TECHNOLOGICAL INNOVATIONS IN COAL MINING INDUSTRY

S Jayanthu*, P Rammohan, and Chandramohan *****
**Professor, ** MTech Scholar, Mining Engg Dept*
National institute of Technology, Rourkela-563 117-Odisha-India
***Former Joint Director, Mines and Geology, Govt of AP-India, Council member IEI

ABSTRACT

This paper presents latest technological innovations applicable for in mining industries with emphasis on mechanisation in coal mining industry. Latest Exploration and Survey techniques utilising GIS, light weight laser scanning systems etc including RADAR applications, are discussed. Automation in underground mining machinery and innovations in heavy earth moving machinery for large scale open cast mining are also presented with impetus on wide utilisation of the latest Information and Communication Technology (ICT) for mining and attempts required for MAKE IN INDIA CONCEPT a reality.

1.0 INTRODUCTION

The mining industry is confronted with a number of well-known systemic challenges, including limited availability of qualified labour (both local and expat), remote and difficult work environments and the unending need to improve yields and reduce costs to meet competitive challenges in an industry where there is limited pricing differentiation. Mining companies has to understand their perspective on future industry trends and their expectations for autonomous equipment. Three areas in which autonomy could provide the most value were in improving overall mine performance, increasing safety and reducing the aggregate labour requirements.

The mining industry typically operates in a cyclic fashion with periods of strong growth followed by inevitable downturns. The industry is currently in the throes of a downturn. In India, coal is the most important energy resource as also the main contributor to the basket of commercial energy of the country. India is the third largest coal producer in the world after China and USA. The biggest reserves of coal are in the USA, Russia, China and India. The details of state –wise representation of 301.56 Billion tones of geological resources of Indian coal are presented in Table 1 [1].

.

Table 1:State-wise Geological Resources of Coal in India as on 1.4.2014 (in Million Tonnes)

State	Proven	Indicated	Inferred	Total
West Bengal	13403	13022	4893	31318
Jharkhand	41377	32780	6559	80716
Bihar	0	0	160	160
Madhya Pradesh	10411	12382	2879	25673
Chhattisgarh	16052	33253	3228	52533
Uttar Pradesh	884	178	0	1062
Maharashtra	5667	3186	2110	10964
Odisha	27791	37873	9408	75073
Andhra Pradesh	9729	9670	3068	22468
Assam	465	47	3	515
Sikkim	0	58	43	101

State	Proven	Indicated	Inferred	Total
Arunachal Pradesh	31	40	19	90
Meghalaya	89	17	471	576
Nagaland	9	0	307	315
Total	125909	142506	33149	301564

Associated with production of coal, mining industry also is a part of indirectly producing about 20 % of Coal as by-product of Thermal Power stations (about 0.67 Kg of coal for generating one unit –KWh of electric power). However, its utilization is nearly 50% of the production (2009-10), which is very less in comparison to the major fly ash producing countries like China, U.S.A. and Germany. Future generation of about 1000 MT of fly ash need to be properly utilised as a resource rather than waste material under the guidance of Centre for Fly Ash and research management –CFARM –Scheme of Government of India [2] (Table 2). Fig 1 shows backfilling wit*h Fly ash in a typical opencast mine where scientific investigations were done for the first time in India* on filed experimental trial of admixture of 25% of the fly ash with Overburden material.

.

Table 2: Generation and Utilisation of Fly Ash in India

Year	FA Generation (Million Tonne)	FA Utilization (Million Tonne)
1994	40	1
2008	160	80
2011-2012	220	110
2031-2032	1000	--

Timely application of innovative practices in various aspects of mining; exploration, surveying, opencast and underground technologies are urgently required to improve productivity, getting more out of existing people, equipment and infrastructure. As owner-operators continue to slash Crores of Rupees of spending, shed jobs, divest underperforming mines, cut back on capital projects, and attempt to reign in wages, many have begun to focus on long-term optimisation of operating costs and capital allocation as sustainable measures for mining industry with the recent set back of DE-ALLOCATION OF COAL BLOCKS.

2.0 EXPLORATION TECHNOLOGY

Recent innovations include geo-scientific database for mineral prognostication in India. The Geological Survey of India has built up a national geo-science database in the form of 1:50,000/1:63,360 scale geological maps covering the entire country, using ground survey, aerial photographs and satellite imageries. In addition to the existing facility of aero geophysical survey by fixed wing aircraft for a faster coverage, procuring new set of equipment's and helicopter will strengthen the continuing program of multi-sensor aerial survey.[3] As more and more exploration data is collected, digitized, and stored, explorers are establishing a stronger focus on understanding the information for making it more easily accessible and preserving as digital data base it for future exploration.

