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AQUEOUS QUENCHANTS FOR INDUCTION HARDENING

Chuck Faulkner
Houghton International Inc. Valley Forge, PA USA
cfaulkner@houghtonintl.com

Abstract

Quenching is a process of cooling a metal at a rapid rate. This is most often done to produce a martensite transformation. In ferrous alloys, this will often product a harder metal, while non-ferrous alloys will usually become softer than normal.

Quenching is a very important part of the induction process in order to get the desired hardness of a metal, and improper quenching may lead to a variety of problems.

Various type of aqueous quenchants for induction hardening will be reviewed along with the three stages of the quenching process. Basic information on care and maintenance of those quenchants will also be reviewed.

Introduction

When induction hardening ferrous metals, quenching is just as important as the proper heating of the metal. Inadequate or improper quenching of the heated part results in low hardness values as well as spotty hardness and may cause quench cracking.

The intent of the quench is to cool the already austenitized material at a rate that converts most of the austenite to martensite. During induction heat treating of steel, it is necessary to mediate cooling rates during quenching to prevent cracking and excessive distortion. A common definition of quenching is the controlled extraction of heat from the component to be hardened. The quenchant is any medium that extracts heat from the part and can be a liquid, solid, or gas.

Stages of Quenching

During quenching there are normally three very distinct stages including the Vapor Phase, Boiling Phase and Convection Phase.

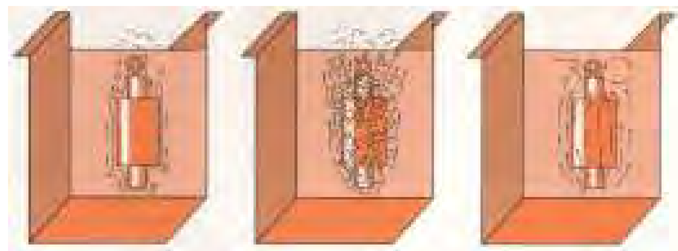

Figure 1 - Schematic showing the three phases of quenching. From left to right: Vapor Phase; Boiling Phase; and Convection Phase

The vapor phase occurs when the hot surface of the heated component first comes into contact with the liquid quenchant. The component becomes surrounded with a blanket of vapor. In this stage, heat transfer is very slow and occurs primarily by radiation through the vapor blanket. The vapor blanket is very stable and its removal can only be enhanced by agitation or speed improving additives.

This stage is responsible for many of the surface soft spots that can be encountered in the quenching process. High pressure sprays (for example in induction processes) and strong agitation eliminate or reduce this stage.

The second or boiling phase occurs in quenching when the vapor phase begins to collapse and all liquid in contact with the component surface erupts into boiling bubbles. This is the fastest stage of the quenching process. The high heat extraction rates are due to extraction of heat from the hot surface and transferring it further into the liquid quenchant, which allows cooled liquid to replace it at the surface.
The boiling phase stops when the temperature of the component's surface reaches a temperature below the boiling point of the liquid.

The third and final phase of the quenching process is the convection phase. This occurs when the component has reached a temperature below the quenchant's boiling temperature. Heat is removed by convection and is controlled by the quenchant's specific heat and thermal conductivity, and the temperature differential between the component and quenchant. The convection phase is usually the slowest of the three phases of quenching.

Selecting a Quenchant

There are many factors to consider when choosing an aqueous quenchant for induction hardening. The choice of quenchant depends on factors such as:

- ✓ Hardenability of material
- ✓ Safety
- ✓ Case depth
- ✓ Compatibility with existing equipment
- ✓ Disposal
- ✓ Ease of cleaning
- ✓ Cost
- ✓ Quenching speed of the particular quenchant

Typical Aqueous Quenchants

The number of aqueous quenchants utilized for induction hardening are almost as numerous as the types of equipment used for heating the parts. Typical aqueous quenchants include:

- ✓ Water
- ✓ Salt solutions
- ✓ Polymer quenchants
    - o PAG – polyalkylene glycol
    - o PEO – polyethyl oxazoline
    - o PVP – polyvinyl pyrrolidone

Water

Water is a common aqueous quenchant used for induction hardening applications and has many favorable characteristics including cost and ease of disposal. Water is corrosive to most irons and steels, and has an initial prolonged vapor phase that can collapse erratically causing uneven stresses in the quenched parts.

Cold water is one of the most severe of the aqueous quenchants and rapid agitation allows it to approach maximum capabilities. The fast heat removal during transformation can crack or distort a part. Water is often used to quench plain carbon steels of massive components with shallow case requirements.

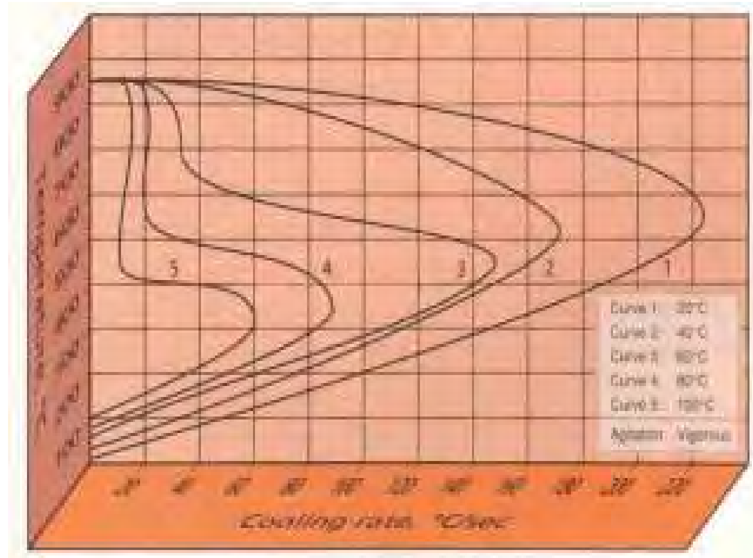

Figure 2 – Effect of temperature on quenching properties of water

Salt Solutions

Salt solutions cooling rates are typically the most rapid of all aqueous quenchants. While the vapor phase breakdown is extremely rapid, higher cooling rates may increase the possibility of distortion and quench cracking of the part may occur.

