Why Fine Filtering for quench oil systems is a must!

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Abstract

One of, if not the biggest variable in the heat treatment of components is achieving a consistent and repeatable cooling process. New quenching oil does a great job of providing the needed cooling at a known rate. The challenge with oil in general is that it breaks down over time and its properties change. The biggest killer of oil is HEAT! For quench oil, these changes affect the oil's cooling curve, which change the performance of the hardening and strength of the part. Surface finish can also be affected because contaminates can be deposited on the treated part. The high heat from the process produces a bunch of contaminates, which gum up the whole system. This in turn, requires lots of maintenance and increases the risk of oil self-ignition. A properly designed fine filtration system can significantly reduce these effects, while improving quality and reducing operating cost.

This paper will focus on what happens to quenching oil over time. How does it change the cooling curve of the oil and the impact on the quality of the heat treatment? The types of contaminates that are produced and their impact on the process will be explained. The shortcomings of a standard filter system will be explained. The benefits of adding a fine filtration system that keeps the oil as clean as possible will be shown. Finally we will show how to design a great fine quenching oil filtration system.

Introduction

One of the biggest variable in the heat treatment of components is achieving a consistent and repeatable cooling process. New quenching oil does a great job and providing the need and cooling at a known rate. It's critical to the operation to have the right oil for the application, which will deliver the right performance and have a long life. Quench oil serves two primary functions. It facilitates hardening of metal by refrigeration, cooling the surface at a known and controlled rate. It also enhances wetting of the metal during quenching to minimize the formation of un-desirable thermal and transformational gradients, which may lead to increased distortion and cracking. To get the performance and quality that you need does not come cheaply. Quality quench oil can be expensive, but it's worth the investment. So once you have invested in your equipment and you have invested in the right premium quench oily you may think that you have done all that is necessary. Well if you're depending on in-line filter equipment to provide the necessary cleaning for your system, you would be wrong. You not doing all that you can to maximize your ROI. An off-line fine filtration will provide tremendous benefits in the process along with significant

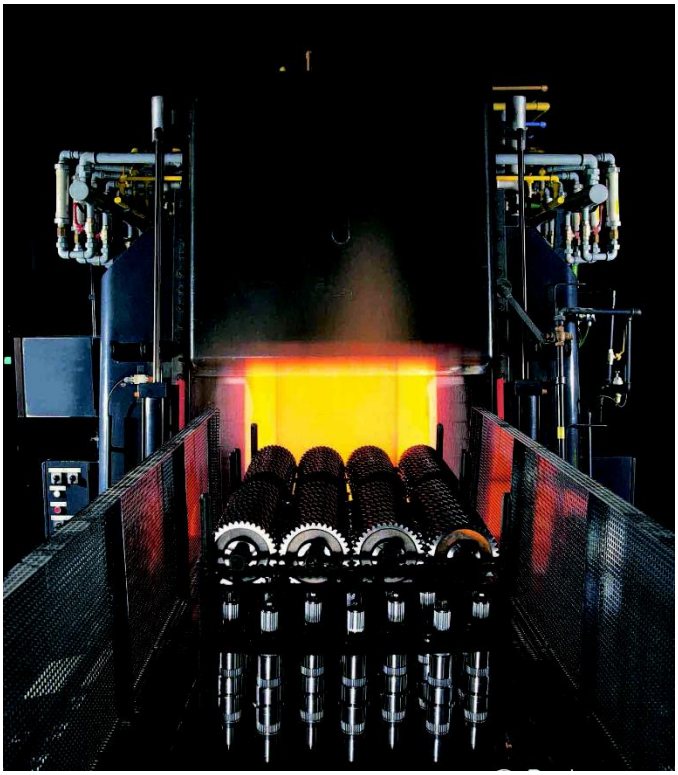

Figure 1. Typical heat treating application.

reductions in maintenance and repair costs.

