INTRODUCTION

The new structures developed in industry are more and more complex (special coatings, smart materials, etc...) and often need to be investigated by non-contact methods. Laser Based Ultrasound technique (LBU) offers for several years an efficient alternative to conventional ultrasound (piezoelectric transducers), especially for the nondestructive evaluation (NDE) and the material characterization [1]. Many structures encountered in aeronautics such as painted metals or composites are made of two layers of completely different materials and the control of such specimens may be intricate. Thus, it is useful to develop a theoretical model able to predict the laser induced acoustic response of a two-layered material [2,3]. So, this paper presents a new and original model adapted to that kind of structures which are homogeneous and transversely isotropic. The cylindrical symmetry of the model allows fast calculation and observation of the displacements over a long duration. The simulations are compared to the experimental results performed with a Nd:Yag laser for the generation and a heterodyne interferometer. Moreover, the NonDestructive Testing (NDT) of metallic structures is difficult because of the very large optical reflection coefficient of the laser light on the surface. A paint covering the surface of the metal allows to improve the ultrasound generation around the normal incidence and then improves the control of the material. The two-layer model is used to characterize this paint and to optimize its thickness in order to ensure the way of testing such as the detection of effects due to corrosion.

TWO-LAYER MODEL

The two-layer model is based on the Christoffel equation, on the heat equation and on the equations given by the boundary conditions. This model takes into account some assumptions which are identical to those already used for the development of a one-layer...
Thus, in each medium i (a and b), the equation of motion for dynamic thermoelasticity is:

\[
\rho_i \frac{\partial^2 \mathbf{u}_i}{\partial t^2} = \text{div}[\{C_i\nabla \mathbf{u}_i - [\lambda_i] \Delta T_i\}]
\]  

(1)

where \( \mathbf{u} \) is the mechanical displacement, \([C]\) the stiffness tensor, \([\alpha]\) the thermal expansion tensor and \([\lambda] = [C][\alpha]\) the stiffness-expansion tensor.

The temperature elevation field \( \Delta T_i \) is defined, in each medium i, from the following heat equation:

\[
\rho_i C_{pi} \frac{\partial \Delta T_i}{\partial t} = \nabla (([K_i]\nabla (\Delta T_i))) + Q_i
\]

(2)

with \( Q \) the heat production per unit volume per unit time, \( \rho \) the material density, \( C_p \) the specific heat and \([K]\) the thermal conductivity tensor.

The model supposes that a laser spot irradiates, normally to its surface, a plate made of two materials of different mechanical, thermal and optical parameters. This plate presents a cylindrical symmetry around the laser beam axis, so that the equations of the problem are described in the cylindrical coordinates system \((r,\theta,z)\). Thus, considering that the laser pulse temporal shape is the one of a Q-switch and that its energy spatial distribution is gaussian, the temperature elevation field calculated from Equation 2, in which the thermal conduction is neglected compared to the optical absorption, is written in each medium (no optical reflections at the interface between the two materials):

\[
\Delta T_a = \frac{E_0(1-R)}{\beta_a C_{pa}} \frac{2\beta_a}{\pi \sigma^2} e^{-2r^2/\sigma^2} e^{-\beta_a z} \left[ 1 - \left(1 + \frac{t}{\tau}\right) e^{-t/\tau} \right]
\]

(3)

\[
\Delta T_b = \frac{E_0(1-R)e^{-\beta a d_a}}{\rho_b C_{pb}} \frac{2\beta_b}{\pi \sigma^2} e^{-2r^2/\sigma^2} e^{-\beta_b (z-d_a)} \left[ 1 - \left(1 + \frac{t}{\tau}\right) e^{-t/\tau} \right]
\]

(4)