Enhancing Infrared Images Contrast for Pulsed Thermography

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Abstract

In pulsed thermography the sample to test is briefly heated ideally with a Dirac *δ* heat impulse and then observed through an infrared (IR) camera recording thermal images as the sample is cooling down. The difference on the IR images between the defective areas and the free defect areas is referred to as a thermal contrast. The SNR of such a contrast is strongly affected by the non uniformity of the initial heating impulse over the specimen. This paper describes a way to enhance this SNR by processing the heat versus time signal of each pixel of the image with a heat transfer model.

1. Introduction

In non destructive testing by infrared thermography, a, thermal contrast designate the difference of heat observed on the IR image between a defective area and a non defective area of the specimen under inspection. A smaller contrast indicates a smaller defect or a defect that is buried deeper inside the specimen. From this definition, a simple raw IR image can be seen as the simplest form of thermal contrast affected by a given offset. Although, when a quantitative or better qualitative analysis is needed it is often required to compute a better thermal contrast. The absolute contrast, the running contrast, the normalized contrast and standard contrast are typical method of computing a thermal contrast as used in IR thermography. To compute these contrasts it is required to know at least one point or an area on the image where the specimen is free of any defect. The drawback is that it is not possible to precisely locate such areas in advance simply from the raw IR images. If it was possible, it would not be necessary to compute contrasts to enhance the IR images. This means that only reasonable assumptions can be made about the non defective areas from the raw IR image to calculate any of those thermal contrasts. In 2001, the Differentiated Absolute Contrast or DAC solved this issue which propelled the limits of thermal contrasts in terms of quality and accuracy. The DAC belongs to a type of extrapolated contrast (EC) that is based on the extrapolation of the transient heat transfer equation.

2. Principle of existing extrapolated contrast methods

In EC methods, the thermal behavior of the surface of the plate is extrapolated in time through a model and then compared to the reality. The extrapolation of temperature of the bottom of the flat plate specimen takes real temperature measurements at a time t_0 as an input because the initial temperature is not affected by the subsurface defects. The time t_0 starts when the Dirac δ heat impulse is thrown over the plate to analyze. This ensures an accurate computation of the thermal behavior and allows locally predicting the expected free defect temperature at any given time after t_0. The difference between the extrapolated temperature and the measured temperature gives the contrast for a given point on the surface of the specimen at a given time. In practice only the time t' slightly after t_0 is considered instead of t_0 as the heat impulse at time t_0 saturates the camera.

There are currently two different EC's.

The first EC is often referred to as the DAC. It uses the assumption that a plate can reasonably be modeled by a semi infinite body for thermal contrast computation. This assumption is quite good for most cases of specimen inspected. The DAC still offers the best compromise between efficiency and complexity as it gives good results with a simpler transient heat transfer model. The DAC uses the temperature evolution T at the surface z=0 at a time t as [1,2]:

$$\Delta T_{Contrast\_DAC\_SIB}(t) = \Delta T_{Measured}(t) - \sqrt{\frac{t'}{t}}\,\Delta T_{Measured}(t') \quad (1)$$

The second existing EC still uses a 1 dimensional heat transfer equation but it takes this time the thickness *L* of the slab to inspect in consideration. The boundary conditions remain adiabatic as it is the case for the DAC. This implies the medium eventually tends to a steady state temperature greater than its environment. Obviously this model works better for contrast computations for flat plate samples that are insulated or have rather low thermal losses. The corresponding transient heat transfer equation can be solved with various methods. The thermal quadrupoles method in which the time space is represented in a Laplace domain is used as an example as shown below.

$$\varphi_{(t)} = Q * Dirac = Q \cdot \delta(t)$$

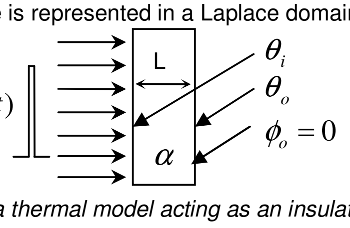

Fig. 1. *EC using a thermal model acting as an insulated slab*

$$\Delta T_{EC\_with\_Thickness}(t) = \Delta T_{Measured}(t) - \frac{L^{-1}(\theta_i')\big|_t}{L^{-1}(\theta_i')\big|_{t'}} \Delta T_{Measured}(t') \text{ where}$$

$$\theta_i = QA/C = \frac{Q}{e} \cdot \frac{\coth\sqrt{pL^2/\alpha}}{\sqrt{p}} = \frac{Q}{e} \cdot \theta_i' \quad (2)$$

