SHTE Conference

“Latest trends and developments in quenching technology”

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ABSTRACT:

State of the art technology in quenching means usage of medium viscosity accelerated quenching-oils with a short vapour-phase for automotive heat-treatment-applications in order to achieve a homogeneous cooling process. Higher viscosity hot quenching oils are often applied to control effectively the quenching speed in the convection phase and thereby reduce thermal stresses. Short vapour phase fast quenching as well as hot quenching oils are now available which enable reduction in distortion for gears & transmission parts.

Vacuum heat-treatment-processes are applied to avoid surface oxidation. Beside high pressure gas quenching in nitrogen or helium, specially designed vacuum quenching oils offer highest heat transfer coefficients [HTC] and the use of costly modified alloyed steels is not necessary.

These latest developments use the new generation of base oils, which are a milestone in evaporation stability, offer lowest emission and also offers an optimum performance in quenching technology for this decade.

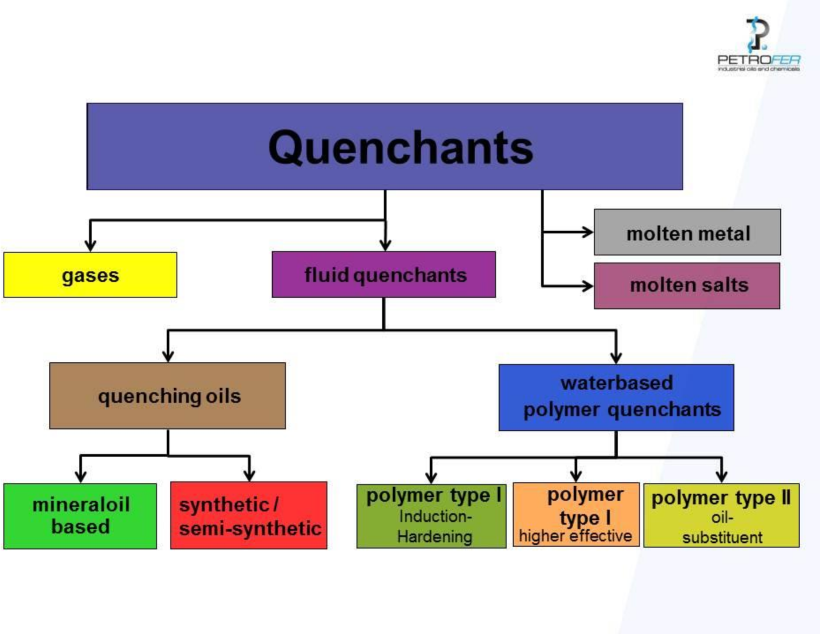
The Quenching Process

Picture 1 shows all available quenchants. They can be devided into 2 different groups:

- those, cooling only by **convection** because their boiling temperature is above the austenizing temperature of the quenched material (molten salt bathes and molten metal)
- those, with **3 phase quenching caracteristic** (as shown in *picture 2*) To this group belong all quench oils and water based quenchants.

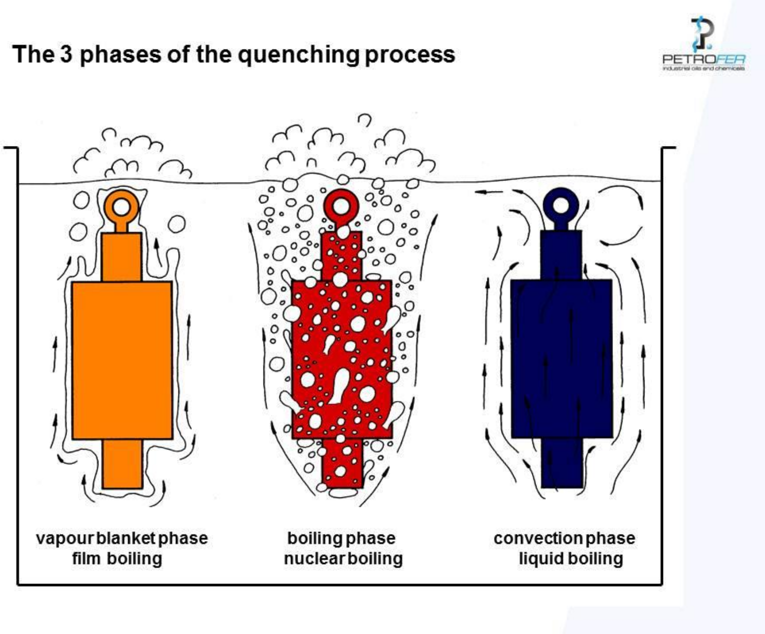
Molten metal (lead) is applied only in wire-patenting processes - today only in very few applications.

