Spring 5-5-1954

Application of the Rotary Principle to Underground Mucking

Walter J. Smit

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APPLICATION OF THE ROTARY PRINCIPLE
TO
UNDERGROUND MUCKING

Submitted to
The Mining Department

By
Walt J. Smith

5 May, 1954
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TO
UNDERGROUND MUCKING

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The Mining Department

by
Walter J. Smit

5 May, 1954
Residence Hall
Montana School of Mines
Butte, Montana
May 5, 1954

Mr. Koehler S. Stout
Assistant Professor of Mining Engineering
Montana School of Mines
Butte, Montana

Dear Professor Stout:

In compliance with your authorization of September, 1953, I submit the following paper, entitled "Application of the Rotary Principle to Underground Mucking." This constitutes the second part of an investigation initiated in August, 1953, and concludes my first paper of this series: Mucking Philosophies (dated January 9, 1954.). I submit this thesis as partial fulfillment for the degree of Bachelor of Science in Mining Engineering.

Because of a lack of physical facilities for undertaking these investigations, this paper can, at best, lead to only general conclusions as to performance of a machine of this type. However, I feel that, in contrast to the limited scope of the investigations performed, the observations lead to a well-defined outline for the future.

This paper, then, may be considered only a rough draft of a general nature as to the desirability of incorporating the rotary principle into a mucking device. There is much work yet to be done before the applications of this principle to even basic mucking problems can be perfected. It is the hope of the author, that, in the near future, a device of the type outlined herein may be utilized by the mining industry to the benefit of the nation and of mankind.

Respectfully submitted,

Walter J. Smit
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ABSTRACT

Since the beginning of man's utilization of rocks and minerals, he has felt a need for an efficient mover of these materials. Thus, he turned from the sole use of his hands to the development of the shovel, and through the other hand tools--the hoe, and the fork, and the rake--he finally came to the manufacture of the heavy, more efficient, large-scale rock movers--the muckers, and scrapers, and duckbill loaders.

However, with the advent of great, mass production underground exploitation methods (block caving and sublevel stoping), a need has developed for more efficient, more universal mucking equipment. These investigations are an attempt at the development of a versatile, efficient, constant-feed mucking device.

Mucking may be divided into three main operations: the crowd and the lift, and the feed. Although these operations may be combined, they must always exist in the transport of a broken muckpile from a development heading (excluding raises) to any other collecting point.

Experiments performed with scale models are favorable as to the potentiality of a rotary-head, gravity-crowd, mucking device. Of course, much work is necessary before a device of this type can be put into operation. However, after analysis of existing equipment, and after cursory experimentation, a device of this sort is indicated as an answer to the problem of cleaning underground development headings.
THE PROBLEM ITSELF

An old, miner's rule-of-thumb has always been: "For every ton of ore exploited, a ton must also be developed." Today, with the advent of large-scale mining methods, a need has arisen for following through with increased speeds in the development operation. Jumbos, airleg drills, and tungsten carbide bits have all aided in a speedup of the drilling phase of the cycle. A bottleneck exists in the mucking phase.

In addition, there has been a singular lack of versatility in mucking machinery. Aside from the shovel and the hoe, there is no mucking equipment suitable for efficiently mucking shafts, inclines, and adits alike. In many of the small and intermediate mining operations of this nation, the added costs of development mucking because of lack of speed, and because of lack of versatility, might very well mean the difference between profit or collapse.

This paper is an attempt at the development of an inexpensive, efficient, more versatile mucking device. Because of lack of facilities, it would be impossible to construct a completed machine based on whatever conclusions were reached here and in previous examinations. However, a scale model of the completely original innovations was selected for trial. While the results that were obtained are not completely conclusive, they are, at the least, indicative of the direction of future work.
ACKNOWLEDGMENTS

The author wishes to here express his appreciation to the many people who kindly gave of their time and advice as to the subject of this paper and its preparation.

In particular, he should like to thank Professor Koehler S. Stout, without whose sagacity and guidance this paper would not be possible. In addition, he wishes to express his gratitude to Mr. Earl Denny for use of his shops, to Mrs. Stephen Nile for her help in the preparation of the photographs used herein, and to the staff of the Mimeographing Office of the Montana School of Mines for their aid in multilithing this material.
FIG 1.

BASIC OPERATIONS IN MUCKING
FIG 1. BASIC OPERATIONS IN MUCKING

2. LIFT
FIG 1. BASIC OPERATIONS IN MUCKING

3. FEED
Mucking may be divided into three main operations. These are the crowd, the lift, and the feed. Figure 1 illustrates these operations. Although these movements may be combined, they must always exist in the transport of a broken muckpile from a development heading (excluding raises) to any other collecting point. It is necessary to analyze these divisions of rock moving in order to define any areas for improvement.

