The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 8 || Pages || 08-17 || 2014 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Analysis of Performance of Jack Hammer to Determine the Penetration Rate on Different Rocks

Vijaya Raghavan, Assistant Professor,
Department of Mining Engineering, Dr.Thimmaiah Institute of Technology, Oorgaum, Kolar Gold Fields-563120,

ABSTRACT

Drilling is one of the most common operation in the mining industry starting from exploration and continuing through every phase of Production until completion of mining activity. Variety of rocks may be encountered in drilling and in selecting the drilling method to determine the Penetration and Performance in Different Rocks. Jack Hammer is an pneumatically operated drilling machine which is used for drilling Horizontal and Vertical Holes in hard rock formation with Airleg. In this research an attempt is made to determine the Penetration Rate of drilling machine with an additional Pneumatic Cylinder behind the drilling machine to increase the Penetration Rate and to decrease time taken for drilling a unit length of Hole.

Date of Submission: 19 July 2014 Date of Publication: 05 August 2014

I. INTRODUCTION

Pneumatic jackhammers are very useful tools that are capable of breaking hard & very hard rocks. A schematic of a typical jackhammer is shown in Figure 1.1. Basically, pneumatic jackhammers are devices that run off of high pressure compressed air. Air from the compressor feeds into a pressure chamber via a hose. A trigger valve, connecting the piston chamber to the pressure chamber, opens and closes with a certain frequency to allow mass flow into the piston chamber, which in turn increases the pressure of the chamber. This increase in pressure does work on a piston, which strikes a bit. The bit in turn strikes the target with a certain velocity and force necessary to cause fragmentation. A design team consisting of Alexandra Beyer, Katherine Wong, Johannes Schneider and Joshua Gafford has been recruited to design and model the thermodynamic processes for a pneumatic jack hammer. A jackhammer (pneumatic drill or demolition hammer in British English) is a pneumatic or electro-mechanical tool that combines a hammer directly with a chisel. It was invented by Charles Brady King. Hand-held jackhammers are typically powered by compressed air, but some use electric motors. Larger jackhammers, such as rig mounted hammers used on construction machinery, are usually hydraulically powered. They are usually used to break up rock, pavement, and concrete.

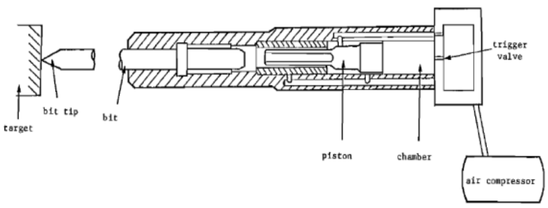


Figure 1.1: Schematic of jack hammer system

A jackhammer operates by driving an internal hammer up and down. The hammer is first driven down to strike the back of the bit and then back up to return the hammer to the original position to repeat the cycle. The bit usually recovers from the stroke by means of a spring. The effectiveness of the jackhammer is dependent on how much force is applied to the tool. In British English electromechanical versions are colloquially known as "Kangos".

Scopes

- To study the penetration rate of jack hammer in metal mine for hard rocks and to improve the drillability in hard rock.
- It is applicable in especially in horizontal drilling in surface metal mining as well as underground metal mine (Drives and Tunnels).

Objectives

- To study the rate of penetration with external force using a pneumatic cylinder and button bit.
- To study the effectiveness and efficiency of jack hammer.

