FIG. 4

FIG. 8
FIG. 7

FIG. 9
This invention relates to mining machines and is particularly directed to means for sensing the presence of coal in the path of a coal cutting bit.

Fig. 1 is a side elevational view of a bore-mining machine embodying this invention.

The bore-mining machine of Fig. 1 is of the typical track laying type comprising the tractor body 1, tracks 2, and boring head 3. The tractor follows in the tunnel dug by the cutting head 3, the coal loosened by the head being conveyed to the rear of the machine and removed by the conveyor mechanisms 4 and 5. The cutting head is pivoted on trunnion 6 so that the bore hole may be biased upward or downward and away from rock which may be found in either the floor or the ceiling of the vein. Specific details of the bore-mining machine are not claimed and are not necessary for an understanding of this invention.

A typical cutting pattern viewed in the face of the vein is shown in Fig. 2. The radius of the cut is adjustable on most commercially obtainable machines from about 1/2 feet to 3 feet. If the cutting tool will enter rock to a depth of 2 inches, the angle a between the vertical and a line through the point of impact with the rock will be about 19 degrees when the radius is 36 inches; the angle a will be about 27 degrees when the radius is 18 inches. If the cutting head is turning at a speed of 17 revolutions per minute, the cutting bit will be in the rock for about 0.5 second. These constants will vary, of course, with different speeds and different cutting radii and are of importance in the design of the electrical circuits hereinafter to be described.

A more common type of bore-mining machine comprises side-by-side cutting heads, as shown in Fig. 3, with overlapping cutting circles. There are two cutting bits on each head which are diametrically opposed and are synchronized by driving gears so that the cutting bits alternately pass the low, or high, points in the swing. The cutting bits on head 15 are marked 16 and 17, while the cutting bits on head 18 are marked 19 and 20. If heads 15 and 18 revolve clockwise and counterclockwise, respectively, the bits would enter the rock in the floor in the following order: 19, 17, 20, and 16.

When the vibrations of the machine are measured at any point along the machine, from the cutting heads to the rear end, considerable rumble-type vibrations are found, as expected. Vibrations caused by movements of cutter chains, conveyor linkage and gears cause a relatively high background of noise. This continuous high level vibration is indicated at 21 in Fig. 4. Each time a cutter bit enters rock, however, a relatively distinct movement throughout the frame of the machine is qualitatively reported by outstanding peaks such as shown at 22, Fig. 4. Commercial accelerometers of various types are capable of reliably identifying vibration including the sharp vibration caused by the bit in rock.

One such accelerometer is sectioned in Fig. 5. The mass 25 comprising a permanent magnet is in the form of a bar of steel, iron, or alnico is mounted to slide with minimum friction along the axis of coil 26. The magnet is lightly pressed with spring 27 against stop 28 to hold the magnet centrally in the coil. The coil...
structure including the stop is fixedly joined to the unitary mounting structure 29 which in turn is bolted, or otherwise fastened, to the frame of the machine, the vibration or motion of which is to be measured. The place of attachment of the accelerometer to the mining machine is preferably a point of maximum travel. This point is preferably well removed from the center of gravity of the machine and may be immediately adjacent the cutting tools in the head 3 or at a point near the rear end of the machine. Further, the accelerometers are so oriented with respect to direction of maximum vibration as to yield the maximum signal output.

Starts the machine frame and the supporting bracket 29 travels to the left, for example, the inertial mass 25 as viewed in Fig. 5 moves to the right relatively, whereupon the magnetic lines of force of the inertial mass cut the coil windings and a voltage is induced. The voltage at terminals 26a is, essentially, a differential function of acceleration. When the movement resulting from shock is of the type shown by the curve 36 in Fig. 6, acceleration increases from zero at time T1 to a maximum at time T2, whereupon direction of motion reverses, velocity changes sign, and acceleration returns to zero at T2. Since the voltage induced in winding 26 is a function of acceleration, the voltage at 26a is a maximum during maximum accelerations, producing positive and negative going loops of voltage during the two maxima of acceleration, respectively, as shown at 31 and 32, respectively. By simple rectification, either voltage loop can be easily eliminated.