Crowd

The crowding operation—of necessity, the first operation—involves the forcing of the mucking medium into the muckpile. It is quite interesting to note that this operation is only incidental to the actual rock moving, and that no work of material transport is actually performed. Figure 2 A illustrates this operation in the cases of the vertical-arc type loaders and the shovel. The Goodman and Joy coal loaders also involve this method of the crowd. The larger, heavier machines of these types require more of this dead work.

In contrast to this method of the crowd, there is the type incorporated in the clamshell buckets, scrapers, and vaned, rotary wheel (Fig. 2 B), all of which utilize gravity rather than mechanical force in the crowding operation. It is easily seen that this method of forcing the mucker head into the muckpile is far more efficient, and that penetration of the feeder varies directly as the weight of the head (and thus, its size).
FIG. 2  CROWD ANALYSIS

FIG. 3  LIFT & FEED ANALYSIS
Lift

The lift is the first step actually effecting movement of the muckpile, and is the second step in the mucking phase. This operation merely involves lifting the material to be moved to an elevation slightly higher than the elevation of the final position desired.

In many instances this lifting operation is combined with that of feeding. The Joy continuous-type loader performs this combined function through the use of an inclined plane and a flight conveyor. The scraper ramps, inclined conveyors, and bucket elevators also effect this combination (Fig. 3).

Feed

The feeding operation involves the actual positioning of the transported material in the final receptacle, and includes the method of clearing the muck from the lifting device.

All of the conventional, rocker-arm muckers utilize a "throw" feed, as does the shovel and the fork. This often results in spillage and inaccurate positioning—hence, inefficiency. In contrast to the throw feed, the straight gravity feed of the clamshell buckets, inclined conveyors, scraper ramps, etc., seems considerably more desirable from the viewpoint of control and efficiency.

Summary—Mechanics

From only cursory examination, we find, then, that a machine utilizing a gravity crowd, combined lift-feed, and simple, gravity feed would seemingly be the most desirable.
DEVELOPMENT OF THE ROTOMUCKER

Based on the types of operations arrived at in the former section, one can conjecture as regards basic design of a more desirable mucking device. First, however, it is necessary to compare existing mucking devices, and to discuss modes of locomotion for this machinery.

Locomotion for Mucking Devices

Locomotion used in mucking varies from the foot and the skid through rail, tire, and crawler. Rail is the principal method of horizontal mucking machine locomotion. However, there is a trend today to rubber tires and tractor-crawlers, with the latter as most suitable for underground universal use (shaft, incline, and adit).

Comparison—Contemporary Underground Mucking Equipment

To better compare existing mucking machinery, a table can better contrast the major operations:

<table>
<thead>
<tr>
<th>MACHINE</th>
<th>CROWD</th>
<th>LIFT</th>
<th>FEED</th>
<th>COMMENTS</th>
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<tr>
<td>Vertical arc</td>
<td>Push</td>
<td>Separate</td>
<td>Throw</td>
<td></td>
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<tr>
<td>Clamshell</td>
<td>Gravity</td>
<td>Separate</td>
<td>Gravity</td>
<td>inflexible</td>
</tr>
<tr>
<td>Continuous</td>
<td>Push</td>
<td>Combined</td>
<td>Gravity</td>
<td></td>
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<td>Horizontal arc</td>
<td>Push</td>
<td>Separate</td>
<td>Gravity</td>
<td>Large-scale</td>
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<tr>
<td>Hand shovel</td>
<td>Push</td>
<td>Separate</td>
<td>Throw</td>
<td>Small-scale</td>
</tr>
<tr>
<td>Scraper ramp</td>
<td>Gravity</td>
<td>Combined</td>
<td>Gravity</td>
<td>Friction loss</td>
</tr>
<tr>
<td>Bucket elev.</td>
<td>Push</td>
<td>Combined</td>
<td>Gravity</td>
<td>Heavy-duty</td>
</tr>
<tr>
<td>ROTOMUCKER</td>
<td>Gravity</td>
<td>Combined</td>
<td>Gravity</td>
<td></td>
</tr>
</tbody>
</table>
FIG. 4

POSSIBLE APPLICATIONS OF THE ROTARY PRINCIPLE TO MUCKING.
The Rotary Principle

Most energy is transmitted into work on an industrial scale in a rotating form. Thus, our electric motors, air motors, and internal combustion engines transmit rotative power. To obtain actual work from these power supplies, most contemporary mucking machines transform rotative work into vertical and horizontal components by mechanical means. It follows that certain losses and inefficiencies exist.

