METHODS OF EVALUATION DEGRADED PARTS

Sylvia Kusmierczak
Jan Evangelista Purkyně University in Ústí nad Labem, Czech Republic
kusmierczak@fvtm.ujep.cz

Abstract. Degradation of parts brings not only a change of defined characteristics and shortening product life. For mass-market products, in adverse cases degradation may cause refraction, which may cause the risk of life for users. Common procedure in the analysis of causes of degradation is engineering already degraded components. There are many methods for evaluation of materials. In this article is presented as an example of the procedure and methodology applied in the search for the causes of degradation of the chosen part. On the degraded part of the core such methodology of evaluation was used, which was based on complex analysis of internal and external factors which could cause degradation of the examined component. Selection of appropriate analysis methodology thus leads to successful detection of causes of degradation of the material components.

Keywords: degradation, complex analyses, factors, methods of evaluation.

Introduction

Degradation of a technical object could be defined as a permanent, functionally adverse change on the surface or dimension of the technical object, which originated as a result of any of the mechanisms of wear. Degradation of parts is bringing a change of specified properties and shortening of product life. For mass-market products, in adverse cases degradation may cause fracture, which may cause the risk of life for the user [1-3].

In the search for the causes of degradation a procedure is often used to make analysis of the degraded components retrospectively. It means to take steps that will lead to the most exact description of the real state of the component.

Degradation processes have a common denominator, which is the material on which these processes occur. It is important to determine which of the internal (chemical composition, presence and type of inclusions, grain size, changing the chemical composition of the surface layer, internal stress, ...) and external (process stress components – heat, fatigue, dynamic, corrosive environment, wear, ...) factors have a dominant influence on the formation causes that lead to degradation [4; 5]. For this purpose the quantitative and qualitative methods to evaluate the properties of the components are used. Therefore it is necessary to personally investigate the actual loading conditions of components, take samples, obtain documentation for products and manufacturing technology and not rely on "second-hand information", but be at most objective.

This detected information is needed to verify, i.e. to confirm the actual chemical composition, to determine the actual dimensions, hardness, strength characteristics and the characteristics of plasticity, toughness, make macro and microscopic analysis, implement REM analysis (e.g., to determine the method of distributing crack fracture, the type of breach material and morphology of the fracture surface, the appearance of oxide particles, corrosion products, non-metallic inclusions, determine the presence of the carbide particles or non-ferrous metal intermetallic phases on the fracture surface) with regard to the objective and this is to find the real cause of degradation [6].

The selection of analytical methods at present is very wide, so it is important to choose a method that reliably detects the cause of degradation of technical components and at the same time will be economical [7-10].

This article deals with degradation of foundry cores in the casting process of automotive pistons, where the change in the properties of the cores results in deterioration of the quality of the resulting castings, resulting in economic losses. Moulds and cores are components that are exposed during casting temperature changes. Therefore, as their product alloyed steels for hot working are used. Steels for hot working should have increased resistance to tempering, high hardness and strength while maintaining relatively high toughness. This is achieved by alloying elements such as Cr, Mo and V. A further increase of the resistance of the material against this loading contributes to creating a hard surface layer, e.g., by nitriding.

The aim of this work is to show on a definite example the necessity of complex approach to dealing with situations, where limit states and subsequent degradation occurred. This means that from

already present degradation retrospectively its cause is determined using available metallographic methods and standardized test materials.

Description of the Situation and Experimental Sample

Degradation of foundry cores occurred during the casting of automotive pistons, as a result of degradation the lifetime of the cores amounts to only a tenth of the required life. On the surfaces of the cores cracks occurred, which can be described as random, see Fig. 1.

Fig. 1. **Experimental sample, area of cracks**

As the material of cores steel by CSN 41 9522 was used, after hardening, nitriding, with surface hardness 50 ± 5 HRC. The requirements for the chemical composition are shown in Table 1.

Table 1

Chemical composition according to ČSN 41 9552

Element, wt. %							
C	Si	Mn	P max	S max	Cr	Mo	V
0.36-0.42	0.90-1.20	0.30-0.50	0.030	0.30	4.0-5.50	1.10-1.40	0.25-0.50

Methods of Evaluation

Chemical analysis of samples

Chemical composition was analyzed spectrophotometrically at the equipment Tasman Q4. Arithmetic averages of five measurements for each sample are listed in a comprehensive table, see Table 2.

