Contamination of Polymer Quenchants in Induction Hardening

Some think coolants or other contamination do not harm the quenchant. This perception couldn’t be farther from the truth.

Induction hardening is a common and effective method of achieving a hard, wear-resistant surface without carburizing or nitriding. It is used extensively to harden gear teeth, as well as wear surfaces. A compressive residual stress at the surface contributes to excellent fatigue resistance. Heating is rapid, and well suited for automation. The preferred process sequence is shown in Figure 1.

In induction hardening, contamination is a common occurrence. Polymer quenchants are commonly used for induction hardening. Contamination is always a problem. The most common contaminants in induction hardening applications are organic contaminants from hydraulic fluid leaks, coolants or forming lubricants, or machine swarf. Rust preventatives and cleaners are also found on parts. Solids, such as soot or high water hardness, can also be present. High inorganic salt content from either rust inhibitors or very hard water can also be present in the quench tank. Parts usually come from prior processes and may be covered with different types of coolants such as oils, synthetic coolants, emulsions, and semi-synthetic. If the parts are cleaned prior to heat treated (recommended, but rarely done), the parts may contain residual soaps. Dirt from the environment, and parts such as machining swarf, are always present. Many parts per hour are processed, with each part carrying a small amount of contaminant. This is compounded by the fact that many induction systems have a very small quench tank — often 100-200 gallons.

Typical customer samples of contaminated polymer quenchants used in induction hardening are shown in Figure 2.

During the machining operations, coolant is used for lubrication and to help carry away chips and swarf. As the part moves to the induction step, parts should be properly washed and rinsed to remove chips, coolant, and machining swarf. However, often the cleaning step is omitted as “non-value added.” The perception is that the coolants or other contamination do not harm the quenchant. This perception is inaccurate.

Contamination by cutting fluids, rust preventatives, cleaners, or hydraulic fluids can provide nutrients for biological growth. These contaminants may also prolong or stabilize the vapor phase of the quenching process, which can contribute to low hardness and inadequate case depth. The effect of oil contamination on the cooling curve of a 5 percent solution of a typical PAG polymer quenchant used in induction hardening is shown in Figure 3.

At lower concentrations of polymeric quenchant, more typical of those used in induction hardening, the presence of organic contamination (mineral oil) was found to be significant in increasing the time to 600° C and 400° C, and decreasing the cooling rate at 300° C. This has the effect of effectively increasing the concentration of the bath by several percent. Depending on the hardenable of the part, this can result in spotty hardness, or a case hardness that does not meet specification.

Often the use of an air knife prior to the heat-treating operation can remove most of the coolant and reduce the contamination. While cleaning the parts prior to heat treatment is always preferred, the use of an air knife is an acceptable alternative. Properly designed skimmers and filtration systems will help minimize this source of contamination from the quench tank (Figure 4).

Sediment and particulate matter such as scale have little effect on the quench rate but can increase the overall quench rate by providing nucleation sites for bubble formation and destabilize the vapor phase. This is not usually a problem in induction hardening because of the direct impingement of quenchant on the parts. However, this particulate matter can hinder concentration control by making the refractive index difficult to measure. This contamination also can affect the cleanliness of the quenched component. Filtration is always recommended to remove this particulate. Typically, filtration of the quenchant to approximately 10 microns is adequate to remove most particulates.

Most bacteria contamination found in polymer quenchants is associated with anaerobic bacteria. This is a common problem for all polymer quenchants. This bacterium is not a health hazard but more
of a smell issue. This smell is caused by large numbers of anaerobic bacteria decaying. Hydrogen sulfide (H₂S) is formed by the decay. Hydrogen chloride (HCl) can sometimes appear as a green cloud over the quench tank when the equipment is first started after a weekend or longer shut-down. Hydrogen sulfide, H₂S, is the rotten-egg smell. Both of these chemical compounds decrease the pH and contribute to increased corrosion of parts and equipment, and increased bacteria growth. It is this bacteria that contribute to “Monday Morning Smells.” This is typically cured by sump additions of a biocide or dumping the system. This is a costly, and potentially dangerous (with regard to biocides), solution to the problem of bacteria growth.

Anaerobic bacteria thrive in oxygen-depleted environments, such as is found at the bottom of a quench tank. Stagnant solutions contribute to localized oxygen depletion, which in turn increases potential for bacteria growth. To prevent stagnant solutions, the quenchant should be kept moving, and the quenchant free from rust and solids. It is these solids that provide much of the food source for anaerobic bacteria.

Bacteria can be controlled without the use of biocides. Cleanliness of the quenchant and quench tank is critical to preventing the growth of bacteria and the subsequent use of biocides. The quenchant should be kept agitated to eliminate stagnant solutions. Once the equipment is shut off for the weekend, the quenchant should be kept agitated. This can be done by keeping the filtration pump “on” over the weekend, or by intermittently initiating the agitation system on a periodic basis. A couple of minutes every hour should be adequate.

Filtration is also effective in reducing bacteria growth. Filtration serves two purposes. First it eliminates particulate, scale, and other debris from the quenchant that can act as a food source. Secondly, it maintains the quenchant cleanliness, so proper quenching can occur. Bag and cartridge filters are commonly used in this application. Typically bag sizes down to approximately 15-20 microns are used. However, these types of filters are not recommended for this application, as the low fluid flows through the filters and the high concentration of food sources can contribute to bacteria growth. Further, this type of filtration, once contaminated, can spread the contamination to other locations in the quench tank.

Sand filters are effective filtration systems for polymer quenchants. The nature of sand filtration has high flow velocities so stagnant solutions do not occur. Further, they are also effective at filtration, with filtration levels often at 6-8 microns or better. They are also cost-effective, as the filtration media is inexpensive, clean white sand.

Quenchants have been developed that will not sustain bacteria growth, and “will not stink” under most circumstances. These quenchants are specially designed for induction hardening applications with enhanced corrosion inhibitor packages. These are proprietary quenchants designed to have long life and not support bacteria growth. Examples are Houghton’s Aqua-Quench 245 and Aqua-Quench 145 polymer quenchants.

Proper control of the polymer quenchant tank is important to ensure long, consistent bath life. Contamination must be held to a minimum for proper quenching. Contamination is controlled by appropriate washing of parts prior to heat treatment. This yields consistent case hardness and depth, while extending bath life.