For this reason, the rotary principle was selected as a basis for investigation. Although utilized in certain ditching machines and on massive German pit muckers, this principle is relatively untried for underground rock moving. However, because of the direct drive that is possible, and because of less loss in power transmission, a smaller, simpler, more efficient machine should be possible to develop.

Rotary Mucking Possibilities

Figure 4 illustrates the four basic rotary-type machines available for mucking. Sketch 4 A pictures the method incorporated in a large number of ditchers and in some European ditch muckers, as well as in some types of pit muckers. This method requires the lifting of the material being moved for a large portion of a revolution. A semi-push feed is also necessary here.

The vaned, bottom-clawing wheel (Fig. 4 B) is, to the knowledge of the author, not utilized in other muckers. It is readily seen that a gravity crowd, a combination lift-feed, and a gravity feed are incorporated in this method. It would seem that this type of rotary
A- PROFILE DETAIL OF THE ROTARY HEAD

B- END VIEW OF ROTARY HEAD

C- ROTOHEAD DETAIL

D- BEARING MOUNT

PLATE I- GENERAL STRUCTURAL DETAIL
construction would, because of its seeming originality and because it complies to all of the conclusions arrived at in the mechanical analysis, be the most desirable for investigation. Inasmuch as a more complete title would be too awkward for further use here, this machine was dubbed Rotomucker for reference.

The bucket elevators and inclined conveyors are further applications of the rotary principle which, conceivably, might be adapted to underground mucking. However, both of these devices incorporate a push crowd which is somewhat inefficient. The versatility that a bucket elevator can afford might possibly offset this disadvantage, and indicates a direction of work for the future. A lift-feed medium must be coupled with the rotomucker head, and so the bucket elevators and inclined conveyors naturally suggest themselves for this function.

THE ROTOHEAD INVESTIGATIONS

The logical step after selection of the rotomucker-type of machine, and short of actual structural design, was to investigate the potentialities of the device through scale-model investigations. Inasmuch as the rotohead is the only "new" section to be tested, it was assumed that modes of locomotion and of conveyance would perform the same functions with the same efficiencies as they do normally.

It was first necessary to obtain an overall visual picture of the machine in order to better determine head size and other physical relationships. This was done with small (1" = 5') non-working scale models executed in balsa wood. These proved the practicability of the
A - EXPERIMENTAL LAYOUT
1 - 1/4 HP MOTOR
2 - GEAR REDUCER
3 - ROTOHEAD

PLATE 2
rotomucker from a size viewpoint with the stringent size restrictions of underground conditions in mind.

It then became necessary to design and build a suitable rotohead model for conducting performance tests. Plate 1 illustrates the design that was finally adapted. On a 1/4 scale, and fabricated of aluminum, the model was designed to simulate structural members which are available to most mines. Aluminum was chosen because of the ease of fabrication. SKF single row, deep groove, double shield, ball bearings were selected for mounting the shaft. The bearings are catalog number 6201 2Z, and have a basic load rating of 1140 lb—deemed more than adequate for experimental purposes. These are mounted in wooden booms, using only friction to keep them in place. Plate 1 D illustrates one bearing already mounted.

Only the rotohead was constructed to scale. After fabrication of this member and mounting of the bearings, the remainder of the support and model were constructed of wood (again, because of ease of construction, and lack of necessity for anything more accurate.) and the motor and gear reducer were mounted. The motor used is an Emerson 1/4 hp, a-c power source, and rotates at 1750 rpm. Plate 2 A very clearly illustrates this mounting. Although a positive drive would be used in actuality (probable chain-and-sprocket drive), the v-belt and pulley were used here because of accessibility. An aluminum pan, 2 in. wide and mounted at 45° to the horizontal was used as a retaining barrier for the material to be moved. This material was minus 1.5 in. (minus six in. to scale), and was siliceous in nature (Plate 2 B).
The position possible at 65 rpm is the maximum. It is interesting to note that, in the case of the potatoes, no satisfactory balance of the support was found. It was therefore decided to try using the forcing and adjusting drive with a small roller drive. The results were surprising, as the potatoes did not fall off or damage the potatoes. In a test with 25 pounds of potatoes, no damage was observed, and the use of the belt drive was successful.
The rotohead rotated at 24 rpm in the initial tests. Despite the fact that belt slippage often occurred, the performance of the head was quite satisfactory at this speed if the supporting booms were raised and lowered whenever the jamming and slippage took place. Even without the optimum conditions that a positive drive would have provided, material of minus six in. was handled effectively. There is little doubt that a full-scale rotohead would work satisfactorily. The six in. maximum size is even more surprising considering that the dimensions of the model rotohead are only six in. dia by six in. length. Because of the slippage caused by the belt feed, little data could be considered representative of actual conditions. Mathematical approximations could be made utilizing the width of the blade, number of revolutions per minute, average angle of incline of the material being handled, and the number of cubic feet per ton of ore. However, approximations of this sort have the obvious inaccuracies involved in not considering losses due to incomplete blade coverage and rpm differences under actual conditions.

