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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（工学）　氏名　Feblil Huda

学 位 論 文 題 名

Structural Health Monitoring by Vibration Measurement with Non-contact Laser Excitation
(非接触レーザー加振を用いた振動計測に基づく構造ヘルスモニタリング)

Damage identification as a part of structural health monitoring plays a significant role to ensure the current condition of structures. In general, there are two main steps constituting a diagnostic procedure in damage identification: the experimental measurement and the data processing. It is evident that, for each measurement technique, a dedicated signal processing strategy should be designed and employed. In this dissertation author proposes new damage identification in structural health monitoring using non-contact laser excitation vibration test in the title " Structural health monitoring by vibration measurement with non-contact laser excitation ".

This dissertation consists of five chapters. The first chapter " Introduction " presents the background, motivation, and objectives of this research. In the second chapter " Laser excitation " author intends to find appropriate non-contact excitation method for damage identification as the basic idea of research in this dissertation. For this purpose, two methods of laser excitation that proposed by some researchers are explored to investigate the reliability of these methods to be combined in structural health monitoring. Two methods of laser excitation are laser ablation and laser-induced breakdown. Excitation by laser ablation to metal structure occurs when laser beam focused and directed to metal and then absorbed by metal generates high-temperature plasma, and large quantities of particles are then released (in the form of a plume) from the metal. Releasing the particle at a velocity from the metal represents the laser induced impulse. Excitation by laser-induced breakdown (LIB) occurs when laser beam focused, plasma is then generated, and a portion of this plasma energy is transformed to a shock wave, which is the source of the sound generated by LIB. This sound can be used as a source of acoustic excitation. Based on the review, author find that these two laser excitation method are eligible to be applied and combined in structural health monitoring. Excitation by laser ablation generates ideal impulse force on metal structure, has high reproducibility, works well in high and low frequencies measurement, so it is applicable to structural health monitoring on metal structure, like detecting bolt loosening in bolted structure. Acoustic excitation by LIB generates ideal point source of sound for ideal acoustic excitation, totally non-contact method, has high reproducibility, so it is suitable for structural health monitoring in light and flexible structure, like membrane.

In the third chapter, a vibration testing and health monitoring system based on an impulse response excited by laser ablation is proposed to detect bolted joint loosening. A high power Nd: YAG pulse laser is used to generate an ideal impulse on a structural surface which offers

the potential to measure high frequency vibration responses on the structure. A health monitoring apparatus is developed with this vibration testing system and a damage detecting algorithm. The joint loosening can be estimated by detecting fluctuations of the high frequency response with the health monitoring system. Additionally, a finite element model of bolted joints is proposed by using three-dimensional elements with a pretension force applied and with contact between components taken into account to support the bolt loosening detection method. Frequency responses obtained from the finite element analysis and the experiments using the laser excitation, are in good agreement. The bolt loosening can be detected and identified by introducing a damage index by statistical evaluations of the frequency response data using the Recognition-Taguchi method. The effectiveness of the present approach is verified by simulations and experimental results, which are able to detect and identify loose bolt positions in a six-bolt joint cantilever.

In the fourth chapter, author proposes a vibration testing and health monitoring system based on an impulse response excited by laser to detect damage in membrane structures. A high power Nd: YAG pulse laser is used to supply an ideal impulse to a membrane structure by generating shock waves via LIB in air. A health monitoring apparatus is developed with this vibration testing system and a damage detecting algorithm which only requires the vibration mode shape of the damaged membrane. Artificial damage is induced in membrane structure by cutting and tearing the membrane. The vibration mode shapes of the membrane structure extracted from vibration testing by using the LIB and laser Doppler vibrometer are then analyzed by 2-D continuous wavelet transformation. The location of damage is determined by the dominant peak of the wavelet coefficient which can be seen clearly by applying a boundary treatment and the concept of an iso-surface to the 2-D wavelet coefficient. The applicability of the present approach is verified by finite element analysis and experimental results, demonstrating the ability of the method to detect and identify the positions of damage induced on the membrane structure.

Finally, in the last part, the fifth chapter presents the conclusion of the overall research that has been conducted and some suggestion to further research.