Performance Analysis of Hydraulic Breaker in the Limestone Mining - A Case Study

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Abstract - *Blasting methods were widely used for hard rock breaking, while the usage of mechanical breaking methods for hard rocks has recently increased mainly in fractured formations. Moreover, mechanical breaking methods involves lower capital costs, higher safety, a cleaner environment and higher strata control than blasting methods. There are several non-explosive or mechanical methods such as hydraulic breaking, ripping, and digging. Hydraulic breaker is used to break up rocks in areas where blasting is not possible due to safety or environmental issues. Breaking is done with a hydraulic hammer, a percussion hammer fitted to an excavator which is typically used for rock excavation and demolishing concrete structures. The performance analysis of a hydraulic breaker typically involves the evaluation of various factors such as impact energy, frequency, noise level, durability and efficiency. Each hydraulic breaker has its strengths and is suited for different operational needs, with Breaker II being the most powerful and heavy-duty, while Breakers I and III offer high efficiency with lighter construction, and Breaker IV providing a balanced option. By evaluating these key metrics, operators can choose a hydraulic breaker that is best suited for actual field working conditions their application to use the machine in productive manner.*

Key Words: Hydraulic breaker, Performance analysis, Fuel consumption, Hardness, Compressive strength, Tensile strength, Noise, Vibrations, etc.

1. INTRODUCTION

Mechanical breaking offers significant advantages over blasting, particularly in terms of safety, environmental impact, precision, regulatory compliance, operational flexibility, and cost efficiency. These benefits make it a preferred method in many construction, demolition, and mining applications, especially in urban and sensitive environments where control and minimal disruption are critical. A hydraulic breaker, also known as a hydraulic hammer, is a powerful percussion hammer fitted to an excavator for demolishing concrete structures or rocks. It operates by converting hydraulic energy from the excavator's hydraulic system into kinetic energy, which is then delivered to the breaker's tool to generate high-impact force.

The performance of a hydraulic breaker is determined by various factors, including the technical specifications and operational conditions. High impact rate and appropriate tool diameter contribute to effective material breaking. Carrier weight class and hydraulic input power ensure compatibility and efficiency. Maintenance and breakdown hours reflect the equipment's reliability and need for service. Operator skills, jobsite conditions, and proper attachment selection also play critical roles. Regular maintenance, including lubrication and wear part replacement, is essential for sustained performance. Ultimately, a well-maintained hydraulic breaker operated by skilled personnel in optimal conditions will deliver high productivity and efficiency.

1.1 Importance of performance analysis

To know the working of hydraulic breaker in mining field with all its specifications. Hydraulic breaker operates by utilizing the hydraulic system of an excavator, where pressurized hydraulic fluid drives a piston back and forth within a hydraulic cylinder. This piston impacts a tool, usually a chisel or moil point, generating high-impact force that breaks the rock or concrete into smaller pieces. The cycle of pressurizing the fluid, moving the piston, and impacting the tool repeats rapidly, often several hundred to a few thousand times per minute, providing a consistent breaking force. Hydraulic breakers are defined by key specifications that ensure their effectiveness and compatibility with specific tasks.

To know the tonnage production achieved per shift and per day. The production achieved by a hydraulic breaker is influenced by several factors, including the impact energy, blow rate, and efficiency of the tool and carrier machine. On average, hydraulic breakers can achieve production rates ranging from several cubic meters to hundreds of cubic meters per hour, depending on these variables.

To know the diesel and hydraulic consumption to meet the profitable output. Hydraulic oil consumption by a hydraulic breaker depends on the tool's size and operating requirements. The precise consumption rate ensures that the breaker operates efficiently, with the hydraulic system providing sufficient power to the piston to deliver effective blows. Properly matching the hydraulic oil flow to the breaker's specifications is essential for optimal performance and to avoid damage to both the breaker and the excavator's hydraulic system.

To find production oriented optimization of hydraulic breaker as compared to blasting. To optimize the production of a hydraulic breaker, start with proper tool selection based on the material and task. Ensure optimal hydraulic settings for flow rate and pressure, matched to the breaker's specifications. Regular maintenance, including parts replacement and lubrication, is crucial for efficiency and uptime. Train operators in efficient techniques and match the breaker to a suitable carrier for stability. Monitor performance data for insights and implement cooling systems to prevent overheating.

To minimize or to mitigate the problems of hydraulic rock breaker with consideration of noise and vibration. Minimizing problems with a hydraulic breaker involves several key strategies. First, ensure proper maintenance by following manufacturer guidelines, including regular inspections, lubrication, and parts replacement as needed. Match the breaker to a compatible carrier machine and monitor hydraulic settings to prevent overheating or excessive wear. Implement a preventive maintenance schedule and address any issues promptly to minimize downtime and maximize the hydraulic breaker's reliability and lifespan.

