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Failure analysis of zirconia ceramic watch bracelet components

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ABSTRACT

This paper presents the failure of one particular design of component used in the production of ceramic bracelets for watches. A ceramic bracelet is made up of many ceramic "links". The ceramic link components are interconnected using a metal skeletal frame to produce the bracelet. However, in service a number of the ceramic link components experienced fracture and subsequently failure. A systematic failure analysis was performed to characterize the different types of failure mechanism and to determine the cause of the failures. Initial examination was followed by detailed characterization using optical and scanning electron microscopy. The size of the fracture origins which were found were then verified by calculations based on the Griffith equation. Failure analysis indicated that significantly large defects were introduced into the components during the injection moulding. The results, conclusions and recommendations of this study are presented.

1. Introduction

Zirconia is a ceramic which possesses a combination of desirable properties including high strength, hardness, wear resistance, low density, bio-compatibility and in the Y-TZP form a relatively good fracture toughness [1–3]. Once polished, zirconia can exhibit a highly mirror like finish which is aesthetically and tactility desirable. Y-TZP can be doped with rare earth oxides to produce ceramics of different colors (the most common are black, silver, gold, grey and white). Since more than 30 years, zirconia ceramics have been used in the watch industry for bracelets and watch casings because of its combination of desirable aesthetic appearance and materials properties [4].

2. Material

A summary of the material used for bracelet components and their manufacturing process is given below. The ceramic material is a 3 mol.% yttria stabilised zirconia (Y-TZP) with metallic additives that give the zirconia a dark black color. The typical strength of such a zirconia is approximately 800 MPa and the fracture toughness, (K_{Ic}), is approximately 5 MPa $m^{1/2}$ (even though in literature of ten much higher values can be found) [5,6]. The process of manufacture includes forming a dough from the ceramic powder with organic binders and then injection moulding the mix into the form of the component [7]. Afterwards, the near net shape components are sintered at a temperature of typically 1400–1500 °C for 1 h. The as finished polished effect is achieved by a process known as "rumbling" where the components are effectively placed in a rotary or vibrating mill with rumbling media with the movement of the media against the component effectively polishing the outer surfaces. The bracelet (Fig. 1) is then formed by assembling the components together using a metal link mechanism.

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