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The last decade of IR thermographic NDT research at Tomsk Polytechnic University: from software to hardware

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Abstract

The first studies in the field of IR thermographic NDT at Tomsk Polytechnic University, Russia, can be traced back to the 1970s. During the past years, the emphasis in the research has been shifted from the mostly theoretical and methodological aspects of this inspection technique toward development of specialized thermal NDT equipment to be used in the aviation and aerospace industries. A short review of the current research is presented in this paper.

1. Introduction

The first studies on infrared (IR) thermography and thermal non-destructive testing (NDT) were launched at Tomsk Polytechnic University in the early 1970s, and their results were summarized in [1]. A lack of mature IR technologies in the former USSR conditioned the fact that the emphasis in the earlier investigations was done on the development of modelling and data processing software, as well as compiling inspection guidelines in important application areas.

2. Thermal NDT software

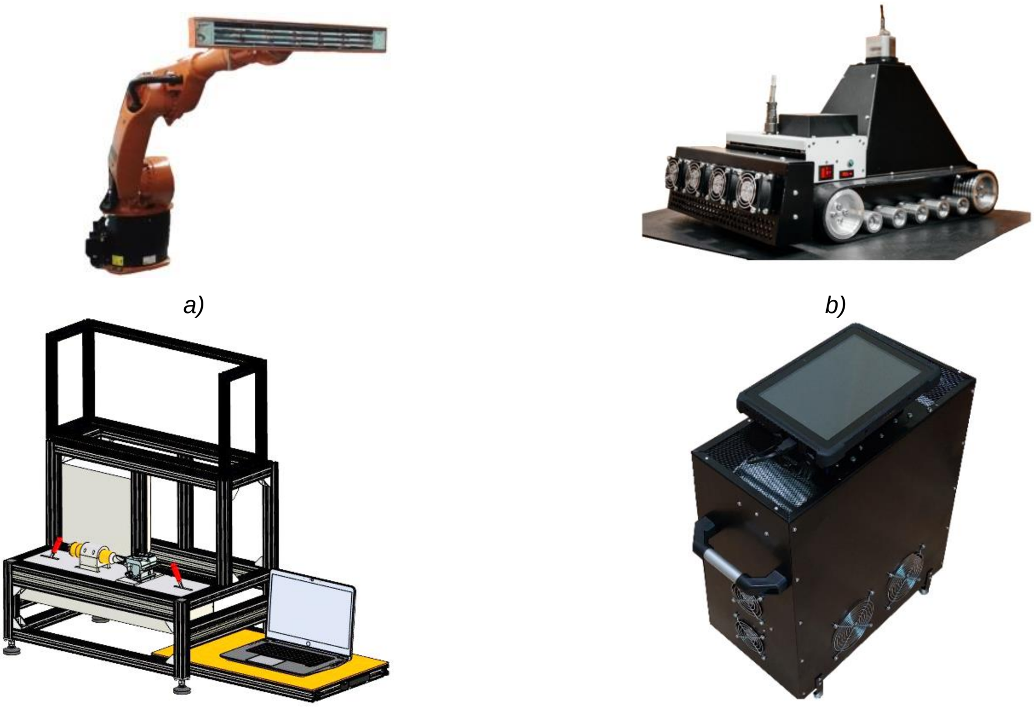
A short description of the computer programs, which are widely used in the current research, is given in table 1. All the programs are in fact an ongoing process of continuous modification and improvement. It is believed that 3D numerical models of heat conduction represent the most flexible and versatile tool for solving both direct and inverse thermal NDT problems by taking into account numerous phenomena, which cannot be simulated analytically, such as non-adiabatic character of surface heat exchange, arbitrary in time and uneven in space heating, material optical transparency, lateral heat diffusion, etc.

Table 1. *Thermal NDT software (Tomsk Polytechnic University) [2]*

Software	Description
Modelling	
Layer 3 Analytic	Analytical solution to the heat conduction problem in a 3-layer non-adiabatic plate. A middle layer simulates either material (adhesive) layer or defect. Dependencies between temperature contrasts and defect depth and thickness can be analysed.
ThermoCalc-2D	A 2D “disk-in-disk” geometry is modelled and solved in the cylindrical coordinates by using a finite-difference calculation scheme.
ThermoCalc-6L	A basic 3D software implementing pulsed and thermal wave heating of a 6-layer non-adiabatic sample containing up to 9 parallelepiped-like defects (obsolete version).
ThermoCalc-3D Pro	A current version of the ThermoCalc-6L program. The sample may include up to 36 anisotropic layers oriented under a certain angle and up to 40 internal defects. Heating with a piece-wise (arbitrary) temporal function is possible. Uneven heating phenomena can be simulated. Calculated images can be saved in the Byte, or floating point, or MatLab formats.
ThermoEdCur	A version of ThermoCalc-3D Pro allowing heating with a moving line heat source.
ThermoSource	A version of ThermoCalc-3D Pro involving defects generating thermal energy.
ThermoSon	A version of ThermoCalc-3D Pro involving stimulation of a sample with ultrasonic waves to cause generation of energy in crack-like defects due to internal friction.
Data processing	
ThermoFit Pro	Experimental and calculated image sequences recorded in both Byte and floating point formats can be processed by applying several algorithms known in thermal NDT. The algorithms include: 1) filtering, 2) normalization, 3) image subtraction, 4) polynomial fitting, 5) derivative analysis, 6) Fourier transform (Pulse Phase Thermography), 7) Principal Component Analysis (PCA), 8) dynamic thermal tomography, 9) wavelet transform, 10) 1D and 3D defect characterization, 11) determining diffusivity in one- and two-sided tests, 12) correlation, 13) polynomial fitting, 14) time-domain treatment in one-sided test, and 15) statistical analysis.
ThermoLab	Modification of ThermoFit Pro compatible with MatLab.

3. Thermal NDT hardware

In the last years, a new interest to line-scanning thermal NDT procedures has demonstrated some evident advantages of this inspection technique, such as high test productivity, uniform heating and easy test automation. A robotic system shown in figure 1a is intended for inspection of large-size cylindrical objects. It includes a 1 m-long line heater to prove a unique test productivity of up to 24 sq. m./hr. The line-scanning principle is also used in a self-moving test device shown in figure 1b. The unit is intended for in-workshop inspection of wings of a new Russian MS-21 aircraft made of graphite/epoxy composite. It enables test productivity of up to 20 sq. m./hr.re Figure 1c shows the scheme of a portable thermoacoustic device developed specifically for detecting surface and subsurface cracks in turbine blades. Finally, a kind of a 'classical' thermal NDT unit allowing area-by-area inspection of water and impact damage in aircraft panels is shown in figure 1d. The unit implements optical heating with power of 1 kW being supplied with facilities to suppress reflected radiation noise.



a) *b)*

c) *d)*

Fig. 1. *Thermal NDT hardware (Tomsk Polytechnic University) [3]:*

a – robotic thermal NDT system,
b – self-moving thermal NDT device,
c – portable thermoacoustic NDT device,
d – portable active IR thermographic NDT unit

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