Background on quenching oil

To understand the need for very fine off-line filtration system on your quench oil systems, let's start at the beginning on what happens to the oil during the heat-treating process. The worst

thing that you can do to oil is to expose it to high temperatures. Yes, the biggest killer of oil is HEAT! This is the major cause of oxidation in the oil. One of the general rules about oil is that as the operating temperature increases by 10° C you reduce the life of the oil by half. Based on this, quench oil will have a high level of thermal degradation from heat. The base oil and the additive package will change from the extreme forces that are put on it. This results in the formation of insoluble products that will cause deposits on the parts, and sludge, varnish and other soft contaminates will be produced in the quench tank. One of the greatest problems with quench oils is sludge formation. The presence of sludge & varnish could cause non-uniform heat transfer, increased thermal gradients, increased cracking and distortion. Sludge may also plug on-line filters and foul heat-exchanger surfaces.

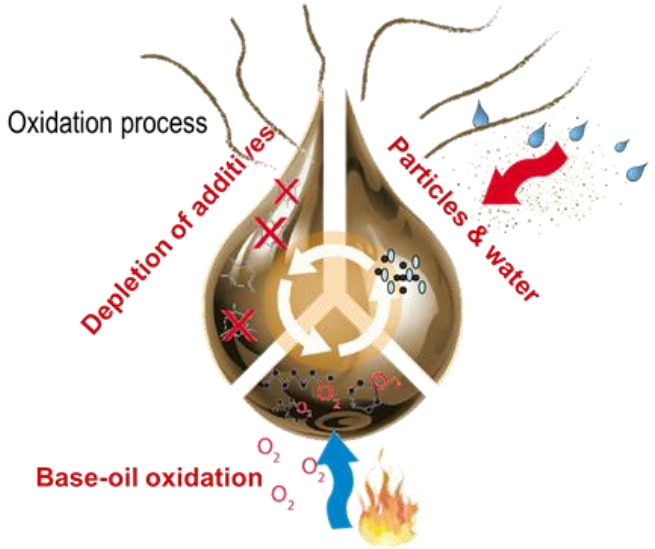

Figure 2. Schematic of oxidation process of quench oil – Illustration source: OelDoc GmbH

The loss of heat-exchanger efficiency can cause overheating, excessive foaming and fires. The sludge and varnish will also attach itself to all of the surfaces inside the tank and piping. This requires extensive cleaning to be done to maintain an effect operation and a safe one.

In addition to the effects from the heat there are other things that will impact the life of the oil. Heat treating is a messy process and there are many contaminates that are introduced to the system from the outside. This can come from many sources. You have dust and other forms of dirt that enter through the air. Then there are particles and debris that fall off of treated parts. With the high heat you might think that moisture is not a problem but it is.

A small amount of water can have a big impact on the oil and operation. Water is the most common and most harmful contaminant and should be avoided. If the concentration of water is higher than 0.1%, it can lead to granular hardness, distortion, spots and furthermore it is also a potential harm to staff health. At a concentration of 0.5% or above the quenching oil may start to foam thereby creating a risk for fire and explosion. The sources or causes of water contamination can be:

- **Bearing, refrigerated with water**
- **Fans**
- **Heat exchangers: oil/water**
- **Condensation in humid environments caused by high temperature changes**

The quenchant base and additives determine the quality and performance of the oil. Additive depletion is normal and expected when the oil is being used. But when the oil becomes more contaminated, the additives are used up faster than if they were not there. One of the jobs of additives is to control and neutralize contaminates so they don't affect the performance of the oil. But with so many particles, water and sludge, the additive package get depleted very quickly.

Impact on increased degradation and contamination of the quench oil:

The increased degradation and contamination has an impact on the operation in many ways:

1. Black deposits of varnish and lacquer on quenched parts, coolers, circulating systems
2. Sludge accumulation in the tanks, deposits on parts' surface
3. Change the cooling curve of the quench oil: resulting is even longer un-predictable cooling times. Unevenly extended vapor phase, foam formation, risk of splashing.
4. Reduced oil life by 2-4x. The varnish, sludge, and hard particles continue to break down the oil faster. The additives get consumed because they are fighting contaminates.
5. Increase presence of organic acids and increased Total Acid Number. As oil degrades, it forms acidic by-products
6. Changes in oil viscosity. As the oil degrades and particles increase and the viscosity will be increased. This results in reduced efficiency, higher energy consumption, and higher oil consumption.
7. Increased maintenance and downtime. Tanks have to scrubbed, and cleaned. Heat exchangers, circulating equipment and other system parts have shorter lives and unplanned repairs happen more frequently.
8. Increased part cost. Additional cleaning is often required, high dirt load is transferred to the washing baths. Sometimes blasting and grinding is required because of deposits and overheating.
9. Reduced part quality. Cooling curve changes add unpredictability into the quenching process. Visible and performance of the heat treatment
10. Safety: Increase danger for operators and the facility. Hard levels of sludge and water increase risk of steam explosions and fires

