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Failure analysis of induction hardened injector body

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ABSTRACT

The failure analysis of induction hardened injector body was carried out to identify surface defects. Producer revealed the defects using nondestructive testing method and requested a detailed analysis to determine the cause of their origin. Metallographic and fracture analysis were performed to study the material microstructure and fracture surface. Metallographic analysis proved the existence of a crack, initiated from the front face of component. Microstructure of the crack vicinity as well as hardness was significantly different with increasing distance from the face of component. Microstructure near the front face consisted of coarse martensite, while finer martensitic structure was observed with increasing distance from the front face. Hardness showed decreasing tendency with increasing distance from the front face. Fractographic analysis revealed the intergranular cleavage fracture near the front face of component. With increasing distance from the front face, quasicleavage fracture was observed with increasing areal fraction characterized by ductile fracture. Due to significant difference in microstructure and corresponding difference in hardness within a small area of component can be assumed, that the crack initiation occurred due to internal stress of the material caused by heat treatment. It is necessary to optimize the parameters of induction hardening process with respect to the different thicknesses of the product.

1. Introduction

Induction hardening of steel components is performed in order to improve strength and wear resistance, but it is necessary to optimize induction hardening process parameters. Induction heating frequency is the very important parameter, which must be chosen correctly to achieve uniform temperature in the shortest time with the highest efficiency. The overheating of component leads to enlargement of martensite needles, high brittleness of the quenched component and formation of cracks, which usually form at the boundaries of initial austenite grains. On the other hand, when quenching temperature is too low, the quenched component is insufficiently hard. After the hardening operation, tempering is usually performed. Component is heated bellow a lower critical temperature, held at this temperature for some time and cooled down. The main purpose of tempering is to reduce hardness to some extent, which leads to increase of toughness and ductility, but more importantly, relieve of internal stress after hardening [1–4].

Failure of components caused by inappropriate induction hardening parameters are reported in the literature [5–8] and mostly connected to fatigue failure caused by inappropriate induction hardening.

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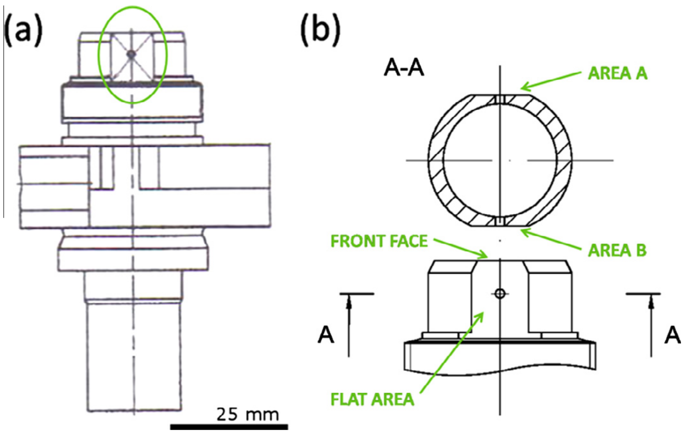

Fig. 1. Drawing of injector body: (a) whole component, and (b) detailed drawing of the region of interest.

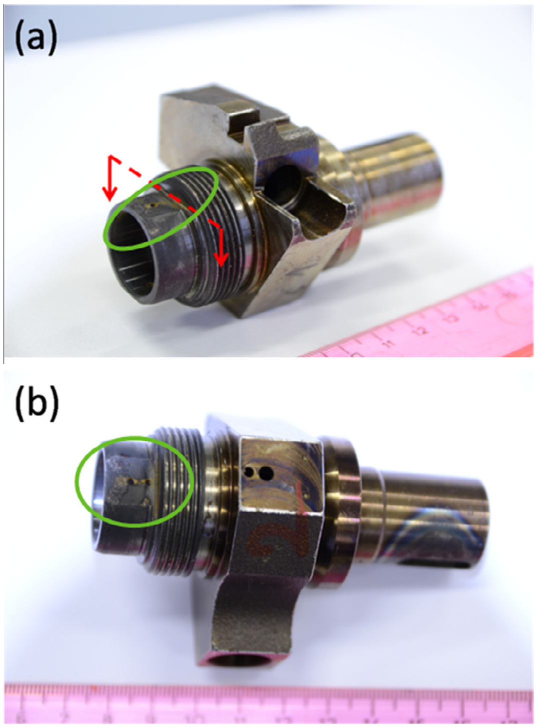

Fig. 2. Component I with indication of holes at the flat areas: (a) flat area A with indication of sectioning for metallographic analysis, and (b) flat area B.

The present work investigates occurrence of cracks at injector bodies. Components were made of 50CrMo4 steel and heat treated. Producer specified heat treatment process as induction hardening with subsequent tempering without any additional information about the process. Required hardness after induction hardening was in the range of 640–750 HV10 (57–62 HRC) and required proof stress after tempering was in the range of 750–850 MPa.

The producer reported surface defects, detected by nondestructive testing methods, at the front face of components and at the flat areas with holes.

2. Material and methods

Two identical injector bodies (marked I and II) were investigated to determine the origin of cracks reported by the producer. The component is shown in Fig. 1a and region of interest, flat area with hole, is highlighted. Detailed drawing of this region is shown in Fig. 1b. As can be seen from the drawing, there are two regions of interest with possible surface defects on