Table 2

Chemical composition

Element, wt. %										
C	Si	Mn	P	S	Cr	Mo	Ni	Cu	V	Fe
0.51	0.79	0.24	0.016	0.013	4.75	1.06	0.06	0.04	0.25	91.90

From the results it is evident that the C content significantly exceeded, on the other hand, there was not the condition of the minimum content of Si, Mn, Cr and Mo met. The presence of these elements in the steel improves its hardening ability.

Evaluation of hardness according to ČSN EN ISO 6507 – 1

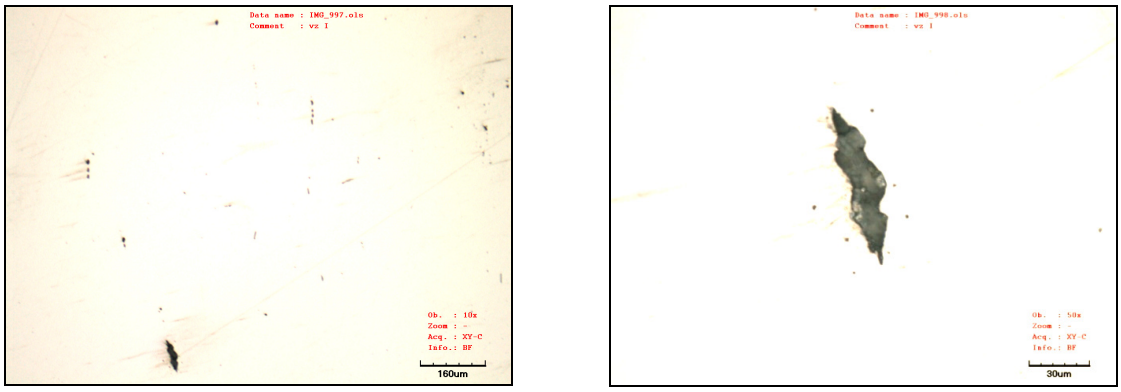
Shimadzu hardness tester was used; the measurement conditions are given norm. Arithmetical mean value of ten measured hardness is HV1 231. The determined value does not comply with the required criteria for material hardness.

Complex microstructural analysis

The material was complexly evaluated microscopically using the methods of light and electron microscopy. The microstructure was examined by using the confocal laser microscope Olympus Lext OLS 3100.

Evaluation of purity of the material in the non-etched state has been in accordance with ČSN ISO 4967 (Determination of non-metallic inclusions). The material contained a large amount of inclusions which were arranged in rows. Two kinds of inclusions are shown.

Gray-colored inclusions predominate here, with sharp ends, elongated in the direction of forming of material - can be assumed that it is a sulphide type inclusion. To a lesser degree around of these inclusions there were smaller inclusions (Fig. 2, b) corresponding to oxide inclusions.



a) Inclusions b) Detail

Fig. 2. **Material, non-etched**

An analysis of around occurring cracks showed that the cracks under the surface of the material significantly interfere. Although with nitride surface of the core, at the surface spreading crack was observed as a layer typical for the corrosion process, see Fig. 3. Under the surface of the material a crack was located that had significant sharp finish.