These will have an impact on the efficiency of the system, increase operational cost and safety.

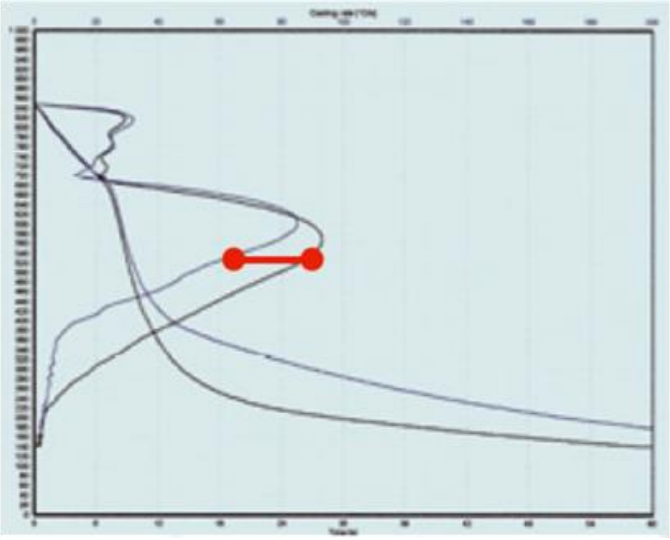

Figure 3. This graph shows the cooling curve of new quench oil and one that has degraded over time. The distance shown in red, is the change in cooling rate.

Why Fine Filtration?

Why I need a fine filtration system on my quench system? The system already has filter(s) to remove contaminates - it should be good enough. However, that is not the case. Unless the filter system can remove particles down to 3µm or less, has a very high load capacity, able to capture hard particles, soft contaminates (sludge & varnish) and remove water; you are wasting time and money. You might think that particles below 10µm cannot cause any harm, but they build up in the system creating sludge and carbon deposits. Contaminated oil will produce sludge and carbon deposits at a faster rate. Fine filtering will reduce the amount of sludge and carbon produced up to 90%. If you analyze the particulate in the oil, a progressive size distribution will be seen (Figure 4. Typical particle distribution in quench oil.Figure 4). Only 10% of the particles are larger than 10µm. If you are using a 10µm or larger filter, you are only able to retain 10% or less of the particulate. Approximately 70-80% of the particles are between 1-5 microns.

There is a common concern that if the oil is filtered too fine that it will remove additives. The truth is that oil additives cannot be filtered out, because they are fully blended, fully dissolved and active in the base oil (even 1 micron filtration cannot). Additives are dissolved like sugar in coffee. There are a few exceptions: Decomposed and "dead" additives can be filtered out (additives will decompose over time performing their intended function). Polar additives will become attached to particles and be filtered out (this is the job of these AW/EP additives, rust inhibitors etc. so this is normal). Anti-foam additives will be sheared in use and some will be filtered out by means of polar attraction by any filter in the system. Experience has shown that a decrease in the anti-foam level will not give any problems if particles, water and oil degradation products are removed from the oil).