Deep and large opencast coal mines of 400 m to 450 m depth are considered important to increase the coal production of India. Planning and managing such large open pits depends upon a thorough understanding of geological and geotechnical aspects of the rock strata comprising the overburden column. The experiences of Singareni Collieries Company Limited (SCCL) located in Telangana, India document borehole geophysical logging as an effective means to generate a continuous description of geological and geotechnical strata features from the surface to total drilled depth. Conventional geophysical logs are used to identify the basic lithologies and construct geological maps of overburden strata. The uniaxial compressive strength (UCS) of sandstones is empirically estimated by correlating P wave velocities (Vp) obtained from sonic logs with the laboratory determined UCS value. Acoustic images help determine the location and trend of fractures and minimum horizontal stress directions. Together, these data provide the basis for characterisation of the rock mass and form the foundation for the effective design of stable pit walls in deep sedimentary strata [4]. A typical iron-ore mining, transport, and shipping activities are already generating 2.4 terabytes of data per minute [5]. The terminology that has gained mindshare is ‘big data’. Big data is the raw material that can be ‘mined’ for insights, and to which algorithms and expert systems can be applied to produce predictive analytics. In an attempt to drive productivity enhancements, the mining industry’s attention has turned towards INNOVATION. INNOVATION is quickly turning tip-of-the-spear technologies into disruptive new capabilities that present opportunities for strong differentiation and massive leaps in efficiency.

INNOVATION comes in many forms. One such innovation embraced by industry is the adoption of digital data, including data-enabled equipment, operating/safety/ environmental sensors, and the growing acceptance of the use of laser scanning or point-cloud data. Digital data will increasingly be used to support real-time tracking, surveillance, traffic management, environmental monitoring, various automated routines (e.g. driverless trucks), improved maintenance and asset management, and production monitoring and reporting.
As data from these various sources becomes readily available to the broader enterprise, the mining industry needs to better leverage this digital data to target specific productivity challenges. This ability to successfully leverage digital data across an enterprise is often described as “information mobility.”Information mobility is a key to unlocking value across the entire lifecycle and without it, data languishes in ‘islands’ where it becomes stale and obsolete. As the mining industry transitions into this era of digital data and information mobility, there is growing recognition of the scale of digital data being created and the need to better manage, maintain, and disseminate this information across the entire enterprise to ensure the right information reaches the right people at the right time.

2. MINE SURVEYING TECHNOLOGY

A mining operation needs to design and develop the necessary infrastructure prior to its operation. However, unlike many other infrastructure projects, once a mine site becomes operational the process of design, develop, and extract becomes an integrated and continuous loop, with this cycle remaining for the life of mine (LOM) which is often measured in years, if not decades. This continual cycle becomes the focal point of a mine’s operation, with particular emphasis directed towards the results achieved throughout the extract phase.

In order to test the execution, effectiveness, and accuracy of mine planning methods it is necessary to measure production against this plan. This tests both the accuracy of the geological and evaluation models on which the targets are based and the efficiency of the ore and metal recovery departments. Key to this is the accurate positioning of the excavations mined and the geological and evaluation features encountered. Unless this is achieved, it is impossible to gauge the progress made with any accuracy. Additionally, there can be no improvement in the base data used for evaluating the next planning cycle.
Timing is a fundamental part of the control issues on a mine. Operations are in effect, continuous, so snapshots have to be taken to measure planned production against actual outputs. Monitoring the actual extraction volumes versus production target rates has traditionally been measured by surveyors at month’s end. However, there is a growing desire by industry to measure the volume of extracted material at much shorter intervals, allowing management to better monitor and define the progress of the mine’s production rate. The ability to accurately monitor this phase is therefore seen as mission critical; and therefore the role of mine surveying is central to the success of this cyclic phase. A mine’s operation is typically governed by a significant number of stringent and rigorous regulatory requirements. These vary from region to region with many requirements directly impacting a raft of mine surveying practices, processes, and workflows.

In many instances, it is imperative that the mining operation maintains and manages its survey data, including legacy data, in a secure environment throughout the LOM. Traditionally this information has been maintained in hard-copy formats; however, as the industry transitions to digital, mechanisms and solutions which manage and maintain this mixed information environment will need to be established. Solutions and systems offering opportunities of secure data management capabilities, including an ability to store all survey data (i.e. raw observations/measurements, calculated information), survey control, survey notes, survey reports, plans of surveys, mine accurate plans, and more will be required.