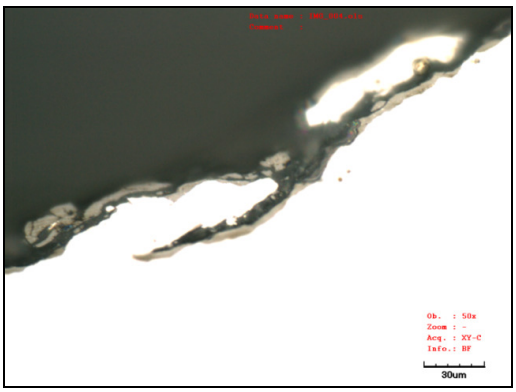


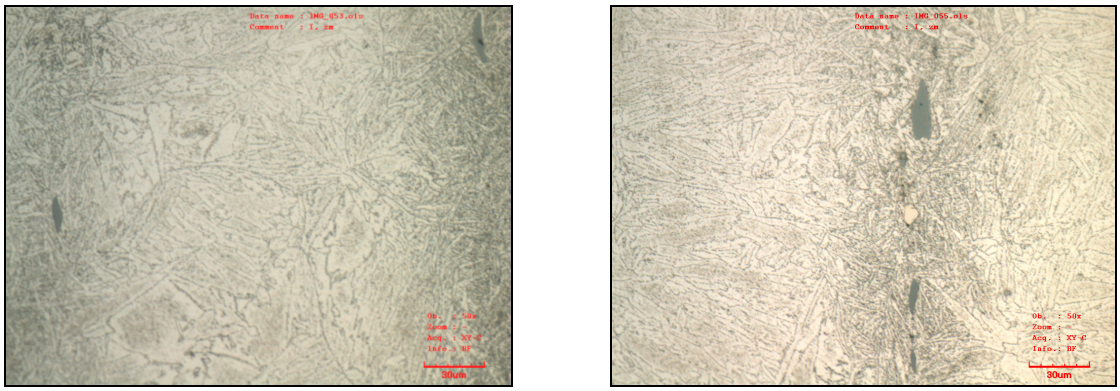
Fig. 3. **Area of crack, non-etched**

After etching the material significant bandpass heterogeneity of the material was observed (Fig. 4), which relates to the method for manufacturing the blank. This heterogeneity is, of course, for this type of products undesirable. Besides, a heterogeneous structure can be observed and array arrangements in inclusions. Microstructure of the sample was composed of fine acicular ferrite and globular carbides. Inclusions form lines, which are probably formed by forming the blank. This distribution of inclusions is definitely undesirable because it causes significant stress fields around the line, which is very sensitive to external stimulus.

Outside the crack area a surface layer was observed.

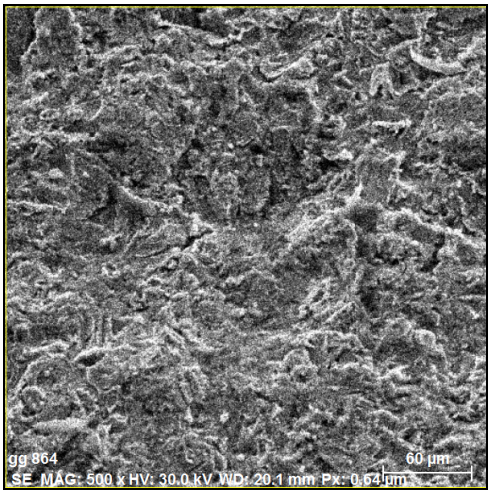
Based on the analysis of the chemical composition of the layers, it was possible to state that the layer with respect to the required chemical heat treatment contained a significant proportion of Fe and N, Fig. 5.

The phase 1 was identified as substantially elongated shape in the direction of the forming material, based on its shape, colour, but in particular chemical composition; it can be assumed that it was inclusion of the type MnS. It was interesting to see that in the vicinity of the inclusions quantities of dimensionally finer globular phases were located.



a) Structure b) Inclusions

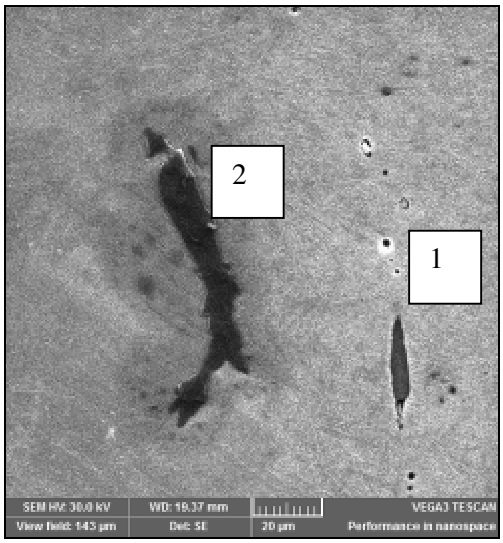
Fig. 4. **Material, etched**



Element	wt.%
Cr	3.9
Fe	53.2
Al	0.3
N	3.7
V	0.2
Mn	0.2
Si	4.0
S	0.1
Ni	0.1
O	20.9
Ca	0.1
Mo	0.9
Sum	100

