MACHINERY EMPLOYED IN SURFACE MINING

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Abstract:

Opencast mining is widely adopted for the extraction of minerals located at shallow depths. With the advancement of highly mechanized equipment, minerals located at depths of up to 500 m are also being extracted using the opencast method. The productivity and efficiency of opencast mining have significantly improved due to the use of Heavy Earth Moving Machinery (HEMM) such as shovels, shovel–dumper combinations, draglines, bucket wheel excavators, and bucket chain excavators. In addition, advanced drilling machines such as wagon drills, well-hole drills, and down-the-hole drills are widely used for drilling operations. These machines play a vital role in the excavation and transportation of overburden and minerals. A notable example is the large-scale excavation of lignite at Neyveli, where bucket wheel excavators and other heavy-duty matching equipment are extensively used. In India, nearly 60% of the total mineral production is obtained from opencast mining operations, which highlights the importance of this method in the mining industry.

Keywords: Opencast mining, Heavy Earth Moving Machinery (HEMM), Bucket Wheel Excavator, Drilling Machines, Lignite Mining.

1.Introduction

Opencast mining, also known as surface mining, is one of the most widely used methods for extracting minerals that are located close to the earth's surface. This method involves removing the overburden (the layer of soil and rock above the mineral deposit) to access the valuable minerals beneath. Compared to underground mining, opencast mining is generally considered more economical, safer, and capable of achieving higher production rates due to the use of large-scale mechanized equipment.

With advancements in mining technology, opencast mining is no longer limited to shallow deposits. Modern mining operations are now capable of extracting minerals from depths of up to 500 m using highly mechanized systems and advanced mining techniques. The introduction of Heavy Earth Moving Machinery (HEMM) has greatly enhanced the efficiency and productivity of opencast mining operations. Equipment such as shovels, shovel–dumper combinations, draglines, bucket wheel excavators, and bucket chain excavators are commonly used for the excavation and transportation of overburden and minerals.

Drilling operations also play a crucial role in opencast mining. Highly mechanized drilling equipment such as wagon drills, well-hole drills, and down-the-hole drills are used to create blast holes for

fragmentation of rock formations. These technologies help improve the efficiency of blasting and excavation processes.

A prominent example of large-scale opencast mining in India is the lignite mining operation at Neyveli, where bucket wheel excavators and other heavy-duty matching equipment are extensively used for continuous excavation and transportation. Today, nearly 60% of the total mineral production in India comes from opencast mines, highlighting their significant role in meeting the country's growing demand for energy and mineral resources.

Scope of Work:

The scope of this work focuses on the study of opencast mining methods and the use of highly mechanized equipment for efficient excavation and transportation of overburden and minerals. It includes the analysis of Heavy Earth Moving Machinery (HEMM) such as shovels, draglines, dumpers, and bucket wheel excavators used in large-scale mining operations. The work also examines drilling machines like wagon drills and down-the-hole drills employed for blasting and excavation processes. Special emphasis is given to lignite mining operations at Neyveli in India, where bucket wheel excavators and other matching equipment are extensively used. This study aims to understand the efficiency, productivity, and operational aspects of mechanized opencast mining.