2. INVESTIGATION

2.1 Study area

The study area involves limestone deposit of Jai- Surjana Mines of M.P. Birla Cement Group in the state of Rajasthan, India. M.P. Birla Cement plant plays a significant role in the cement industry, contributing to economic growth and infrastructure development in Rajasthan and India as a whole. Limestone samples were taken from the Jai-Surjana limestone mine.

2.2 Physio-mechanical properties of limestone

Limestone is off-white to slightly grayish sedimentary rock with fine granular texture and slight cementation. Its density ranges from 2.3 to 2.7 g/cm^3, and it has a moderate porosity of 0.25 to 0.3, indicating a considerable amount of pore space. With low thermal conductivity (0.06 to 0.09 W/(m*K)), limestone is a poor heat conductor, which is advantageous for insulation purposes. Its solubility in acidic water highlights its susceptibility to chemical weathering. Limestone with a Mohr's hardness of 3.4 is a relatively soft sedimentary rock.

Table-1: Instrument used in analyzing mechanical properties of limestone

S. No.	Instrument used	Analytical methods	parameters
1	Mohr's hardness kit	Mohr's hardness scale	Hardness on Mohr's scale
2	Hydraulic compressive press	Universal testing machine	Compressive strength
3	Schmidt hammer rebound machine	L-type Schmidt hammer rebound testing machine	Hardness , strength
4	Brazilian test apparatus	Hydraulic compressive press with curved jaws	Tensile strength
5	Vibration meter and sound level meter	Handy equipment for measuring sound level and vibration	Sound level and vibrational frequency

Table-1 shows that the limestone samples undergoes the different testing for determining the mechanical properties.

The production performance of a hydraulic breaker is influenced by several factors, including its impact rate, tool diameter, and hydraulic input power. High impact rates and appropriate tool sizes ensure efficient material breaking, while optimal hydraulic power enhances operational effectiveness. The carrier's compatibility and proper attachment selection also play crucial roles. Regular maintenance, including lubrication and wear part replacement, ensures sustained performance and minimizes downtime. Skilled operators and favorable jobsite conditions further enhance productivity. Overall, a well-maintained hydraulic breaker, operated under optimal conditions, delivers high productivity and efficiency in construction and demolition task.

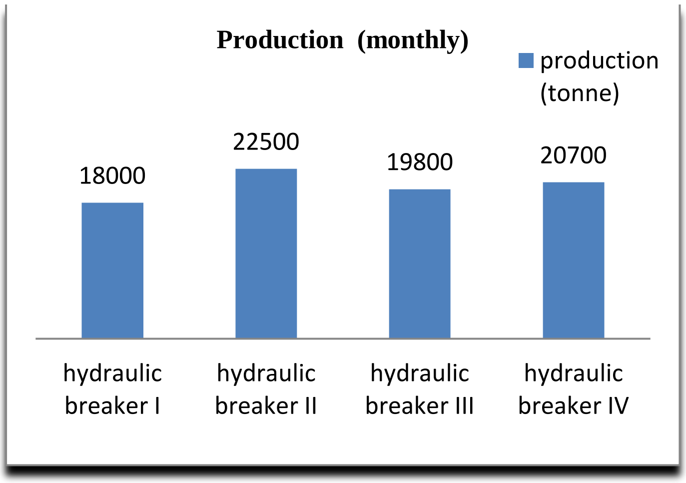

Figure-1 Monthly production achieved by hydraulic breaker

Fig.1 clearly describing that hydraulic breaker II with high operational hours leads to higher production volumes But more operational hours can lead to increased wear and tear, necessitating more frequent maintenance.

Table-2 Hours attained by hydraulic breakers in their respective state

	Maintenance hours				Breakdown hours				Working hours				Idle hours
	Shift	day	week	month	Shift	day	week	month	Shift	day	week	month	weekly
Hydraulic breaker I	1	3	18	90	1	3	18	90	5	15	90	450	6
Hydraulic breaker II	0.75	2.25	13.5	67.5	1	2	12	60	6	17	102	510	4.5
Hydraulic breaker III	1	3	18	90	1	3	18	90	5	15	90	450	6
Hydraulic breaker IV	0.5	2.5	15	75	1.5	2	12	60	5.5	16	96	480	3

Table-2 gives the performance of the four hydraulic breakers in context to their working hours, breakdown and maintenance hours.

