A NEW APPROACH TO THE SHOCK ENERGY/GAS ENERGY CONCEPT

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ABSTRACT

Today, experimental measurement of the shock energy/gas energy pair, or pool test, has now become virtually standard. But pool" energy per m(exp 3) of bedrock has no significance for explosives used in any medium other than water. This is why the notion of energy dissipated according to firing conditions must be difined by:

- * The conditions for setting off explosives:
- * The explosives characteristics:
- * The geometry of firing
- * The mechanical characteristics of the rock:

Formulating of physical phenomena as equations helps study how one parameter influences the others.

Quantification of the energy dissipated can accurately estimate firing results in advance on the basis of data on firing or, conversely, determine the firing plan on the basis of the desired result.

The definition of shock and gas energy gives only a synthetic view of the effects of firing. Moreover, knowledge of the origin of these effects of firing. Moreover, knowledge of the origin of these effects helps explain and compute most common mining phenomena, i.e., decoupling, "dead pressing," "air deck," firing with moderate effects, computation of damage, etc.

I-CONTEXT OF THE NEW APPROACH

The shock energy/gas energy concept developed in the fifties is based on the distribution of energy obtained by underwater detonation. Today, experimental measurement of the shock energy/gas energy pair, or pool test, has now become virtually standard.

To describe the method of this test briefly, a submerged charge of approx.

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50mm in diameter is fired. A hydrophone records the compression wave in the fluid. Temporal integration of the first peak of this wave defines the so-called shock energy dissipated. The oscillation frequency of the gas bubble generated by combustion gases measures the work of the hydrostatic pressure forces, or gas energy.

In summary, the main part of the compression wave is associated with the notion of shock responsible for destructive effects, while expansion is associated with the notion of gas responsible for setting in motion the surrounding medium. The ideal notion for comparing the effects of different quality explosives must be revised to determine the amount of explosive needed for a specific purpose.

For 1MJ (Megajoule) of explosive per m(exp. 3) of bedrock, will the result be the same if it is fired in marl or granite?

Similarly, can 1MJ/m(exp. 3) of 90mm cartridges in a 102mm hole yield the same results as 1MJ/m(exp.3) of prilled explosive in the same size hole?

Obviously, the answer is no.

"Pool" energy per cubic metre of bedrock has no significance for explosives used in any medium other than water.

This is why the notion of energy dissipated according to firing conditions must be defined.

Our approach is based on defining energy subject to:

-1-The conditions for setting off explosives:
  - borehole diameter
  - cartridge diameter
  - type of primer

-2-The explosives' characteristics:
  - real detonation velocity
  - density
  - detonation by-products

-3-The geometry of firing

-4-The mechanical characteristics of the rock:
  - E, nu, ro, Rc, Rt

On the basis of 1 and 2 above and the laws of thermodynamics, the pressure, volume, temperature and velocity of the gases produced in the borehole by detonation can be computed. This determines the pressure at each point on the

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borehole wall and at each instant. Together, these pressures on the wall are at the origin of the effects of firing.

II-DEFINITIONS

This cause and the laws governing the reaction of the surrounding material lead us to the two following definitions:

SHOCK ENERGY = energy dissipated by the front of wave P between the wall of the borehole and the first open firing surface.

GAS ENERGY =work supplied by gases expanding in the borehole to set in motion the mass of material in front of the hole.

III-DETERMINATION OF PRESSURE

3 - METHOD OF DETERMINATION

3 - 1 - HYPOTHESES

It is assumed that the characteristics of the explosive material are constant along the length of the cartridge.

It is also assumed that detonation velocity - velocity of the combustion front - is independent of time, which, with the previous hypothesis, implies that the characteristics of the chemical combustion reaction zone remain constant.

It is assumed that the flow of gases produced by combustion downstream from the detonation front is unidimensional.

Moreover, considering the very short total combustion time, it is legitimate to admit that this flow is adiabatic. Since expansion of the gases is necessarily continuous, irreversible effects due to viscosity are negligible. Expansion of the gases is thus adiabatic and reversible, i.e., isentropic.

3 - 2 - DETERMINATION

3 - 2 - 1 - SHOCK PRESSURE

In fact, this involves determination of the characteristics of the elemental section of gas in which shock pressure occurs. These so-called shock characteristics are absolute temperature, pressure, volume and particle velocity in the elemental section of gas according to the above definition.

The four equations or relations required to determine the four above unknown factors result from the application of the basic principle of dynamics, the

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conservation of mass, the equation of state of combustion gas and the principle of energy conservation.

The resolution was conducted in the general case, i.e., of an explosive cartridge with a smaller diameter than the cavity. A specific study of the case in which the cartridge has the same diameter as the cavity (prills) has been undertaken. Compliance of the results of this approach with the application of general expressions to this specific case has been verified.

3 - 2 - 2 - GAS PRESSURE

The particle velocity of shock - velocity of the section of gas located immediately downstream from the detonation front - is known. It is demonstrated to be colinear with detonation velocity.