2.Literature Review

Several researchers have studied the development and efficiency of opencast mining methods and the role of mechanization in improving productivity. William A. Hustrulid (1995) and Mark Kuchta (1995) explained the fundamental principles of surface mining and emphasized the importance of large-scale excavation equipment for efficient mineral extraction. Howard L. Hartman (1992) highlighted the operational advantages of Heavy Earth Moving Machinery (HEMM) such as draglines, shovels, and dumpers in increasing production rates in opencast mines. T. N. Singh (2004) and P. K. Roy (2005) analyzed drilling and blasting techniques used in surface mines to improve rock fragmentation and reduce operational costs. Furthermore, Ibrahim Dincer and Marc A. Rosen (2016) discussed the importance of energy efficiency and advanced technologies in large-scale industrial systems. In addition, Christopher J. Bise (2003) reported that the use of bucket wheel excavators and continuous conveying systems significantly improves productivity in large lignite mining operations such as those at Neyveli in India. These studies collectively highlight that modern mechanization and advanced mining technologies play a vital role in enhancing efficiency, safety, and cost-effectiveness in opencast mining. Recent studies have highlighted the growing role of advanced technologies and optimization techniques in opencast mining. Guangwei Liu, Weiqiang Guo, Senlin Chai and Jiaming Li (2023) developed a production capacity planning model for open-pit coal mines, showing that proper planning of working face length and advance rate significantly improves mine productivity and operational efficiency. Vinay Kumar Singh, Maneeb Masood and Tarun Verma (2024) reviewed modern slope monitoring techniques in opencast mines and emphasized the use of LiDAR, radar scanning, GPS, and remote sensing technologies to predict slope failure and enhance mine safety. Similarly, Michael Long, Steven Schafrik, Peter Kolapo and Zach Agioutantis (2024) reported that automation technologies such as autonomous haul trucks and intelligent monitoring systems significantly improve safety, productivity, and operational efficiency in surface mining. Further studies have focused on digital and data-driven approaches for improving mining operations. Sujit Kumar and A. K. Mishra (2025) conducted digital analysis of shovel digging time and showed that optimization of blasting energy and excavation cycles can enhance excavator productivity in opencast mines. In addition, Siyu Teng, Xuan Li and Long Chen (2024) proposed autonomous transportation systems for open-pit mines using advanced scenario engineering methods to improve reliability and operational performance.

3. Methodology

The methodology for studying the machinery employed in surface mining, particularly in opencast operations, focuses on identifying the types of equipment used, their roles in the mining process, and how they contribute to the efficiency and productivity of operations. The key steps in this methodology are as follows:

Identification of Machinery Types:

A detailed review is conducted to identify the various machinery used in opencast mining operations. This includes:

- **Heavy Earth Moving Machinery (HEMM)**: Such as shovels, shovel-dumper combinations, draglines, bucket wheel excavators, and bucket chain excavators, all of which are essential for excavation and transportation of materials.
- **Drilling Machines**: Various types of drilling equipment, including wagon drills, well-hole drills, and down-the-hole drills, are evaluated for their effectiveness in creating blast holes and preparing the site for excavation.

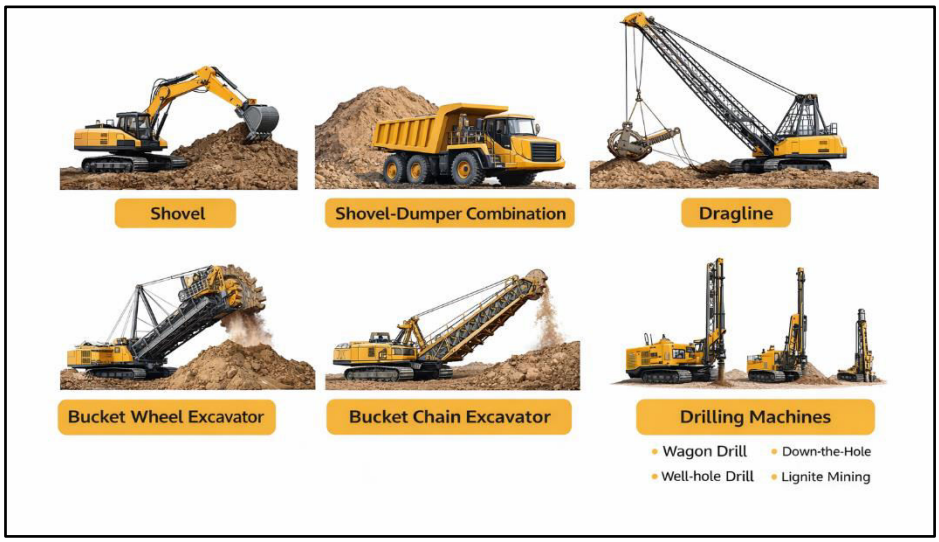

Figure 1: Heavy Earth Moving Machinery

Examination of Operational Roles:

The operational roles of each type of equipment are analyzed. This involves studying how these machines are employed in different stages of the mining process:

- **Excavation**: The use of shovels, draglines, and bucket wheel excavators in the removal of overburden and minerals.
- **Transportation**: The role of shovel-dumper combinations and conveyor systems in moving excavated materials to processing areas.
- **Drilling Operations**: Understanding how drilling machines prepare the site for blasting, a critical component in breaking up rock formations for further excavation.