II. LITERATURE REVIEW

Pneumatic drills were developed in response to the needs of mining, quarrying, excavating, and tunneling. The first "percussion drill" was made in 1848 and patented in 1849 by Jonathan J. Couch of Philadelphia, Pennsylvania. In this drill, the drill bit passed through the piston of a steam engine. The piston snagged the drill bit and hurled it against the rock face. It was an experimental model. In 1849, Couch's assistant, Joseph W. Fowle, filed a caveat for a percussion drill of his own design. In Fowle's drill, the drill bit was connected directly to the piston in the steam cylinder; specifically, the drill bit was connected to the piston's cross head. The drill also had a mechanism for turning the drill bit around its axis between strokes and for advancing the drill as the hole deepened. By 1850 or 1851, Fowle was using compressed air to drive his drill, making it the first true pneumatic drill.The demand for pneumatic drills was driven especially by miners and tunnelers because steam engines required fires in order to operate and the ventilation in mines and tunnels was inadequate to vent the fires' fumes; there was also no way to convey steam over long distances (e.g., from the surface to the bottom of a mine); furthermore, mines and tunnels occasionally contained flammable explosive gases such as methane. By contrast, compressed air could be conveyed over long distances without loss of its energy, and after the compressed air had been used to power equipment, it could still serve to ventilate a mine or tunnel. In Europe since the late 1840s, the king of Sardinia, Carlo Alberto, had been contemplating the excavation of a 12-kilometer (7.5 mi) tunnel through Mount Fréjus in order to create a rail link between Italy and France, which would cross his realm. The need for a mechanical rock drill was obvious and this sparked research on pneumatic rock drills in Europe. A Frenchman, Cave, designed, and in 1851 patented, a rock drill that used compressed air; however, the air had to be admitted manually to the cylinder during each stroke, so it was not successful. In 1854, in England, Thomas Bartlett made and then patented (1855) a rock drill in which the drill bit was connected directly to the piston of a steam engine. In 1855 Bartlett demonstrated his drill, powered by compressed air, to officials of the Mt. Fréjus tunnel project. (In 1855, a German, Schumann, invented a similar pneumatic rock drill in Freiburg, Germany.) Bartlett's drill was refined by the Savoy-born engineer Germain Sommeiller (1815-1871) and his colleagues, Grandis and Grattoni, by 1861. Thereafter, many inventors refined the pneumatic drill.

III. MECHANISM OF ROCK BREAKING

When a tool is loaded onto a rock surface, stress is built up under the contact area. The way the rock responds to this stress depends on the rock type and the type of loading, for example, the drilling method. Rock breakage by percussive drilling can be divided into four phases.

3.1. Crushed zone

As the tool tip begins to dent the rock surface, stress grows with the increasing load and the material is elastically deformed, zone III in Figure 3 .1. At the contact surface, irregularities are immediately formed and a zone of crushed rock develops beneath the indenter (the button or insert of a drill bit) Figure 3.1. The crushed zone comprises numerous micro-cracks that pulverize the rock into powder or extremely small particles. 70-85% of the indenter's work is consumed by the formation of the crushed zone. The crushed zone transmits the main force component into the rock.

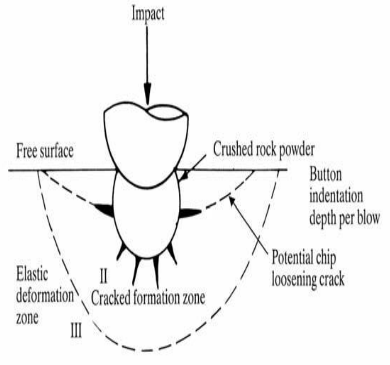


Figure 3.1: Rock breakages in percussive drilling

Crack formation : As the process continues, dominant cracks begin to form in the rock. This initial stage of restricted growth is described as an energy barrier to full propagation. The placement of major cracks depends on the indenter shape. Generally, the dominant placement of major cracks with blunt indenters, such as a sphere, is located just outside the contact area, pointing down and away from the surface.

Crack propagation : After the energy barrier has been overcome, spontaneous and rapid propagation follows, zone II in Figure 3.1. At a lower depth than the contact dimension, the tensile driving force falls below that necessary to maintain growth, thus the crack again becomes stable. The crack is then said to be "well developed".

Chipping : When the load reaches a sufficient level, the rock breaks and one or more large chips is formed by lateral cracks propagating from beneath the tip of the indenter to the surface. This process is called surface chipping. Each time a chip is formed, the force temporarily drops and must be built up to a new, higher level to achieve chipping. Crushing and chipping creates a crater.