At all times, the spatial distribution of the particle velocity of elemental sections is that of PRANDTL and MEYER's unidimensional expansion.

The perfect gas hypothesis, simplifies the picture to show distribution, at any given time, as a linear function of the position of the sections of gas located between a specific abscissa where velocity is nil and that of the combustion front. Real gas equations show distribution that is no longer linear.

Such variation leads to simultaneous variations in pressure, absolute temperature and volume.

Discussion of the previous results leads to the expression of the pressure of immobile gases, which, at any given instant, fills the space between the bottom of the cavity and the previous specific abscissa, from which the gases begin to move.

Using the previous equations and the equation of state, it is also possible to determine the volume and absolute temperature of immobile gases.

IV-AN EXPERIMENTAL STUDY PROGRAMME

An experimental study programme has shown that these definitions are coherent with firing results. This programme included firing charged with an amount of explosives corresponding to 1.5MJ/m3. The type of explosives and the conditions of their firing were variable. Different parameters of firing results were measured (blocometry, spread, clearance) and compared to computation of the shock energy/gas energy pair. It appears that the relative correlation of cases has yielded very good results.

Concrete cases (not described in this summary) have demonstrated the validity of these definitions.

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V-INFLUENCE OF VARIOUS PARAMETERS ON FIRING RESULTS

Formulating of physical phenomena as equations helps study how one parameter influences the others. The three curves below illustrate this approach. The variation in the shock/gas energy pair in terms of decoupling helps study in what proportion the latter may intervene on the blocometry of firing or the presplitting process for instance.

The other two curves illustrate the influence of the parameters of detonation velocity and density, which can now be adjusted with the appearance of mobile manufacturing units.

VII-CONCLUSION

Quantification of the energy dissipated can accurately estimate firing results in advance on the basis of data on firing or, conversely, determine the firing plan on the basis of the desired result.

The definition of shock and gas energy gives only a synthetic view of the effects of firing. Moreover, knowledge of the origin of these effects helps explain and compute most common mining phenomena, i.e., decoupling, "dead pressing," "air deck," firing with moderate effects, computation of damage, etc.

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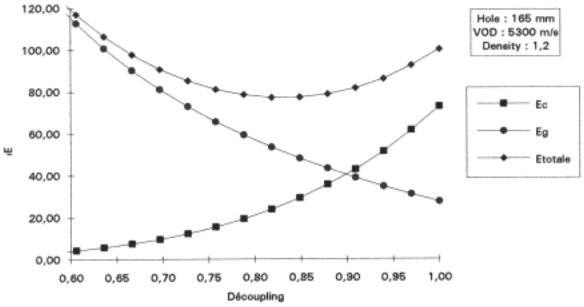
Eshock/Egas variation, according to decoupling



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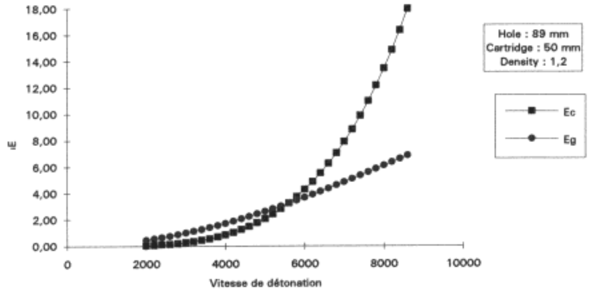
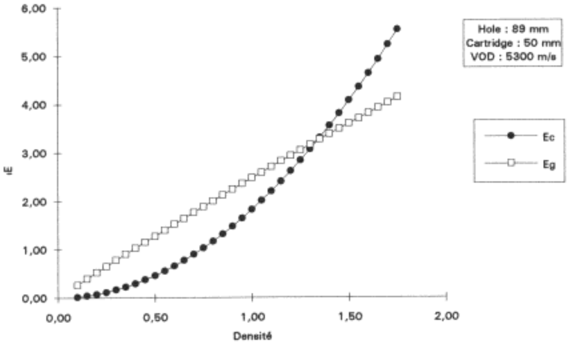
Eshock/Egas variation, according to VOD

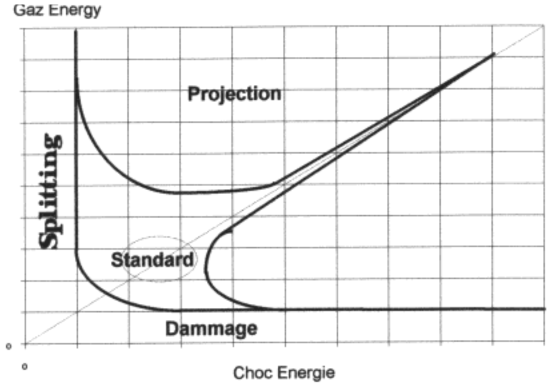


Eshock/Egas variation, according to density



VI - CURVE FOR FIRING POSITION

(Choc/gaz Energie)



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