3. Extrapolated Contrast using thickness and thermal losses

The previous EC described is using the thickness and is considered as perfectly adiabatic. The EC proposed in this paper is not adiabatic anymore and takes the thermal loses from the convective effect in account.

$$\varphi_{(t)} = Q * Dirac = Q \cdot \delta(t)$$

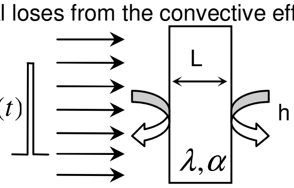

Fig. 2. *EC using a thermal model acting as a non insulated slab*

Eq. (2) is still valid, where $\theta_i' = \dfrac{hs/\lambda k + c}{2ch + \lambda ks + h^2 s/\lambda k}$ with $c = \cosh(kL)$ and $s = \sinh(kL)$ (3)

4. Preliminary Results

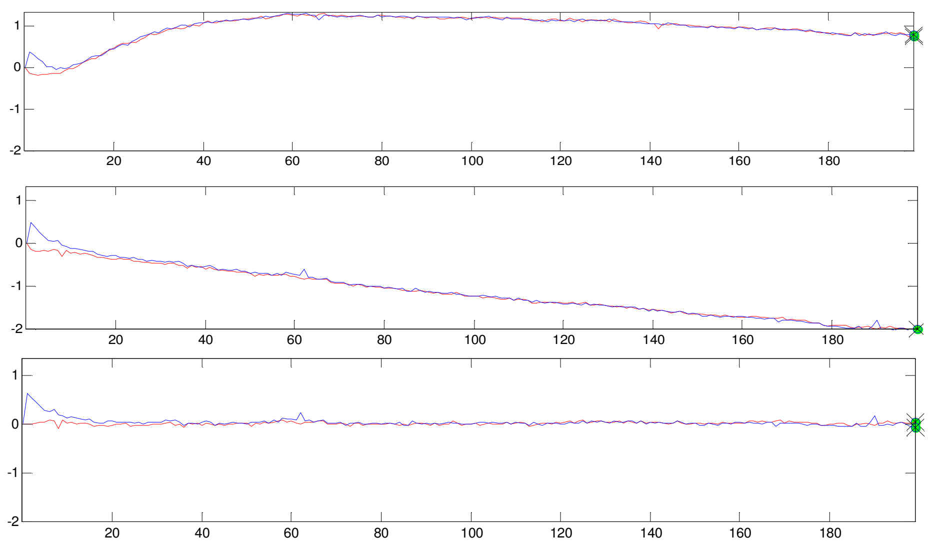

Fig. 3. *Contrast vs time over a defective area (blue) and a free defect area (red) respectively for the 3 contrasts.*

All the contrast are correct at the beginning. Only the EC using the thickness and thermal losses is correct at longer times and remains close to 0.

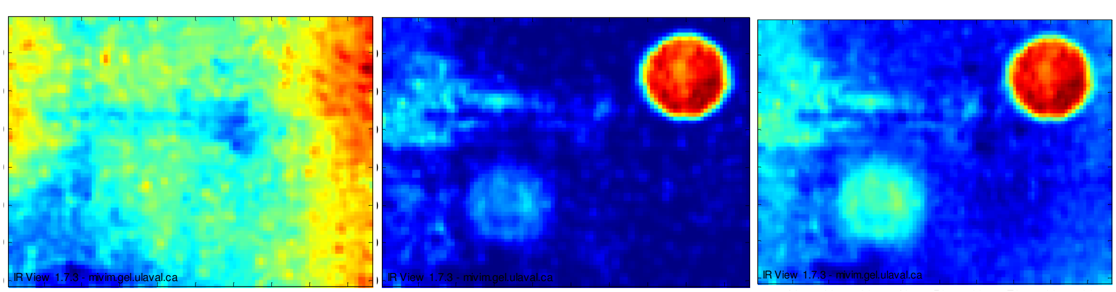

Fig. 4. The maximum contrast over the whole sequence for the 3 contrasts presented respectively.