IV. PERCUSSIVE DRILLING PARAMETERS

Percussive drilling consists of four drilling parameters which affect performance: percussion power (percussion energy and frequency), feed force, bit rotation speed and flushing.

Percussion power: Percussion output power in percussive drilling is produced by the rock drill's impact energy and frequency. Pneumatic drilling has a typical impact frequency of between 1,600 -3,400 hits per minute; pneumatic drilling, 2,000 - 4,500 hits per minute. Percussion output power is a function of hydraulic or pneumatic pressure and flow rates. Compared to pneumatic drills, hydraulic drills are capable of higher percussion power and faster penetration rates. The net penetration rate achieved with TAMROCK hydraulic rock drills as a function of drill hole diameter and rock Drillability. One limitation in percussion drilling is the capacity of the drill steel to transmit energy. Only maximum kinetic energy is transmitted through particular steel before excessive drill string deterioration occurs. For field drilling, the optimum percussion pressure setting depends on financial aspects. Higher penetration rates are achieved through increased percussion power, however, the drill steel's life time simultaneously decreases. Possible increased hole deviation and its impact on burden and spacing must also be taken into account.

Bit Rotation: The main purpose of bit rotation is to index the drill bit between consecutive blows. After each blow, the drill bit must be turned to ensure there is always fresh rock under the inserts or buttons. Bit rotation speed is adjusted to the point where the penetration rate is at its maximum. The following factors affect optimum bit rotation speed

- Rock type
- Rock drill frequency
- Drill bit diameter
- Gauge button diameter (in case of button bit) at optimum rotation speed, the size of the disintegrated chips is greatest and thus the penetration rate is maximum.

V. ROCK DRILL AND JACK HAMMER

The rock drill of the jack hammer will takes place in wet rock and dry rock as they follows

Dry Type Rock Drill : This air flushed, medium heavy duty Rock drill is used for a variety of surface drilling applications in quarries and construction sites. It is capable of drilling 27-40 mm diameter holes with H22 Integral/Extension steels up to a depth of 6 M. Drill man model DM 041 is a powerful Rock drill with proven performance.

Wet Type Rock Drill : This water flushed Rock drill is used in underground mines and tunnels for horizontal or inclined drilling in conjunction with Pusher leg. It is capable of drilling 27-40 mm diameter holes with H22 integral steels up to a depth of 6 M. Drillman model DM 041 W is one of the most reliable Rock drill available for underground application. It has low air consumption and a very high drilling rate in relation to weight.

- Light weight
- Low air consumption
- High impact
- Economical, heavy duty
- Reliable

VI. METHODOLOGY

The jack hammer is a percussive type of drilling machine used to drill hard and very hard rock. The machine (fig 5.1) consists of a horizontal mast mounted with jack hammer for easy movement while drilling. The machine in turn connected to a pneumatic cylinder which provides external thrust to the drilling machine when in operation.The machine is capable of drilling horizontal, incline holes at any angle. The machine is designed to drill a drive of 3m x 3m which can drill faster than normal jack hammer mounted on air leg. The pneumatic cylinder which is assembled to the horizontal mast gives external thrust to the drilling machine which gives an extra pressure, so that the drill can be made at shorter duration and many holes can be made in given time. The horizontal mast, jack hammer and pneumatic cylinders are mounted on firm base capable to be shifted from places. The jack hammer gets an external thrust via a pneumatically operated piston. This modification was made keeping in mind, the motive power available in most of the underground metal mines. The pneumatic piston is controlled by a joy stick for controlling the quantity of air to pass through the cylinder. The quantity of air is measured with a pressure gauge. Usually the drilling is made with a chisel bit, but in this project we have replaced with button bit.

