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Experimental study of hydrogen embrittlement in Maraging steels

M. Barsanti[a,b], M. Beghini[a], F. Frasconi[b], R. Ishak[a], B. D. Monelli[a], R. Valentini[a,b,*]

[a] *Università di Pisa, Dipartimento di Ingegneria Civile e Industriale, 56122 Pisa, Italy*
[b] *INFN Sezione di Pisa, Largo Pontecorvo 2, 56125 Pisa, Italy*

Abstract

This research activity aims at investigating the hydrogen embrittlement of Maraging steels in connection to real sudden failures of some of the suspension blades of the Virgo Project experimental apparatus. Some of them failed after 15 years of service in working conditions. Typically, in the Virgo detector, blades are loaded up to 50-60% of the material yield strength. For a deeper understanding of the failure, the relationship between hydrogen concentration and mechanical properties of the material,have been investigated with specimens prepared in order to simulate blade working conditions. A mechanical characterization of the material has been carried out by standard tensile testing in order to establish the effect of hydrogen content on the material strength. Further experimental activity was executed in order to characterize the fracture surface and to measure the hydrogen content. Finally, some of the failed blades have been analyzed in DICI-UNIPI laboratory. The experimental results show that the blades failure can be related with the hydrogen embrittlement phenomenon.

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Keywords: Hydrogen embrittlement; Maraging; fracture analysis.

1. Introduction

Purpose of this work is the study of Hydrogen embrittlement of Maraging steel. Maraging is a class of Ultra High Strength Steels (UHSS) with a yield strength that can reach 2400 MPa, hardened by precipitation of intermetallic compounds during an aging process [Sha and Guo (2009)]. These steels are highly susceptible to hydrogen damage, as is common for high-strength alloys.

Maraging steel is the material used for the construction of some crucial components of the Virgo experiment [Beccaria et al. (1998)], like the blades of the suspension system of the interferometer mirrors (super-attenuators) shown in Fig. 1. The loads acting on the blades are very strong, because each filter must carry the weight of the underlying ones. Therefore these high loads can cause microcreep [Gurewitz et al. (1977)], that is present also in the

* R. Valentini Tel.: +39-50-221-7859 ; fax: +39-50-221-8065.
E-mail address: renzo.valentini@unipi.it

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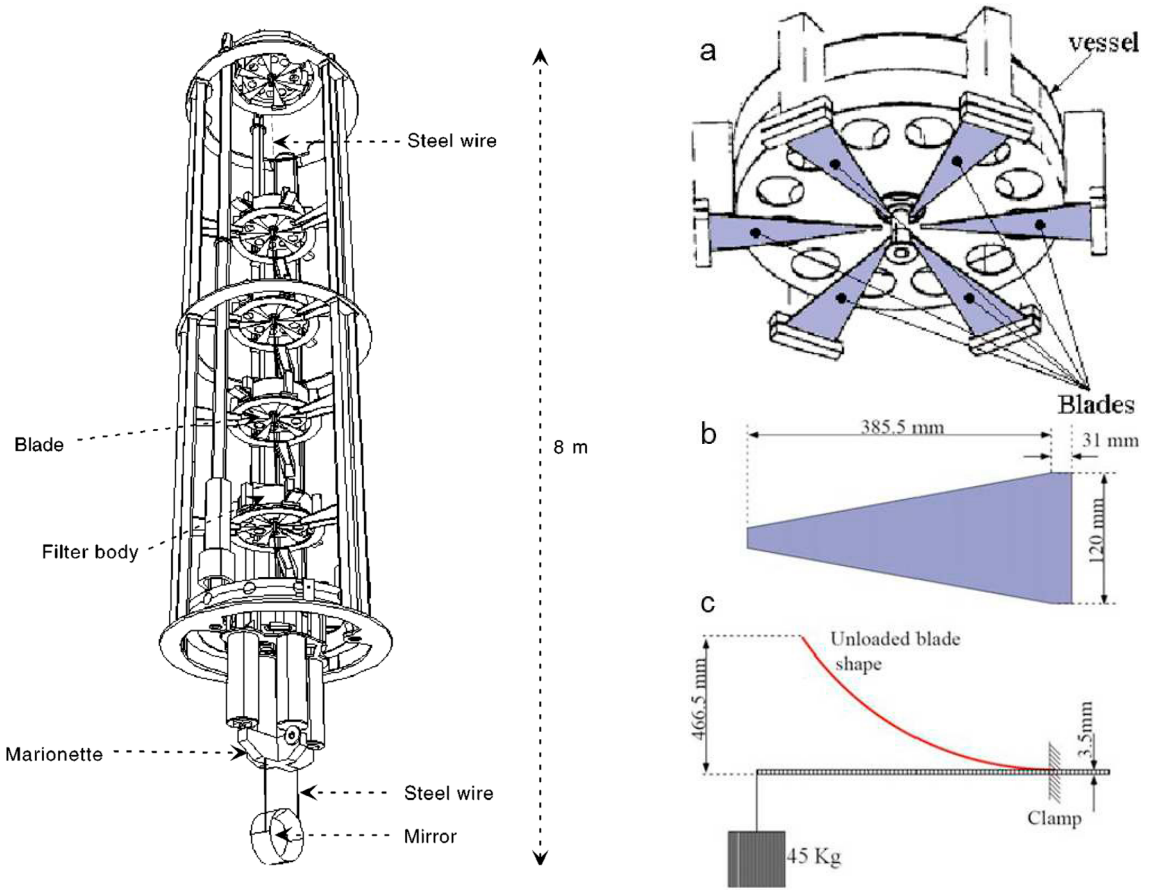

Fig. 1. The seismic super attenuator chain of Virgo (from Braccini et al. (2000)). The blades (b, c on the right) are clamped on the outer circumference of the filter bottom part (a on the right).

elastic regime. As the creep permanently modifies the position of the mirror and influences the measurement, a very high yielding strength was imposed.

Since nickel plating by surface deposition can produce hydrogen absorption, the possibility that this phenomenon could affect the mechanical properties of the Maraging steel used in the Virgo project has been investigated.

2. Material and methods

2.1. Material

This study examined a commercially available Maraging steel (Marval 18 produced by Aubert & Duvall) whose chemical composition is reported in table 1. The material was supplied as plates 3.4 mm thick. To improve its mechanical properties, the material has undergone an aging treatment (100 hours @435 °C). The values of the most important mechanical properties are shown in table 2.

Four groups of samples were prepared and studied as follows:

1. Failed blades: hydrogen content was measured.
2. Specimens with nickel electroless plating to simulate the plating procedure adopted for blade surface finishing, without de–hydrogenation treatment. Hydrogen content and mechanical properties were measured. This group helps to check the effect of missed steps in the adopted plating procedure for the blades.