oil for heat treatment of these heavy forgings in spite of the high risks involved due to fire hazard. However, today new generation water based Polymer Quenchants with oil like quenching properties are being widely used overseas for these applications and are fast replacing quenching oils. This new generation Polymer Quenchant is now available locally. This paper discusses the features of quenching oils, conventional polymer quenchants and the new generation polymer quenchants, the polymer quenching mechanism and the comparative cooling characteristics of different quenching media. This paper also discusses the various applications of the new generation polymer quenchants and the various critical quench system parameters that need to be considered while designing the quenching system for the new generation polymer quenchants.

Introduction:
Traditionally, heavy forgings have been quenched in large volume open tanks using quenching oil. Even though water based polymer quenchants are presently being widely used for quenching of automotive forgings in India due to the many techno- commercial and environmental advantages that they offer; quenching oils are still being widely preferred for the quenching of heavy forgings in India. The main reason for preferring to use quenching oil over conventional aqueous polymer quenchants is the perceived higher risk of cracking associated with the aqueous polymer quenching process due to the higher quench severity produced by aqueous polymer quenchants. However, new generation polymer quenchants with oil-like quenching characteristics are now available and these polymer quenchants have proven to be an attractive alternative as a quenchant for quenching of heavy forgings.

Features Of Quenching Oils
Large forgings have been traditionally quenched in quenching oil due to following reasons:

- Slow cooling speeds, hence less risk of cracking
- Easy availability
- Low maintenance & care

However, the following are the major disadvantages of using quenching oils for quenching of heavy forgings:

- Serious Fire Hazard due to the large volume of quenching oil involved in quenching of heavy forgings

- Huge Flame Heights during quenching, which require increased height of shed
- Hazardous Work Environment contaminated with fumes and oily floors
- Removal of Scales from tank is difficult and scrap value of scales is low
- Inert Gas Blanketing (N2, Co2) on quench tanks is required
- Requirement of Fire Extinguishers
- Higher Insurance premium
- Inferior metallurgical properties due to limited quench severity of quenching oils

Features of Conventional Polymer Quenchants

The conventional polymer quenchants eliminate most of the disadvantages of quenching oils but they have the following limitations

- Higher risk of cracking, hence high hardenabilty materials such as die-steels, tool steels, etc are very difficult to quench in these polymer quenchants
- Higher distortion of quenched parts
- High concentrations required for quenching oil quenching grades, hence higher cost of initial tank fill as well as higher consumption cost

Features of New Generation Polymer Quenchants

The new generation polymer quenchants offer the following advantages

- No fire hazard, hence no fire extinguishers or inert gas blanketing is required
- No fumes or oily floors. Operator friendly work environment
- Cooling characteristics similar to quenching oils, hence less risk of cracking and distortion of quenched parts
- Lower concentrations are required as compared to conventional polymer quenchants, hence more economical
- Wide range of steel grades including typically oil quenched grades can be quenched

Polymer Quenchants- Mechanism of Quenching

Polymer quenchants work by forming films around the components which act as an insulating layer during the cooling process. Due to this insulating layer the heat flow from the work piece to the quenching medium is reduced and oil like slow cooling is achieved.

Several types of polymers are used in formulating today's Polymer Quenchants. The different types can be broadly classified into two main categories as follows:

a) **Polymer Quenchants which exhibit the Inverse Solubility phenomenon :**
   - These are currently the most widely used type of Polymer Quenchants.
   - These polymer quenchants generally provide intermediate quench severity.
   - They are completely soluble in water at room temperatures but they are insoluble at higher temperatures. The inverse solubility temperatures can range from 60°C to 85°C depending upon the chemical structure of the polymer quenchant.

- The phenomenon of inverse solubility modifies the conventional three-stage quenching mechanism and provides greater flexibility of cooling rates.

These types of polymer quenchants are presently being widely used in India for the through hardening of critical parts and surface hardening of forgings made out of a variety of steel grades requiring intermediate cooling rates. These types of polymer quenchants are popular in induction hardening and case hardening applications also.

b) Polymer Quenchant which exhibits oil like quenching characteristics:

- This is the advanced technology polymer quenchant having cooling speeds similar to oil quenching. (please refer Figure 1)

