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# Application of polymeric quenchant in heat treatment of crack-sensitive steel mechanical parts: Modeling and experiments

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ABSTRACT

Success or failure of a quenching process is determined by selecting an appropriate quenchant. In this work, the quenching process of the automobile tie rods in different media including water, oil, and a polymeric solution was investigated. The microstructures and mechanical properties of the rods were predicted by a finite element simulation model. Several specimens were cut from the tie rods and heat treated by quenching in five different quenching media including water, oil, and PAG aqueous solutions with polymer concentrations of 10, 20, and 30%. The hardness tests and metallographic analyses were performed on the specimens. Considering the results of the simulations and the experiments, the optimum quenchant was selected and the tie rods were heat treated using this quenchant. The results showed that the use of Poly Alkylene Glycol (PAG) solution quenchants, with respect to its unique cooling mechanism, outperformed water and oil quenchants. The distortion and cracking was reduced compared to water quenching and, on the other hand, the mechanical properties which were not achievable by oil quenching were resulted using polymer-based quenching medium.



## 1. Introduction

Quenching is one of the crucial heat treatment processes for manufacture of the products with desired mechanical properties. Quench-induced cracking is often occurred in crack-sensitive parts as a result of improper processing. Preventing the crack formation is important not only to reduce the production cost during quality control but also to hinder the in-service failure due to fatigue emanating from hidden quench crack [1]. The quench cracking phenomenon has attracted many authors in the field of heat treatment of metals and alloys [2].

With the exception of water, oil quenchants have traditionally been the most commonly used quenching media in the heat treating industry, particularly for crack-sensitive steel parts [3]. One of the most commonly considered alternatives to quench oils is aqueous solution of water-soluble polymers such as Poly Alkylene Glycol (PAG). In addition to providing substantially greater safety with respect to fire and disposal, polymer quenchants have been shown to provide more uniform heat removal during quenching resulting in reduced thermal gradients and reduced distortion [3,4]. High molecular weight PAG is completely soluble in water at room temperature and therefore has been used extensively in the quenching of hot metals. PAG also exhibits a unique property in which it has inverse solubility as temperature increases in the water. As the temperature rises, the PAG precipitates out of the solution and deposits on the surface of the part. The deposited layer serves as an insulator, which governs the rate of heat extraction from the quenched part. This layer also causes complete wetting of the surface and therefore does not prolong the vapor blanket stage. As a result, a more uniform quench is experienced and the risk of distortion and cracking is minimized. As the temperature of the part decreased, the polymer dissolves back into the aqueous solution and maintains the concentration of the quenchant bath [5].

Success or failure of heat treatment not only affects manufacturing costs but also determines product quality and reliability. Heat treatment must therefore be taken into account during development and design, and it has to be controlled in the manufacturing process. For this reason, modeling of heat treatment processes has a great importance to engineers and scientists. Many researchers such as Brimacombe et al. [6–8], Sjöström [9], Denis et al. [10–13], Inoue et al. [14,15], Kang and Im [16], Lee and Lee [17], Şimşir and Gür [18] have done many valuable works on modeling of phase transformations during quenching of steel.

It should be emphasized that most of the previous works on modeling of heat treatment in steels have been focused on modeling of austenite–pearlite transformation in the eutectoid steel on the simple geometries in 2D, and less work has been done on multiphase steels with complex geometries in 3D. The present authors have recently developed a 3D FEM model on the simulation of temperature and phase transformations for low alloy steel mechanical parts [19].

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