A comparison between hydraulic and pneumatic rockdrills

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SYNOPSIS

The greatly increased output of rockdrills has placed new demands on booms, carriers, and drill steels and bits. Limited scope for further improvement in pneumatic rockdrills has led to the development of hydraulic rockdrills, which compare favourably with their pneumatic counterparts: they are more efficient, more flexible in coping with variations in the working conditions, more economical in the consumption of drill steel, and less productive of noise and mist. Their disadvantages include a greater need for a reliable power supply, a greater vulnerability to dirt, greater complexity (requiring more skilful maintenance), and the liberation of heat into the working environment. They should be regarded as a complement to, and not as a substitute for, pneumatic rockdrills.

SAMEVATTING

Die veel groter lewering van rotsbore het nuwe eise aan arms, draers en boorstaal en -punte gestel. Die beperkte geleentheid vir die verdere verbetering van pneumatiese rotsbore het gelei tot die ontwikkeling van hidrauliese rotsbore wat gunstig met hul pneumatiese teenhangers vergelyk: hulle is meer doeltreffend, meer buigsaam wat betref die hantering van verskille in die werktoestande, meer ekonomies wat betref die verbruik van boorstaal, en veroorsaak minder geraas en mis. Hul nadele sluit in 'n groter behoefte aan 'n betroubare kragtoevoer, groter kwesbaarheid deur vuiligheid, groter ingewikkeldheid (wat meer bedrewe onderhoud vereis) en die vrystelling van hitte in die werkomgewing. Hulle behoort beskou te word as 'n toevoeging tot pneumatiese rotsbore, en nie as 'n plaasvervanger daarvoor nie.

During the last quarter of a century, technological development has resulted in many new products and great improvements to existing products. As an example, the introduction of new grades of materials and a better understanding of rock characteristics, coupled with more accurate heat-treatment processes, strength calculations, and computer simulations, have meant that a modern, pneumatically powered drifter rockdrill today has an output about three times greater than that available twenty-five years ago. This increase in output has naturally placed new demands on booms and carriers, and also on drill steels and bits; these have had to be developed simultaneously with rockdrills to meet the higher performance required of them.

Two factors mitigate against the further development of pneumatic rockdrills in terms of power output.

Firstly, because of limited compressed-air pressures, any increase in output requires an increase in the size of the basic working part of the machine, namely the hammer piston. Thus, the physical size of the machine starts to become unattractive. An increase in air pressure could be countenanced, but this has the attendant disadvantage of reduced safety and the high probability of increased transmission losses.

Secondly, higher outputs require proportionally higher consumptions of air, with resultant increased transmission losses. A modern high-performance drifter consumes some 15 m^3 of air per minute at a design working pressure of 600 kPa. New installations would have to incorporate larger pipes, with a resultant loss in shaft-and-tunnel area. In existing installations, it is not uncommon to find booster compressors installed close to drill rigs in an attempt to reduce the transmission losses arising from remoteness of the main compressor station.

These basic limitations have stimulated manufacturers of rockdrills to investigate alternative power sources. Of the alternatives, hydraulic power was a natural selection, and the past few years has seen the appearance of a new breed that derives its power from this source. The development of hydraulic rockdrills has taken a long time owing to problems that arose because of the use of a relatively incompressible fluid at high pressures. Extensive testing has been necessary to overcome damaging pressure shocks that would have destroyed parts of the rockdrill or components of the hydraulic system. Similarly, high oil pressures place great demands on the seals against oil leakage, which, for reasons easily understood, is more troublesome than air leakage.

These, then, are the reasons for the development of hydraulic rock drills, which are now compared with pneumatic rockdrills.

ADVANTAGES

Efficiency

The overall efficiency (i.e., the relationship between the input power at the compressor and the output power of the rockdrill, is about 10 per cent for a pneumatic drifter and some 30 per cent for an electro-hydraulic rockdrill. The power costs and energy-conservation aspects thus favour hydraulic drills.