Due to the innovations in **survey technologies**, traditional and historical surveying workflows are continuously being challenged. However, unlike other surveying disciplines, some aspects of mine surveying deal with unique circumstances. This is especially evident for underground operations, where surveying methods and techniques need to overcome the challenges of this environment. For this reason, traditional and historical survey workflows (i.e. tape and offset surveys) are still evident within industry today, however, there is an industry desire and need to promote innovative techniques to survey the underground environment. Over the past 50 years, the survey industry has undergone massive changes due to technology advancements, including the introduction of electronic distance meters (EDMs), total stations, global navigation satellite systems (GNSS), and robotic total stations [6]. Today, point-cloud creation technologies are challenging those traditional mine surveying workflows, with surveyors now looking at solutions capable of quickly producing accurate point-cloud data of the mine's in-progress state. Technologies such as unmanned aerial vehicles (UAV) combined with photogrammetric processes are now used to create point-cloud data quickly, effectively, and safely. In many regions, laser scanning workflows have been slow to make an impression within the mining industry. However, the past few years have seen a very different trend with terrestrial laser scanning (TLS), airborne laser scanning (ALS), and mobile laser scanning (MLS) systems becoming ever present within the industry. The increase use of this technology can be traced back to a combination of factors, including reduced size and costs of units, coupled with better performing and durable hardware suitable for the mining environment. In addition, software vendors are now catching up with the hardware, providing innovative solutions capable of efficiently working with, managing, and maintaining voluminous amounts of point-cloud data. Today laser scanners are used on a broad range of survey related workflows, including end-of-month reconciliation surveys, overburden and/or stockpile volume surveys, mine subsidence surveys, general 3D topographical surveys (surface and underground), and many other surveys where cost-effective data collection is required.

With the introduction of lightweight laser scanners to the market, the combined benefits of UAVs and laser scanning offers surveyors another option to **create point clouds.** These combined technologies provide a relatively low cost, safe, quick, and accurate option to map a mine's in-progress state leveraging the point-cloud data to create 3D information models. Within a mining environment various laser scanning techniques have been used to collect and map a mine's in-progress state. More recently, advanced MLS techniques have been adopted for underground mining environments. Leveraging **a simultaneous localisation and mapping** (SLAM) technique that consists of a spinning 2D LiDAR unit and an **industrial-grade mounted inertial measurement unit** (**IMU**), the acquired scan data is processed through a series of steps to produce a dense and accurate geo-referenced 3D point cloud that can be collected quickly and efficiently, without disrupting mining operations. An extension of this SLAM technique has recently been successfully completed in South Africa using a handheld version of the vehicle-mounted SLAM technology. Regardless of the survey technology adopted, mine surveying still remains the technique and science of accurately determining the 3D spatial location of points and or features on or below the Earth's surface.

3. OPENCAST MINING TECHNOLOGY

Surface mining is the main pillar for meeting the rising demand of metals and minerals as the total production of limestone, dolomite, bauxite, and iron ore and lignite is to come from these mines for ever while nearly 90% of total coal production. With rising demand of the coal, estimated to cross 1000 million tons by 2024, this share is going to cross 95% limit and the working depth is going to cross 300 m and the mine size for the mission will cross on average 5 million tons per mine. Heavy mechanization of the surface mining is therefore going to be the panacea of the mining sector [7].

There is need to amalgamate the latest IT modules in these machines, improve their efficiency, safety and economy in operation and maintenance. The conveyor system is found to be most economical in material transport in coal mines and needs perfection in fabrication, operational and energy efficiency. In addition, the machinery/ package demand will rise in coal mining sector during and be sustained over the next 50 years are In pit crusher conveyor package, Surface miner. conveyor package, Dragline and auxiliary machines, High wall miner /conveyor package etc. Biggest causality with the surface mining is the land, environment, hydraulic regime and green cover, the basic need of the life to survive. The land of interim use for mining is the lifeline for the posterity, and the society realizing this fact has started resisting the mining so necessary for their own development. All effort should be made to make the surface mining eco-friendly , ensuring restoration of the land to the stake holders after it is of no use to the industry – forest land for forestation, agricultural land to the farmers for cultivation, dwelling land for the settlement of the displaced persons rather than making it water land for ever. These are possible only by clubbing these objectives to the mining practice, and undertake concurrent backfilling, reclamation and restoration to its prime stage. The in pit crusher – conveyor transport system should be hooked with the spreader like the one adopted with the bucket wheel excavator to reclaim the land for common use. Remote Control of equipment, Fleet management, Process management, and Proximity Detection are some of the areas requiring more research in application to the field conditions in opencast mines.