Case Study Analysis:

A case study approach is used, such as the large-scale lignite mining operation at Neyveli, where the performance of heavy-duty machinery like bucket wheel excavators is observed. This case study allows for a practical understanding of the machinery's role in high-efficiency mining operations.

Efficiency and Productivity Assessment:

The productivity of the machines is assessed through performance metrics such as:

- **Excavation Rate**: The quantity of overburden and mineral extracted within a given time frame.
- **Fuel and Energy Consumption**: Analyzing the efficiency of machines in terms of fuel consumption per unit of material moved.
- **Maintenance and Downtime**: Assessing the operational availability of machines, considering factors like maintenance schedules and breakdown occurrences.

4. Machinery Employed in Surface Mining methods

Surface mining, also known as opencast mining, involves the extraction of valuable minerals from shallow deposits using a variety of specialized machinery. The selection of equipment depends on the type of minerals being extracted, the nature of the overburden, and the mining conditions. The main methods used in surface mining and the corresponding machinery employed include:

1. Open-Pit Mining

Open-pit mining is used for minerals that are located in horizontal or gently inclined deposits close to the surface. The process involves removing overburden and extracting the ore in large steps or benches.

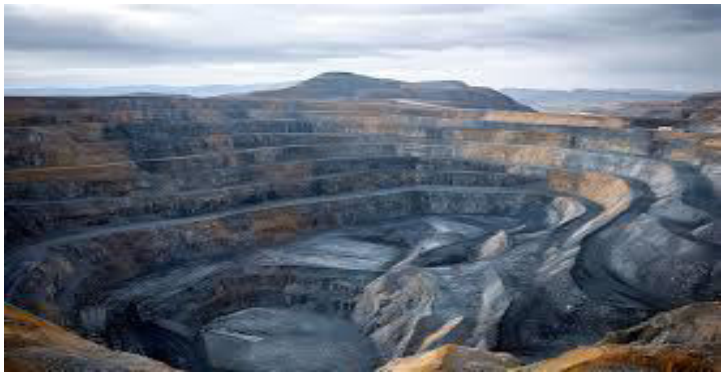

Figure 2: Open-Pit Mining

- **Machinery Employed**:
    - **Shovels and Excavators**: Used for digging and loading material from the mine to transport trucks.
    - **Dumper Trucks**: Heavy-duty trucks used to transport the excavated material to the processing plant or waste dumps.
    - **Draglines**: Large, bucket-equipped machines that remove large quantities of overburden.
    - **Blasting Machines**: Drills, blast-hole drills, and blasting agents are used for breaking up hard rock in preparation for excavation.

2. Strip Mining

Strip mining involves removing overburden in layers or strips to expose and extract the minerals. This method is typically used for minerals like coal, lignite, and certain ores located in horizontal layers.

- **Machinery Employed**:
    - **Bucket Wheel Excavators**: These machines have large rotating wheels with buckets that scoop up the overburden and mineral material, allowing for continuous extraction.
    - **Shovel-Dumper Combinations**: Shovels remove overburden and place it into dump trucks for transportation.
    - **Dozers and Graders**: Used for leveling the ground and clearing paths for the excavation machinery.

3. Mountaintop Removal Mining

Mountaintop removal is a method used to mine coal in which the tops of mountains are removed to access coal seams. This technique is most commonly used in areas where coal is found in steep terrain.

- **Machinery Employed**:
    - **Draglines**: Primarily used for removing vast quantities of overburden and coal seams.
    - **Shovels and Excavators**: For digging and loading the materials into transport trucks.
    - **Highwall Miners**: Machines that cut the coal seams located high on the mountain slopes.:

Shovel and Shovel-Dumper Combination:

Shovels are essential for the excavation of both overburden and minerals, directly impacting the excavation stage. They perform the digging tasks, ensuring material is efficiently loaded onto dumper trucks for transportation. The shovel-dumper combination improves the overall efficiency by continuously digging and transporting material, allowing for uninterrupted workflow between excavation and transportation stages. This combination increases overall productivity and reduces downtime.