Flexibility of Output

It is fairly simple, with a hydraulic drill, to vary the working parameters, namely volume flow, pressure, and blow frequency. Thus, it is possible to suit the output characteristics to the prevalent working conditions, e.g., type of rock and diameter of hole. This is not easily achieved with a pneumatic drill.

Economy and Performance of Drill Steel

Hydraulic drills can be operated at very much higher pressures than pneumatic drills, and the piston shape can therefore be chosen to provide a more attractive stress-wave shape. A longer piston of fairly uniform cross-section with a diameter approximating that of the drill steel would result in a stress wave of fairly uniform amplitude. It is thus possible to select one of two alternatives:

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(a) the same energy content per blow as for a pneumatic drifter, which would result in a significantly reduced peak stress, or

(b) the same peak stress, which would result in a significantly higher energy content.

The limiting factor in the amount of energy that can be channelled down the drill-string is the peak stress to which the drill-string is subjected. It is possible, therefore, to achieve greater performance (i.e. penetration rate) with hydraulic drills whilst retaining good drill-steel economy.

Environment

There are two basic sources of noise from a pneumatic rockdrill, namely the mechanical and process noise, and the noise due to the exhaust air expanding suddenly into the atmosphere. With hydraulic rockdrills, the latter is absent and decreases in the former of about 10 dB are achieved. Moreover, this decrease in the noise level occurs mainly in the lower frequencies, which are the most disturbing and the least easily controlled by means of ear protectors. The higher frequencies are fairly well damped by the use of efficient ear-muffs.

A second advantage accruing from the absence of exhaust air is the elimination of mist and oil in the drilling environment. The mist associated with pneumatic drifters in tunnels is a nuisance in that it greatly impairs visibility and communication. Flame burners are used to combat this with some success, but their use in fiery mines or in tunnels that may encounter methane is untenable.

Thirdly, the exhaust air from pneumatic drills is charged with lubricating oil. This oil, which is finely divided, is deposited on the surroundings and on the drilling rig. It has been noticed that hydraulic drill rigs tend to stay cleaner owing to the cleaner air, and this in turn encourages better attention on the part of maintenance staff.

DISADVANTAGES

Need for Reliability

It is not practical to transmit high-pressure hydraulic power over long distances, and hence the power source for hydraulic drills is married to the drill rig (i.e. it must be very close to the drills compared with an air-compressor installation for pneumatic drills). Thus, the hydraulic power pack is generally in a much poorer environment than that of a compressor centre. This means that much greater reliability and environmental demands are placed on the components.

Operational Inflexibility

It is well established that hydraulically operated systems require a fine degree of cleanliness for successful operation. Also, compared with pneumatic systems, the number of associated fluid hoses tends to be large (although the hoses are generally smaller in size). Changes of components in hydraulic systems therefore require a high degree of attendant cleanliness and a greater amount of time than with pneumatic systems. Hydraulic rockdrills and power systems are therefore more vulnerable, and consequently less flexible (than their pneumatic counterparts) in operation.

Service

Hydraulic rockdrills and control systems are, by their very nature, more complex than their pneumatic counterparts. Coupled with this, the fine clearances of hydraulic components require that the working fluid should be kept very clean to ensure acceptable life.

Compared with pneumatic machinery, therefore, the level of knowledge and the skill required in maintenance from engineering staff is much higher.

Heating Effect

Nearly all of the electric energy provided to a hydraulic drill rig will be liberated into the working environment as heat.

Conversely, with pneumatic drills, a considerable amount of cooling effect is introduced. This disadvantage is valid only for hot conditions (which is normal for South Africa). In other situations this might, of course, be an advantage.

CONCLUSIONS

The advantages of hydraulic rockdrills over their pneumatic counterparts are significant, and the disadvantages are not insurmountable. However, there are situations in which it would prove more favourable to use pneumatic machines, especially where the necessary compressor capacity is already available.

At this stage in time, therefore, it is better to view hydraulic rockdrills as a complement to, rather than a substitute for, pneumatic rockdrills.