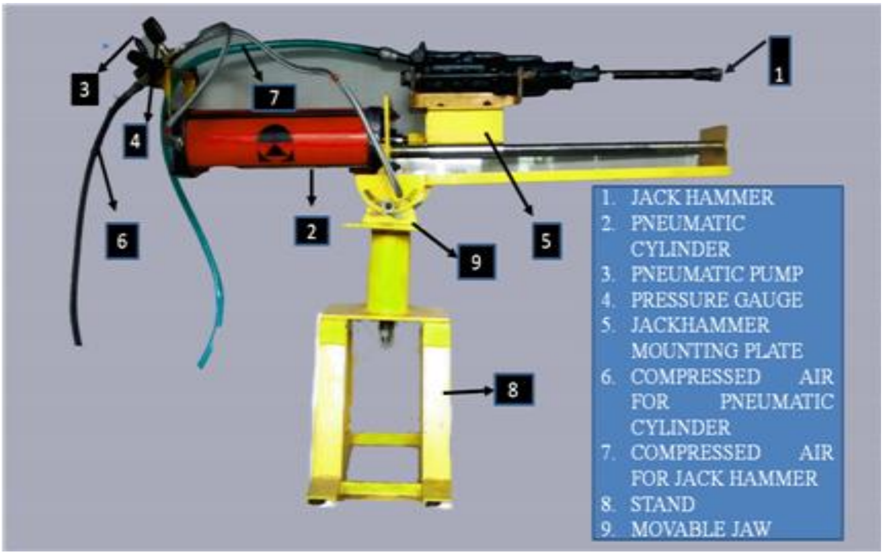


Figure 6.1: Pneumatic cylinder fitted with jack hammer

Movable plate : Movable plate which is assembled with jack hammer used for mounting the jack hammer and for smooth movement on the mast..

Figure 6.2: Movable plate fitted with jack hammer

Horizontal mast

The horizontal mast, jack hammer and pneumatic cylinders are mounted on firm base capable to be shifted from places.

Figure 6.3: Horizontal mast

Pneumatic cylinder

Pneumatic cylinder which is used to feed the pressure to the jack hammer while drilling the hole and the penetration rate increases compared to the normal jack hammer drilling. Pneumatic cylinder mainly used for enhance the penetration rate.

Figure 6.4: Pneumatic cylinder

Joy stick : Joy stick used to move the jack hammer to and fro movement in horizontal drilling by applying pressure to the pneumatic cylinder movement of jack hammer is controlled by joy stick.

Figure 6.5: Joy stick

Pressure gauge : Pressure gauge which used to indicate how much pressure is applied for pneumatic cylinder.

Figure 6.6: Pressure gauge

Base : Base which has been placed between stand and horizontal mast as well as pneumatic cylinder. Base which supports horizontal mast as well as pneumatic cylinder.

Figure 6.7: Base

Button bit : The drilling hole in horizontal position by using button bit rod. The length of the button bit rod is 1.5 feet as shown in the figure 6.7.

Figure 6.8: Button bit

VII. FIELD VISIT

Location of mine: Kempapura, Kolar district, Karnataka. 12km East of KGF. The latitude and longitude is 13^{o}6’6” North and 78^{o}18’34” East.

Geology of area : This is a very coarse-grained, equigranular igneous rock dominated by perthitic feldspar (35 vol%), plagioclase (20 vol%), quartz (40%), hornblende (3%), and biotite (2%). Perthite consists of anhedral polycrystalline grains up to up to 1.5 cm in size. In most cases feldspars lack twinning, however, some show host plagioclase with albite twinning with thick orthoclase lamellae (<0.1 mm wide). Several perthite crystals also exhibit simple twins. Quartz crystals are an hedral and up to 1 cm in size.

