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Analysis of turbo impeller rotor failure

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ABSTRACT

The aim of the current study is to analyze the failure of a turbo impeller rotor made of AA 7075 aluminum alloy. We found a drilled hole partially out of position, and it might have been the possible cause of failure. The aim of the analysis is to check the influence of the machining mistake on the failure. Fracture analysis techniques were performed through scanning electron microscopy and low-magnification optical microscopy. The alloy was characterized through chemical, microhardness and microstructural analyses. The numerical simulation was performed to check the stress level generated in the impeller depending on the size of the hole chamfer and on the introduction of the machining mistake. We concluded that the failure in the rotor began in a hole adjacent to the partially drilled one and attributed the fracture onset to the stress concentration caused by the chamfer burrs and by the unbalance caused by the partially drilled hole.

1. Introduction

Turbo impeller rotors are components used in gas treatment and pressurization systems, as well as in turbo compressors, power generation plants, engines and air compressors. The turbo-expansion system allows increasing the net power efficiency and protects the components. These rotors have blades that provide and receive power from a fluid – which is in constant motion – and they are usually made of stainless steel, titanium alloys and aluminum alloys [1–2]. Failures in the compressor may seriously compromise the operation of the system. Looing a blade due to fatigue or having a fragment of it inside the turbine may cause catastrophic damages to the system because of the high-rotating impeller [2, 3].

Chu et al. [4] analyzed the failure of a stainless steel centrifugal compressor rotor exposed to H_2S through the surface, chemical and microstructural analyses of the fracture. They checked the stress level in the rotor through finite elements and concluded that the rotor stress was too high and that the material was subjected to a brittle fracture. Alexander et al. [5] investigated the failure of the blades in an impeller. They performed a vibrational analysis and found a large deformation in the part, which resulted in failure due to material fatigue.

Rotors operating at high rotations are subjected to constant centrifugal force variations due to system shutdown and activation. Therefore, low cycle fatigue is expected; however, the instability may worsen the vibrations or cause unbalance, thus exposing the part to high cycle fatigue.

We analyzed the failure of a turbo impeller rotor in the current study and found a partially drilled hole out of position; fact that might have been the cause of the failure. This drilling mistake was made during the manufacturing process. The aim of the current study is to identify the location of the fracture onset, its micromechanisms and the stress range near the defect.

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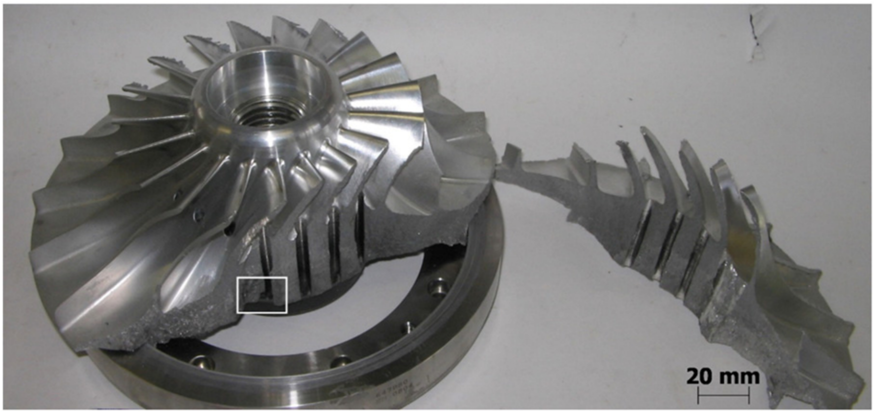

Fig. 1. Turbo impeller rotor fractured during operation. The white rectangle indicates the partially drilled hole.

The machining mistake might have caused a change in the section and it might have been the stress generator or might have caused the unbalance in the rotor, thus favoring the failure onset.

2. Materials and methods

The herein analyzed rotor is a turbo impeller made of AA 7075-T6 aluminum alloy. It weighs 6 kg and its external diameter is 280 mm. The shaft operates at 989 kW, with rotation at 22,918.31 rpm. The input pressure in the impeller is 6423 kPa, at −25 °C; and the discharge pressure is 2170 kPa, at −69 °C. On the other hand, the pressure in the impeller during operation is 4317 kPa, at −47 °C. The rotor has nineteen 5-mm-diameters through-holes disposed around the circumference along the flange base. The manufacturer interrupted the machining of the first hole when he realized that the drilling was being done at the wrong coordinates. Next, he corrected the coordinates and restarted machining. Such correction left a partially drilled hole next to the correct one. Finally, the adjacent holes were drilled.

The aluminum turbo impeller rotor with fracture in two parts of the maze ring is shown in Fig. 1. There is no contact between these two parts due to the assembly. However, the failure forced the rotor to fit the internal thread of the maze. The hole out of specification is shown in Fig. 2.

2.1. Fracture analysis

The fracture analysis was performed through a digital camera (Canon Powershot A400) and scanning electron microscopy (SEM Jeol Carry Scope 5700). The analysis was done to identify the location of the fracture onset and its mechanism, as well as to verify whether the fracture onset resulted from the partially drilled hole.

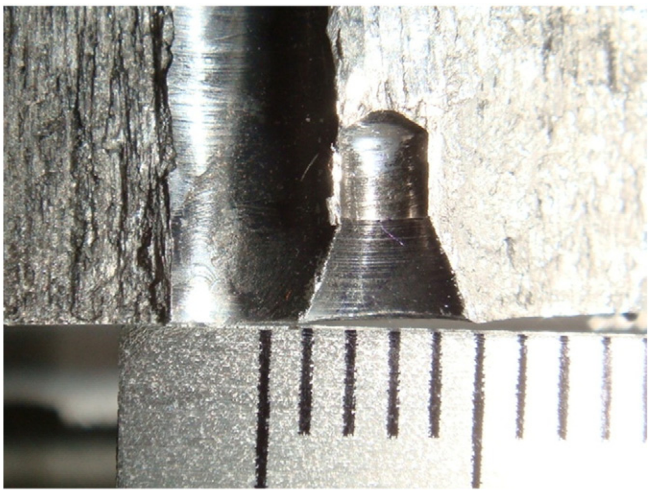

Fig. 2. Partially drilled hole shown in Fig. 1.