CASE STUDY OF VALVE FRACTURE OF DIESEL ENGINE LOCOMOTIVE

V. Šijački-Žeravčić[1], L. Baćanji[2], A. Ljevar[3], Z. Stamenić[1]

Case study of valve fracture of diesel engine locomotive of 641-013 type, was carried out. Design of this type of engine belongs to the early construction types, from 1934., with 600hp and 16 cylinders in V arrangement. Fracture occurred on the outlet valve trunk, more precisely near the interface section between the trunk and the valve head. Trunk valve material belongs to the class of steel with austenitic structure. The large part of the fracture surface was damaged during the accident which happened after the downfall of broken valve part into the engine. Undamaged part of the fracture surface, investigated by scanning electron microscopy, is characterized with ductile failure with a great number of inclusions, chromium carbides. EDAX analysis is showing the presence of sigma phase also. Hardness measurements, as well as the structure investigation by optical microscopy for the purpose of case studies were carried out.

INTRODUCTION

Stainless steel class, with high content of Cr and Ni and increased content of carbon, are used for engine valves manufacturing. They have to fulfill many properties of the engine valves, considering service conditions. Usually, their structures consists of austenite, δ-ferrite and carbide $(Cr,Fe)_4C$. However, under certain circumstances another phase, intermedial compound FeCr (known as σ-phase) can occur. Presence of this phase is very unfavorable, because it evokes brittleness of this steel, in range from room temperature up to 800°C. Kind of structural components in such steel classes depends on chemical composition, thermal treatment, duration of elevated temperatures, and applied cold plastic deformation (1). Aim of this paper was to show that under applied disadvantageous heat treatment of such stainless steel, σ-phase appeared, which resulted in material failure.

[1] Faculty of Mechanical Engineering, University of Belgrade;
[2] "Šinvoz", Zrenjanin; [3] High Technical School, Zrenjanin, Yugoslavia

BACKGROUND

On locomotive diesel engine of 641-013 type, fracture took place on exhaust valve trunk in transition zone between trunk and valve head. Valve fracture area was, in a big portion, damaged after the downfall in the engine. Basic features of this diesel engine type are: nominal effective power, Pe=600hp, nominal rpm, n(e)=1100, minimal rpm, n(min)=600, idle rpm, n(ph)=450, average effective pressure, Peh=55,30 N/cm^2 and 16 cylinders in V arrangement. Failure occurred after approximately 10 hours in service since valve was mounted, whereby the valve was subdued to the standard test which included 100h on a trial table.

PROCEDURES

Toward the investigation of this failure, chemical analysis, optical microscopy were scanning electron microscopy were accomplished.

Chemical analysis. Valve trunk composition was obtained by spectroscopic chemical analysis: 0.48% C; 2.7%Si; 1.2%Mn; 16,58%Cr; 0,146%Mo; 0,99%W; 0,12%V; 0.12%Al; 8.72%Ni; 0.09%Cu. That means that investigated material belongs to the stainless steel class for engine valves.

Optical microscopy. Usual metallographic preparation and investigation techniques for stainless steel specimen provided us valve trunk structure, Figure 1. Same structure was discovered on complete trunk cross section area, which consists of prior austenite grains, δ-ferrite (big white areas), carbides (dark spots) and σ-phase (thin needle structure).

Scanning Electron Microscopy (SEM). By studying of fractured area by SEM method, it is visible that all characteristics of ductile failure are present, although certain presence of secondary cracks is discovered in the middle of the specimen. That indicates some possibility of material brittleness, Figure 2.

Figure 3 is presenting the ductile fracture with a lot of carbide inclu-sions, broken carbide inclusions and δ-ferrite, or places wherethey were before failure. EDAX analysis (Energo Dispersive X-ray Analysis) indicates the presence of σ-phase, carbide of $Cr_{23}C_6$ type, as well as places with high concentration of Al with small amount of Si.