VIII. RESULT AND DISCUSSION

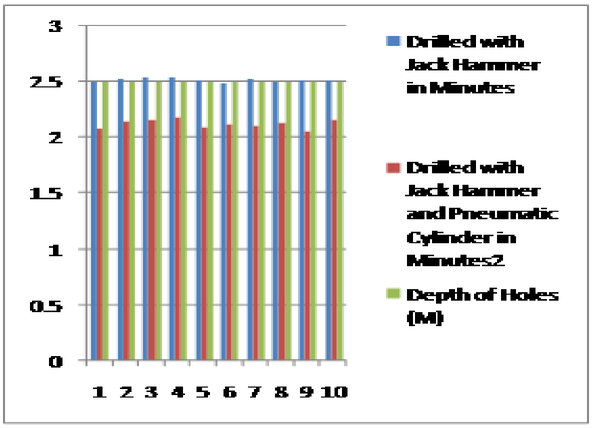
The penetration rate increases using jack hammer with pneumatic cylinder. The difference between normal jack hammer and jack hammer with pneumatic cylinder penetration rate as shown in Table 8.1, 8.2, 8.3, 8.4 and 8.5.

Biotite granite (chisel bit)

Table 8.1: Biotite Granite (Chisel Bit)

Sl.No	Depth of the hole (M)	Drilled with jackhammer in minutes	Drilled with jackhammer and Pneumatic cylinder in minutes	Difference (seconds)
1	2.5	2.50	2.08	42
2	2.5	2.53	2.14	39
3	2.5	2.54	2.16	38
4	2.5	2.54	2.18	36
5	2.5	2.52	2.09	43
6	2.5	2.49	2.12	37
7	2.5	2.53	2.11	42
8	2.5	2.50	2.13	37
9	2.5	2.52	2.06	46
10	2.5	2.51	2.16	35

Chart for chisel bit



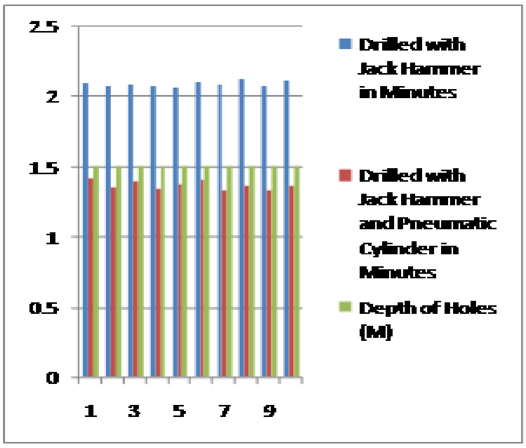
X – axis indicates: Number of holes drilled.
Y - axis indicates : Holes drilled in time(minutes). Each interval 0 – 0.5 = 30 seconds.

Biotite Granite (button bit)

Table 8.2: Biotite Granite (Button Bit)

Sl.No	Depth of the hole (ft)	Drilled with jack hammer in minutes	Drilled with jackhammer and Pneumatic cylinder in minutes	Difference in seconds
1	1.5	2.10	1.42	28
2	1.5	2.08	1.36	32
3	1.5	2.09	1.40	29
4	1.5	2.08	1.35	33
5	1.5	2.07	1.38	29
6	1.5	2.11	1.41	30
7	1.5	2.09	1.34	35
8	1.5	2.13	1.37	36
9	1.5	2.08	1.33	35
10	1.5	2.12	1.37	35

Chart for button bit



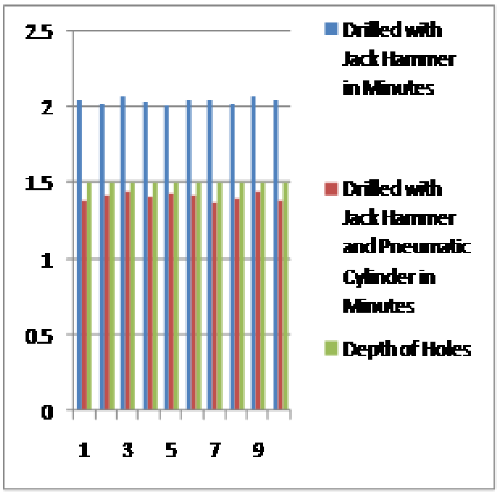
X – axis indicates: Number of holes drilled
Y - axis indicates : Holes drilled in time (minutes). Each interval 0 – 0.5 = 30 seconds.

