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Algorithm for Automatic Chute Motion Control

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Abstract: This paper is focused on the problematic of the conveyor belts life increasing by the chute moving under dropping rocks. At the first the suitable criterion of hardness and lumpiness of rock transported by the conveyor belt has to be find. At the second part of this project the suitable algorithm for chute motion control should to be suggested. Based on the criterion satisfaction this algorithm will automatically decide of the chute position.

Keywords: Belt; Conveyor; Life Increasing; Algorithm; Automation.

1 Introduction

In the surface mines belt conveyors are very important part of the transport chain. Conveyer line consists from several conveyor belts, usually of the 1 km length. In the driving and return stations (see Fig. 1) the rock is poured from one belt to another. This is done approximately from a height of 10 mm. This causes a great wear of the belt [1]. The solution, how to increase service life of the belt, is to find a suitable way to reduce the kinetic energy of the dropping mass. There is only solution, how to do it – falling height reduction. This change can be reached by two ways. By change of the station construction at the first or by insertion of another part between incoming and outgoing belt. Modification of station construction should be based on decreasing of height of incoming belt above ground (and outgoing belt also). After studying of construction drawings and after a few consultations with station producer this solution was found as impossible. The reason is in necessary to keep some space for technology background of station, like belt tensioning, clearing, etc. Therefore it had to be proceeded to falling height reduction by insertion another part between belts. This part has to be abrasion resistant and it has be stiff enough. In according to this conditions as decided to insert a steel chute between both of the belts. This chute is equipped with hardened steel plates which are easy to change for a new one in case of their damage.

The advantage of this conception is a significant reduction of the rocks impact energy, the disadvantage is the danger of clogging of the hopper area, when the adhesive material is transported. Therefore, the chute must be automatically positioned according to hardness and lumpiness of the transported rock.

For this reason it was necessary to find suitable criterion to identify transported material properties. Almost three possibilities were considered:

- scanning of the circuit of transported material cross-section by laser sensor (laser weight). This measure should recognize circuit curve smoothness. The advantage of this method is that this sensor is still used for measuring of quantity of transported material. But it was shown finally, that this method is unsuitable for measuring of material lumpiness and hardness, because lumpiness material doesn't automatically means harness material and in advance, big parts of materials can be hidden inside of material mass.
- Manually by wheel-excavator operator intervention. Operator of wheel-excavator can directly see structure of mined material. Therefore operator is one of the best indicators to say, whether to chute slide in or not. But, instead of mentioned above, this possibility is unreliable, because it depends on operator experience at the first and on operator tiredness secondly.
- The last possibility is based on knowledge that transported material is in contact with the steel shield during falling from incoming belt to outgoing one. This steel shield has a function of directing of transported material to the center of outgoing belt. Consequently it have to be in contact with falling rocks (transported material). By pouring of transported material from one belt to another, it is bounced from steel shield. This shield is placed between both belts. After a many of measures was decided to identify

Fig. 1: Return (1) and driving (2) station.

hardness and lumpiness of transported material by the excitation extent of this steel shield eigenfrequencies. By impact of the hard material, eigenfrequencies are excited with much greater intensity than in the case of the soft adhesive material.

2 Identification of the Transported Material

At the first, 3D vibration sensor was mounted on the shield to measure vibration caused by falling rocks. By vibration analysis with many types of transported material properties was determined these conclusions:

- The last possibility is based on knowledge that transported material is in contact with the steel shield during falling from incoming belt to outgoing one. This steel shield has a function of directing of transported material to the center of outgoing belt. Consequently it have to be in contact with falling rocks (transported material). By pouring of transported material from one belt to another, it is bounced from steel shield. This shield is placed between both belts. After a many of measures was decided to identify hardness and lumpiness of transported material by the excitation extent of this steel shield eigenfrequencies. By impact of the hard material, eigenfrequencies are excited with much greater intensity than in the case of the soft adhesive material.
- Approximately the same level of vibrations in each measure direction.

