CONDITION MONITORING SYSTEM FOR ROCKFALL CATCH FENCES

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Rockfall incidents on catch fences along railways are generally monitored by regular site inspections. This inefficient and laborious process cannot ensure a high level of safety because incidents can happen between inspections. An alarm system is needed to signal these events in real-time to prevent accidents. A real-time condition monitoring system (CMS) for rockfall catch fences is currently under development. The proposed CMS is a compact device which is attached to the posts of catch fences: the device is activated by a built-in shock sensor. Proper selection of sensor characteristics is needed in order to provide reliable monitoring; to prevent the sensor from damage due to overloading and to prevent false alarms. In this study, a finite element model analysis of rockfall catch fences is used to predict CMS sensor requirements by simulating various impact scenarios.

Keywords: Rockfall monitoring, explicit finite element modelling, shock sensor

INTRODUCTION

The records of the British Geological Survey (BGS) show that there has been a significant increase in the number of rockfall accidents in the UK in recent years (Fig.1.) Rockfall accidents present a significant threat to transportation routes such as railways. Figure 2 shows a derailed train after collision with a fallen rock on a train line in Scotland, UK [2].

Low-energy rockfall catch fences are frequently used to protect railway infrastructure but these fences need to be monitored to ensure that they provide reliable protection. Currently, regular site inspections are conducted for catch fence maintenance but these are inefficient, time-consuming and expensive, as most catch fences are built in remote areas. Crucially, they cannot ensure a high level of safety because rockfall accidents can happen between inspections. In addition, when a rockfall event occurs, a rapid response is needed to avert accidents and to minimize disruption. Thus, a monitoring system with real-time notification capability can provide significant benefits.

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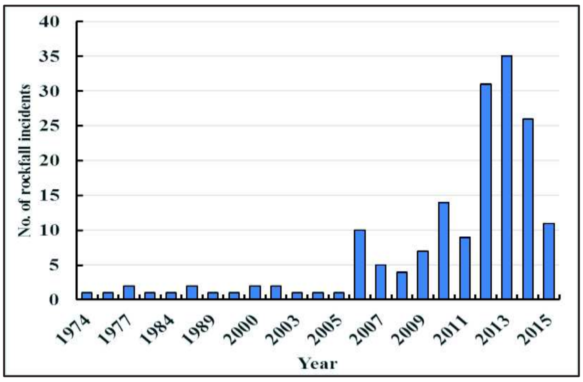

Fig. 1 Major rockfalls in the UK [1].

Fig. 2 Derailed train after collision with a fallen rock. [2]

A condition monitoring system (CMS) to remotely monitor rockfall catch fences is currently under development. The device has an integral shock sensor to monitor vibrations. When a rock impacts the catch fence, the sensor activates the CMS which transmits a signal through the mobile telephone network to pre-defined users. CMS has the ability to:

- send real-time warnings of rockfall incidents;
- provide detailed information of incident via photos/videos;
- work as an autonomous unit, thus increasing its reliability;
- run as a self-powered device, re-charged by solar cells;
- provide regular check data on the serviceability of the catch fence;
- perform health checks on itself.

The communication system between the CMS device and the control centre is illustrated schematically in Fig. 3.

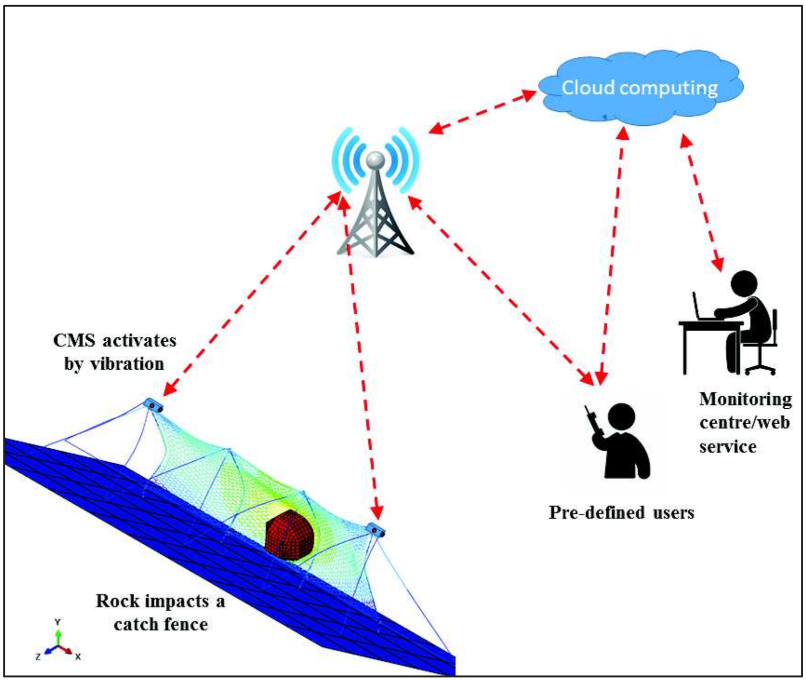

Fig. 3 CMS communication diagram.

MODELLING OF ROCKFALLS ON CATCH FENCES

To ensure that the monitoring device is only activated by serious rockfall incidents, the shock sensor should only trigger the CMS when predefined threshold vibrations are exceeded. To predict the required dynamic characteristics of the sensor (such as sensitivity, dynamic range and frequency response), a numerical model to simulate impacts on catch fences was created in Abaqus/Explicit [3]. A number of impact loading scenarios, involving a range of masses with various impact velocities, were simulated. The acceleration responses at the top of the posts, where the CMS devices would be located, were extracted.