Blue metal (button bit)

Table 8.3: Blue Metal (Button Bit)

Sl. No	Depth of the hole (M)	Drilled with jack hammer in minutes	Drilled with jackhammer and Pneumatic cylinder in minutes	Difference in seconds
1	1.5	2.05	1.39	26
2	1.5	2.03	1.42	21
3	1.5	2.07	1.44	23
4	1.5	2.04	1.41	23
5	1.5	2.02	1.43	19
6	1.5	2.05	1.42	23
7	1.5	2.05	1.38	27
8	1.5	2.03	1.40	23
9	1.5	2.07	1.44	23
10	1.5	2.05	1.39	26

Chart for blue metal



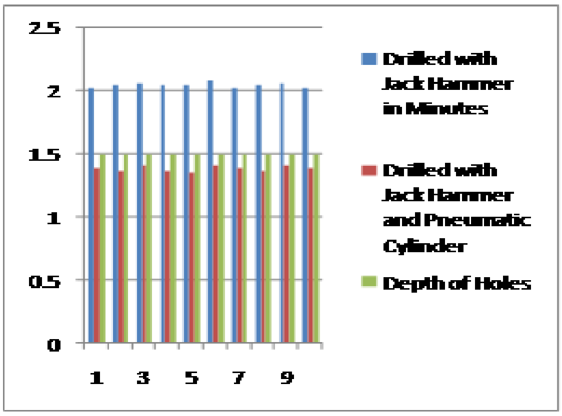
X – axis indicates: Number of holes drilled
Y - axis indicates : Holes drilled in time (minutes). Each interval 0 – 0.5 = 30 seconds.

Syenite (button bit)

Table 8.4: Syenite (Button Bit)

Sl.No	Depth of the hole (M)	Drilled with jack hammer in minutes	Drilled with jackhammer and Pneumatic cylinder in minutes	Difference in seconds
1	1.5	2.03	1.39	24
2	1.5	2.05	1.37	28
3	1.5	2.06	1.41	25
4	1.5	2.05	1.36	29
5	1.5	2.05	1.35	20
6	1.5	2.08	1.41	27
7	1.5	2.03	1.39	23
8	1.5	2.05	1.37	27
9	1.5	2.06	1.41	26
10	1.5	2.03	1.39	26

Chart for syenite



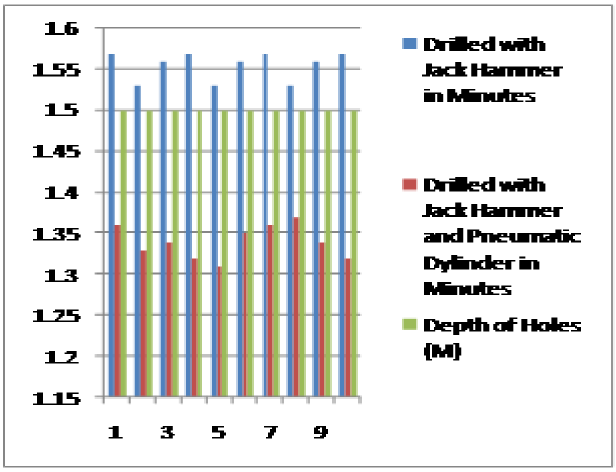
X – axis indicates: Number of holes drilled
Y - axis indicates : Holes drilled in time(minutes). Each interval 0 – 0.5 = 30 seconds.

Limestone (button bit)

Table 8.5: Limestone (Button Bit)

Sl. no	Depth of the hole (M)	Drilled with jack hammer in minutes	Drilled with jackhammer and Pneumatic cylinder in minutes	Difference in seconds
1	1.5	1.57	1.36	21
2	1.5	1.53	1.33	20
3	1.5	1.56	1.34	22
4	1.5	1.57	1.32	25
5	1.5	1.53	1.31	22
6	1.5	1.56	1.35	21
7	1.5	1.57	1.36	21
8	1.5	1.53	1.37	16
9	1.5	1.56	1.34	22
10	1.5	1.57	1.32	25

Chart for limestone



X – axis indicates: Number of holes drilled

Y - axis indicates : Holes drilled in time(minutes). Each interval 0 – 0.5 = 30 seconds.

