The Use of Dimensional Analysis to Analyse The Relationship Between Penetration Rate of Jack Hammer and Rock properties and Operational Characteristics

Suseno Kramadibrata[1)], Made Astawa Rai[2)], Juju Juanda[2)], Ganda Marihot Simangunsong[2)], Nuhindro Priagung[2)]

1) Rio Tinto Indonesia

2) Department of Mining Engineering, Institut Teknologi Bandung

ABSTRACT

Drilling operation at mine sites has always been associated with heterogeneous, and an-isotropic rocks. Taking account that drill bit remains a constant variable, penetration rate of a rotary-percussive drill type, such as Jack Hammer, is influenced by the operational variables and the rock properties. This paper describes a method to develop an empirical equation that includes such variables using concrete and andesite rock samples.

In order to measure the penetration rate of the Jack Hammer a drill rig was exclusively designed and manufactured. Laboratory tests were then carried out in order to obtain the physical, mechanical and dynamic properties of the samples. The concrete samples were made of various compositions of sand and cement.

Empirical equations associated with the penetration rate have mostly been derived by means of regression-statistics method. This method however does not specifically account for the most appropriate variables included into the equation. In order to overcome this drawback, dimensional analysis was used to derive relevant dimensional groups leading to the development of empirical equation of penetration rate.

The experimental test revealed that the penetration rate is proportionally function of Supply Energy and Density, but inversely function of Uniaxial Compressive Strength (UCS=σ_c). It is however important to note that this equation only apply to brittle fracture material such as concrete and andesite.

1. INTRODUCTION

The most important variable in rock drilling including Jack Hammer is penetration rate. The prediction of penetration rate is very important in mine planning. Total drilling cost could be estimated by using prediction equations. Also, one could use the prediction equation to select drill rig type, which is best suited for given conditions. The penetration rate of drill in rock depends on many variables. Bit type and diameter, rotational speed, thrust, blow frequency and flushing are the controllable variables. On the other hand the variables such as rock properties and geological conditions are the uncontrollable variables.

Variables used to predict penetration rate could be classified into three main groups such as, drill bit characteristics, characteristics of rock and operational variables. Jack Hammer as a simple type of drilling machine is very popular for small diameter (2.5 inch) and shallow holes (2.2 m), or for pioneering in difficult ground. In addition, the Jack Hammer is classified as pneumatic drilling machine and its mechanism is based upon rotary percussive.

In order to understand how these three groups play role in the penetration rate, a laboratory scale research was carried out using a Jack Hammer at the Geomechanics Laboratory of the Department of Mining Engineering, Institut Teknologi Bandung. A special rig for holding the Jack Hammer and grips for securing rock samples was designed and manufactured in house. Data logging arrangement was also incorporated within the design.

Drill bits of a pneumatic Jack Hammer do not have variation as many as other medium size and large size of pneumatic drill types. Hence, a steel bit type of 2 inch in diameter and 80 cm length was chosen for the research. As the maximum thickness of rock samples was 60 cm, the bit variable was therefore considered constant. Beside, no discontinuity planes were identified within all rock samples tested. Thus, interaction between drill bit and rock sample is purely affected by intact rock properties.

As the drill hole is considered very shallow, thrust force, as one of the operational variables is excluded from the analysis. Consequently, the variables involved to estimate the drilling rate are the physical and mechanical properties of intact rock being drilled and compressed air energy.

Bearing in mind the shortcoming of using statistic regression in deriving penetration rate equation, dimensional analysis of the Buckingham Pi Theorem was applied. Dimensional analysis as a mathematical tool is used to resolve complex solution of the relationship between experimental variables, which are formed into dimensional groups. This method allows relevant dimensional groups accounted for the penetration rate of drill in rock be established in the stage of experimental design.