Contribution to the above paper by R. M. F. Seawright*

I wish to congratulate Mr Marshall on the presentation of his paper. I would say that, basically, the difference between hydraulic and pneumatic rockdrills lies mainly in the nature of the transmission fluid, the one being elastic, the other being inelastic. (In the latter case, however, it is generally necessary to introduce elasticity by way of an accumulator and so achieve the characteristics required.)

My own observations lead me to observe that, at all times, the pneumatic rockdrills available to the user have been capable of greater performance than the available drill-string medium was able to handle economically under actual working conditions.

I should also mention that air pressures are limited only by convention. In fact, in the nineteen-thirties, some underground mining organizations were using pneumatic stopehammers with direct air feed, with air pressure of 150 lb/in^2 on the drills. Naturally, drilling speed was spectacular, but drill-steel failure was unacceptably high. Incidentally, higher air pressures for the same energy outputs involve reduced transmission losses by way of fluid friction.

I shall limit my comments on design to the statement *that there are significant differences implicit in design criteria* when one is considering rockdrilling machines that are rigidly mounted and mechanically thrusted and transported, as against those that are required to be manually transported, and also, at least, partially supported, guided, and thrusted by the operator. In other words, I wish to emphasize the

*Seco.

distinction between mounted drifters and handheld jackhammers.

When completely mounted, thrusted, and transported by mechanical means, the weight, size, and power of machines are not limited. In this role, the drifter can be designed accordingly. In South African mining, however, the handheld machine is dominant in the production role.

Regarding efficiency, I can comment that, if academic efficiencies were significant *regardless of application*, then one might be trying to replace gas turbines in jet aircraft with marine diesels. When the gas turbine is operated well above ground, the exhaust provides a substantial bonus. Likewise, the exhaust of the pneumatic rockdrill, when used substantially below ground, provides a bonus. If one were to re-introduce pneumatic rockdrills operating with the dense air system, academic efficiency considerably higher than that attributed to a hydraulic system could be achieved.

Regarding flexibility, there has been no reason in the past why so-called variation of output characteristics is not just as readily effected with one type of machine as with another, provided that the percussion and rotation elements are independently controlled.

The endurance limit of the drillstring media, or any structural member transmitting energy, is generally accepted to be a function, not only of peak stress, but also of the frequency and the total number and amplitude of stress applications. What can be achieved in this connection with hydraulic machines can also be done with other types. Frequency can be greatly exceeded if necessary with more direct application of electric energy. However, I do not suggest that any benefit would result from this.

Under South African underground stoping conditions, the output in holes per shift depends, not only on the machine, but also on its ease of handling, the comfort and ability of the operator in the hot, humid, working conditions, and other factors relating to the environment. The overall handleability and portability of the equipment has to be acceptable.

In the final instance, actual operating under day-in and day-out production conditions will inevitably determine the acceptability of any particular equipment.

The pneumatic rockdrill as currently used is, in addition to being a rockdrill, also a highly effective refrigerating machine under the conditions referred to. Compressed air is expanded to the atmosphere and is, in fact, a refrigerant. The temperature at the exhaust of the pneumatic machine is usually well below freezing. In fact, manufacturers are frequently put to considerable trouble to overcome difficulties arising from the freezing up of exhausts. Where exhaust mufflers are incorporated, ice formation can be a problem.

Example

(1) *Direct Cooling from Exhaust Air*
130 ft^3/min at 60 °F temperature drop.
Sp.ht=0,265 11 lb of air.
BTU=11×0,265×60=160 BTU/min=174 kJ/min.

(2) *Cooling Due to Absorption of Moisture by Re-evaporation*
This is the main element contributing to localized cooling around the pneumatic drill.
PAU (potential absorption unit) is the mass of moisture absorbed per minute from the mine atmosphere.
11 lb (5 kg) of dry air exhaust reheated to ambient 90 °F (32,2 °C) saturated=0,312 PAU (0,141 kg).
Evaporative cooling=0,312×1025=320 BTU/min.
=(0,141×2395=337 kJ/min).
Total (1) and (2)=480 BTU/min (506 kJ/min).
Total cooling=±2,5 tons of refrigeration.