IX. DISCUSSION

Using pneumatic cylinder as a external force, the penetration rate increases. The performance of the altered jackhammer (using pneumatic cylinder) is much better when compared with normal jack hammer.

X. RECOMMENDATION

- Pneumatic cylinder which is used to move the piston to and fro by the movement of the piston which increased the penetration rate. The pneumatic cylinder with jack hammer is easy to operate and easy to achieve the target.
- Button bit has more efficiency than chisel bit. Life of the button bit is more than the chisel bit. The bit can be removed and replaced with the new button bits.

XI. CONCLUSION

- The penetration rate of jack hammer with both arrangements was experimented on four different rock granite, blue metal, limestone, syenite samples at compressed air pressure of 4 kg/cm^2. The results show that penetration rate increases with pneumatic cylinder.
- To increase the penetration rate here the hydraulic cylinder is used for the external force. The overall performance of this machine is to drill the rock faster than any jack hammer with the less time compared to previous drilling. This model as more advantageous because in this model 34mm diameter button bit is used in the place of chisel bit so that it can be replaced with present practice and chisel bit 32mm diameter also used.
- The results shows the comparison of pneumatic jack hammer with chisel bit and jack hammer with pneumatic cylinder power pack and button bit. Button bit is higher efficient than chisel bit in combination with jack hammer and pneumatic cylinder. This also reduces cost of drilling and improves safety of worker.

REFERENCE

[1] ASTM.2001. Standard test method for determination of rock hardness by rebound hammers method. Bell, F.G.1992.
[2] Bingham, MG,1965. "A new approach to interpreting rock drillability", Technical Manual Reprint.
[3] Detournay, E. and P. Defourny, "A phenomenological model for the drilling action or drag bits", internal journal of rock mechanics and mining Sciences & Geomechanics Abtracts, 29, 13-23 Stavropoulou M ., 2006.
[4] Hartman, HL. And Mutmansky,"Introductry mining engineering", John Wiley and Sons, New York, NY, USA ,J.M.2002.
[5] ISRM. 1981. Rock characterization, "Testing and monitoring. In: Brown, E.T.(ed.)". Commission on Testing Methods, Internationals Society for Rock Mechanics (ISRM), Pergamon Press, Oxford, UK, pp.75-105.
[6] Kramadibrata, S.; Made, A.R;Juanda,J.; Simangunsong, G.M; and Priagung N.2001. "The use of dimentional analysis to analyze the relationship between penetration rate of jack hammer and rock properties and operational characteristics" . Proc. Indonesian Mining Conference and Exhibition, 7-8 November 2001, Jakarta.
[7] Singh, D.P., 1969. "Driiability and Physical Properties of Rocks, Proceeding of the Rock Mechanics Symposium", University of Sydney.
[8] Pang, S.S. and Goldsmith, W.: "A Model of a Pneumatic Jackhammer System," (1992) 25, 49-61.

VIJAYA RAGHAVAN

- Started Professional Qualification with a Diploma in Mining Engineering from School of Mines, K.G.F in 2002, Bachelor of Engineering in Mining Engineering from Vishvesvaraya Technological University, Belgaum in 2006, Master of Engineering in Environmental Engineering from Sathyabama University, Chennai in 2010 and Presently Pursuing PhD in Mine Environmental Engineering From **National Institute of TechnologyKarnataka,Suratkal,Mangalore, Karnataka.**
- **Working as Assistant Professor & Head, Department of Mining,DrTTIT,K.G.F**
- **AREA OFINTEREST**: Drilling and Blasting Mine Environmental Engineering,, Rock Mechanics