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Methane Management of a Degree III Underground Gassy Coal Mine of BCCL : Case Study of Moonidih Underground Project

J.S.Mahapatra*

At a time when the thrust of Indian Coal Industry in on Surface Mining, Moonidih and Jhanjra UG coal mines of Coal India have made a significant place for themselves in breaking new records of production. These two mines have not only adopted state-of-the-art technologies but also have introduced some site specific solutions in mining to meet the varying geological and geotechnical parameters of Indian Coal measure strata. Ever since Moonidih and adjoining Sudamdih coal mines were developed by erstwhile NCDC Ltd in the 60's, it had come under BCCL after Coal Mine Nationalisation, and the management had paid attention to augment their production through new technologies. Mass production technology concept had dramatically changed the UG coal mining scenario of India. It included Longwall equipment, Continuous miners (owned by the coal company or hired by coal company on MDO basis), ploughs or shearers accompanied by effective roof supporting practices. India also has followed the world trend in 1975. 'Project Black Diamond' envisaged introduction of 130 Power Support Longwall (PSLW) faces by the year 2000. Initially, the first fully mechanized self- advancing PSLW face was introduced in Moonidih mine in Jharia Coalfield in 1978.

More mines were planned with PSLW in the eighties, namely, East Katras (BCCL), Seetalpur, Dhemo-Main, Jhanjra, Khottadih (in ECL), Patharkhera (in WCL) and Churcha (in SECL) and first long wall in SCCL was introduced at GDK 7 incline in 1983 followed by a few other mines in SCCL. In the process about 30 PSLW sets had been imported from different countries like UK, Poland, Russia, Germany, France and China. The Power Support Longwall faces gained moderate success in some of the mines but most have not achieved the desired production level. In addition, largescale introduction of longwall technology received severe setbacks due to failures at Churcha (SECL) and Khottadih (ECL). In the recent years SCCL had commissioned Punch Longwall method of coal extraction ad Adriyala UG Mines. Jhanjra achieved highest ever UG coal production in India in 2021-22 by producing over 3.63 Million Tonnes.

The Moonidih project was conceived in 1964 to produce MTY. Due to complex geo-mining conditions and tough UG-environmental parameters, it was de-rated to 1.5 MTY and in the year 1988-89 the project achieved its pick production 1.2 Million ton. Production was planned with Longwall mechanization and alongwith hand held supports. However, in 1978 the first ever Powered Support Longwall (PSLW) technology in India was deployed in this mine. Simultaneously with PSLW equipment alongwith Road-headers for gate road development and panel formation were installed. Moonidih is having India's one of the deepest operating shaft of 545m and 560m in depth equipped with high capacity Kopee winders. To improve the grade the mine has a Washery and a captive power plant. The multiple seams are successfully and safely worked by Horizon Mining. With the deployment of Loco, horizons have made men & material transport comparatively safe, ease.

The coal evacuation from the mine is through a series of belt conveyors and about 1800 T worth of bunkerage capacity inclusive of the main strata bunker of 1200 T capacity have been built up underground. The coal from the mine through strata bunker is loaded in hoisting skips, brought to surface and discharged through a belt conveyor to adjoining Moonidih Washery directly. Since 2018, mono rail system, up to the XV Seam is in operation to enhance the productivity and efficiency of the workmen, as a part of the increased production level to 2.5 Million Tonnes per year. Today, Moonidih is one of the Star studded UG mine of BCCL, and had produced 0.593691 Million Tonnes of Coal during 2021-22 financial year of Coking Coal (Washable).

- Editorial input

** Area General Manager, Bharat Coking Coal Ltd*

INTRODUCTION

Moonidih Underground Project is situated in the South central part of Jharia Coalfield, Bharat Coking Coal Limited. This mine was designed in early 1960's by Polish Consultants under a Technical Collaboration for horizon mining system to produce coking coal from seams XVIII to XV bottom.

