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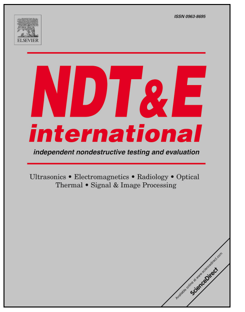

Non-contact damage detection on a rotating blade by Lamb wave analysis

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Non-contact damage detection on a rotating blade by Lamb wave analysis.

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Abstract

Propeller inspection is mandatory for safe operation of aircraft. Damage evaluation on such rotating structures requires dedicated measurement techniques. In this study efforts to create a stroboscopic technique are reported. Lamb waves were excited on a rotating blade with a Q-switched Nd:YAG laser synchronized to the sample rotation, whereas the wave amplitude was obtained by a laser Doppler vibrometer. A surface breaking notch on an aluminum sample rotating at 415 rpm was detected and sized with millimeter accuracy. The technique has potential for automatic non-contacting damage detection on rotating structures such as helicopter blades and turbines.

Keywords: Non-contacting NDE, Lamb waves, notch detection, rotating target.

I. INTRODUCTION

Propellers are key components in vehicles and machinery, such as helicopters, ships, and power plants. Technical inspection is required to ensure safe operation. According to the US Federal Aviation Administration (FAA), aircraft propeller integrity can be compromised due to e.g. delamination, corrosion, lightning strikes, stone nicks, *etc* [1] [2] [3]. Northrop Inc., under a contract from the US Air Force, set several requirements for flaw detection techniques: the inspection should be carried out with reliable sensors capable of detecting cracks, 1.25mm in length, situated in complicated locations such as sharp edges, apertures, and rivets [4]. The fact that propellers carry coatings often made of composites, make testing challenging. Ideally, one would want to quickly inspect propellers in motion since then aircraft could immediately take off after scanning. This would increase the service time of the machine and decrease inspection costs.

To achieve flaw detection that fulfils these specifications, several techniques are used but all have certain limitations. Thermal imaging [5] cannot detect small internal defects and is limited to heat conducting materials. X-rays can scan a wide range of materials of different thickness and can provide high resolution images of defects [6]. However, radiography is expensive and a sample must be extracted for analysis which makes it impossible to do in-service damage detection [7]. Eddy-current testing allows flaw detection [8], however, this inexpensive and sensitive technique is limited to surface defects in conductive samples. Ultrasonic damage evaluation is an alternative/complement to the aforementioned inspection methods. This method, often based on bulk waves or Lamb wave excitation and detection, can image both surfaces and internal defects in moving samples [9] [10].

Lamb waves are guided elastic waves that are suitable for flaw detection. These dispersive surface waves propagate in plates with free boundaries [11] [12], featuring two particle displacement components, one parallel to the surface of the plate and another one perpendicular to it. The velocity of these symmetric and antisymmetric modes is a function of the plate thickness and the sound frequency. Hence the wave modes travel at different speed when they propagate across defects compared to when they travel across unharmed parts of the plate. The reason is that the damaged region is thinner than the undamaged plate. These

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