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Development of steel bridge clattering-detecting device utilizing vibration-powered generator

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Abstract

When a bridge loses support from one pier due to causes such as shoe subsidence, this imbalance causes repercussions known as "clattering". Clattering is so harmful that it may cause not only damages to shoes but also rapid extension of cracks in peripheral structures, and greatly affects total soundness of beams. However, it is difficult to pinpoint the occurrence and progress of clattering by inspections at fixed interval (every two years). In this paper, we introduce a development of clattering-detecting device utilizing vibration-powered generator as a new monitoring system to complement inspections.

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Keywords: Steel bridge,monitoring, accleration,vibration-powered generator

1. Introduction

When a bridge loses support from one pier due to causes such as shoe subsidence, this imbalance causes repercussions known as "clattering" (figure 1). Clattering is so harmful that it may cause not only damages to shoes but also rapid extension of cracks in peripheral structures, and greatly affects total soundness of beams. East Japan Railway Company (JR East) holds about 12,000 spans of steel bridges (average age 70 years) and we maintain them by inspections at fixed interval (every two years). However, it is difficult to pinpoint the occurrence and progress of clattering (figure 2).The general approach for monitoring bridges is to install sensors, for instance acceleration sensors, on bridges and monitoring the transition of these variables [1]. However, this requires an outside power supply and installation of sensors that would lead to high running costs. We are developing a clattering-detecting device utilizing vibration-powered generator as a new monitoring system to complement inspections. This is a joint development between JR East and Panasonic Corporation and is patent pending internationally.

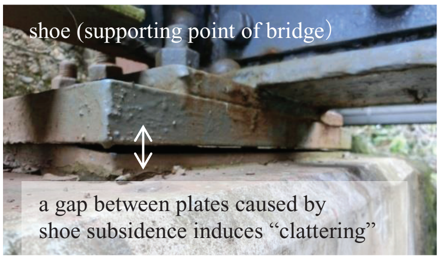

Fig.1. A image of "clattering"

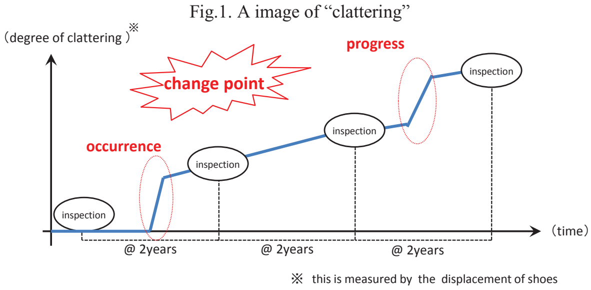

Fig.2. Difficulty to pinpoint the occurrence and progress of clattering.

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2. Concepts of development

Conducting a pre-survey of clattering bridges, we have been developing the clattering-detecting device with the three following concepts:

(1) vibration-powered generator to save energy

(2) detecting method focused on the difference of vibration strength between right and left beams

(3) detection monitored by operating trains

Details of these concepts are described below.

2.1. Vibration-powered generator to save energy

We adopted a vibration-powered generator as power resource utilizing the vibration of beams when trains pass over bridges, eliminating the need for outside supply. From among main power generation principles such as piezoelectric type, electrostatic type, and electromagnetic guidance, we adopted piezoelectric type which has high voltage and a wide range of oscillation frequency. This consists of thick piezoelectric film, weight, mass, and rubber, collecting electric power from electric potential difference when film vibrates and deforms (figure 3). Rubber plays the role of a damper, amplifying specific frequency band to enhance electric generation efficiency.

2.2. Detecting method focused on the difference of vibration strength between right and left beams

Clattering is caused by the difference of vibration strength between right and left beams. However, vibration strength itself is affected by specifications or rigidity of bridges, external factors, etc. Focusing on the difference or ratio between clattering and non-clattering vibration strength, the threshold value is aimed to be standardized and applicable to all metal bridges.

2.3. Detection monitored by operating trains

Track monitoring device, which we are introducing step by step, is considered to be utilized for efficient detection of clattering. This device is equipped on trains in operation and consists of a track irregularity measuring device and track material monitoring system. Track material monitoring system has a photographing function, for example using for checking soundness of rail fasteners. A clattering-state can be easily identified by a photo of LED lighting (figure 4). For judging and reporting, technology of image analysis by AI is expected.

3. Development of the prototypes

We developed prototypes based on the concepts above (figure 5). The vibration-powered generator has an oscillation frequency range of 30-60 Hz (figure 6). The moment electric power generation by the vibration of beams reaches the minimum amount to boost the device (about 50 μ J), the device records right and left electric power generation one second and two seconds after.

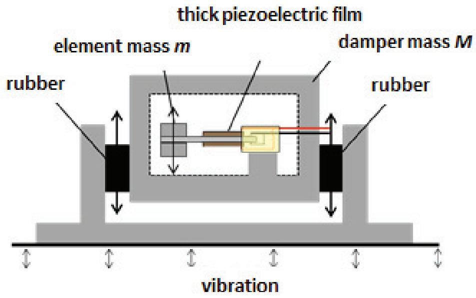

Fig.3. Piezoelectric type of vibration-powered generator

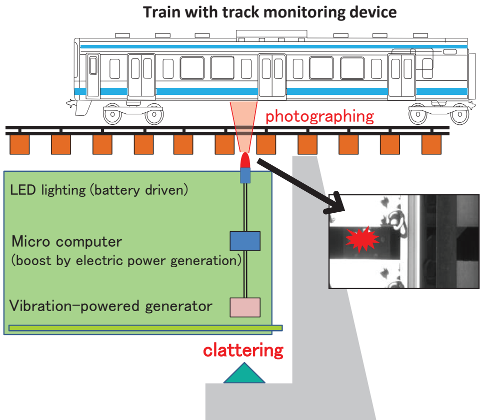

Fig.4. Image of clattering detection by LED lighting

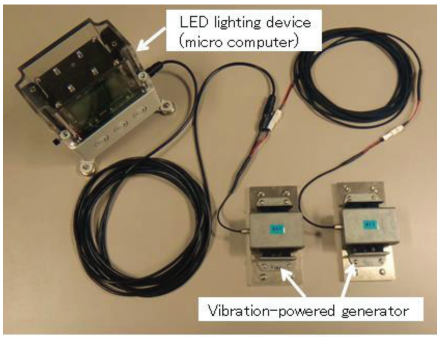

Fig.5. Prototypes

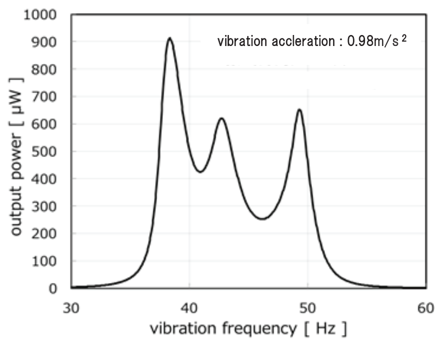

Fig.6. Oscillation frequency range