GEOLOGY OF THE AREA

Jharia Coalfield holds eighteen seams from XVII Ttop to Seam I in descending order, but starting of top seam differs from area to area. At Moonidih being at south side at dip side of coal fields it contains all seams starting from XVII seam. At present geological reports are prepared up to XV seam up to 1200m depth and working is going up to XV (Figure 1).

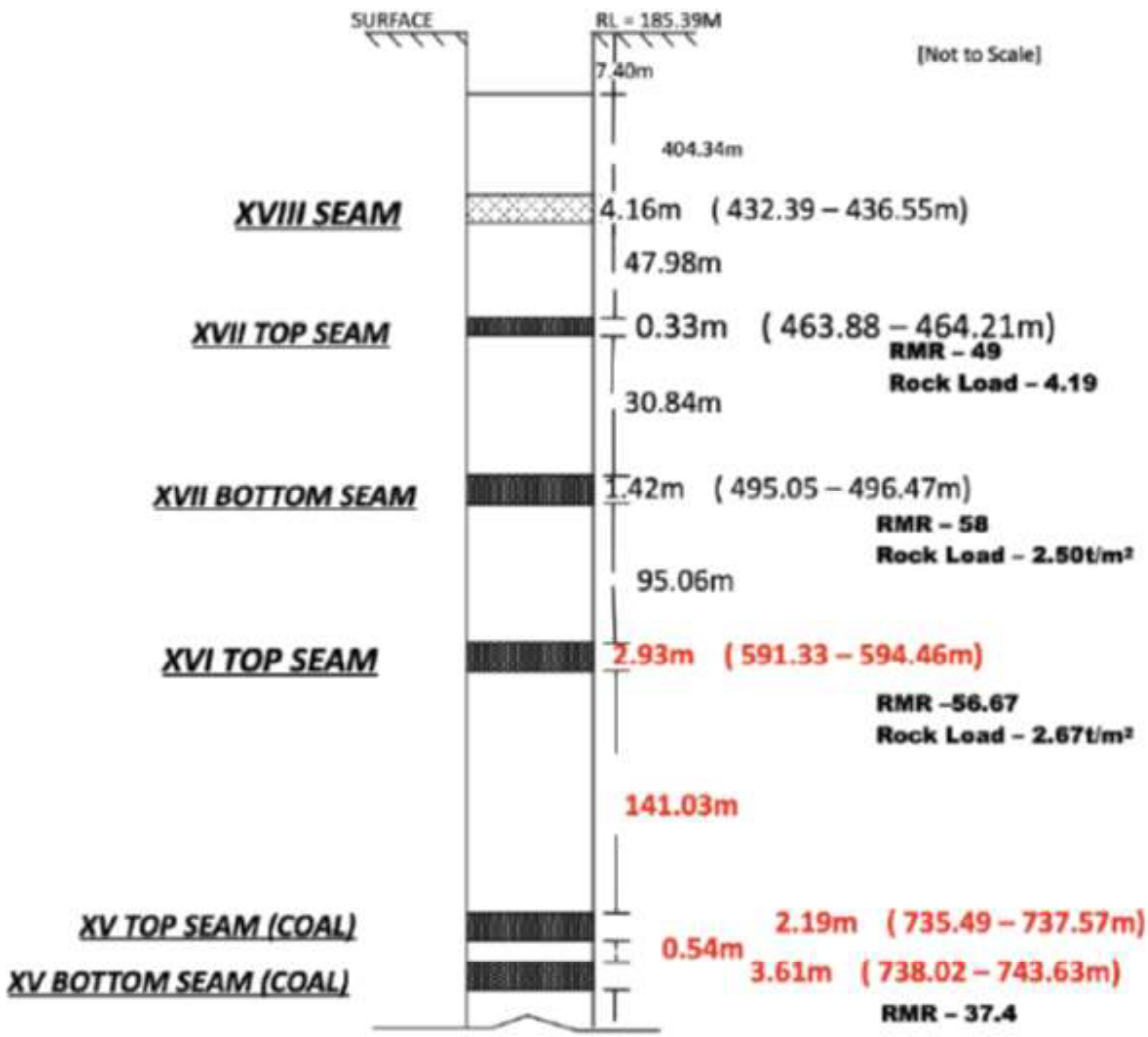

Figure 1 : Shows the general seam sequence of Moonidih

Moonidih is designed in Horizon System of mining to ease approaching different seams. Different horizons are 220m , 280m, 400m, and 500m. 220m and 280m are exhausted and sealed off. Presently 400m and 500m horizons are in operation to approach XVI and XV seams (Figure 2).

Figure 2 : Shows the Schematic Mine Model diagram

GASSINESS