While observing the working of hydraulic breaker with sound level meter and vibration meter. We found Sound Level of 124.4 dB is extremely high. Requires strict hearing protection and noise management to comply with safety regulations and protect operator health. Vibrational Frequency of 32.2 Hz is effective for breaking tough materials. Requires vibration control measures to prevent operator fatigue and health issues.

$$\%\ Availability = \frac{\text{working hours} + \text{idle hours} \times 100}{\text{Total shift hours}}$$

Total shift hours = working hours + breakdown hours + maintenance hours + idle hours

$$\%\ Utilization = \frac{\text{working hours} \times 100}{\text{Total shift hours}}$$

Table-3 Utilization and availability % of hydraulic breakers

Hydraulic breaker	Availability			Utilization		
	Day	weekly	Monthly	Day	weekly	Monthly
Hydraulic breaker I	72.7	72.7	72.4	68.18	68.18	68.80
Hydraulic breaker II	80.6	80.6	80.5	77.27	77.27	77.80
Hydraulic breaker III	72.7	72.7	72.4	68.18	68.18	68.80
Hydraulic breaker IV	78.5	78.5	78.4	76.19	76.19	76.55

Availability refers to the proportion of time the hydraulic breaker is operational and ready for use compared to the total scheduled time, often influenced by maintenance, repairs, and unexpected downtime. High availability indicates minimal downtime and effective maintenance practices. Utilization percentage, on the other hand, measures the actual usage time of the hydraulic breaker against its available time. High utilization suggests optimal use of the equipment during its available period, reflecting efficient project management and scheduling. Both metrics are essential for maximizing productivity and cost-efficiency in construction operations.

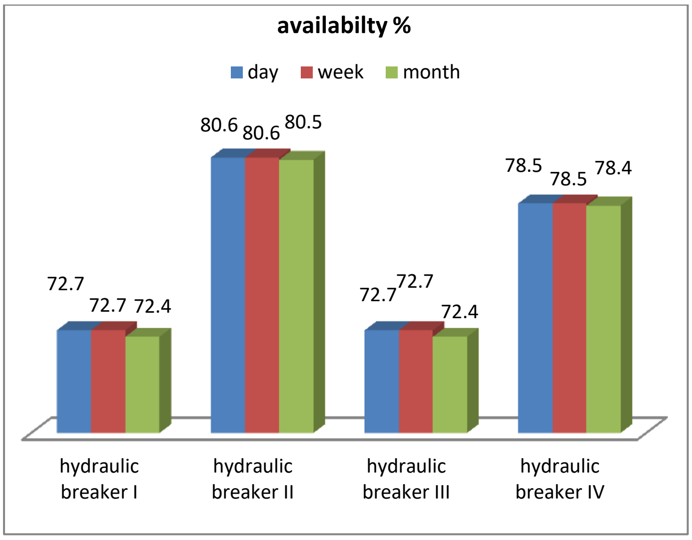

Figure-2 Comparison of availability % of hydraulic breakers

Fig.2 illustrates the same by comparing them on availability of breakers on daily, weekly and monthly basis. The availability percentage of a machine indicates the proportion of the scheduled time that the machine is actually available for operation.

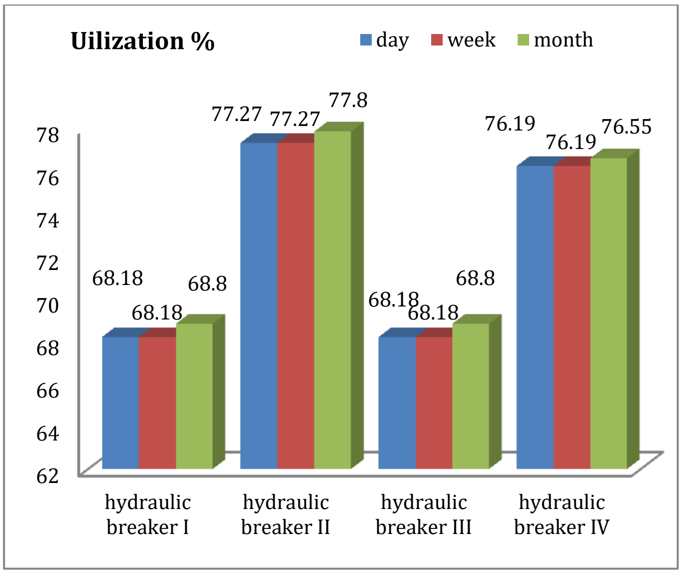

Figure-3 Comparison of utilization of hydraulic breakers

Fig 3 illustrates the same by comparing them on utilization of breakers on daily, weekly and monthly basis. Utilization helps in understanding the operational efficiency of the machine and can guide decisions on improving scheduling, load balancing, and resource allocation to enhance overall productivity The utilization percentage of a machine indicates the proportion of the total available time that the machine is actually in operation.