Salt bath quenching after carburising in an atmosphere controlled furnace is in most cases carried out in quench tanks outside the furnace. The quenching properties of salts can be increased by adding water in quantities of 1 max. 2 % to the molten salt - and of course by agitation.



Picture 1 :

Available Quenchants



Picture 2:

The 3 phases of the quenching process

Fluid quenchants following the **3 phase caracteristic** shall have a **vapour phase** as short as possible.

For quenching of steels with low hardenability a short vapourphase is an absolute necessity to obtain a martensitic structure as deep as possible below the surface, resp. over the whole cross-section or at least to reach a microstructure free of ferrite to obtain best impact properties.

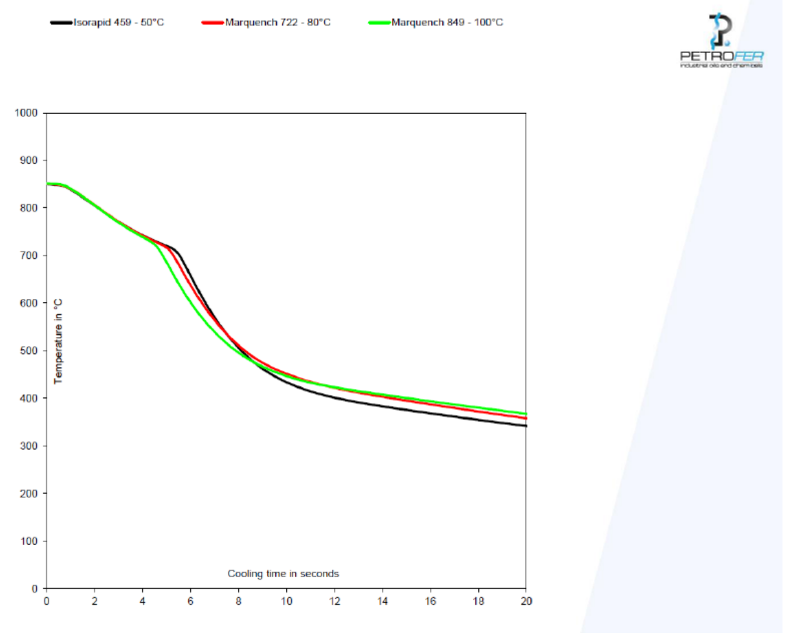
Steels with better hardenabilty may allow slower cooling in the beginning of the quenching process yet to reach the above mentioned requirements. But it is very recommendable to apply also in these cases a quenchant with a very short vapourphase, because this guarantees a most homogene cooling of the entire surface of a work piece. Only this avoids significant temperature differences in a work piece and thereby unnecessary stresses during the cooling process.

The quenching properties at the end of the quenching process (range of martensitic transformation, **convection phase**) should only be as high as necessary to obtain the required microstructure, resp. hardness in the core of pieces, or in the roots of a gear's teeth.

Specially developed oils like, ISORAPID 459, MARQUENCH 722 and MARQUENCH 849 have a reduced final quenching rate related to their viscosity.

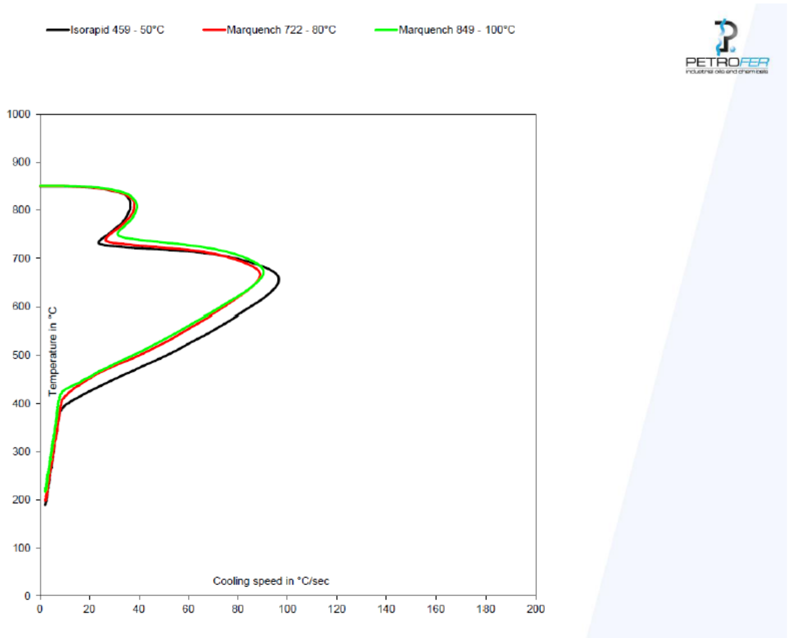
ISORAPID 459 can be operated as a two-range oil (50-100 or up to 150°C when the quench-tank is under protective atmosphere). The optimum hardness and lowest distortion is achieved with MARQUENCH 722 and the more MARQUENCH 849 because of the extremly short vapour phase blanket stage and the cooling rate being kept low during martensite transformation.