The gassiness of the seam proposed to be worked at Moonidih Underground Project (XVIII to XV) is degree – III. ("Gassy seam of degree-III" means a coal seam or part thereof lying within the precincts of a mine not being an opencast working in which the rate of emission of inflammable gas per tons of coal produced exceeds ten cubic meters.)

Methane gas blowers have been encountered at various places while working XVIII, XVII Top, XVII Bot., XVI Top and XVI Comb. Seam at Moonidih Underground Project.(Figure 3) If we see Jharia Coal Field, mines adjacent to Damodar river are prone to high methane contents. Moonidih being near Damodar river is a Degree III mine and methane emission has always been an operational hurdle to achieve planned production.

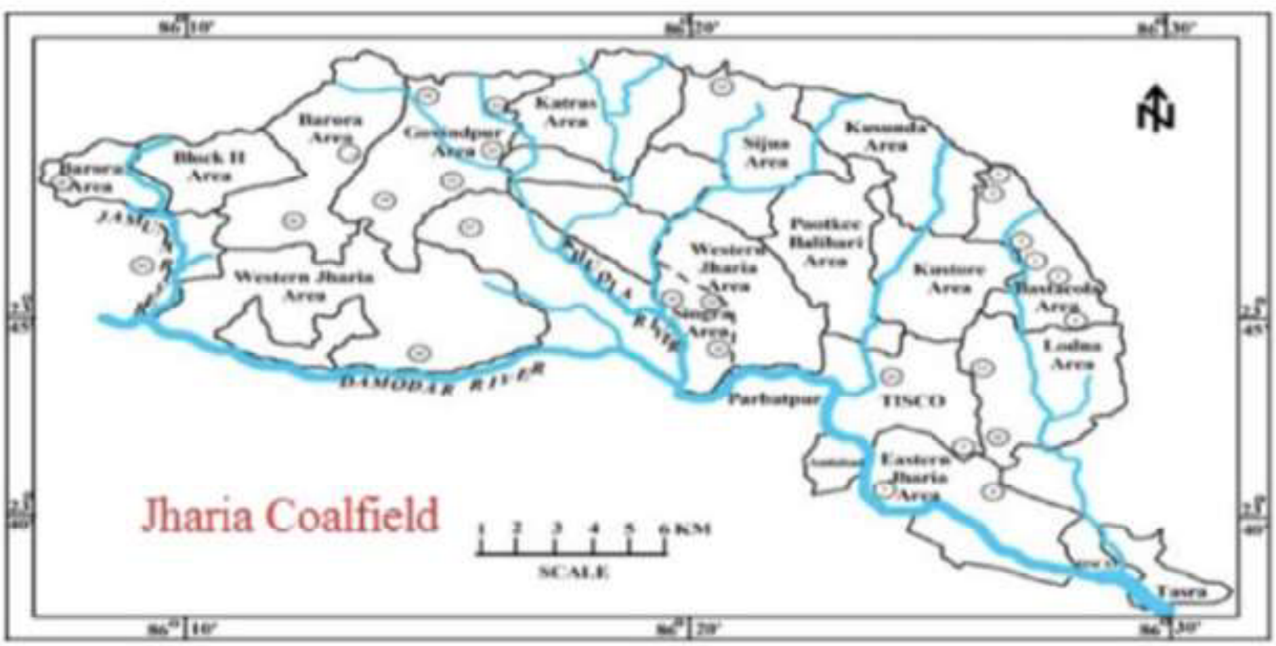

Figure 3 : Shows the different BCCL Areas of Jharia Coalfields

GAS DESORPTION STUDIES/IN SITU GAS CONTENT (TABLE 1)