DISCUSSION AND CONCLUSIONS

On the basis of these investigations, it can be concluded that the σ-phase is present in the structure of investigated steel. That is a very frequent phenomenon in the steels where the chromium is one of the major alloying elements. Presence of σ-phase in the structure is disadvantageous, because it decreases ductility of material. According to the atomic structure, it is presenting equiatomic FeCr intermetallic phase with tetragonal structure. This phase, in majority of austenitic steels, is formed after prolonged holding on the temperatures of 500-900°C in the form of long dark needles oriented along the octaedar austenite planes. Sigma phase generating can be accelerated in the presence of second phase rich with chromium, as are, e.g., δ-iron or carbide of the $Me_{23}C_6$ type. With correct thermical treatment it is possible to avoid σ-phase forming, whereby the redistribution of alloying elements is occurring between δ-phase, carbides and of δ-ferrite.

On the basis of investigation, we can conclude that the thermal treatment of engine valve wasn't done correctly, what produced the σ-phase segregation. Because this segregation is taking place along grain boundaries, accompanied with appearance of secondary cracks, as well as acting of the variable loads which were affecting the valve, fracture occurred on the valve trunk after the relatively short period of time.

REFERENCES

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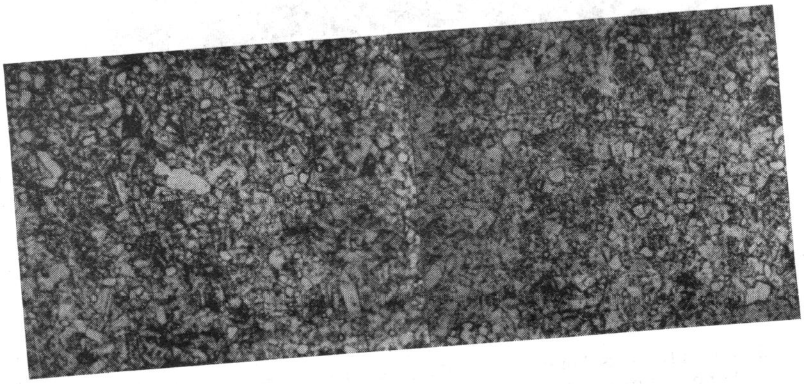

Figure 1. Microstructure of valve trunk

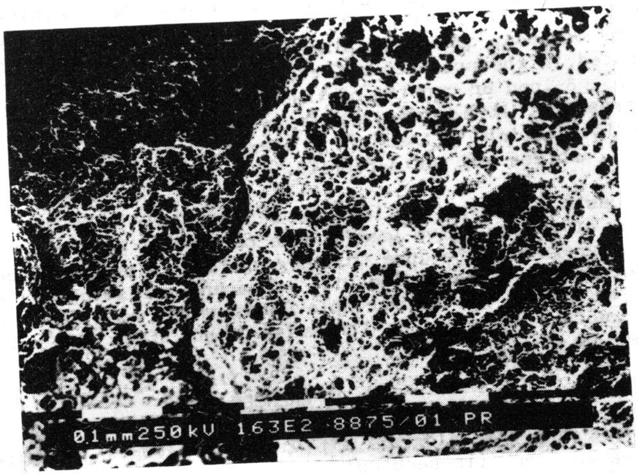

Figure 2 Secondary cracks in the middle of the sample. Ductile fracture.

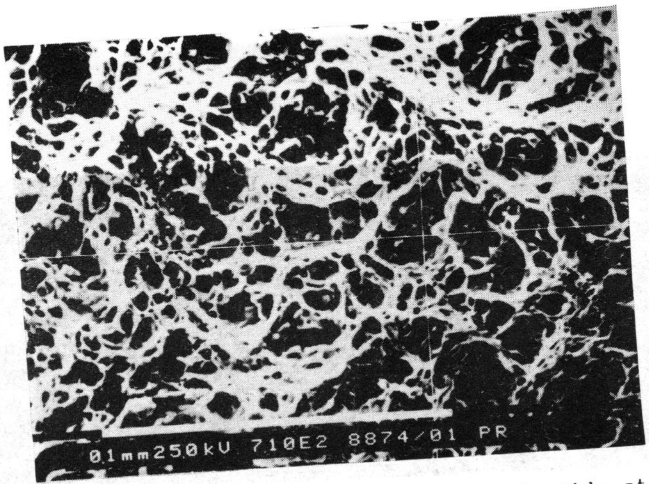

Figure 3 Ductile fracture. Carbides, σ-phase and voids at the places where carbides were before.