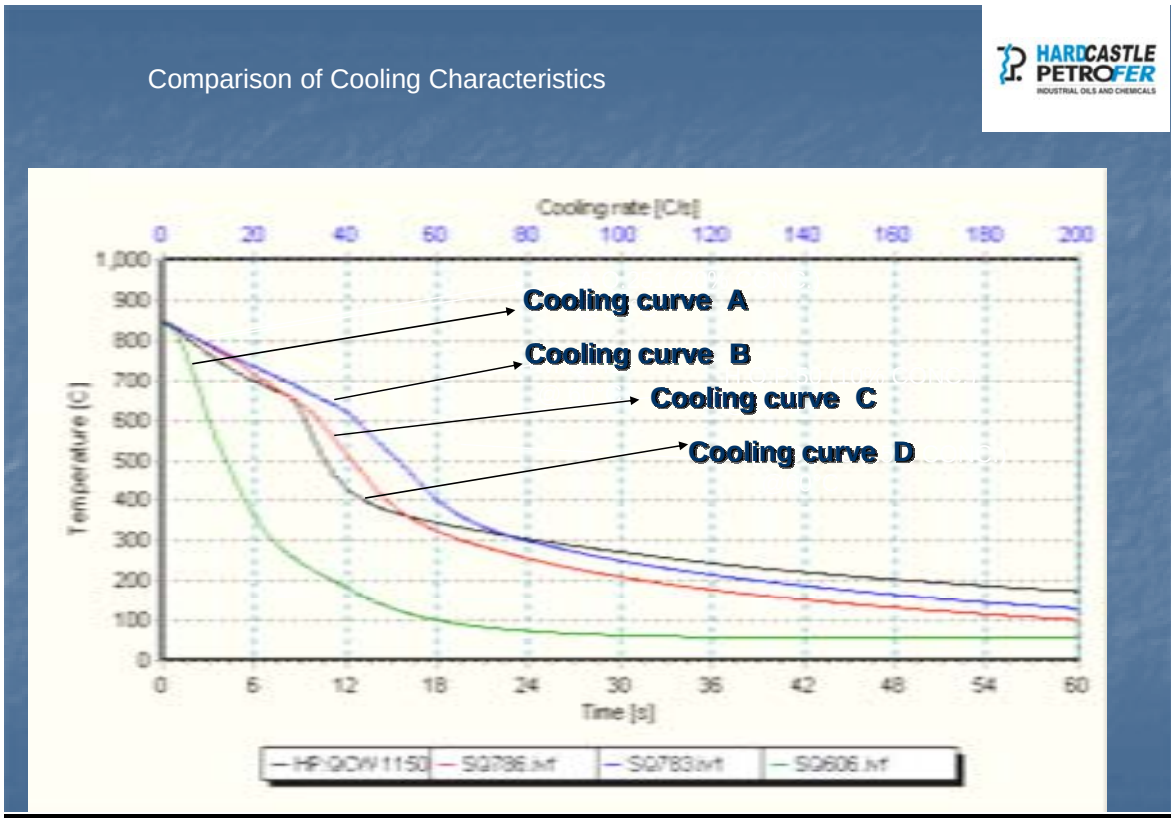

Figure 1: Comparison of Cooling Characteristics

Captions
Cooling Curve A – Conventional Polymer Quenchant @ 20%
Cooling Curve B – New Generation Polymer Quenchant @ 15%
Cooling Curve C – New Generation Polymer Quenchant @ 10%
Cooling Curve D – Medium Speed Quenching Oil

- This type of polymer quenchant does not exhibit the inverse solubility phenomenon but modifies the conventional three-stage quenching process by producing high viscosity, polymer-rich layers around the hot components. This

polymer generates a much thicker and more effective insulating film by evaporation of water near the work piece surface so that a stable film of high concentration is formed on the work piece and slow oil like cooling properties are achieved. (refer Figure 2). This phenomenon is called the up-concentration phenomenon.

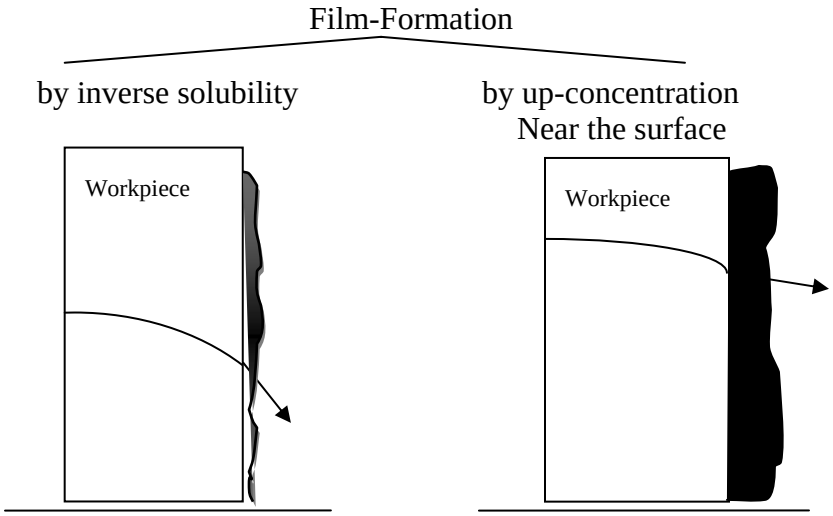

Figure 2 Heat Flow Mechanism

- This polymer quenchant can be used for a variety of steel grades including tool steels, die steels, which are generally oil quenched. Thus this polymer quenchants can replace oil quenching in almost all such open tank quenching applications.
- This superior technology polymer quenchant is well accepted in the developed countries due to its technological advantages and overall cost benefits and is now made available in India.