Table-4 Fuel consumption of hydraulic breakers

	Fuel consumption (in litres)	
	Hour	Day
Hydraulic breaker I	69.41	1041.15
Hydraulic breaker II	72.20	1227.40
Hydraulic breaker III	69.50	1042.50
Hydraulic breaker IV	70.10	1121.60
Average	70.30	1108.27

Table-5 shows that high speed diesel consumption by four different breakers. Fuel Consumption of 1108 liters/day indicates high power output and extensive use and leads to significant operational costs and environmental impact, necessitating efficient fuel management and possibly exploring more fuel-efficient alternatives.

3. CONCLUSIONS

Hydraulic Breaker I and III: Identical specifications in most aspects, suitable for similar applications, and supporting a broad carrier weight range. Both are relatively lighter and quieter, with high impact rates and moderate hydraulic power requirements. Hydraulic Breaker II: Stands out with the highest carrier weight class, service weight, tool diameter, hydraulic input power, and oil flow rate. It is designed for heavy-duty applications requiring robust performance but is also the loudest. Hydraulic Breaker IV: Falls in between in most specifications, suitable for a specific carrier weight range with moderate service weight and power requirements. It offers a balance between performance and operational efficiency with slightly lower noise levels and a moderate impact rate.

Hydraulic breaker II with high operational hours leads to higher production volumes. On the basis of Availability and Utilization, hydraulic breaker I and III are at same percentage of availability and utilization in day and week whereas hydraulic breaker II showing highest % of availability and utilization. Breaker II stands out as the most efficient and reliable, with the highest working hours, the least maintenance time, and relatively low idle hours. Breaker IV also performs well with high working hours and low idle time but requires slightly more maintenance. Breakers I and III show identical performance metrics, indicating average utilization and reliability compared to Breakers II and IV. By focusing on reducing maintenance and breakdown hours for Breakers I and III and further optimizing the operations of Breaker IV, overall efficiency and productivity can be improved. Each hydraulic breaker has its strengths and is suited for different operational needs, with Breaker II being the most powerful and heavy-duty, while Breakers I and III offer high efficiency with lighter construction, and Breaker IV providing a balanced option.

The productivity of hydraulic breakers depends on several key factors. The properties of the rock material impact efficiency, with harder rocks requiring more effort. Jobsite conditions, organization, accessibility, and visibility affect operational speed and accuracy. Operator skills, experience, and proper training are crucial for optimal performance. Selecting the right attachment, including appropriate carrier size, oil flow, and attachment size, ensures effective operation. Correct installation, preferably by an authorized and trained partner, reduces breakdowns. Regular service and maintenance, including machine condition checks, lubrication, wear part exchanges, and maintaining chisel shape, are essential for sustained productivity.

REFERENCES

[1] J. Toraño& R. Rodríguez (2003) Simulation Of The Vibrations Produced During Th e Rock Excavation By Different Methods. *Computational and Experimental Methods,* **4:** 343-349.

[2] Aksoy, C. O. (2009): Performance prediction of impact hammers by block punch index for weak rock masses. International Journal of Rock Mechanics and Mining Science, **46:**1383-1388.

[3] Guoping Yang & Yubao Chen (2012) The Research of New Type Hydraulic Breaker with Strike Energy and Frequency of Adjusted. *Mechanical Engineering Research. Published by Canadian Center of Science and Education*; **2:** 45-51

[4] Aksoy, C.O. Ozacar, V., Safak, S. (2013): An updated formula and method to predict the performance of impact hammers. *International Journal of Rock Mechanics and Mining Science*,**61** :289-295.

[5] Hoang Nguyen, Xuan-Nam Bui (2015) Simulation of the breaking rock processing by hydraulic breaker in surface mines according to the results of bousinessq mathematical model. *International Workshop on Advances in Surface Mining for Environment Protection and Sustainable Development.* at Hanoi, Vietnam, *Researchgate publication* pp: 107-112

[6] Tumac, D., Hojjati, S. (2016): Predicting performance of impact hammers from, rock quality designation and compressive strength properties in various rock masses. *Tunneling and Underground Space Technology*, **59 :** 38-47.

[7] Dae-Kyung NohYoung-Ky KangJae-Sang ChoJoosup Jang (2016) Case study on impact performance optimization of hydraulic breakers *Springer Plus ,* **5:** 1-14

[8] Changheon Song, DaeJi Kim, Jintai Chung,1 Kang Won Lee, Sang SeukKweon, and Young Ky Kang (2017) : Estimation of Impact Loads in a Hydraulic Breaker by Transfer Path Analysis, *Shock and Vibration,* **2 :** 1-15

[9] Mohamed Elkarmoty, Mohamed Ismael Khaled, Abdelghafar, Mohamed Sholqamy Performance prediction of hydraulic breakers in excavation of a rock mass (2021*). The Mining-Geology-Petroleum Engineering Bulletin* **36:**107-119

[10] Manual of hydraulic breaker.