4. UNDERGROUND MINING TECHNOLOGY

Continued strong growth in the global demand for energy, driven by both developed and developing markets, has lead to the coal sector playing a major role in meeting current demand and in raising production to meet annual planned increases. The most important of these markets for coal is the Asian Pacific area with consumption at over 3.3 billion tonnes last year, or over half the world's consumption. China is the most important coal-consuming country by far with its energy sector growing at between 7 to 9% per year. With this booming growth, underground coal owners and operators are looking at ever more productive and powerful equipment. Man riding systems for underground mines are very much required to cut down the time for reaching to work place and efficiently utilise the equipment. Fig 2 shows the man riding facility at a typical underground mine.

Fig 1 : Backfilling with Fly ash in a opencast mine

Fig 2: Man riding facility in a typical mine

Particular emphasis is made on the high capacity Chinese, Australian and the US markets where high productivity is coupled with maximising the extraction of coal reserves in both very thick seams and in thin high quality seams where premium prices can be commanded. As a result of this demand for increased production, manufacturers have made significant advances in thin seam and ultra-high seam extraction equipment.

Roof Support Electronics using the FACEBOSS electronic control system Integrating the long wall and mine-wide system to enable automatic control of the long wall operation, including fully automatic shearer and roof support gate turn rounds appears to be a better choice for futre long wall equipment for better performance. ComPak Valve System for controlling modern automatically operated longwall roof supports and facility for online and continuous monitoring of health of equipment, and stability of workings with appropriate sensors may be explored using Wire Less sensor networks, wherever feasible. Fig 3 and 4 shows Remote LHD used in BG method along with OC hydraulic props and Longwall equipment with Chock Shield supports, respectively in typical UG coal mines.

Major portion of this reserve will come from underground mines, to be worked by Long wall method of mining. First requirement for this will be the sinking of deep shafts, may be through backfilled loose burden. The mining will be possible only by fully mechanized long wall package, with high capacity double telescopic power support (600-800 tons) and high shearers. The fast advancing long wall faces will need advanced preparation of the panels that will need 3 heading drivage pattern , possible only by continuous miner conveyor combination with self advancing bolting machines. It is therefore, necessary that instead of multisource shopping of package of different specifications, the country should select, fabricate and modify the most trusted package with the latest IT modules by the time this stage comes, The present long walling in different pockets may be used to derive conclusive guideline for such in house development . As per the mining condition of India and the past experiences, some of the machine/ equipment which will be the most befitting mechanization for deep working which should be developed at home to meet the future requirement include Sophisticated shield support of 600-1000t capacity for thin to thick seams, Shearer for seams of different thickness and compatible panzer conveyor, Continuous miner shuttle car/ conveyor package, Self advancing bolter etc.

Fig 3: Remote LHD used in a typical mine (Blasting typical Gallery method)

Fig 4: Longwall equipment in a typical Mechanised mine of SCCL

This is possible by joint effort of the engineers and the technologists who should put in their expertise in deciding the package characteristic most likely suitable for deep seated coal seams under hard roof formation, Once, the decision is finalized, the MAKE IN INDIA exercise should start with the cooperation of different R&D agencies and the manufacturing units in translating the technology.

5. UNDERGROUND COAL GASIFICATION (UCG) TECHNOLOGY

India has total resources of 301.56 billion tonnes of coal and about 43.22 billion tonnes of lignite resources. The coals in Kaitha and Thesgoda ‘C’ blocks are at greater than 300m depth with more than 150 MT coal resource. Conventional mining is not suitable for these blocks. To utilize this unmined coal reserve underground coal gasification is one of the most suitable technologies which is economically viable and environmental friendly.

UCG is similar to surface gasification, occurs in a manufactured reactor whereas the reactor for a UCG system is a natural geological formation containing unmined coal.UCG typically consists of two adjacent bore holes drilled into a coal seam and pressurized oxidant such as air or oxygen/steam is used for ignition of coal seam. The oxidant and the gasifying agent are fed through the injection borehole and the combustion and gasification products are recovered from the production bore hole. Injecting oxygen and steam instead of air produces the most useful product gas. The main constituents of the product gas are H_2, CO_2, CO, CH_4 and steam. The proportion of these gases varies with the type of coal and the efficiency of the gasification process (Fig 5).