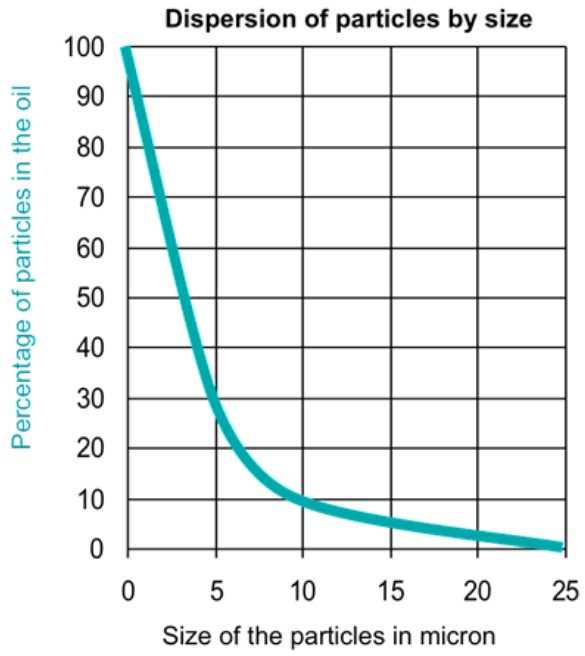

Figure 4. Typical particle distribution in quench oil.

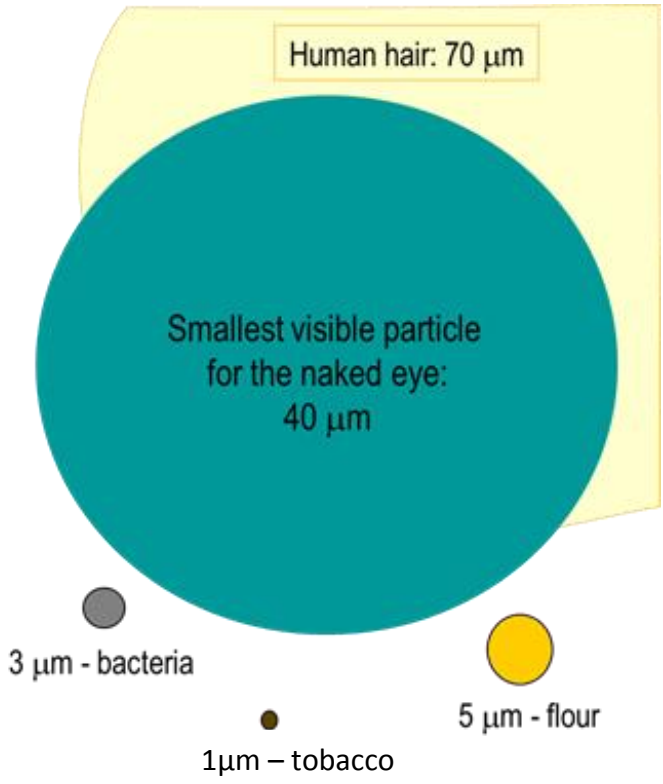

Figure 5. The size of the particles that need to be filtrated is extremely small

Benefits of fine oil filtration

It is important to know what you can expect if you add an off-line fine filtrations system to your quenching operation. These benefits will help justify the upfront cost of the system and help you quantify the savings and other advantages over time.

1. Reducing unplanned down-time (typically by 50 – 70 %)
2. Longer service intervals and lower maintenance costs (typically 50 %)
3. Stable quench, slower change in the cooling curve
4. Reduced costs for system inline filters (longer life of in-line filters and/or less cleaning of filter mesh)
5. Less or no tank cleaning
6. Significantly reduce or eliminated: Sludge, carbon, varnish, hard particles and water
7. Eliminating/reducing cost for oil changes (2-5x the life)
8. Improve surface quality (happy clients)
9. Less or no extra cleaning of quenched parts
10. Reduced risk of fire
11. Reduced environmental impact (less oil changes)

Figure 6. Part on the left is from a system before a fine filtration system has added. You can see the deposits of carbon. The picture on the right was from the same quenching system after fine filtration was installed.

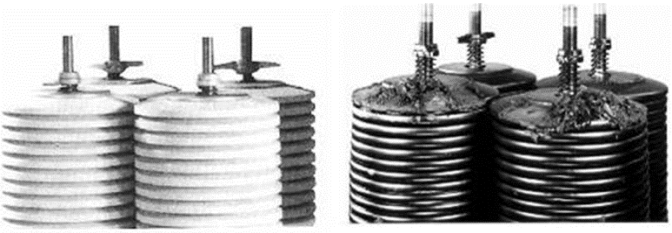

Figure 7. Filter inserts that have captured what the in-line filter could not.