The benefit of salt solutions comes from the solids deposited on the hot surface as the water evaporates causing a faster and more even dissipation of the vapor phase.

It should be noted that brine solutions can possibly cause corrosion issues during the induction hardening process.

Polymer Quenchants

Polymer quenchants have seen wide acceptance in induction hardening applications. Many of the benefits of water quenching also pertain to polymer quenchants. These include non-flammability, ease of part cleaning and minimal disposal issues.

Polymer quenchants are aqueous materials that are added to water to simulate a variety of quenching characteristics. This is obtained by varying the concentration of the polymer in water. The specific polymers help develop a film at the interface of the heated part and the quenchant acts as an insulator to slow down the cooling rate.

The polymer film on the surface of the heated part dissolves into the fluid when the surface temperature of the part falls below the separation temperature of the polymer quenchant, as in the case of PAG based polymer quenchants.

Each polymer has its own physical characteristics. PVP type chemistry products have normal solubility while PAG and PEO type products have inverse solubility as described above.

The choice of product is normally dictated by the induction hardening application, steel hardenability and compatibility requirements such as any pre and post metalworking fluids utilized either upstream or downstream of the induction process.

A range of quench characteristics can be achieved through variations in the concentration of the polymer. For example in PAG based polymer quenchants, a lower molecular weight PAG will provide fast heat extraction capabilities and higher molecular weight PAG's will provide slower heat extraction capabilities. The quench characteristics are also controlled by the temperature and agitation (which must be uniform) of the specific polymer quenchant will also aid in maintaining uniformity of quench.

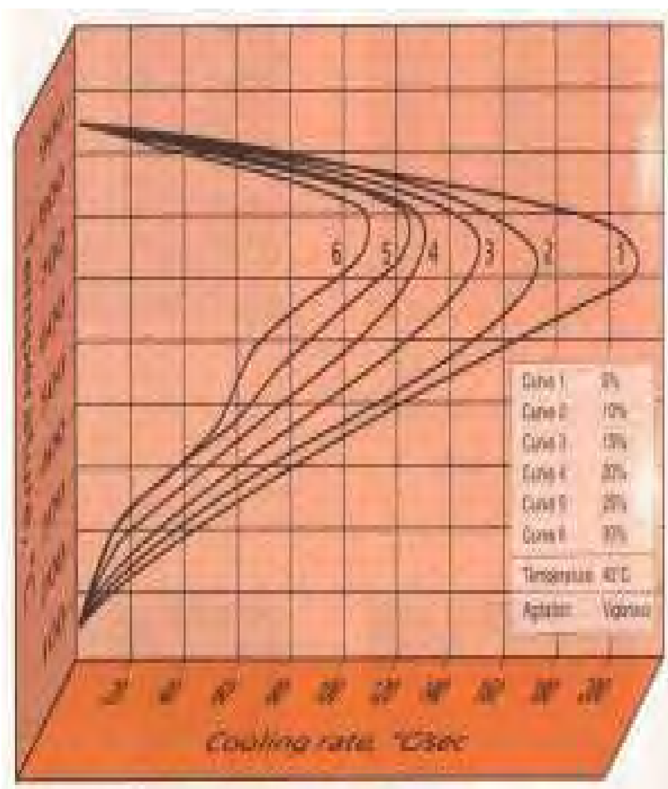

Figure #3 – PAG effect of concentration of quenching characteristics

Basic Care & Maintenance

Because the performance of the aqueous quenchant is dependent on the condition of the product, it is extremely important that a proactive maintenance plan be implemented for monitoring the quenchant.

Typical routine testing includes:

- ✓ Concentration using refractometer or kinematic viscosity (preferred)
- ✓ pH should be maintained between 8-10
- ✓ Contamination from pre-heat treatment process fluids or lubricants utilized in the induction hardening equipment
- ✓ Corrosion inhibition package
- ✓ Microbiological testing
- ✓ Cooling curve analysis if desired or required

Common Induction Quench Issues

- ✓ Part always too soft
  - o Check quench flow and quench pressure
  - o Check quench temperature for high level
  - o Check quench concentration
- ✓ Part sometimes too soft
  - o Check for air in quench
  - o Check quench level in tank
- ✓ Part hard: pattern not deep enough
  - o Check quench pressure
  - o Check quench concentration
  - o Check quench temperature
- ✓ Part pattern too deep
  - o Check dwell time to quench
  - o Check if quench concentration is too low
  - o Check if quench temperature is too low
  - o Check quench flow/pressure
- ✓ Cracked part
  - o Check if concentration is too low
  - o Check if quench water temperature is too low
- ✓ Spotty surface hardness
  - o Check quench flow
  - o Check the alignment of the quench heads
  - o Check quench pressure
- ✓ Part is distorting irregularly after processing
  - o Check quench concentration, temperature, flow and pressure
  - o Inspect quench heads for even pattern
  - o Make sure there is proper quench impingement on the part

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