Relation between defect depth and standard thermal contrast on the steel surface in pulsed thermography

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1. Introduction

Pulsed thermography (PT) is a non-destructive testing method based on short thermal stimulation of a specimen surface and observation of its cooling process. After the heat pulse, the temperature of the material surface decreases rapidly mainly by the thermal diffusion process. The presence of the defect with different thermal properties causes the change of diffusion rate with respect to that of the sound material. Thus the time dependence of the temperature distribution on a surface over defect is different in comparison with that over the surface of the sound material. This difference is an indicator of the presence of defects. The problem is to find the parameter allows determining the depth of the defect [1].

The aim of this paper is an attempt to find experimentally such parameter.

2. Experimental procedure and results

The experiments were performed on the specimen made of 316L austenitic steel plate with flat-bottom hole defects. The diameters of defects d are 1, 2, 3, 4, 5 mm of the depths 0.3, 0.5, 0.7, 0.9, 1.2, 1.5 mm (Fig.1). The surface of specimen was coated by graphite paint and uniformly heated using the lamp of the pulse energy of 5 kJ. Pulse duration was 2 ms and the lamp to specimen distance was 0.5 m. The temperature distribution on the surface during its self cooling process was measured by Phoenix IR camera with a frame rate 346 Hz.

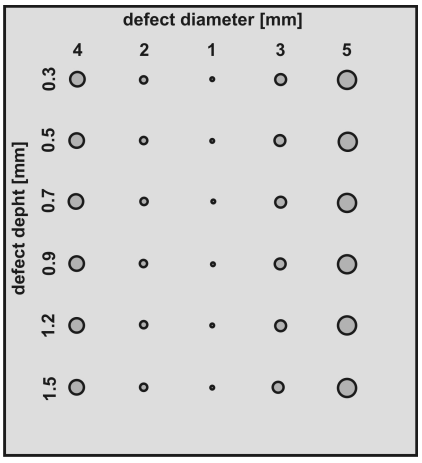

Fig. 1. *The geometry of tested specimen.*

The temperature vs. time dependence was obtained for the surface zones over defects and over sound material. From this data the standard thermal contrast $C(t)$ defined as follows, was calculated [2]:

$$C(t)=\frac{T_{def}(t)-T_{def}(t_0)}{T_s(t)-T_s(t_0)}, \tag{1}$$

where T_{def} is the surface temperature over the defect, T_s is the temperature over the sound material, t_0 is the time before heating and t is the current time of the process.

Fig. 2 shows the time dependence of the thermal contrast for defects of 3 mm diameter on different depths. It is seen that the dependence has a maximum. It is characteristic that the time of the $C(t)$ maximum appearance is different for different depths of the defects. The smaller depth of defect corresponds to the shorter time to reach the maximum.

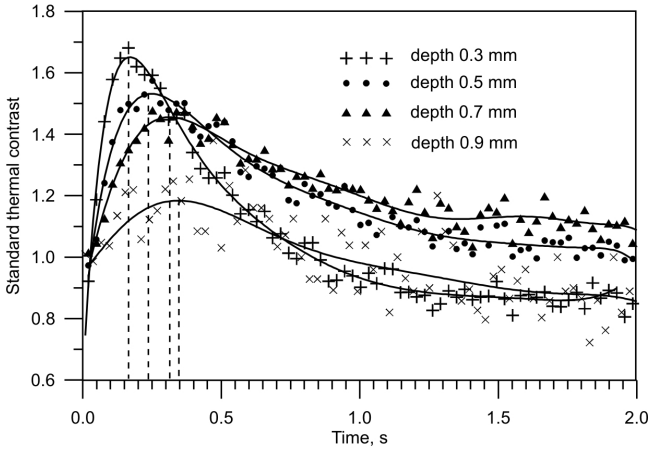

Fig. 2. *Time evolution of the standard thermal contrast. Defect diameter* $d = 3mm$.

The dependence of defect depth vs. time of thermal contrast maximum is shown in Fig. 3. It is seen that for every defects diameter this dependence is a straight line with the same slope.

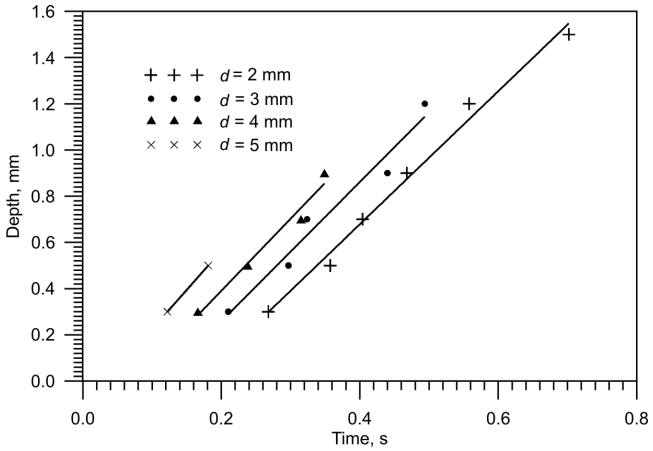

Fig. 3. *Dependence of depth vs. time of thermal contrast maximum.*

Determination of the defect depth is possible only when the diameter of the defect is known. This parameter can be estimated from the surface distribution of time derivative of temperature (Fig.4).

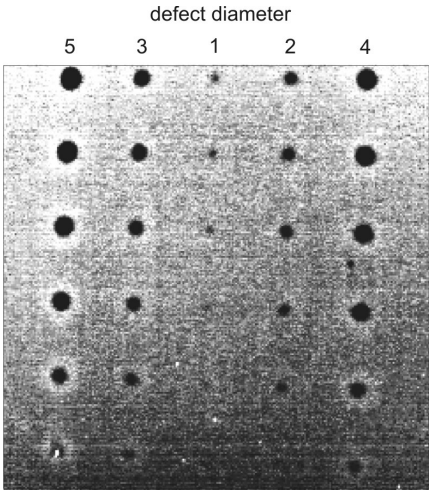

Fig. 4. *Surface distribution of time derivative of temperature.*

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[2] X.P.V. Maldague, Theory and Practice of Infrared Thermography for Nondestructive Testing, Willey – Interscience (2001) 198-199.