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Response surface application for estimating failure time and other creep properties using the Small Punch Creep Test

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ABSTRACT

Design of experiments is a statistical technique to identify and quantify the causes of an effect in an experimental study. The design of experiments based on the response surface methodology (RSM) makes it possible to optimize the number of experiments performed to determine the influence of a number of factors in the final answer. This is very important when such experiments are costly, either in a computational or economic sense, as well as duration. The latter is the case of material creep behavior where the experimental tests can last quite a while. The main objective of this paper is to make use of the response surface methodology using the Small Punch Creep Test for the estimation of the creep parameters. This test is being used today as a feasible alternative for the estimation of creep behavior, especially in those cases when there is not sufficient material to perform standard tests. It basically consists of punching under constant load a miniature specimen, in which the sides of the specimen are clamped between two dies.

1. Introduction

Design of experiments is a statistical technique to identify and quantify the most important factors in an experimental study. It has been used successfully in many fields since the early 1920s [1–3]. This technique makes it possible to optimize the number of experiments performed to determine the influence of a number of factors in the final answer. This is very important when such experiments are costly, either in a computational or economic sense, as well as duration.

The latter is the case of material creep behavior where the experimental tests can last for quite some time. If the disadvantage of having an insufficient amount of material to extract standard specimens is also added, the combined use of the Small Punch Creep Test (SPCT) and the design of experiments may be the most appropriate solution.

In this sense, the Small Punch Creep Test is being used today as a feasible alternative for the estimation of creep behavior, especially in those cases when there is not sufficient material to perform standard tests. It was developed in the nuclear field in the 1980s [4] and has since been used successfully on numerous occasions [5–8].

It basically consists of fixing the periphery of the specimen, embedding it between two dies, a rigid lower die on which the specimen rests and an upper die, screwed to the lower one (Fig. 1). The miniature specimen is then punched under constant load until fracture by means of a small punch. The experimental setup can be consulted in the CEN Code of Practice for small punch testing [9,10]. Typical SPCT curves for ductile materials can be seen in Fig. 2. The typical parameters obtained can be observed: initial displacement (δ_0), minimum deflection rate ($\dot{\delta}_m$), time at which the minimum deflection rate is reached (t_m), failure time (t_f) and total punch displacement ($\delta = \delta_f - \delta_0$), where δ_f is the failure displacement.

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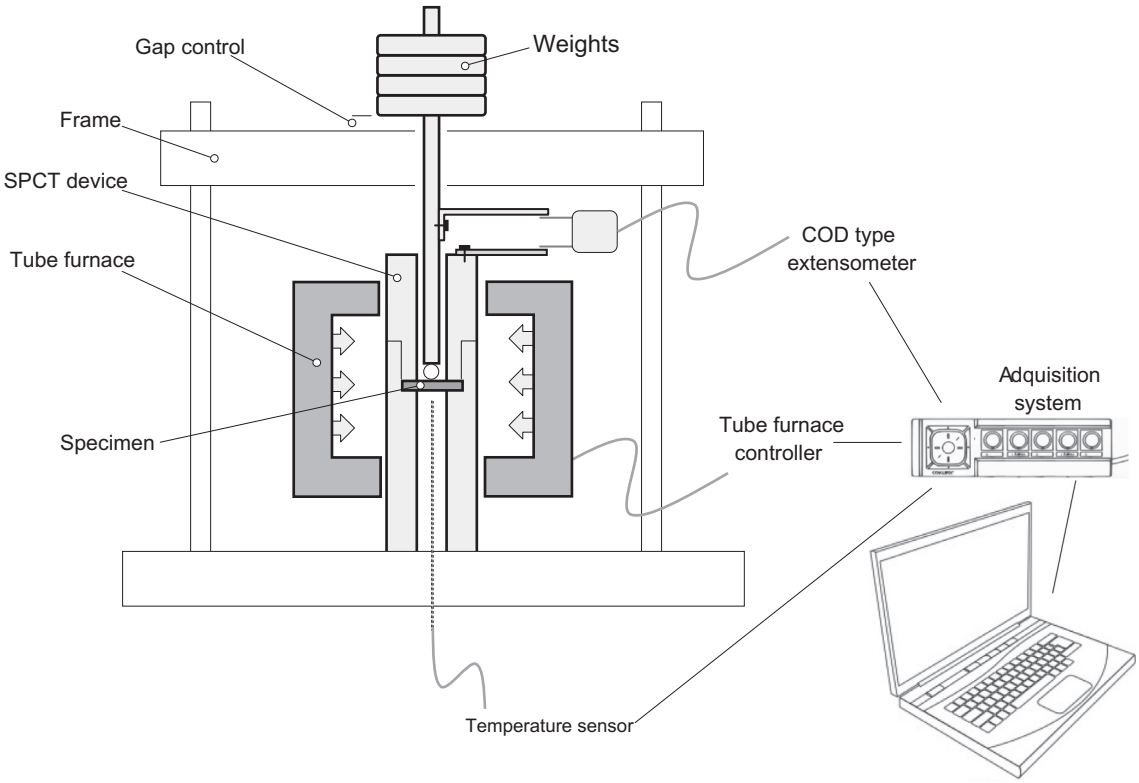

Fig. 1. Small Punch Creep Test device.

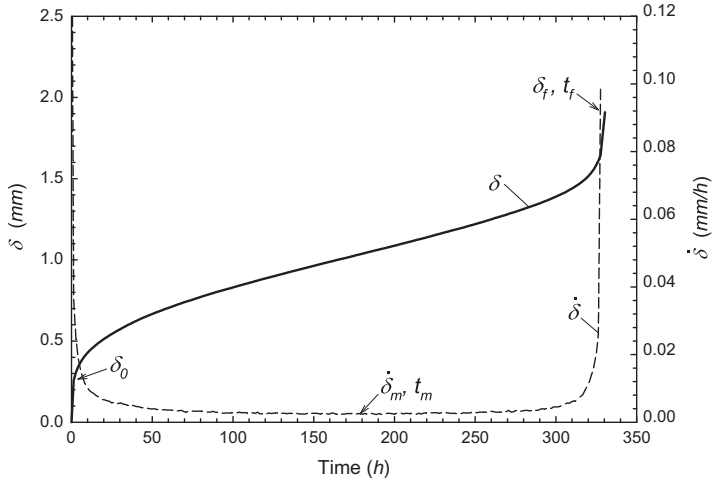

Fig. 2. Typical SPCT curves for ductile materials.

The uniqueness of this paper is the use of the Small Punch Creep Test and response surface methodology (RSM) based on the design of experiments for the estimation of the creep parameters for any combination of factors (temperature and constant load) within the range analyzed.

2. Material

To carry out this study, a magnesium alloy AZ31B-O was selected, because recently this type of alloy is gaining interest for the manufacturing of stamped components in the automotive industry. Generally, the base materials in these components