Dsignation	viscosity at 40°C (mm²/s)	Application temperature range (°C)
ISORAPID 459	49	50-100 (max. 150)
MARQUENCH 722	78	60-150 (max. 180)
MARQUENCH 849	156	70-150 (max. 180)



Picture 3:

Quench curves – 12,5 mm testprobe (without agitation)



Picture 4:

Quench curves – 12,5 mm testprobe (without agitation)

Of course a quenchant for pieces with thicker cross-sections made from heat treatable steel must have a high final quenching speed to cool down the core as rapidly as possible and thereby to avoid grain-border ferrite. This can be reached with low viscosity accelerated quench oils or even better with water based polymer quenchants.

If more expensive steels (higher alloyed) are quenched in a slow quench oil replacement by a water based quenchant is very recommendable to reduce production costs, because the water based quenchant allows the application of a non- or lower- alloyed, cheaper steel.

Applying accelerated hot quenching oils with an extremely short vapourphase and a controlled final quenching speed reduces distortion significantly.

Also our water based polymer quenchants have a short vapour phase. The final quenching speed and thereby the "core-hardening properties" as well as control of distortion are adjusted by the choice of the concentration of the polymer concentrate in water.

Properties of quench oils

As already mentioned above oils for open quench tanks must have excellent oxidation stability. Furtheron the following properties are required, resp. important

- the flash point should be in accordance to the applied oil bath temperature and to the thermal strain in case of batch quenching
- the stability against evaporation should be high to avoid a negative influence on the atmosphere in the furnace when a batch is cooled (this is especially important for pusher furnace where one batch after the other is quenched within a short time cycle). Evaporation stability is, in combination with a short vapourphase, important to reach the cooling properties which are described in the next chapter
- oil residues should be easily removable from the surface of the quenched work
- the washed off quench oil should easily separate from the washing fluid to reach a long service life of the cleaner solution (to avoid frequent change and expensive disposal) Thereby costs and an unneccessary impact on the environment would be reduced, resp. avoided.

How does a short vapour phase and the evaporation stability influence the cooling conditions for heat treated pieces ?

When quenching long pieces with thin cross-sections, the breakdown of the vapour film starts from all points "disturbing" the "homogeneous" surface as e.g.

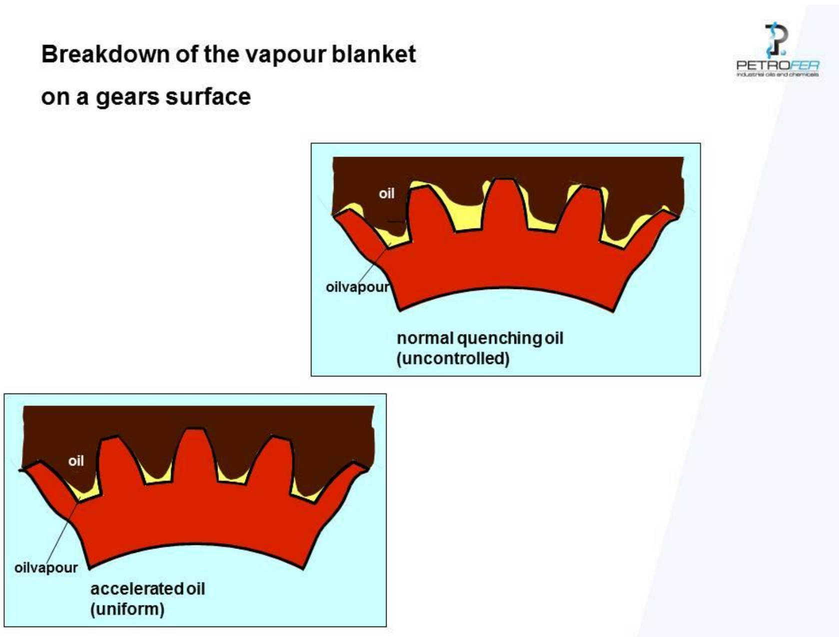
- sharp edges,
- threads,
- gear teeth etc.

