1. Introduction

Rigid guide, as the track of conveyance, is widely used in mine hoist system. Faults occurring in it may lead to fatal breakdowns, personal casualties and economic losses [1]. A guiding system is shown in Fig. 1, which consists of a conveyance and two rigid guides. The conveyance is lifted by a wire rope and restricted by two rigid guides. Four sets of rollers are mounted on the conveyance with the purpose of guiding the conveyance along the rigid guide. It can be seen from Fig. 1(b) that each set of rollers comprises three singular and orthogonal rollers, which are pressed on the rigid guide. An entire rigid guide is made up of many tracks, which are attached to a grid of buntons. In practice, the rigid guide suffers inevitable faults due to various factors such as shaft deformation and installation precision, resulting in undesirable vibrations to conveyance. Therefore, it is necessary to detect the rigid guide fault to ensure production safety [2-3].

To date, several measurement techniques have been applied in condition monitoring and fault detection of rigid guide, which can be mainly summarized into two categories: static measurements and dynamic measurements. Static measurements are based on visual inspections, they are widely used to evaluate the state of rigid guide in industrial field at present [4]. Typical static indexes are the distance between two rigid guides and their individual perpendicularities. The disadvantages of these methods lie in that they require mine hoister downtime, and the status of rigid guide represented by the static indexes is not equal to the operational status which is more important. Dynamic measurements, as an alternative solution, are mainly based on vibration signals. Some works have been done through this way for monitoring purpose. Jiang [5] adopted Laplace wavelet to process signals and diagnose the rigid guide failures. Li [6] utilized singularity analysis to detect faults. Ma [7] first extracted five features from raw vibration signals and then investigated six algorithms for classification of rigid guide faults. The development of rail fault diagnosis used in train transport system is more mature [8-11], which provides valuable reference for rigid guide fault detection.
According to the non-stationary and nonlinear characteristics of the vibrations collected from the running conveyance, traditional diagnostic methods become inefficient. Thus, we propose a simple but efficient time-domain method to detect the rigid guide fault based on an experimental analysis. A series of tests are conducted on a rigid guide fault simulator to show the influence of faulty rigid guide on the vibration signals of an operational conveyance. As a case of the dynamic measurement, the failures of rigid guide can be detected by the proposed method accurately.

![Diagram of a guiding system](image1.png)

**Figure 1:** Diagram of a guiding system.

2. **Experimental setup**

   As shown in Fig. 2, three types of rigid guide faults which can excite impulses to conveyance are considered in this paper.

![Types of rigid guide failure](image2.png)

**Figure 2:** Types of rigid guide failure.

   A special experimental setup has been designed to simulate the dynamic contact between rollers and rigid guide. The photos of the rigid guide fault simulator are shown in Fig. 3. A metal framework is equipped with two rigid guides. On the top of the framework there mounted a head sheave. A winding drum is fixed on a platform before the framework for hoisting purpose. Between the drum and the conveyance a steel wire rope is installed passing by the sliding head sheave. An accelerometer is attached beneath the top surface of the conveyance to collect vibration signals at a sampling frequency of 20 kHz.
3. Results and discussion

A series of tests were carried out under different rigid guide fault categories and the results discussed below are based primarily on those tests. As a reference, a primordial vibration signal of the normal rigid guide is shown in Fig. 4.

![Primordial signal of the normal rigid guide](image)

**Figure 4:** A primordial signal of the normal rigid guide.

### 3.1 Embossment fault

The original signal under embossment fault is shown in Fig. 5. Compared with Fig. 4, there are two sets of impulses which are caused by the upper and lower guide rollers, respectively. The distinction in impulse amplitudes of these two sets is because of the variation in the stiffness and damping of the guide rollers. This explanation is also valid for the bump and clearance faults which will be discussed later. It is obvious that each set consists of two bursts. The first burst represents the defect commencement when the guide roller hits the embossment, while the second burst is regarded as the defect exit when the guide roller departs from the edge of the embossment and knocks the rigid guide.
3.2 Bump fault

The primary signal under bump fault is depicted in Fig. 6(a). The corresponding diagram between localized waveform and lifting process is presented in Fig. 6(b). From the illustration we can see that the bump fault excites one impact for a single roller passage and the mutation in the enlarged view of the vibration signal is correlated to the collision of the guide roller with joint corner in the rigid guide.

3.3 Clearance fault

The raw signal under clearance fault is described in Fig. 7(a). By synchronizing the vibration at defect point and positions of guide roller, the lifting process is graphically represented in Fig. 7(b). Similar to the bump fault, there is also one impact when guide roller travels over the clearance fault. However, the detailed pattern of impulse is quite different. At point A, the entry transient event on the vibration response starts. After the gradual de-stressing process the contact force between rigid guide and guide roller becomes smallest at point B. At last, the guide roller strikes the exit of the clearance at point C.

Figure 5: An original signal under embossment fault.

Figure 6: An original signal under bump fault.

Figure 7: An original signal under clearance fault.
In summary, four health conditions of rigid guide are presented including normal, embossment, bump and clearance. The vibration signals for each corresponding status show great discrepancies in the entire profiles or in the localized waveforms at defect points. This result is expected to be a solid foundation for rigid guide fault detection.

4. Conclusion

Fault identification of rigid guide can improve the reliability of mine hoist system and reduce maintenance time. Due to the strong non-stationary and nonlinear properties of vibrations excited by faulty rigid guide, a time-domain method is proposed in this paper. A series of experiments are carried out to display the effect of rigid guide faulty conditions on the vibrations of an operational conveyance. The results of the enlarged signals at defect points are pretty different from each other corresponding to the fault categories, which can be used as an efficient technique for rigid guide fault recognition.

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