From reasons mentioned above followed expectations about dependency between material harness and excitation of shield vibrations (eigenfrequencies concretely), which can be measured only in one direction (direction of falling material flow especially). To show this dependency it was necessary to find shield eigenfrequencies and to show unique relationship between harness of transported material and intensity of shield vibration in the field of shield eigenfrequencies.

2.1 Measurement of the Shield Eigenfrequencies

These values was found by a several independent measures. Each measure was realized during driving station layout. One dimensional vibration sensor was mounted to the shield. For each measurement different place of shield excitation (by hammer) was used. From next FFT analyses comparison follows eigenfrequencies and their intensity level (weights) mentioned in Tab. 1.

These values was compared with FFT analyses of vibrations measured during station working and it seemed to be corresponding. This claim was necessary to verify by another measures focusing to eigenfrequencies excitation.

Tab. 1: Table of shield eigenfrequencies.

No. of eigenfrequency	1	2	3	4	5	6	7
value [Hz]	300	340	390	430	500	550	790
weight [-]	1	2	4	3	2	3	4

2.2 Algorithm Suggestion

To verify relationship between transported material hardness and intensity of exited shield eigenfrequencies suitable measuring algorithm was suggested. Measuring chain consists from 1D vibration sensor, real-time PC, comparator and software for shield vibrations evaluation. Sensor is mounted to shield in the place, which was chosen on the base of eigenfrequencies measurement. Sensor is connected with real-time PC CompactRIO 9022 from National Instruments. PC is placed in the distribution case of the driving station. The requirement for algorithm is to give only one value (criterion), which will depends on hardness of transported material. This value will change in time and will be compared with reference value set by operator. This will decide about chute slide in or slide out.

From reasons mentioned above follows next structure of algorithm:

- The last possibility is based on knowledge that transported material is in contact with the steel shield during falling from incoming belt to outgoing one. This steel shield has a function of directing of transported material to the center of outgoing belt. Consequently it have to be in contact with falling rocks (transported material). By pouring of transported material from one belt to another, it is bounced from steel shield. This shield is placed between both belts. After a many of measures was decided to identify hardness and lumpiness of transported material by the excitation extent of this steel shield eigenfrequencies. By impact of the hard material, eigenfrequencies are excited with much greater intensity than in the case of the soft adhesive material.
- Approximately the same level of vibrations in each measure direction.
- It seemed, that the level of vibrations closely corresponded with harness of transported material.
- Measured signal is split by set time constant to separate signals.
- For each separated signal FFT analysis is computed.
- To highlight fields with eigenfrequencies the results of FFT analysis are multiplied by function of weight coefficients. This function consists of given number of sin waves of different amplitudes (see the 3rd row in Tab. 1), which are 20 Hz wide. Each wave corresponds with one eigenfrequency. Frequencies below 150 Hz and above 800 Hz are suppressed (see Fig. 2). Multiplication by weight function gives better sensitivity to vibration effect in the field of shield eigenfrequencies. Schema of this operation is shown on Fig. 3.

