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ANÁLISE DE FALHA EM PROLONGADOR DE PRENSA MECÂNICA PARA COMPACTAÇÃO DE PÓS METÁLICOS: UM ESTUDO DE CASO[1]

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Resumo

Este trabalho investiga as causas que levaram à fratura de um dispositivo prolongador. O componente faz parte de um conjunto de fixação de punções e machos de um equipamento para compactação de pós metálicos. A análise identificou mecanismos macro e microscópicos através de análise da superfície de fratura. Foram adotadas técnicas de caracterização como análise visual, ensaio de dureza Rockwell C, análise metalográfica e microscopia eletrônica de varredura. Os resultados indicam que a trinca iniciou na região próxima à superfície, devido à uma fragilização do material. A falha resultou em nucleação de trincas intergranulares no material. À medida que a trinca avançou, o micromecanismo de fratura alterou para fratura frágil por clivagem, até a ruptura final da peça.
Palavras-chave: Fratura; Análise de falha; Componentes mecânicos.

FAILURE ANALYSIS OF AN EXTENSOR IN A MECHANICAL PRESS FOR METAL POWDER COMPRESSION: A CASE STUDY

Abstract

This study aimed to investigate the causes that led to fracture the screwed component that is part of an extender device of a press for compacting metal powder. Analyses were carried out to identify the possible macroscopic and the microscopic fracture mechanism. The characterization techniques used were: visual analysis, hardness Rockwell C tests, metallographic analysis and scanning electron microscopy. Results showed the crack nucleated at the surface, close to screw thread, possibly due to a heat treatment embrittlement resulting in intergranular cracks through the material. As long as the crack propagates, fracture micromechanism changes to quasi-cleavage until the final rupture of the part.
Key words: Fracture; Failure analysis; Mechanical devices.

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1 INTRODUCTION

Powder metallurgy is the process for blending powdered materials, shaping then into a desired shape by compression or other techniques, and heating the shaped material in controlled conditions to acquire mechanical strength for the final part. Powder metallurgy process combines the features of shape-making technology for powder compaction with the development of final material and design properties.[1,2]
The catastrophic failure of materials has been observed for a long time. Its occurrence is usually the result of deficiency of the project, inadequate materials processing (impurities, internal defects, inadequate heat treatment, etc.). Other factors such as deterioration in service (corrosion, erosion, chemical attack) and inadequate equipment operation (overhead, maintenance inefficient and collisions) can lead to unexpected failures.[3] According to Metals Handbook,[3] the analysis of failures causes can be made with the interpretation and characterization of the fracture surface. Those areas analyzed show a topographic map that often reveals the history of pre-failure events. The objective of fracture analysis is to identify the reasons that led some part or equipment to fail before the time expected, helping to prevent the occurrence of future unexpected failures.
The mechanical component analyzed supports a male used for compaction of metal powders and non-metallic and assembly it to an extender. The device is necessary in order to provide an adjustment of height of the device in the equipment.
A press of 100.000 kg capacity is the equipment in which mechanical components are assembled. This equipment has a floating table, with extraction driven by a pneumatic cylinder independent of the column guides, but synchronized with the hammer pressing. Figure 1 illustrates the pressing machine, used for pressing powder and where the devices are coupled.

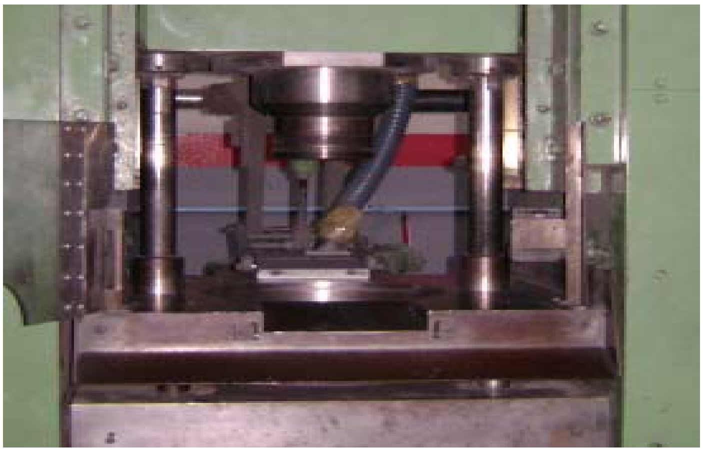

Figure 1: Press for compression of powder metal (LdTM - UFRGS).

