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Increasing quenchant temperature is effective in reducing distortion in heat-treated components, but a cost-benefit analysis must be weighed against shortened oil life and consumption and disposal costs.

Effect of temperature on oxidation of oil quenchants

In this column, I will discuss the effect of temperature on the oxidation behavior of martempering oil used for distortion control.

INTRODUCTION

Martempering oils are used to control the distortion of precision parts by the reduction of thermal gradients, and to allow martensite to transform uniformly. Elevated oil temperatures are used, at temperatures greater than greater than 120°C. This means that very high-quality base oils and additives are used to prevent oxidation of the oil.

The operating temperature of the martempering oil is used to control distortion. Generally, the higher the temperature, the lower the distortion. However, even minor changes in the operating temperature can have a large impact on the life of the quench oil. An oxidation study showing the effects of temperature on the life of three oils will be presented.

Engineered quench oil is governed by the desired quenching performance, the necessary thermal and oxidative stability, and, finally, price or market considerations. Quenching performance is generally considered to be the heat-transfer characteristics and the thermal stability of the oil. This includes having an acceptable flash temperature that is a minimum of 50 C above the expected use temperature; low sludge forming tendency; long life; and the necessary quenching speed.

Premium quality heat-treating quenching and martempering oils are formulated from refined base stocks (usually paraffinic) of high thermal stability with additives to improve performance and increase tank life. These additives are a combination of specially chosen ingredients compatible with the base oil; in particular, carefully selected and tested antioxidants, which retard the aging process.

The oxidation mechanism of quenching oils is very complex [1] [2] [3] [4] [5] [6] [7]. The presence of iron and copper catalyzes the reactions and plays an important part in chain initiation reaction. Typically, reactions are slow at room temperatures but become increasingly faster above 100°C. This is why, for high quality quenching oil, "cold" oils (those used below 80°C) do not experience the severe oxidation with attendant increases in viscosity and Total Acid Number (TAN) that martempering oils experience. A schematic of the oxidation process is shown in Figure 1.

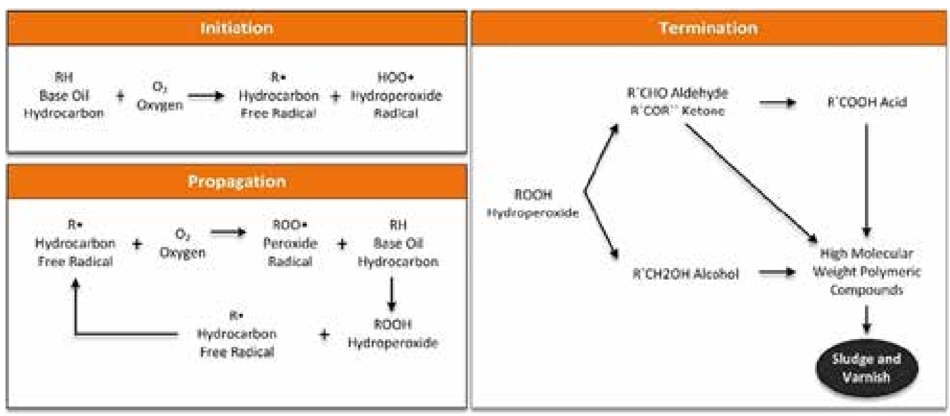

Figure 1: Schematic of the mechanism of oil quenchant oxidation.

The side reactions of the formation of aldehydes and ketones are probably the most important in maintenance of quench oils because their subsequent reactions eventually form sludge and deposits [7] [8].

EFFECT OF TEMPERATURE

To illustrate the effect of temperature on the oxidation of typical martempering quenching oils, a simple oxidation test was performed. Three martempering oils were evaluated to ASTM D4336 [9] at 130°C and 160°C. The initial physical properties of the oils are shown in Table 1. These temperatures are commonly used for martempering.

Characteristics	Method	Oil A	Oil B	Oil C
Color	ASTM D1500	2.5	2	<1.5
Visc. 40°C. cSt	ASTM D445	223.6	93.85	80.04
Visc. 100°C. cSt	ASTM D445	19.12	10.87	9.85
Viscosity Index	ASTM D2270	96	100	102
TAN. mg KOH/g	ASTM D664	0.28	0.05	0.09
Flash Point - °C	ASTM D93	268	240	262

Table 1: Initial physical properties of the oils tested.

Copper, carbon steel, and aluminum strips were used as catalysts in the oxidation process. The sample size was 200 mL of fluid. The catalyst strips were immersed in the oxidation tube. An air flow of 14 liters/minute was passed through the oxidation tubes. The tubes were heated to the testing temperatures of 130°C and 160°C. The viscosity [10] and TAN [11] were measured at 8-hour intervals. Testing was terminated when the TAN of the samples exceeded 3.0 mg KOH/g. Results of the TAN testing is shown in Figure 2.