Study was conducted with three bore holes of different seams for gas adsorption/ In Situ gas content. From the report it is found that -

Ï% Methane gas content increases from upper seam to lower seam. XVI top seam is about 8- 10 cum/ton and XV seam is about 15 cum/ton. % Methane content also increases as we move toward the dipper section of the same seam. .ie increase in depth, gas content also increases.

Table 1 : Presents the Gas Desorption details from different Boreholes

BORE HOLE NO.	SEAM NO.	SAMPLE NO.	DEPTH/CORE INTERVAL	Q1 LOST GAS(CC)	Q2 DESORBED GAS(CC)	Q3 RESIDUAL GAS(CC)	AS RECEIVED (M/TON)
MSG-14	XVI(T)	G-03	S98.90-599.90	244.5	506.5	191.0	0.58
MSG-14	XVI(T)	G-04	599.9-602.90	271.4	507.5	176.2	0.60
MSG-14	XVII(B)	G-05	617.90-620.90	262.1	489.8	138.4	0.80
MSG-38	X	G-24	1138.70-1341.70	1242.0	5654.5	483.9	4.28
MSG-38	XII	G-19	1057.20-1060.20	1013.1	10050.5	483.6	7.39
MSG-38	XII	G-20	1060.20-1063.20	1279.8	10219.8	475.1	8.25
MSG-13	XV(T)	G-07	799.50-801.00	1785.10	7370.50	115.14	8.27
MSG-38	XVI(T)	G-10	772.70-775.70	2073.0	11121.3	456.1	8.78
MSG-13	XII	G-11	878.00-881.00	2935.40	9052.30	400.78	8.86
MSG-13	XIV	G-09	842.00-845.00	1851.80	8222.23	291.51	8.95
MSG-13	XV(T)	G-04	791.00-793.00	1754.90	7891.80	300.60	9.03
MSG-13	XV(T)	G-06	796.50-799.50	2359.50	8551.70	134.40	9.06
MSG-13	XV(T)	G-05	793.50-796.50	2247.80	7377.40	297.00	9.20
MSG-13	XIV	G-10	875.00-878.00	1939.80	9053.30	296.36	9.77
MSG-13	XIV	G-08	839.00-842.00	1702.40	8912.65	289.94	10.04
MSG-13	XV(T)	G-03	788.00-197.00	1900.10	10261.0	281.30	11.21
MSG-38	XIV	G-18	1036.70-1039.70	2801.7	19728.7	536.4	13.50
MSG-38	XV(T)	G-13	916.70-919.00	1925.8	15767.6	407.1	14.16
MSG-38	XI	G-22	1111.70-1114.70	2113.7	21004.9	540.1	14.41
MSG-38	XV(T)	G-14	919.70-922.70	1939.1	15913.6	383.1	14.93
MSG-38	XV(B)	G-16	934.70-937.70	1893.1	20021.4	409.4	16.78
MSG-38	XI	G-23	1114.70-1117.70	2558.8	21297.0	422.6	19.47
MSG-.8	XI	G-21	1108.70-1111.70	2089.3	20228.7	384.0	19.64
MSG-38	XV(B)	G-15	931.70-934.70	2029.2	20027.4	354.0	19.00
MSG-38	X	G-28	1195.70-1198.70	2371.4	27364.5	449.8	22.26
MSG-38	X	G-29	1192.70-1195.70	2234.6	27278.9	427.7	23.48
MSG-38	X	G-27	1192.70-1196.70	2571.2	29920.6	446.1	24.53

EXPLOSIVE LIMIT OF METHANE GAS

Explosive limit of methane gas is 5.4% to 14.8 % in general body air. Explosion limit changes with mixture of other explosive gas like Hydrogen , acetylene etc. Further with changes of temperature and pressure it also changes like under adiabatic conditions it can lower to 2%.