The direct refrigeration effect of the pneumatic rockdrill arising from the chilled, dry exhaust air is approximately at the rate of 1 ton of refrigeration, which is the rate of heat removal of 200 BTU (211 kJ) per minute, or the equivalent of melting 1 ton (2000 lb, or 907 kg) of ice in 24 hours.

It is this chilling effect of the cold exhaust on the highly humid, hot ambient air that produces the well-known fog when the machine is running. Those acquainted with the working conditions are well aware of the immediate comfort provided when the pneumatic rockdrill is generating a bubble of concentrated chilled air that envelopes the operator and those working in the vicinity.

In addition to the direct cooling and movement of air generated by the exhaust, the potential absorption capacity of this exhaust air to re-evaporate moisture back to ambient conditions is in excess of the direct cooling, so that the total refrigeration effect of the exhaust air while the machine is running is of the order of 2½ tons of refrigeration, and this is concentrated precisely at the immediate working face, where and when the expenditure of human physical effort gives rise to the most discomfort. The movement of the chilled air due to the exhaust blast against the face further contributes to the psychometric effect.

The hydraulic hammer (or electrical, mechanical, or any type not using a fluid as a refrigerant) would be the equivalent of a heat engine producing heat in the zone of operation at the rate of 42,4 BTU/min (44,7 kJ/min) per total energy input (h.p.). If we assume this figure to be about 15 to 20 h.p. (11 to 15 kW) and we take the lower figure, we are talking of a device concentrating heat at a rate that would require 3,18 tons of refrigeration in the working place for its removal.

The exhaust from the pneumatic machine, however, generates an envelope of chilled atmosphere that is produced by a refrigeration system not requiring heat to be extracted and rejected elsewhere, i.e. *no heat rejection is involved*.

In making comparisons, therefore, we are already faced with the difference of direct cooling applied at the working environment of something of the order of 5½ tons of refrigeration in order to displace the refrigerating tool by a heat-generating tool. In addition, the compounding of refrigeration and heat-rejection losses engendered by the apparatus necessary to supply this direct amount of refrigeration exactly *where and when it is needed* is considerably more than the $5\frac{1}{2}$ tons alluded to.

The considerations referred to certainly should be borne in mind if machines other than pneumatic are to be introduced on any significant scale under the conditions applying to deep-level mining.

Briefly, the basic principle of percussion and rotation is, for all cases of rockdrilling machines referred to, fundamentally the same. The selection of fluid, whether elastic or inelastic, and the operating pressures selected should not pose any insurmountable difficulties to any manufacturer or designer. Neither, for that matter, do direct mechanical or direct electrical machines operating on the same principle. They do exist commercially. In 1954 a hydraulic rockdrill of the rotary percussive type with which my firm was associated was tested in the hardest Pennant sandstone available. This machine was powered by a 17 h.p. unit for rotation and a 10 h.p. unit for percussion. When thrusted on a 1,5/8 inch modified T.C. bit at 4000 lb, a drilling speed of 44 inches a minute was achieved. When the percussion element was cut out and the thrust increased to the maximum available (over 5000 lb), the drilling speed on pure rotary operation went up to 55 inches a minute.

All the methods referred to have been used before and are not novel. As a responsible manufacturer and designer, one can be objective should developments favour one approach more than any other. The rockdrill industry, I am sure, will be able to supply the most suitable and economic equipment to meet any particular conditions, as and when favourable factors arise.

To conclude, one can state that, generally, the stoping conditions in South African mining practice govern the drilling output. It is the overall effectiveness of combination of machine and operator that is the main determinant of output. This factor is still the main consideration regardless of the type of machine. Here I refer specifically to the most frequently encountered stoping conditions. Thus far, I know of no existing hydraulic machine that can advantageously be applied in this particular situation.

It can be stated that the obvious answer to this limitation is a mounting capable of replacing the effort-consuming function of the machine operator. I can comment only that the company with which I am associated has, over many years, devoted a great deal of time and effort in attempting to devise a suitable mounting and feed. Many devices have been built and tried. To date no completely satisfactory solution has been found.

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