Figure 3: Shovel and Shovel-Dumper

Dragline:

The dragline is a key machine for large-scale excavation and overburden removal, capable of handling massive volumes of material. This machinery is most effective in mining operations where large

amounts of overburden need to be moved before accessing the mineral deposit. Its continuous operation allows for high-volume material removal, making it suitable for operations involving heavy overburden.

Bucket Wheel and Bucket Chain Excavators:

Both the bucket wheel excavator and bucket chain excavator serve similar roles in excavation but differ in their construction and the way they handle material. The bucket wheel excavator provides continuous material extraction using a rotating wheel, making it ideal for strip mining and large-scale operations. The bucket chain excavator, with its chain system, also performs large-scale excavation but is better suited for high-volume material handling in more specific conditions where traditional excavators might not be as efficient.

Figure 4: Bucket Wheel and Bucket Chain Excavators

Drilling Machines:

Drilling machines such as the wagon drill, well-hole drill, and down-the-hole drill play a critical role in the preparation phase of opencast mining. They create blast holes, which are necessary for breaking rock formations before excavation. The wagon drill is used for creating shallow blast holes, while the well-hole drill handles deeper, narrower holes for more precise explosive charges. The down-the-hole drill excels in hard rock conditions, offering high precision in deep drilling operations.

Impact on Mining Operations:

The machinery employed in surface mining significantly enhances the efficiency, speed, and safety of mining operations. The ability to quickly remove overburden, drill precise blast holes, and transport materials efficiently has increased productivity, reduced operational costs, and improved safety in the mining environment. By combining different machinery types for excavation, material handling, and drilling, mining operations have seen enhanced overall performance and optimized workflows, making opencast mining the most efficient method for large-scale mineral extraction.

Conclusions

This study underscores the pivotal role that heavy machinery plays in enhancing the efficiency and productivity of opencast mining operations. The use of various types of machinery, including shovels, draglines, bucket wheel excavators, and advanced drilling machines, has significantly improved the excavation, material handling, and drilling processes. As mining depths and material volumes increase, the integration of specialized machinery such as shovel-dumper combinations and bucket chain excavators has optimized the flow of operations. Additionally, drilling machines have enabled precise blast hole creation, crucial for effective rock breakage. The results highlight the effectiveness of modern machinery in reducing energy consumption, operational downtime, and costs, while improving safety and environmental impact. In conclusion, the continued use and advancement of heavy machinery, in

combination with technological innovations like machine learning and automation, will drive further efficiencies, ensuring that opencast mining remains a critical method for large-scale mineral extraction.

References

1. Howard L. Hartman (1992). *Introductory Mining Engineering*. John Wiley & Sons, New York.
2. William A. Hustrulid and Mark Kuchta (1995). *Open Pit Mine Planning and Design*. A.A. Balkema Publishers, Rotterdam.
3. Christopher J. Bise (2003). *Mining Engineering Analysis*. Society for Mining, Metallurgy, and Exploration (SME), USA.
4. T. N. Singh (2004). "Rock Fragmentation by Blasting in Opencast Mines." *Mining Engineers Journal*, India.
5. P. K. Roy (2005). *Rock Blasting Effects and Operations*. CRC Press.
6. Ibrahim Dincer and Marc A. Rosen (2016). *Exergy: Energy, Environment and Sustainable Development*. Elsevier.
7. Liu, G., Guo, W., Chai, S., & Li, J. (2023). "Production capacity planning model for open-pit coal mines." *Scientific Reports*.
8. Singh, V. K., Masood, M., & Verma, T. (2024). "Advanced monitoring techniques for slope stability in opencast mines." *Journal of Mining Science*.
9. Long, M., Schafrik, S., Kolapo, P., & Agioutantis, Z. (2024). "Automation technologies in surface mining operations." *Mining Engineering Journal*.
10. Kumar, S., & Mishra, A. K. (2025). "Digital analysis and optimization of shovel digging time in opencast mines." *Sustainable Mining Journal*.