If the direction of force applied to the mining machine caused by the cutting bit at the instant of entry of the bit into rock is F1, Fig. 2, the vertical component of that force would be F2 and the horizontal component would be F3. According to this invention, the components F2 and F3 can be combined to indicate in which of the four quadrants the force F1 is applied. Two accelerometers for indicating forces F2 and F3 in either direction and two additional accelerometers for indicating force F3 in either direction, respectively, will produce four signals which, when properly combined, according to this invention, will reliably indicate the quadrant in which rock is encountered, and where there are two cutting heads, as in Fig. 3, rock at the bottom left or right side and rock at the top right or left side is instantaneously indicated to the operator who can thereupon take appropriate action in steering the machine to move the cutting bits away from the objectionable rock.

In Fig. 7, accelerometers 40 and 41 are fixed to the machine, the vibration of which is to be indicated. It is assumed, in the example of Fig. 7, that forces F2 and F3 are to be detected. When the accelerometers are of the type shown in Fig. 5, voltage output signals are generated in response to accelerations in one direction only. These directions are preferably at right angles and preferably are oriented with the true vertical and horizontal. The output signals of the accelerometers which are of the type shown in Fig. 4 are fed to pulse shapers 42 and 43, respectively. The pulse shapers are typical amplifiers with clipping circuits for isolating the rock impact signals 22, Fig. 4, from the background noise of the accelerometers. The more or less rectangular pulses at the output circuits of the pulse shapers are applied to two control circuits of gate 44 which will produce an output at 45 only when the two inputs are of the same sign and are coincident in time. Such a gate is sometimes termed an And gate. A series of violent vibrations result in a series of pulses at the gate during the time the cutting bit is moving in rock. These pulses may be integrated as by a simple lamp 46.

One gate circuit which functions efficiently is shown in detail in Fig. 8. The two input or control circuits 42a and 43a are capacitively coupled to the bases, respectively, of two transistors having a common emitter resistor 44a. The output circuit is connected to the upper end of 44a.

In operation, current continues to flow in the collector-emitter circuits of the two transistors and through 44a, holding the output at some high potential. This potential drops only when both transistors are biased to cutoff simultaneously, thereupon the output voltage drops to some low value and remains during the coincident time of the two negative-going input pulses.

In Fig. 9, two additional accelerometers 41a and 42a are added to the system to sense forces F2 and F3 of either sign. Gate 44 is connected between accelerometers 40 and 41, gate 45 is connected between accelerometers 40a and 41a, gate 45a is connected between accelerometers 40a and 41a. Each gate produces an output signal only when forces F2 and F3 indicate a rock impulse in one of the four quadrants. Indicators 51 and 52 indicate rock at the top left and top right quadrants, respectively, of the cut face. Indicators 53 and 54 indicate rock at the bottom left and bottom right quadrants, respectively, of the cut face.

One accelerometer only has been shown. There are numerous accelerometers of the inertial type, and otherwise, which could be substituted. It is preferred, of course, that the accelerometers be sensitive to accelerations in only one direction and that at least some modifications may be made be made by those skilled in the electrical arts without departing from the scope of this invention as defined in the appended claims.

What is claimed is:

1. In combination with a coal bore-mining machine having a rotary cutting head and tractor for driving the head and carrying forward the head into a coal vein, means for indicating the entry of a cutting bit into roof or floor rock comprising a plurality of inertial accelerometers affixed to said tractor, said accelerometers being of the type which produces a voltage analogous to acceleration and being orthogonally arranged for responding to different components of vibratory accelerations imparted to said tractor by the bits of said cutting head, means for combining the voltage responses of said accelerometers, and means for instantaneously indicating coincidence in time of said voltages to show the direction of the resultant acceleration of the tractor and cutting head.

2. The combination comprising two accelerometers, each accelerometer being primarily responsive to accelerations in one direction, said two accelerometers being affixed to a base the vibratory accelerations of which are to be analyzed and the two accelerometers being oriented so that the directions of response are at right angles; an And gate circuit with two control circuits and one output circuit, said accelerometers being directly coupled, respectively, to said two control circuits, and an indicating circuit coupled to said output circuit.

3. In combination in a system for determining the direction of principal vibratory acceleration of a machine comprising two accelerometers, said accelerometers being affixed to said machine and so oriented as to generate signals, respectively, in response to orthogonal components of acceleration of said machine, said accelerometers being capable of generating a voltage analogous to acceleration, a pulse shaper connected to the output circuit of each accelerometer, an And gate with two control circuits, said pulse shapers being connected, respectively, to said two control circuits, and a utilization circuit connected to the output of said And gate.

References Cited in the file of this patent

UNITED STATES PATENTS

2,365,218 Rogers Dec. 19, 1944
2,613,071 Hansel Oct. 7, 1952
2,620,386 Alspaugh et al. Dec. 2, 1952