This study aims to identify the causes that led to failure the extender during service, when cyclic tensile stresses in the longitudinal direction are involved. These efforts are critical during the extraction of parts in the press.

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2 MATERIALS AND METHODS

2.1 Device Analysis

The failed device belongs to a set of fastening elements and needle. Figures 2 and 3 illustrate the needle and extender, respectively.

Figure 2: Needle holder.

Figure 3: Extender.

2.2 Assembly of the Devices

The two elements are fixed one to another and this is done manually putting the extender in a wrench. The needle holder is screwed to its limit and on its flat base is positioned the needle. The needle is coupled to the components through a cap that has four perforation holes with a head screw of 6mm. The threads are made on the face of non-threaded device, with a safe distance to not interfere in the assembly. Figure 4 illustrates the assembled components.

Figure 4: Needle holder and extender assembled.

The needle holder failed during service, more precisely during the extraction step. The extraction step is considered the most critical of the process, since it concentrates the highest tensile stress in the interface between the needle holder´s thread to the extender´s thread .Figure 5 illustrates the needle holder failed.

Figure 2: Needle holder failed.

2.3 Characterization Methods

The following characterization methods were applied to help in investigating the causes that led to the component failure.

2.3.1 Macrographs of the fractured surface
Macrographs were taken to visualize the fracture surface in order to identify the macromechanism of failure and possible regions of initiation and crack propagation as well as the final rupture region.

2.3.2 Chemical composition analysis
Chemical Composition Analysis was performed by optical emission spectrometry using a spectrometer SPECTRO, model Spectrolab LAVFA18B, in order to identify chemical elements present in the composition and the type of steel used in the manufacture of the component.

2.3.3 Rockwell C Hardness
Rockwell C Hardness measurements were performed to identify possible thermal and / or surface treatment done on the component, using a PRECISION durometer, model MRS, applying a load of 150 kgf and using diamond indenter.

2.3.4 Metallographic analysis
For the metallographic analysis a sample was extracted from the region of the fracture and after mounting it was grinded and polished according to the ABNT NBR – 15454(5) standard from 2007. The sample was etched using Nital 2% and observed under optical microscopy.

2.3.5 Scanning Electron Microscopy (SEM)
Samples of the fracture surface were analyzed by scanning electron microscopy using a scanning electron microscope JEOL, model JSM 6060, using secondary electron imaging. SEM was used to identify the micromechanism of failure and detect possible cracks and other defects on the surface.

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3 RESULTS AND DISCUSSION

3.1 Macrographs of the Fractured Surface

According to Figures 6 and 7, there is no considerable plastic deformation on the surface, characterizing a brittle fracture and there are no signs of torsion loading or beach marks. In the upper region of the fracture surface (indicated by arrows) close to the screw thread, smooth fracture morphology was observed, possible a crack initiation region. This region was subjected to SEM for more detailed analysis.

Figure 6: Fractography illustrating a , smooth fracture with little plastic deformation.