STATUTORY PROVISIONS FOR VENTILATION QUANTITY AND TO DEAL WITH METHANE GAS

Statutory provisions as per Coal Mines Regulation and circulars for ventilations and permissible limits of methane gas to work safely are as follows:-

Coal Mines Regulations, 2017 :

CMR Reg - 153. Standard of ventilation

(i) In every ventilating district, not less than six cubic meters per minute of air per person Employed in the district on the largest shift or not less than 2.5 cubic meters per Minute of air per daily tone output whichever is larger.

(ii) The percentage of inflammable gas does not exceed 0.75 in the general body of the Return air of any ventilating district and 1.25 in any place in the mine;

160. Velocity of Air Current – The velocity of air current measured in meters per minute at the maximum span of along wall face in Third degree Shall be not less than 75.

Circular 42/1974 - maximum air velocities in longwall face is 4 meter/sec i.e. 240 m /min.

Reg.169. Determination of percentage of inflammable gas and of environmental conditions –
(e) If any determination in any ventilating district shows the percentage of Inflammable gas to exceed one and a quarter, the supply of electric energy shall be cut off immediately from all cables and apparatus in the district, and a written report thereof submitted to the Regional Inspector forthwith.

EXEMPTION FOR VENTILATION QUANTITY

Air quantity of air in a panel is mainly considered with three major parameters , those are
1) Manpower deployed in the largest shift.
2) Daily production quantity.
3) dilution of methane to safe limits

As mechanised operation system calculation for manpower deployed in the largest shift will not be suitable for low manpower deployed. Due to high rate of production air quantity will be too high which will also not be suitable on maximum velocity limit at face. But dilution of methane is definitely to be done to a permissible limit for safety. In case of high methane emission , quantity may be required too high and may not be practicable considering total available quantity, resistance , pressure and the same time air required at other parts of mine. Accordingly exemption is to be taken with suitable safety arrangements.

METHANE GAS EMISSION

At Moonidih mine methane gas emission has always been an operational hurdle to achieve planned production considering safety aspects of methane emission dealing. From the statutory provisions it is learnet that methane gas can be managed by ventilation air quantity. But sometimes in case of emission of large quantities of methane it gets difficult to manage by quantity only. It needs some technical improvement. Problems associated with methane gas emission at different stages of mining activity and its managements, is stated below.

GAS EMISSION PROBLEM DURING DEVELOPMENT

Though there is emission of gas from coal during development of galleries, the main problem arises due to blowers in roof and floor cracks, small and large slip and faults. Initially in gas blowers there is irruption of water and then followed by emission of methane. During encounters of blowers the following steps are taken to deal with –

1) All the gate roads were being developed as a blind gallery for a long distance up to one kilometer. Now a pair of galleries is being driven and inter-connected at certain intervals to shift the last ventilation connection and to reduce the length of blind headings and resistance in the auxiliary fan with ducting.
2) If the gas percentage is more and it is not controlled in one auxiliary fan, two fans are installed in the intake sides with two sets of ducting to increase the quantity of air at the face.
3) In case the gas percentage is not controlled, works are suspended for some days and wait till the reduction or dying of gas percentage in blowers. The works may be suspended for a few days to even some months. In such incidents equipment and electrical setup are withdrawn and ventilation by auxiliary fan is maintained.
4) On some occasions also water and gas emissions are so high that there is no other option to allow submerging the gallery and all equipment in water after isolating power from that section.

