論文の内容の要旨

論文題目　Damage identification of belt conveyors using periodic and isolated local vibration modes
(周期的局部振動モードと孤立局部振動モードを利用したベルトコンベアの損傷同定)

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Due to aging and corrosion, large number of support structure of belt-conveyors in industrial plants has degraded over the past decades. These structures are in damage condition and may cause human injury or death and economy impacts as several structural accidents of belt conveyors have been reported in Japan and overseas which caused the operation of factory stopped. Therefore structural condition assessment of these structures is urgent.

To get rid of the problems of global vibration modes in damage identification (i.e. need of before-and-after comparison, incapable to be applied for structures with large number of damaged elements, considering effects of non-structural elements, considering environmental conditions) a new method is proposed based on two specific local vibration modes named Periodic Local Vibration Modes (PLVM) and Isolated Local Vibration Modes (ILVM). These modes are distinguished from other types of local vibration modes. PLVM is a mode in which vibrations of one group of the identical secondary members are much larger than the other members. The idea in damage identification is when one of these identical members damages, this member no longer vibrates in PLVM, instead it has ILVM in a lower frequency.

The existence of PLVM and ILVM in systems consisting of main and secondary members is investigated using mass-spring system. A 3DOF system including coupler, main, and secondary members is considered and mode localization phenomenon is mathematically explained. Then a more complicated lamped mass-spring system which has 21DOF is compared with the FEM model of the support structure of belt-conveyor to find a correspondence between these two models and the existence condition of PLVM and ILVM is numerically discussed. It is found that when main members are much stiffer than secondary members, PLVM and ILVM of secondary members exist and their frequencies are nearly the same as natural frequencies of the secondary members themselves.

Next, damaged members of a finite element model of the support structure of a typical belt-conveyor are identified utilizing the methods based on global vibration modes, PLVM and ILVM, and the methods are compared to each other. In order to find the appropriate parameters involved in updating procedure to estimate the degree of damage, sensitivity analyses of frequencies of PLVM and ILVM are done. These analyses show that the appropriate parameters in damage quantification are the local internal connections and properties of the corresponding member. Based on this result, beam theory and its applicability on the quantification of damage

degree are discussed and the stiffness of local boundary conditions and the stiffness reduction of damaged members are reliably identified without need of before-and-after comparison.

Likewise, this method is applied to two laboratory models. One has continuous longitudinal members and the other has separated longitudinal members. The method is applicable for all secondary members (i.e. diagonal and lateral members) of the structure with continuous main members and all damaged and undamaged members vibrates in their own natural frequencies; yet, this damage identification method is not applicable to lateral members of the structure with non-continuous main members since coupling of modes happens for these members. The reason is due to the fact that the stiffness of the main members are not much larger than the lateral members and no other secondary members attached to one of the connections of each lateral member.

To be close to real belt-conveyors, the existence of PLVM and ILVM in braces and lateral members of a planar full scale model of a belt-conveyor is investigated and the rotational stiffness of connections is estimated based on the special properties of PLVM and ILVM. Finally, damaged secondary members of a real belt-conveyor are correctly detected using PLVM and ILVM and the equivalent damage degree is identified for each damaged member while each member is directly hit and the method is experimentally verified.

Numerical and experimental results show that PLVM and ILVM are better observed when each secondary member is directly hit. As an alternative method to easily observe PLVM, one of the undamaged members in each identical members set can be hit. Theoretical and numerical analyses and experimental results show that by hitting one of the undamaged members in each identical members set, damaged secondary members of the identical members set are localized and the relative severity of damage is identified by comparing the maximum amplitude of Fourier spectrum of the identical members of the corresponding set at their PLVM rang

In conclusion, damage identification techniques to identify damages on belt conveyor support structures utilizing local vibration modes taking advantage of the non-contact measurement device have been proposed. These techniques are capable of identifying multiple damages on a structure without the need of before-and-after comparison. The Laser Doppler Vibrometer allows a quick assessment of damages. The applicability to belt conveyors is confirmed through numerical and experimental verifications. Further studies on criteria to distinguish local vibration modes and on the applicability to structures of other types such as truss bridges and towers are considered to advance the techniques toward their full-fledged use.