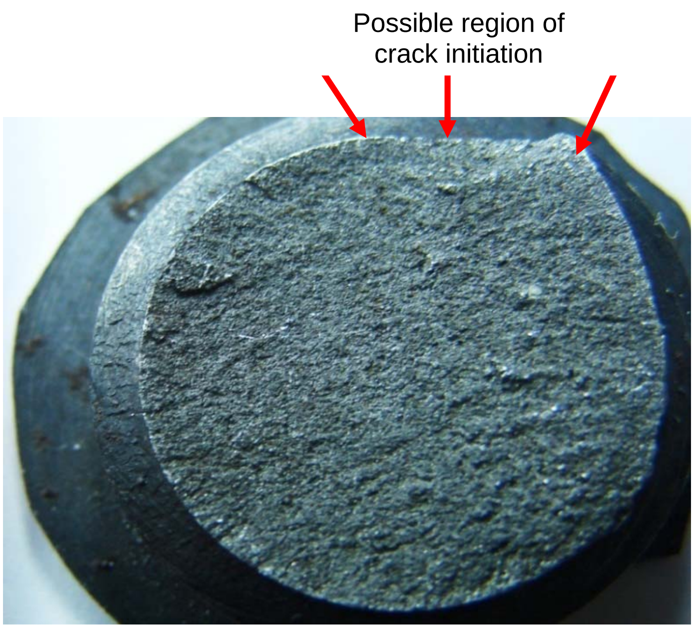

Figure 3: Fractography illustrating possible crack initiation.

3.2 Chemical Composition Analysis

Table 1 shows the chemical composition obtained from the results and comparing with the chemical composition for AISI O2 steel.

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Table 1: Chemical analysis results (%wt)

Material	C	Si	Mn	Cr	W	S	P
Sample	0,87	0,13	1,78	0,18	--	> 0,06	0,018
AISI O2	0,85-0,95	0,50 max	1,60-1,70	0,50 max	--	0,03 max	0,03 max

Results in Table 1 indicate that there is high sulfur content in the material. According to Chiaverini(4) it is undesirable since it can form non-metallic inclusions, decreasing mechanical properties such as tensile strength, ductility and toughness for steels with higher amount of carbon.

3.3 Rockwell C Hardness

Table 2 shows results for hardness measurements. According to the results, the material has an average hardness of 68 HRC, high for this class of steel, which could be significantly reducing its toughness.

Table 2: Results for Rockwell C hardness measurements.

Sample	HRC
1	66
2	68
3	68
4	70
5	68
6	70

3.4 Metallographic Analysis

Figures 8 and 9 illustrate metallographic analysis results. It is possible to observe a typical martensitic microstructure and some possible MnS inclusions possibly due to the high manganese content, as shown in Table 1.

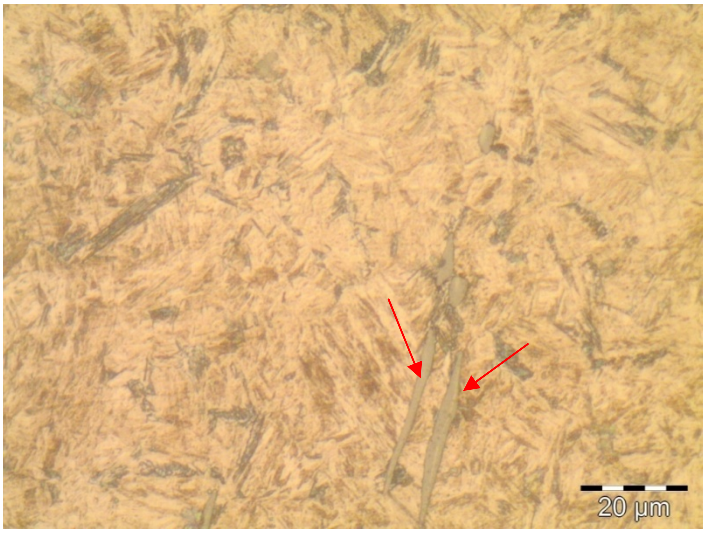

Figure 4: Typical martensitic microstructure with possible MnS inclusions (indicated by arrows).