From there, a boiling front starts running in the direction to the middle of the piece (this was also found by (Tensi et al.) (Lübben et al.)).

The boiling front runs the faster, the shorter the vapour phase of a quench oil is whereby the entire surface is cooled relative homogeneously, while a long vapourphase produces an uncontrolled breakdown of the vapour film.

When quenching heavier cross-sections in an oil with a short vapour phase, boiling starts from many points, simultaneously on the entire surface of the piece.

This means only by application of oils with a short vapourphase a most homogene cooling of the surface is achieved.



Picture 5:

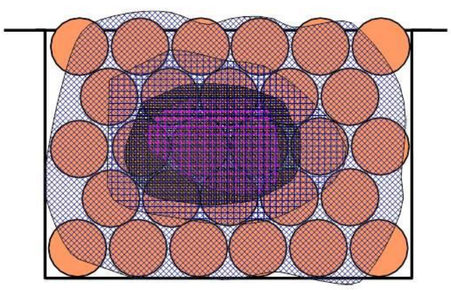
Breakdown of the vapour film on a gear's surface (schematically)

Picture 5 shows schematically how the vapour film disappears from the surface of a gear

- in the **upper part** for a quench oil with a **long vapourphase** (breakdown inhomogene, uncontrolled)
- in the **lower part** for an oil with a short **vapourphase** (very homogene and controlled breakdown of the vapour film).

Only the best homogenity of the cooling of each tooth guarantees lowest thermal stresses during the first step of the quenching process.
Inhomogeneous cooling will produce stresses which can easily lead to plastic deformation due to the low yield strength at high temperatures.
Besides the short vapour phase, good evaporation stability of an oil is equally important.
Picture 6 shows the formation of a vapour cushion within an immersed batch. Only a good evaporation stability avoids continuous formation of new oil vapours. Thereby, the vapour cushion can disappear (break down) rapidly. Also the way of packing a batch will influence this effect.

It has to be ensured that not only each piece but also the entire batch will be cooled homogeneously.



Picture 6:

A long-lasting vapour cushion in a batch must be avoided

Not only a short vapour phase and good evaporation stability, but also adjustment of the quenching properties in the final part of the quenching process - as mentioned before - is important. A quenchant should not cool faster at this stage than necessary to reach the required hardness and to avoid high thermal stresses.

Agitation

It has to be considered that even a high flow velocity does not influence significantly the breakdown of the vapour film. This is mainly influenced by the properties of the quench oil itself, by its "quench-power".

A high flow speed will be most effective during the convection phase, but in general, its effect will be always stronger on the side of a workpiece which is directed to the flow while the opposite side may be in the flow-shade, which would cause uneven cooling and thereby unnecessary thermal stresses.

Therefore, a flow which just creates sufficient replacement of the quenchant - being extremely heated close to the workspiece's surface - by cooler quenchant is most recommendable.

As interesting experience, especially from the automotive industry, quenching transmission parts shall be mentioned:

> To stop bath agitation totally before immersing a batch and to start it after approx. 10 to max. 30 s, can reduce distortion as well.
>
> Also in this case, only the "quench-power" is effective, i.e. that the breakdown of the vapour film is only affected by the quench oil itself, and not by - often inhomogeneous - external influence.

Outlook

Today highly accelerated quenching oils based on the new GTL (gas to liquid)-base-oil-technology have in addition to the other described advantages a significant higher evaporation stability to avoid a long and stable vapour cushion in batch quenching-processes.

Consequently the emmisions are also reduced during the quenching-process - beside the low sulphur-content this is another big advantage.

The new GTL-technology opens a wild field of applications and is extremly interesting for quenching after vacuum heat-treatment-processes.

Details will be presented in the oral presentation.

Conclusion

It has been described why a short vapourphase for any quenchant is an essential independently of its kind.

Describing the quenching properties it was shown how the requirements in regard to reach a certain hardness, to reduce, resp. to avoid distortion by the correct choice of the quenchant can be fulfilled.

The choice of a system cleaner/ washing machine which fits best with the applied quench oil has advantages because it reduces down-times and disposal costs for the cleaner because a long service life of the washing fluid will be reached.

References

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