# 学位論文内容の要旨


The research of structural health monitoring (SHM) and damage detection has recently become an area of interest for a large number of academic and commercial laboratories. Especially, a need to develop in-service and on-line health monitoring techniques is increasing. This kind of technique allows systems and structures to monitor their own structural integrity while in operation and throughout their life, and is useful not only to improve reliability but also to reduce maintenance and inspection cost of systems and structures. Vibration-based damage identification techniques may meet the requirements for on-line SHM. Damage or fault detection, as determined by changes in the dynamic properties or response of structures, is a subject which has received considerable attention in the technical literature beginning approximately 30 years ago, and with a significant increase in reported studies appearing during the last five years. The basic idea of these techniques is that modal parameters, notably frequencies, mode shapes, and modal damping, are a function of the physical properties of the structure (mass, damping, stiffness, and boundary conditions). Therefore, changes in physical properties of the structure, such as its stiffness or flexibility, will cause changes in the modal properties.

In this thesis, techniques are developed to detect, localize and quantify damage in steel structures by vibration monitoring. The same methodology can also be applied to reinforced concrete structures. The changes in Strain Energy, Power Spectral Density (PSD), Phase Angle, and Transfer Function Estimates (TFE) techniques, presented here, are new techniques to assess damage in civil engineering structures and monitor the damage growth in the structure. All proposed techniques assume that the displacement or the acceleration response time histories at various locations along the structure both before and after damage are available for damage assessment. These responses are used to estimate the dynamic response of the structure using several spectral functions. The change in the dynamic response between the baseline state and the current state is then used to identify the location of possible damage in the structure. All proposed techniques require only measured responses before and after damage without the need to use a correlated finite element model (FEM). Model-updating damage identification methods, which require correlated FEMs, are difficult to be implemented for continuous health monitoring of bridges because it is the author's opinion that it would be impractical to develop correlated FEMs for a large population of bridges. Another advantage of using the proposed techniques is that they do not require measuring the excitation forces. If automated damage identification methods are to become an accepted part of a comprehensive bridge management system, these methods will have to monitor the response of a bridge to ambient (typically traffic-induced) vibration, hence a measure of the input will not be available. To this end, the proposed methods used in this study have assumed that the input is not monitored. The use of piezoelectric actuators as a local excitation source for continuous health monitoring of large structures such as steel bridges is also presented.

Damaged as well as intact structures are being used as validation tools. A test program on steel beams, steel bridge model, aluminum building model and finite element models is set up. Structures are gradually damaged and the changes of the dynamic responses monitored from the initial to the damaged state. As examples of real structures, a railway steel bridge in Kitami city is considered. Several damage scenarios are applied to the bridge and the change in the dynamic response is estimated. The results of the different damage assessment techniques prove that dynamic analysis is a helpful tool in SHM. Experimental and numerical results show that the proposed approaches may be successfully implemented on-line to detect the damage and to locate regions where damage occurred. This study demonstrates the great promise of these schemes for on-line SHM.

# 論文審査結果の要旨

社会基盤を支える土木構造物の老朽化が重要な課題となりつつある．構造物の劣化によって卓越振動数・減衰特性などの振動特性の変化として劣化をとらえる研究や構造物の維持管理のために劣化をモニタリングする研究も盛んである．本論文は，維持管理の対象となる構造部材の局部損傷を対象として損傷位置や損傷程度を評価する手法の開発を行っている．

本論文は，構造物に圧電アクチュエータを用いた局部加振を行い，圧電型加速度計による振動測定システムを構築し，鋼構造部材や鋼構造物をモデル化して，損傷として部材連結部のボルトのゆるみや亀裂などの損傷をモデル化し損傷位置や損傷の程度を同定する手法について検討している．構造部材の損傷による振動特性の変化を歪エネルギー、スペクトル密度(PSD)、位相角および伝達関数(TFE)によって損傷位置や損傷程度の評価を行っている．また，本手法を実構造物に適用し損傷検出手法の実用化のための検討結果も示している．本論文は土木構造物中の損傷の成長をモニタリングによって評価する新しい技術を提案したものである。

これは要するに、申請者は、構造物の健全度モニタリング手法を用いて損傷を検出する新たな手法を提案したものであり、社会資本の維持管理分野の発展に対して工学的に貢献するところ大なるものがある。

よって、申請者は、北見工業大学博士（工学）の学位を授与される資格があるものと認める。