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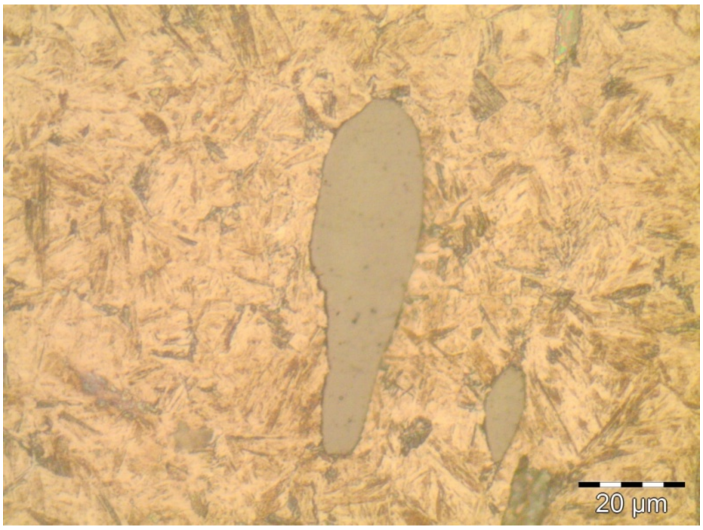

Figure 5: Typical martensitic microstructure with possible MnS inclusions.

3.5 Scanning Electron Microscopy

The SEM analysis of the region close to the screw thread, evidenced by arrows in Figure 7, shows that the crack propagation is intergranular. Figure 10 shows the unmistakable intergranular feature. It is evident that some embrittlement of the grain boundaries has occurred. The material high carbon content may lead to the presence of carbides in the grain boundaries due to inadequate heat treatment. Besides, a screw thread is a stress raiser itself, which facilitates nucleation and propagation of cracks, according to Metals Handbook.(6) Another possibility to be considered is hydrogen embrittlement, which also leads to intergranular crack failure.(7) The possibility of stress corrosion was not considered since the component presented neither any surface corrosion nor intergranular corrosion evidence. One more possibility to be considered is excessive load during assembly, according to the Material Property Data.(8) It could be an over stressing agent contributing to the nucleation of surface cracks in the region of the screw thread.

Observing the crack surface in the regions not close to the nucleation crack point one clearly sees that the fracture micromechanism changes. Cleavage facets are seen and also some void coalescence. The considerably small volume of dimpled areas indicates the very limited ductility of the material. Since the component was stressed under tension, one may conclude that cracks propagated until a critical situation was reached that lead to the failure. Thus, failure was initiated in the embrittled region where intergranular fracture occurred and propagated due to the low ductility presented by the high strength material. Figures 10, 11, 12, 13, 14 and 15 illustrate the features found in the crack surface that led the component to fail.

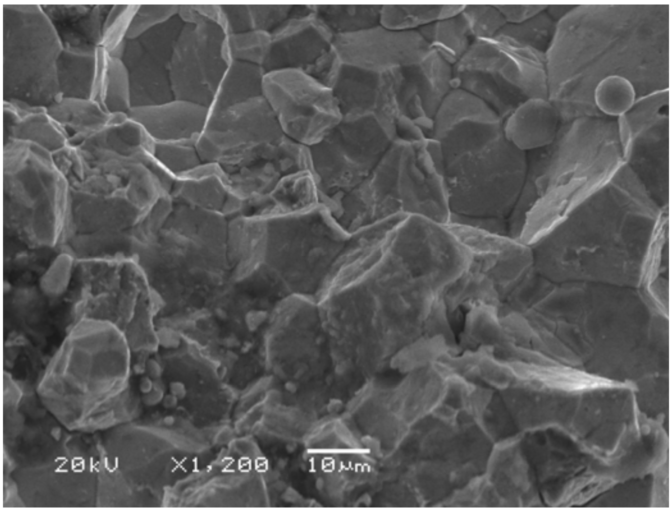

Figure 6: Fractography of the region close to the screw thread, where the unmistakable intergranular fracture is seen.

