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Study of the failure of one machining tool

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ABSTRACT

This paper presents the study of the failure of one tool that was broken in two pieces inducing a serious damage in the component that was being machined. The main difficulty for this analysis came up against the need of keeping the broken tool in the as-received condition due to legal requirements. Due to this situation it was not possible obtaining tensile test specimens to determine the strength and ductility of the material or metallographic samples which could reveal its microstructure. Consequently, the study was restricted to observing the fracture surfaces in the scanning electron microscope and identifying by X-ray energy dispersive spectrometry, the nature of the substances which could have played a role in the failure process. This analysis allowed identifying the failure origin was sited on a notch induced on the periphery of the tool in a zone where a section change and a marked stress concentration existed. This notch was covered by a dark substance whose composition was near the same than that of the blueing coating, indicating that it was already opened when this surface treatment was applied. These results, leaded to a conclusion blaming the machining operation previous to the blueing coating for the failure.

1. Introduction

Failure analysis is a process performed in order to determine the root causes or factors that led to an undesired loss of functionality. During the investigation the analyst must collect, examine and evaluate all the available data in order to determine its plausible origins and the sequence of the events which leaded to the failure. The immediate objective is to find the root causes of the failure in order to obtain the compensation for the induced damage even if the really important is to prevent similar failures in new components. Usually these failure analyses involve obtaining samples for chemical analysis, mechanical tests and metallographic studies. It is not necessary to remark that this process has a destructive nature and the original as-received condition is lost.

However, in some cases the failure analysis is restricted to identifying its origins without destroying the failed component, making it more difficult determining the root causes of the failure. This situation was found in the failure analysis of a machining tool whose fracture induced a serious damage in the component that was being machined. The high cost of this component induced a legal process to determine the root causes of the failure and who is responsible for it and must pay the requested compensation but precluded destroying the part for obtaining samples even when obtaining previously evidence of its as-received condition. Consequently, the failure analysis had to be performed using a non-destructive methodology analysis, keeping the broken tool without modifying it.

The present paper describes the failure analysis of one machining tool carried out by non-destructive methods and the provisional conclusions reached after this study.

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2. Experimental procedure

The first step in the analysis consisted in obtaining the maximum information on the previous history of the failed tool. Unfortunately, the only data available was the known fact that the tool failed suddenly, damaging the costly component which was being machined. Fig. 1 presents a general view of the two pieces in which was broken the machining tool, as it was received in the laboratory. No information about the steel grade used for manufacturing the tool or the heat or surface treatments was given.

It is convenient remarking that the failure analysis must possess a fully non-destructive character. Consequently, the visual examination, which constitutes always an important stage in these studies, is even more transcendental in this case when no metallographic samples can be obtained. Not only the fracture surfaces but also the whole tool was examined both by the naked eye and using a small stereoscopic microscope for detecting the finest facets. The limitation of no destroying the tool precluded cutting it but, fortunately, one of the two broken pieces was small enough to allow introducing it into the vacuum chamber of the scanning electron microscope, carrying out its fractographic analysis. Moreover, the X-ray energy dispersive spectrometer incorporated to this microscope facilitated identifying the nature of the phases which were present on the fracture surface.

In order to overcome the limitation arisen from the impossibility of obtaining the samples from the tool an alternative via, based on the use of metallographic replicas for revealing the microstructure of the steel, was considered. Actually, this methodology possesses a near no destructive character as the induced damage is just that due to the polishing and kindly etching of a small area of the periphery. However, this possibility had to be also rejected as the periphery of the tool was covered by a coating, which seems to correspond to blueing by its morphology, which precluded gaining access to the base steel without eliminating it from a reduced area, action that was not permitted.

3. Results and discussion

Visual examination of the fracture surfaces pointed towards a fracture of brittle morphology, in good agreement with the sudden and premature failure. Both, the naked eye examination and that more detailed, performed with the help of the stereoscopic microscope, revealed the presence of a marked notch, darker than the remaining fracture surface, sited on the left hand side of Fig. 2. The morphology of this notch points towards the machining of the section change of the tool existing at that point, with an accentuated neck, clearly visible in Fig. 3, which presents a lateral view of the two halves of the tool. From this origin the crack grew circumferentially until the sudden failure of the tool was induced when the unbroken ligament was not able for withstanding the loads applied on it. Fig. 4 presents schematically the whole failure process while in figure, can be observed the necking of the tool in this zone.

Fractographic analysis in the scanning electron microscope of the smallest piece of the broken tool yielded some very interesting data for knowing not only the fracture origin but also the mechanism responsible for its progression. It was observed that the dark notch was covered by a cracked substance deposited on it. Fig. 5 presents a micrograph obtained in this area. X-ray energy dispersive spectrometry led to the spectrum shown in Fig. 6, where significant peaks of iron, oxygen and carbon are observed. Considering this results it looks logical identifying the layer that covers the notch as iron oxide. The origin of the peak of carbon is later discussed.

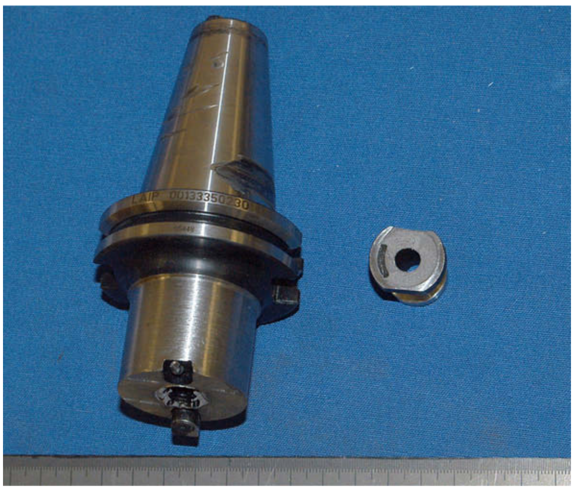

Fig. 1. General view of the two pieces of the failed tool.