PROBLEMS DUE TO ‘GASES’ DURING EXTRACTION OF COAL BY LONGWALL TECHNOLOGY

Longwall panel is developed with two gate roads parallel to each other at a distance of 150-250 m, which are connected at end in dip- rise as a longwall face and a panel. The gate road in the dip side is named as the main gate/ bottom gate which serves as intake for ventilation and all electrical setup and conveyor belt. Gate road on the rise side is named as top gate/ tailgate and serves mainly to return the airway of the panel.

During development of a gallery of 4.8 meter width and up to one kilometer length a lot of blowers are encountered. So in a panel, of 150-250 m face length and one kilometer panel length, there is every chance of encountering gas blowers in large numbers during extraction. It is seen that during cutting in longwall, gas emission from coal face is less than the emission of gas from goaf, which comes out to the tail gate by the side of the last power support and barrier pillar of tailgate. It shows that not only coal contains methane; there is a large quantity of gas trapped in coal bearing strata, which come out as blowers.

Methane gas being lighter in weight than normal air has a tendency to flow to the rise side of the panel and come out to the tailgate . With high methane emission methane gas gets concentrated at near last power support, near AFC tail end and tail gets and reaches beyond permissible limit when can not be diluted by ventilated air quantity. In that case power is shut down and all operations stopped to wait for gas dilution.

Action taken to find out a solution to make it safe to some extent to reduce down time for operation of longwall face.

STEP 1(FIGURE 3)

With Normal Ventilation with normal ventilation of 1600-1800 M^3/Min air quantity, intake air passes through maingate Face- and returns through tail gate. Some quantity of air passes through goaf which carries methane gas from goaf. This gas gets concentrated at AFC Tail end and tail gate (Figure 4).

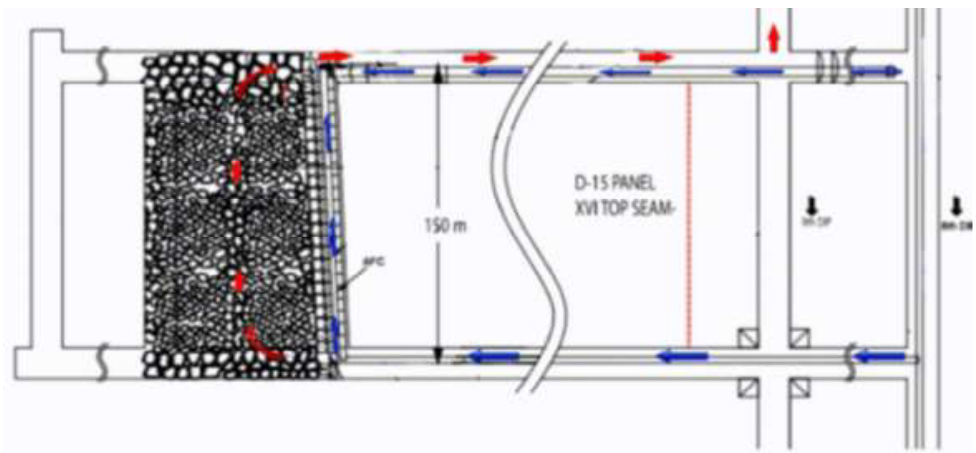

Figure 4 : Showing Step 1 Arrangements with normal Ventilation

STEP 2(FIGURE 5)

With increased ventilation

When gas emission from goaf is so high that gas concentration goes beyond safe limits, a trial was made to increase ventilation quantity to dilute it. Up to a certain level of air quantity is optimal, after that gas concentration again increases. Air quantity was increased up to 2700 M^3/Min. The increase in gas flow to tailgate increases because air leakage through goaf increases and carries more methane reserved in goaf. To reduce leakage of less ventilation air through goaf support gaps were blocked by brattice cloth starting from the main gate barrier pillar up to middle of face. With this there was a minor reduction of gas percentage.