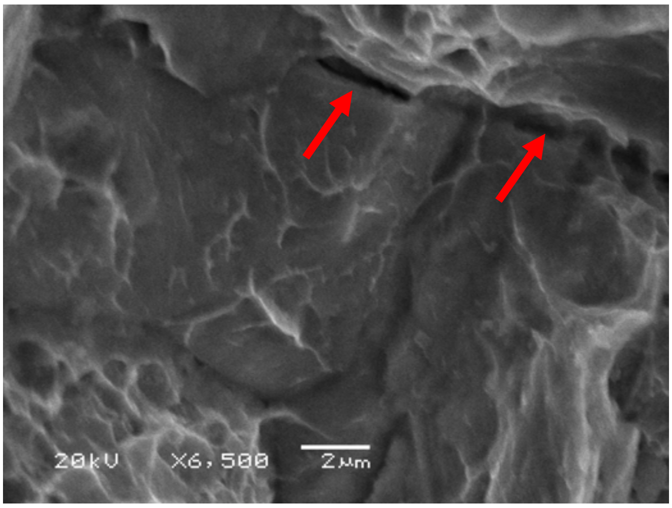

Figure 7: Fractography of the region close to the screw thread showing some grain boundary secondary cracks.

Figure 11 illustrates possible microcracks on grain boundaries (indicated by arrows).

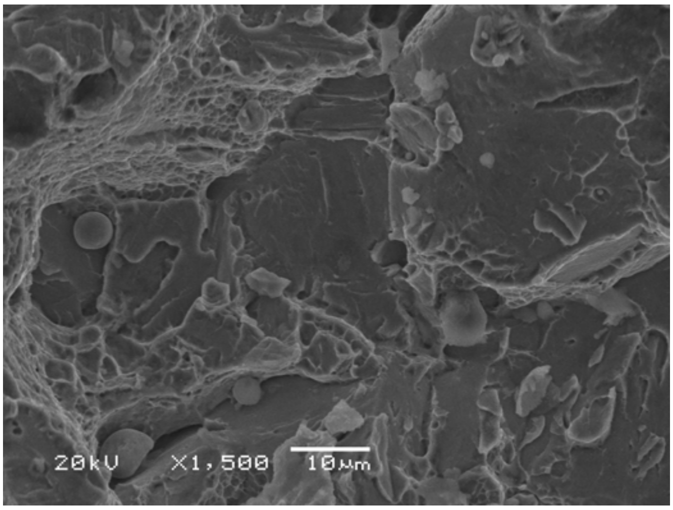

Figure 8: Fractography in the central region of the fracture surface showing the fracture micromechanism change. Cleavage facets and regions of shallow dimples are seen.

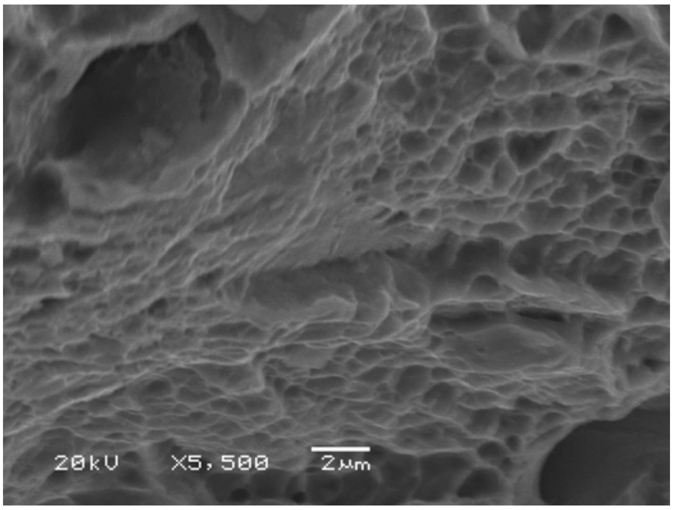

Figure 9: The shallow dimples are an evidence of the low ductility of the material.