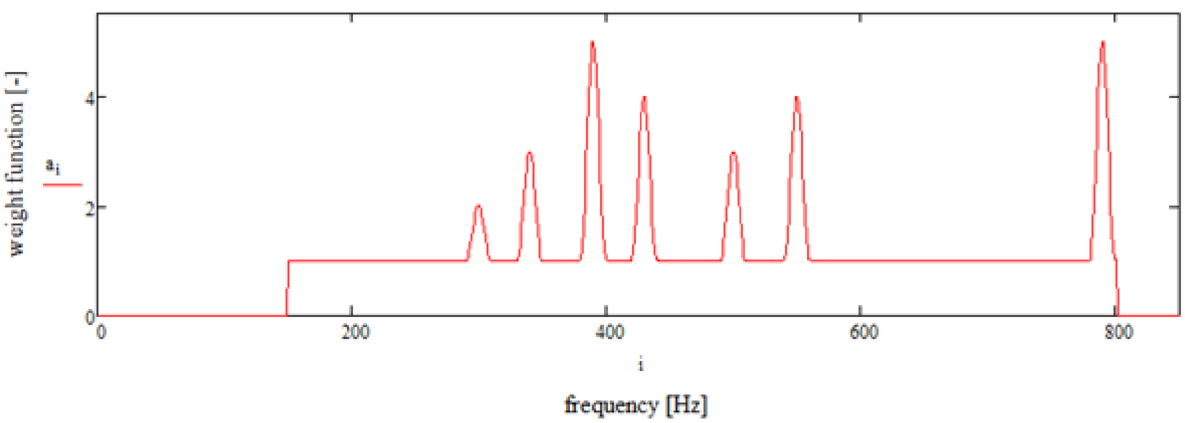

Fig. 2: The weight function for FFT multiplication.

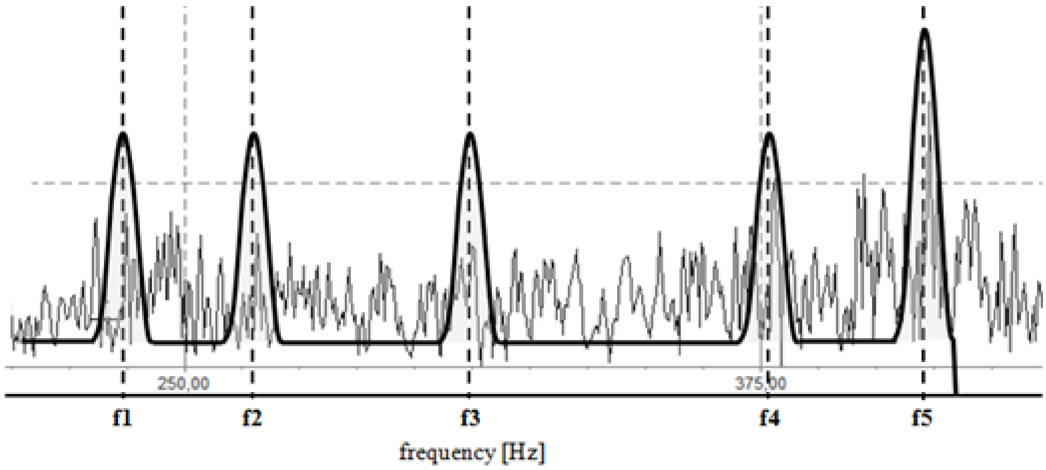

Fig. 3: The Scheme of FFT multiplication by the weight function.

2.3 Algorithm Verification

Special software in LabView environment was developed to real-time PC control. From the results mentioned above follows that some parameters needs to change by users:

- The weight function – this function is given by a vector containing a total of 1000 values. Each value corresponds to the weight of the respective frequency (1 Hz to 1000 Hz).
- The length of the matrix, where values of area under curve are stored. This parameter allows user to change the sensitivity of the algorithm to sudden changes in the properties of transported material.
- The sensitivity (scale) of the output signal, respectively. Conversion between acceleration values (in multiples of the gravitational constant) and the size of the output current in mA (constant A).
- The offset of the result output current (constant B).

Suggested algorithm was verified by four series of measures with different properties of transported material. At the first, hard and lumpy rocks was measured to obtain maximal of criterion value (see Fig. 4). This value is then modified by control software to current limit from 20 mA to 30 mA (input of driving station control system). Constant A was set to 100000 mA/g.

The next series of measures with soft material (Fig. 5) confirmed significant decrease of criterion value like expected. However, due to the requirement of safety the value of constant B was chosen to 4 mA. The reason for this is the recognition state with empty belt from faults, e.g. due to breakage of the data cable.

At the last step a several series of measures was realized with transported rocks of random properties. The aim was to confirm the size of the individual constants A and B determined in previous measurements and to verify the appropriate weight function for application in the real conditions.

Fig. 4: Example of the hard transported material.

Fig. 5: Example of the sandy transported material.

3 Conclusion

Under this research algorithm to control chute motion was developed. This algorithm will automatically slide out steel chute between incoming and outgoing belt when hard and lumpy rock is transported. This causes reduction of falling rocks kinetic energy and increasing of belt service life.

Acknowledgement

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