Slower speeds resulted in less efficiencies in the rotohead tests. Higher speeds were not available with the materials at hand. In all, the experiments indicated the success of the basic principle, and they directed further areas of research which shall be covered in the next section.

Some of the limiting factors in the experiment were: the use of aluminum as the fabrication material, the excessive weights of the power units in relation to the head, and the use of the belt drive.
FIG. 5
ROTMUCKER VARIATIONS

LIFT & FEED

LOCOMOTION
FIG. 5

ROTOMUCKER VARIATIONS

CONVEYOR & PAN FEEDER

WHEEL - RAIL OR TIRE
FIG. 5

ROTMUCKER VARIATIONS

BUCKET ELEVATOR

CRAWLER
Plate 3 illustrates the model rotohead in action. As previously mentioned, the tests proved the rotohead to be quite feasible. It then remains to conjecture as to possible variations, to analyze of the parts of the machine, and to discuss the possible versatility of the machine.

Variations

As illustrated in Fig. 5, possible variations exist in the modes of locomotion and in methods of lift-feed. Modes of locomotion include the rail and tire and the presently popular tractor-crawler. The tractor-crawler would seem to have the more universal applications, and, if only one locomotion device were to be selected, this type of locomotion would probably be chosen. In addition to these variations, there is the use of overhead cables for shaft work, and the use of skids.

Methods of lift-feed, as illustrated, are the pan feeders or ribbed, inclined conveyors and the bucket elevators. Because these methods are applicable in conflicting situations, perhaps some method of quickly changing from one to the other could be developed.

Major Subdivisions of the Rotomucker

The major subdivisions of the rotomucker can be considered from the functional rather than from the physical viewpoint. These then would include the rotohead (including booms, cylinders, and pan), the lift-feed device, the locomotive unit, the power source, and the
carriage (actually more structural than functional).

The rotohead assembly indicates many areas for further work. The design of the blades, the pan, the type of cylinder (pneumatic or hydraulic), the material, and structural design—all require further research in order to ascertain the optimum conditions. It is the opinion of the author (prejudiced?) that a straight, toothed blade, a closely-fitting, adjustable—for universal conditions—pan, a hydraulic cylinder, and the channel-type of design that was used in the model would all prove satisfactory.

The lift-feed and locomotion have previously been discussed. The power source could well be centralized, although air-electric combinations are possible. A centralized diesel unit could well be employed here, with rotohead drive extending through the booms. This probably would account for a more economical power—and space—arrangement.

Versatility

As mentioned in a prior section, there is a need, particularly in the marginal mining operations, for a completely versatile mucker. As illustrated in Fig. 6, the rotomucker could well fill this need.

With minor adjustments, the rotomucker could efficiently operate in shafts, inclines, and adits. These adjustments would occur in the pan (to compensate for changes in the vertical) and in the lift-feed to compensate for vertical angle differences. In each case, the adjustment is a minor one.
FIG. 7
IDEALIZED
ROTOMUCKER
CRAWLER ADAPTATION WITH
CONVEYOR FEED.
$1:3$
Without completely designing the machine, it would be quite difficult to even estimate the initial cost of constructing a roto-mucker. However, any fairly large mining operation should have the accumulation of scrap and the shops to fabricate one. Of course, the machine would lack some of the refinements of the factory-constructed device, but the basic function should not be radically changed.

THE FUTURE

This paper has constituted only the initial scratchings of, what is hoped to be, the answer to one of the major bottlenecks of the mining industry. There is much philosophying and analytical calculating to be done before a full-scale machine can be built. There is much testing to be done before a roto-mucker can be perfected. It is hoped that in the near future a machine of the type outlined herein can be available to the mining industry for the benefit of the nation.

While much further work is indicated in order to put the roto-mucker on a production line, there should not be too much work for the individual mine operator to construct an inexpensive, serviceable model. Inasmuch as the principle is simple and the machinery required is not ornate, perhaps some of the smaller operations can benefit from the roto-mucker in the nearer-than-we-think future.