6. CONCLUSIONS

The recent Information and Communication systems (ICT) along with WSN systems for all aspects of mining industry can be widely implemented in opencast and underground mines for reliable monitoring of stability of workings and location of men and machnary in conjunction with audio-visual alarming systems for warning of impending ground failures in right time for taking proper control measures as per the requirement. coal mining sector will need heavy mechanization; giant size shovel dumpers, draglines, in pit crushers surface miners and High wall miners for different situations and along with ancillary equipments like spreaders, reclaimers etc . There is need for the mining industry to come out of the cell, invite engineers and technologists of different allied streams for the joint effort to cope up to the demand. But before that, the mining engineers have to have clear perception, dedication and commitment to customize the options and inculcate confidence in the manufacturing units to come forward for the investment and resources to make in India mission a success. For the underground mining, modern high capacity power support, panzer conveyor and shearer suitable for high to moderately thick and thin seam will be required in large number in days to come. The Industry on date is depending upon the foreign sources for most these machines/ equipments while the nation has capability to develop them at own. Underground coal gasification should be widely practiced with due regard to identification of proper blocks unsuitable for mining but most suitable for UCG.

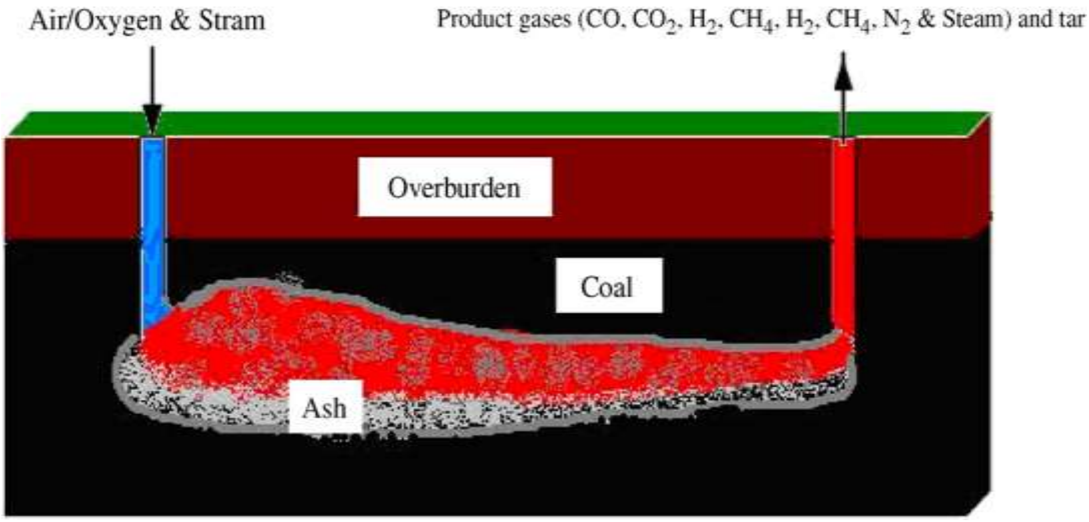

Figure 5: Schematic Plan UCG process [12]

7. REFERENCES

1. Government of India Annual report 2013-2014 (website:http:coal.nic.in)
2. S Jayanthu , 2014, Mass Utilization Of Fly Ash As Backfilling Material In Open Pit Mines – A Case Study, Seminar on Sustainable Development in Mineral & Earth Resources, 21-22 June 2014, New Delhi, India.
3. Report Of The Working Group On Mineral Exploration & Development For The Twelfth Five Year Plan., 2011, (website:www.dgms.net/)
4. G. Uday Bhaskar, A. Srinivasa Rao, G. V. S. Prasad and B. Shravan Kumar,2014, Characterisation Of Opencast Mines Using Geophysical Logs-An Example From Opencast-Ii Expansion Project, Ramagundam, Singareni Collieries, Telangana, Proceedings of All India Seminar on Mining – Recent Advances, Challenges And Scenario Beyond 2015 (MRACSB15-2014), November 8-9, 2014 , pp 19-.
5. Fresh Perspective: Solutions for Mineral Exploration - Geosoft (website:*www.geosoft.com/resources/goto/fresh-perspective)*
6. Overview of mine automation,2014, (website:http://www.saimm.co.za/Journal/v103n04p233.pdf)
7. Singh T N, 2014, Recent advances, challenges and scenario of mining beyond 2015, souvenir on All India Seminar on Mining – Recent Advances, Challenges And Scenario Beyond 2015 (MRACSB15-2014), November 8-9, 2014 , pp 21-28.
8. P. Garg, 2012, Energy Scenario and Vision 2020 In India, Journal of Sustainable Energy and Environment 3, pp. 7-17.