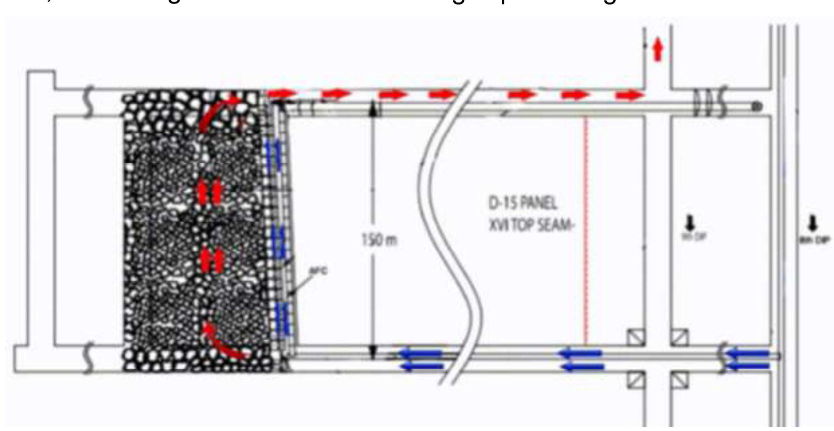

Figure 5 : Step 2 with Increased Ventilation

STEP 3 (FIGURE 6)

With normal ventilation and supplying additional supply of fresh air near the tail end of AFC . One auxiliary fan is installed in the main intake side to supply fresh air near to AFC tail end for further dilution of gas. By this way air quantity in bottom gate is reduced to 1500 M^3/Min and leakage air in goaf also reduced, whereas total quantity in top gate remains 2000 M^3/Min So dilution of methane gas is more effective.

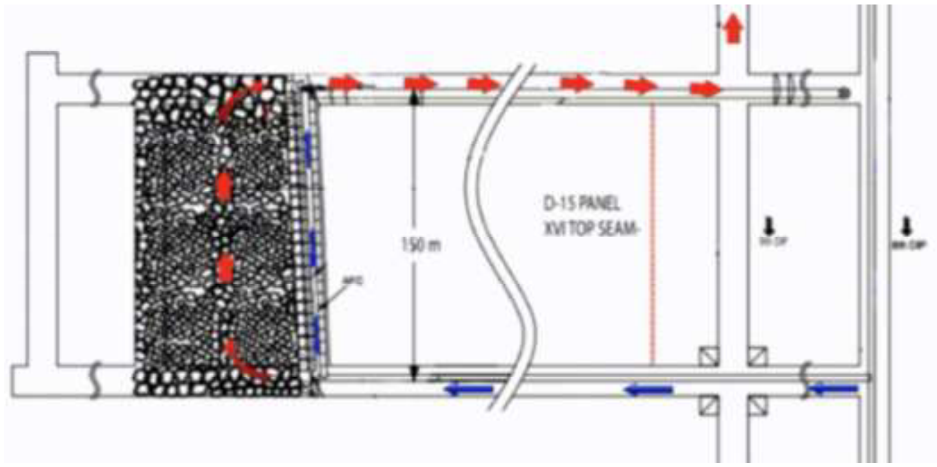

Figure 6 : Shows the Normal Ventilation with Additional supply of fresh air near the tail end of AFC

Step 4

Further safety arrangements with step 3

- Channel is made by brattice cloth to rise side of AFC tail end for making an escape route for methane gas from goaf to tailgate to a distance of about twenty five meters.
- Diverting air from face to side of the last power support in the tailgate to mix with methane gas for diluting through the channel.
- Two numbers of LMD are installed. LMD1 is to sense the air near AFC tail end which is the last electrical and moving part of PSLW equipment. LMD2 is to sense the air in the vicinity of the last reach of the shearer drum while cutting near the tail end.
- During periodic weighting, it is observed that gas emission from goaf increases compared to normal operation period. Periodic weighting comes in an interval of twenty meters and after two minor weighting there occurs one major weighting I e in every sixty meter interval. In the weighting period, it is to wait till gas level is reduced.
- During cutting through gas emission is not increased from coal face, due to support advance and immediate fall of roof behind support disturb goaf and gas emission from goaf increases. So cutting speed is restricted to control gas emission.