The testing shows that the oxidation rate is much faster at 160°C

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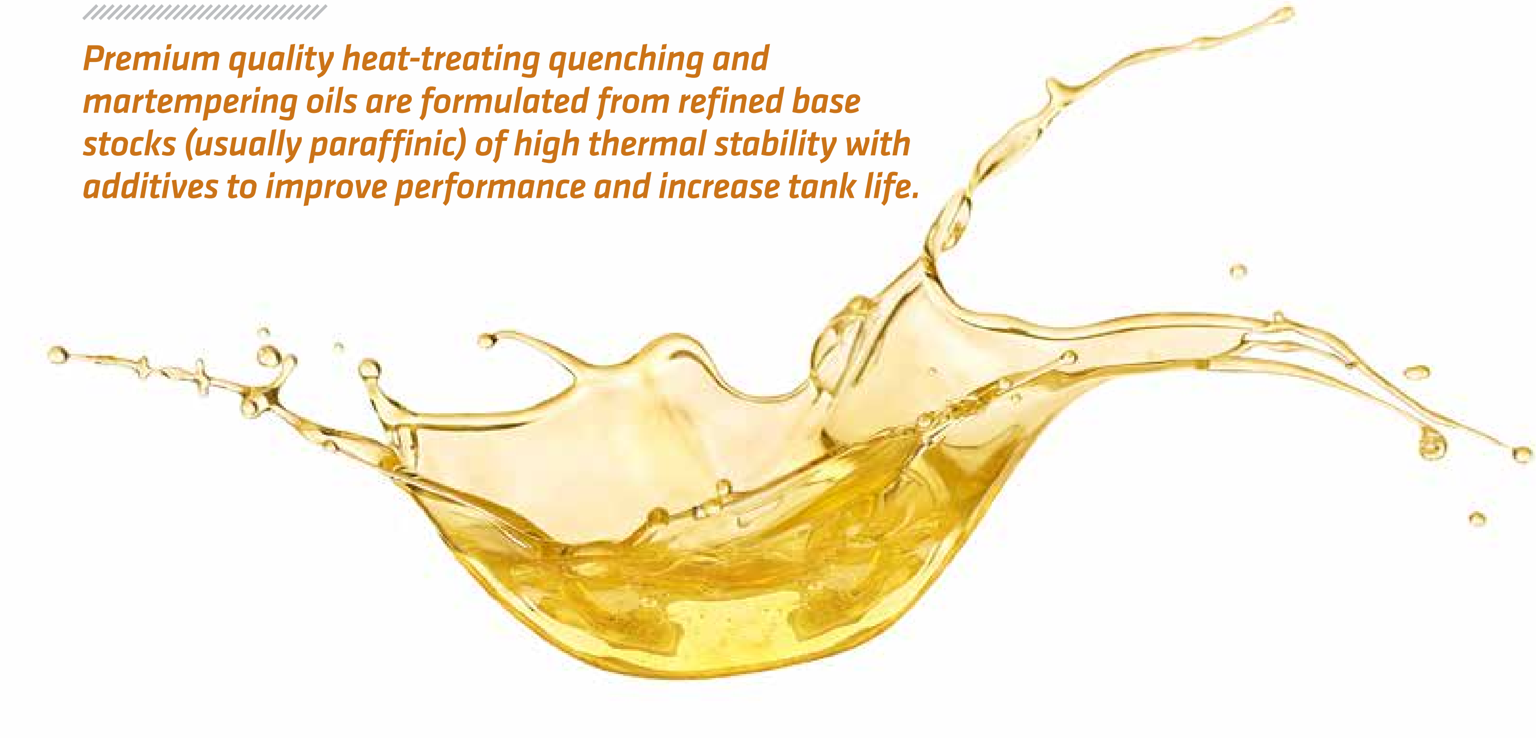

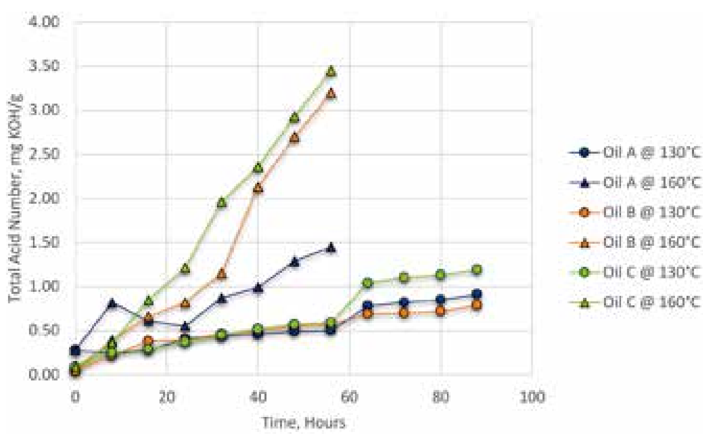

Figure 2: Results of oxidation testing of three martempering quench oils.

than at 130°C. The oxidation rates at 160°C are at least twice the oxidation rates at 130°C. The viscosity, as well as the quality of the oxidation package, plays a critical effect on the thermal stability of the oil over extended use.

CONCLUSIONS

Increasing the temperature of the quenchant is an effective method of reducing distortion and residual stresses in heat-treated components. However, increasing the temperature by only 30°C, which is a small increase in temperature in metallurgical terms, can drastically impact the life of the oil. In this simple example, it was shown that this small temperature can reduce the life of the oil by half. A cost-benefit analysis weighing the benefits and savings associated with parts having lower distortion (reduced straightening, lower residual stress, etc.) must be weighed against the shortened life of the oil, and the increased consumption and disposal costs of the oil. Finally, it is important that the proper oil be chosen to operate at the desired temperature. The oil must provide consistent quenching, as well as resist oxidation at the desired temperature of operation.

If you have any questions regarding this article, please contact the author or editor.

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