Fig. 5. **Surface layer, REM, Planar analysis**

The phase 2 can be described as the phase which reached the size of about 80 microns, it is branched, at the ends of the branches it has sharp ends and it is not oriented in the direction to forming material. In its chemical composition there is a a substantial part of C, N and O, which are elements of the characteristic formation of the characteristic phases, such as carbides, nitrides and oxides of iron, Fig. 6. The present phase can be in a material which is subjected to rapid temperature changes during the casting phase considered, which will adversely affect the life of the core material.



a) Phases

Element	[wt.%]
C	11.4
S	27.4
Cr	6.9
Fe	4.6
Mn	45.5
O	0.0
N	3.5
Al	0.2
P	0.1
Si	0.1
Ni	0.0
Ti	0.0
V	0.4
Sum	100

b) Phase 1, EDS

Element	[wt.%]
C	34.7
Cr	3.4
Fe	46.9
O	7.4
N	6.9
Na	0.8
Sum	100

c) Phase 2, EDS

Fig. 6. **Phases in material, REM, point analyses**

Conclusion

Before chemical-thermal treatment the material is not prepared for correct processing of nitriding, it can be assumed that the cause of crack formation is dealing with the formation of the nitride layer. Propagation of cracks was also supported by repeated thermal stress cores during casting. In this case, we can say that degradation of cores was response to the limit state, which occurred as a result of:

Internal factors:

- chemical composition of the material cores - not complied with the limits set for individual elements,
- occurrence of inclusions, their chemical composition and distribution in the microstructure of the material – and the subsequent significant changes of stress in their area,
- microstructure which did not correspond to the desired microstructure,
- changes in interfacial stress nitride layer - base material, which are caused by the difference in volumetric expansion of the nitriding layer and the base material cores.

External factors:

- thermal stress of material cores,
- corrosion loading.

It follows that the main proportions to degradation and subsequent formation of cracks in this case are caused by the internal factors of the material. For this determination it was necessary not only to make use of the basic metallographic methods and procedures, but also complex approach to the assessment of the external and internal factors that led to the degradation of the technical object.

References

1. Dvorak I. Degradation and limit states. VA Brno, 2003.
2. Janicek P., Vlk M., Peslova F. Limit states of technical objects in technical expertness, In Forensic Engineering. Vol. 13, 2002, n. 4, pp. 187-205, ISSN 1211-443X.
3. Ondracek E. Prediction of mechanical properties of metallic materials on the basis of structural characteristics. 362 p. 1985.
4. Stodola J., Peslova F., Krmela J. Wear of machine parts. University of Defence Brno, 2008, 197 p., ISBN 978-80-7231-552-9.
5. Puskar A. Limit states of materials and components. Veda, 1989, pp. 304, ISBN 80-224-0020-3.
6. Michna S., Kusmierczak S., Bajcura M. Metallography – methods and procedures. Adin, 2010, 192 p., ISBN 978-80-89244-74-4.
7. Kusmierczak S., Kraus P., Analysis of the causes of degradation of surface-treated sheet metal of part the lift. In Internation Multidisciplinary Conference, IMD 2013. The 10th edition, Proceedings, May 22nd-24th, 2013, Baia Mara, Romania, Nyíregyháza, Hungary, 2013, pp. 83-86, ISBN 978-615-5097-66-9.
8. Naprstkova N., Michna S. Identification and evaluation of machining product defects in teaching of students at college, Engineering for Rural Development, pp. 569-572, 2013, Vol. ISSN 1691-3043
9. Novak M., Naprstkova N. The influence of cutting conditions on surface roughness during steel X38CrMoV5 grinding. In Key Engineering Materials, vol. 581: Precision Machining VII. TTP. Zurich. pp. 247-254. ISBN 978-3-03785-840-0.
10. Michna S., Kusmierczak S., Contribution Into Changes in the Structure of Two-Phase Titanium Alloys in Forging, Engineering for rural Development, Jelgava, 23.-24.05.2013, pp. 228-231, ISSN 1691-5976.