What does a great fine filtration system look like?

Now that we know that we need to have great filtration on our quench system, what does that look like? The system must be off-line, meaning that it is not in the flow of the oil going to the system's pump or the heat exchanger. The required flow and the importance of unrestricted pathway for the oil through these components is vital and this limits how much the filter can do.

A good filter system must be able to capture all contaminates: hard particles, and soft contaminates (sludge, varnish, carbon and water). Depending on the manufacturer, the filter system might have require multiple types of filters to remove all contaminates. There are systems that can accomplish this with one filter media. Be careful when evaluating solutions, though the initial cost is important, the cost of the filter media will determine the true ROI on the investment. The fine filtration system must be able to capture contaminates down to at least 5µm, with the finer the better. All contaminate count, no matter what the size.

The filtration system must be continuous, and running all of the time. The goal is not to just clean contaminate to a specific level and then wait for it to get dirty again. By continuously cleaning the oil, you minimize the degradation of the oil and the opportunity to create new contaminates. There might be a desire to use a mobile filtration system that can be moved from one tank to another. In theory this sounds great, but in practice it significantly reduces that effectiveness of the filtration system. The problem is that you do not totally clean up both the oil and the system surfaces. The contamination that is left in the oil during times that the mobile system is not being used will do harm to the all of the benefits that you are able to achieve with a continuous system. This reduces the effectiveness to less than 50%.

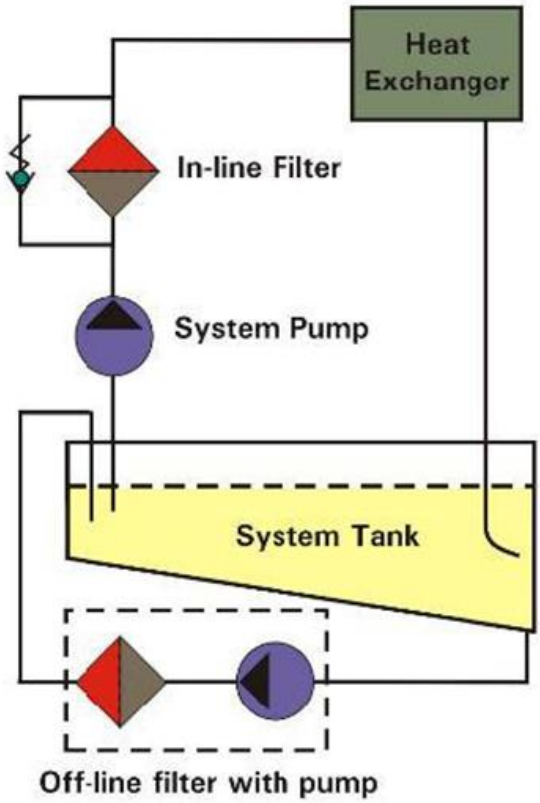

Figure 8. Configuration of an off-line filter system.

One of the great properties of very clean oil is that it acts like a cleaner. Meaning it will clean all of the surfaces of the system over time. Don't expect the clean up to happen overnight. If the system was run without a fine filtration

system for years, it could take months for clean oil to scrub all of the surfaces clean.

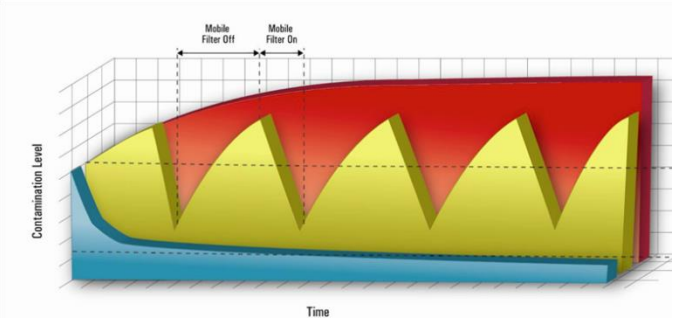

Figure 9. Filtering using a mobile system will have limited impact.