Materials & Applications

This new generation Polymer quenchant has found a wide field of application to replace quenching oils. Wide range of higher alloyed steels has successfully been quenched in this polymer quenchant including tool steels of high hardenability. Listed below are a few examples of steel grades which are being quenched in this polymer quenchant.

Tool Steels and Die steels (For example D2, DB6,H11, H13, etc)
Heat –Treatable alloy steels (For example SAE 1045, SAE 4130,SAE 4140, SAE 4340, EN 19, EN 24, etc)
Stainless Steels (For example AISI 420, AISI 431, AISI 430F, etc)

Some of the typical applications for which the new generation polymer quenchant can be used include windmill shafts, turbine shafts, forged rings for bearings or slewing rings, heavy crank shafts, CNG cylinders for automobiles, tool steel die blocks, Bars of Stainless Steels, Field Gun Barrels, etc Please refer to Exhibits 1 to 4.

Exhibit 1: Alloy Steel Turbine Shaft being polymer quenched

Exhibit 2: Tool Steel Block being polymer quenched

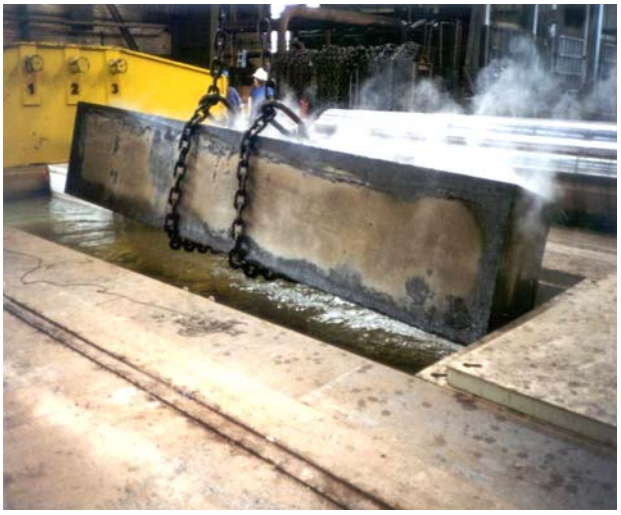

Exhibit 3: Tool Steel Block after quenching in polymer quenched

Exhibit 4: Forged Half Rings being polymer quenched

Quench System Parameters:

Certain Parameters have to be carefully evaluated before changing over from conventional oil quenching to the new generation polymer quenchant

- **Agitation System & Flow Velocity**
  Water based polymer quenchants start boiling at around 100 Deg C and hence it is necessary to maintain bath temperature and have a uniform agitation in the quench tank. Flow of the quenchant should allow for replacement of the heated quenchant in the vicinity of the quenched work piece. Normally flow speeds of 0.1m/sec to 0.4 m/sec are recommended in the area where work pieces are to be quenched. Strong flows & jet streams on work pieces are to be avoided.

- **Temperature Control of Bath**
  Temperature of the polymer quenchant bath must be maintained to achieve the desired quench severity & achieve consistently uniform hardness on the work piece. An adequate capacity plate type heat exchanger is normally used to control the bath temperature. The specific heat of water based polymer quenchants is nearly double the specific heat of quenching oil, hence the temperature rise for the same mass of steel quenched in polymer quenchant will be half that of quenching oil.

- **Maintenance of the Bath**
  It is recommended to routinely monitor the condition of the bath on a regular basis to ensure consistent results and longer service life. Some of the routine condition monitoring tests can be done at site by the user and the detailed laboratory analysis including cooling curve analysis is normally carried out by the polymer quenchant supplier and corrective preventive actions, if any, are recommended by the polymer quenchant supplier.

Conclusion:

New generation polymer quenchant which exhibits up-concentration phenomenon with oil like quenching characteristics is now available in India. It offers a number of techno-commercial and environmental advantages over quenching oil for the heavy forging industry. Collaboration between the user and the supplier is essential for appropriate design of the quench system, standardization of the process parameters during production trials and during the continuous use of the polymer to ensure satisfactory and consistent results over a long period of service life of the polymer quenching bath.