The model can simulate a very wide range of catch fence designs, including arbitrary separation between the posts. For illustrative purposes, Fig. 4 shows a model of 12 m section of a low-energy catch fence with seven posts; the simulated acceleration responses on Post 5 due to the impact of a 1 tonne polyhedral boulder travelling at a speed of 10 m/s is presented in Fig. 5. Acceleration responses (raw) data are recorded for every time increment of the explicit solver in order to include the highest possible frequency response. The figure shows that the highest accelerations (which exceed 10E3 g) can be observed between 0.02 s and 0.06 s after impact.

However, explicit dynamic analysis of elastic-plastic impact behaviour using the finite element method can be corrupted by noise at high frequencies [4]. This particularly affects the calculation of accelerations. In order to remove this effect, data filtering using digital signal processing (DSP) was conducted by using a low-pass filter to delete the responses obtained at frequencies higher than a prescribed frequency threshold (cutoff frequency). The filtered acceleration data are presented in Fig. 5 which reveals in this case a peak vertical acceleration of c580 g and a peak lateral acceleration of c550 g.

To demonstrate that the filtered data are valid, and to avoid corrupted results by aliasing, these data were integrated to calculate velocity and displacement components. For illustrative purposes, the integrated results for displacements are compared in Fig. 6, with the data obtained directly from the Abaqus/Explicit analysis for Post 5 (P5). The agreement in the y and z directions is excellent and the difference in the x-direction is not significant. These differences might be reduced by further signal processing.

These data can be used to optimise the separation between CMS devices on the catch fence, by examining the attenuation of accelerations at neighbouring posts. Evidently, the interplay between sensor sensitivity, magnitude of the impact event and its remoteness from the sensor requires careful consideration in order to avoid false alarms on the one hand and the risk of failing to detect significant incidents on the other.

CONCLUSIONS

A condition monitoring system (CMS) which provides real-time notification of rock fall incidents enhances the capacity of rockfall catch fences to provide reliable protection for railways. A numerical approach has been developed to simulate rockfall impact on catch fences which shows promise as an aid to designing an optimum system.

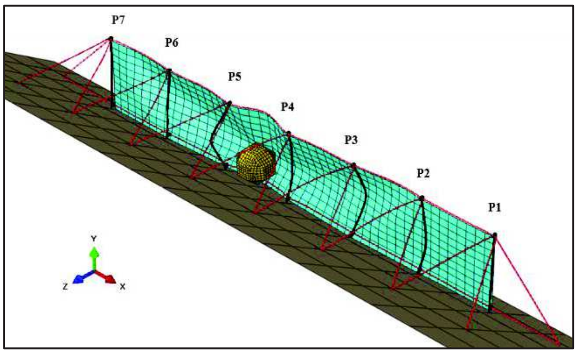

Fig. 4 Modelling of a rock impact on a low-energy catch fence.

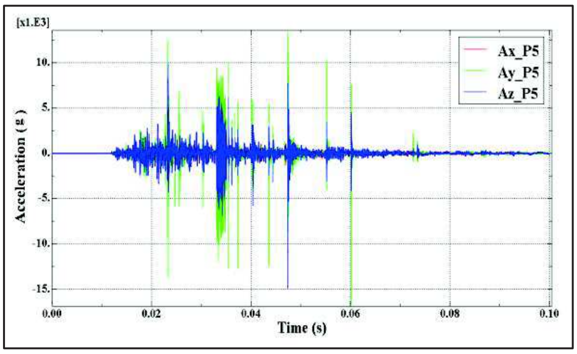

Fig. 5 Acceleration response components (raw data) of P5.

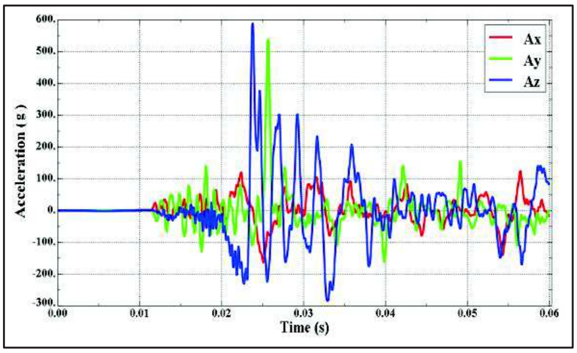

Fig. 6 Acceleration response components (filtered data) of Post 5.

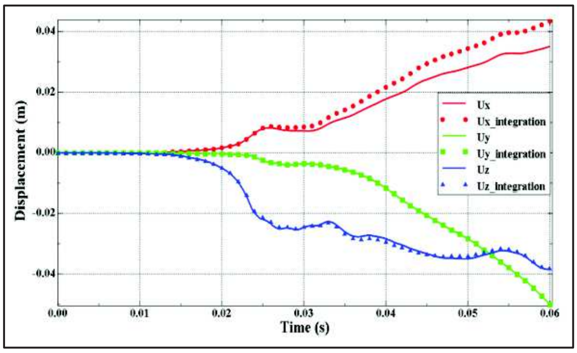

Fig. 7 Comparison between filtered and unfiltered displacement components of Post 5.

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REFERENCES

[1] DEPARTMENT OF TRANSPORT (2011) Rail Accident Investigation Branch (RAIB): Rail Accident Report.
[2] ABAQUS ANALYSIS USER'S MANUAL (2014) Dassault Systems Simulia Corp, Providence, RI.
[3] AL-BUDAIRI H, GAO Z, STEEL A, WHEELER S, DAVIES T (2016) Modelling and optimising of a light-weight rockfall catch fence system. NAFEMS UK Conference, pp 129-132.
[4] DIEHL T, CARROLL D, NAGARAJ B (2000) Applications of DSP to explicit dynamic FEA simulations of elastically-dominated impact problems. Shock and Vibration 7, pp 167-177.