Now let's turn our focus to the filter element itself. This is the replaceable part that captures contaminates. It must be able to hold high levels of contaminates. The most common type of filter element is a pressure filter. They can come in different sizes and made from different materials. These are great for inline filters that capture large particles that could damage pumps or clog heat exchangers. The down side of pressure filters is that they have limited dirt-holding capacity and they are not a good solution for the off-line fine filtration system.

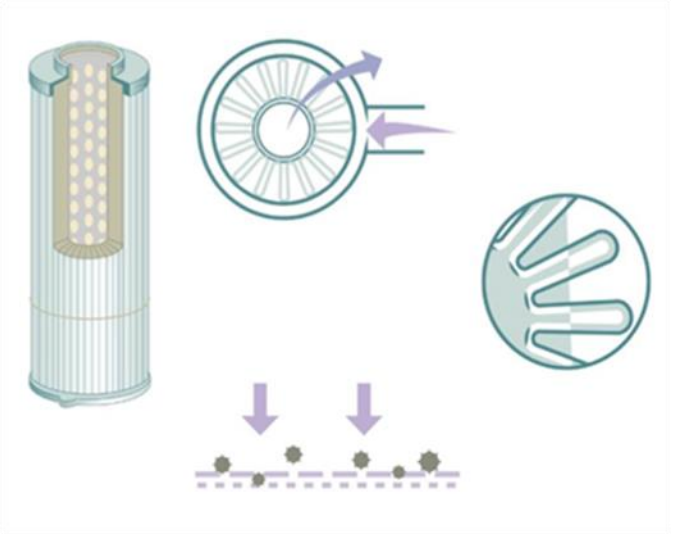

Figure 100. Pressure style filter. There is limited surface area to capture particles and cannot absorb many of the soft contaminates.

A depth type filter is a much better choice because it can hold lots of dirt and has layers that can capture different size particles and soft contaminates. The filter media should be able to last months if not a year. If not, you are trading maintenance on the quenching system for maintenance on the filter system.

This is asking a lot from this filter system, and it has to be very cost effective. The ROI on the system should be 12 months or less. The system must also have a low cost of operation going forward. It may sound too good to be true, but there are fine filter systems in the marketplace that can meet all of these requirement. A fine filtration system should never be looked at as an additional cost or a nice option. Instead it generates you money by lower costs, higher quality parts, less labor and a safer operation.

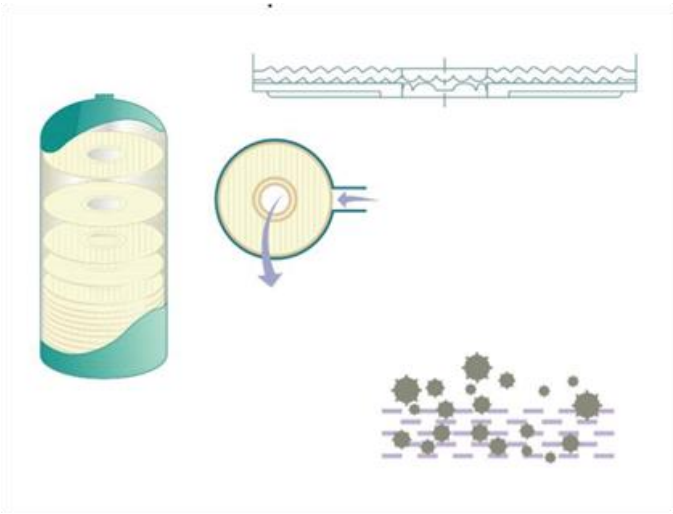

Figure 111. Depth style filter. There is significantly more surface area to capture particles. Depending on the material, it may also be able to absorb many of the soft contaminates.

Conclusions

As discussed in the beginning of this paper, there are going to be conditions in the oil quenching process that will destroy the oil, no matter how good the oil is or how well it is maintained. The heat from the quenching process will slowly kill both the base oil and the additives. There is the dirt that is added from the heat treat shop environment. These contaminates are smaller in size that most people realize and they cannot be remove/captured by standard means. By installing an off-line filtration system that is fine enough to capture the smallest of hard particles; can absorb the soft contaminates and remove water; you can significantly increase the life of the oil, reduce maintenance costs and improve safety.

References

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