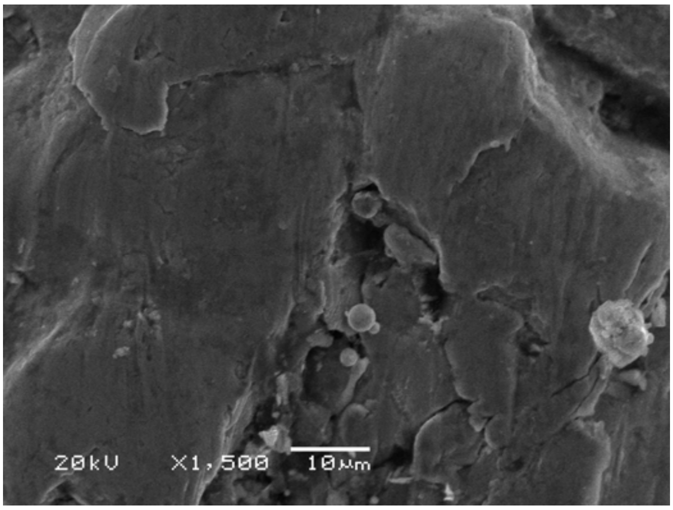

Figure 10: The fracture surface in the central region of the specimen shows signs of deformation.

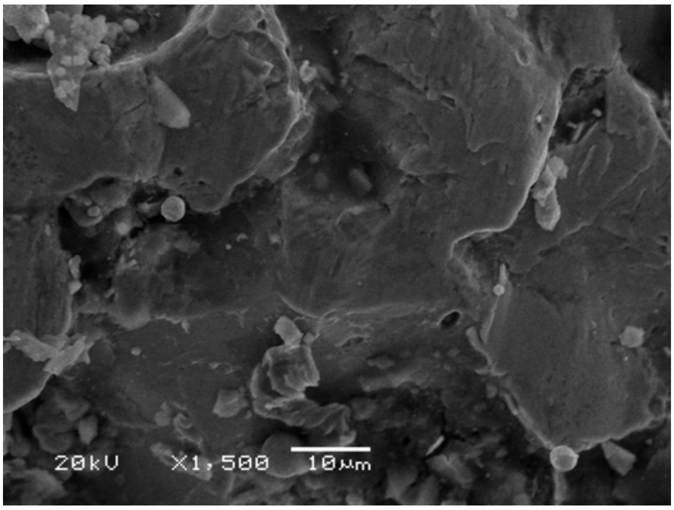

Figure 11: A typical cleavage facet in the central region of the fracture surface.

4 CONCLUSION

According to the chemical analysis the material chemical indicated that the material may be O2 tool material. Hardness measurements showed that hardness values are higher than appropriate for this class of steel.

Optical microscopy showed that the microstructure is completely martensitic, which is in accordance with the high hardness values found. It seems that the structure was not annealed or annealing was performed under an excessive low temperature or a short time. The structure presents non-metallic inclusions, possibly MnS, definitely deleterious for aimed mechanical properties.

Fractography showed that the crack nucleated close to the screw thread and the fracture micromechanism was intergranular. Intergranular fracture was identified only in a small region and the sample presented cleavage as the dominating fracture mode, as well as some localized dimpled regions.

Results show that the material underwent embrittlement in the region close to the screw thread. Embrittlement may have come from inadequate heat treatment or contamination, like non-metallic inclusions or hydrogen embrittlement. Screw threads are stress raisers and may enhance crack propagation. There is also the possibility of an excessive load applied during utilization of the component. No doubt, crack initiation was close to the screw thread and since the material presents high hardness and considerable low ductility crack propagation was not precluded.

At last, it is recommended to use a tougher material for the application and also an adequate heat treatment. Chemical composition should be carefully controlled in order to avoid contamination and the presence of non-metallic inclusions.

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