FINAL ARRANGEMENT AT TAILGATE

Other approaches for methane management in Longwall face In normal conditions at Moonidih the ventilation system is practiced in U type ventilation where the air route is Main Gate- Face - Tail gate to main return (Figure 7).

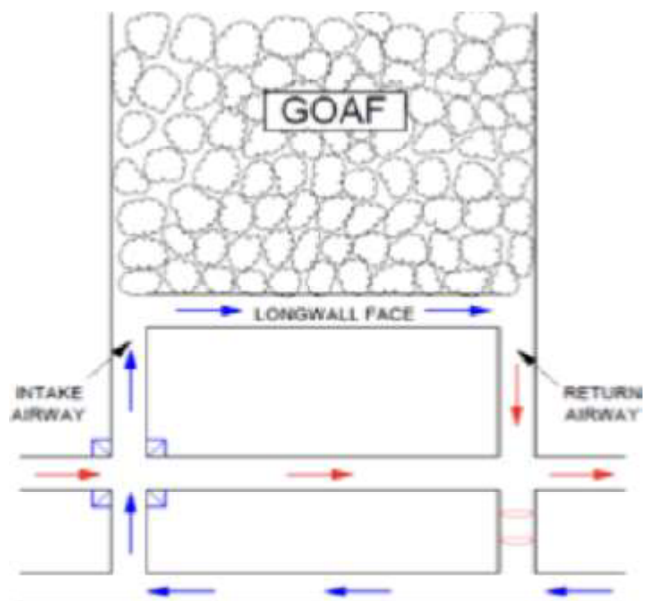

Figure 7 : 'U' Ventilation system

Other systems those can be adopted in which decision can taken during planning stage for effective methane managements are –

1) Y type Ventilation

In this system both gate roads are kept as intake airways and return is maintained in top gate in goved area with heavy support. Return airways are connected to the main return at the other side of the panel at the beginning face side as shown in Figure 8.

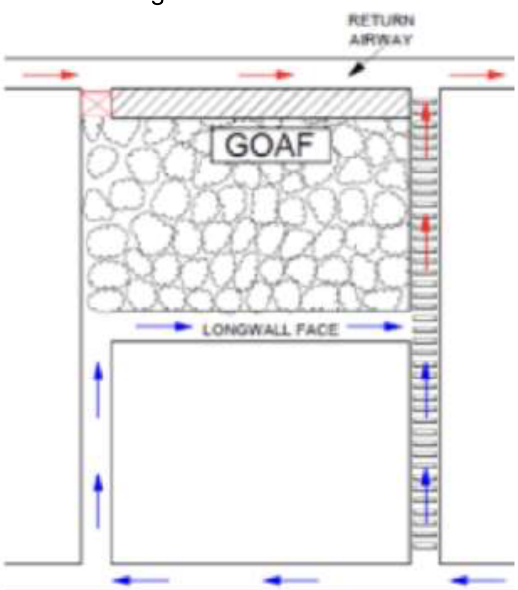

Figure 8 : 'Y' Type Ventilation

CONCLUSIONS

Methane being an explosive gas, it is definitely to be managed to keep mine safe. For highly gassy mine planning of methane management, ventilation system is to be planned and changes to be made from time to time based on site condition. However, methane drainage is also to be planned for gassy mines as being practiced in many countries to reduce methane content and subsequent emission and at the same time extracted methane can be used gainfully as a clean energy source because drain to atmosphere will affect the environment to 30 times more than Carbon Dioxide.

ACKNOWLEDGEMENT

Thanks are due to the BCCL Management and also organizers of the Conference organized by The IME Journal, being held at AKS University, Satna(MP) during 25-26, Feb 2023.

2) Alternate ventilation system with additional gate road. In this system two top gate roads are developed with intermediate interconnections. As shown in Figure 9, return air with methane gas escapes through additional gate road. This gate road can also be used for methane drainage gallery for gainful utilisation of methane gas at surface.

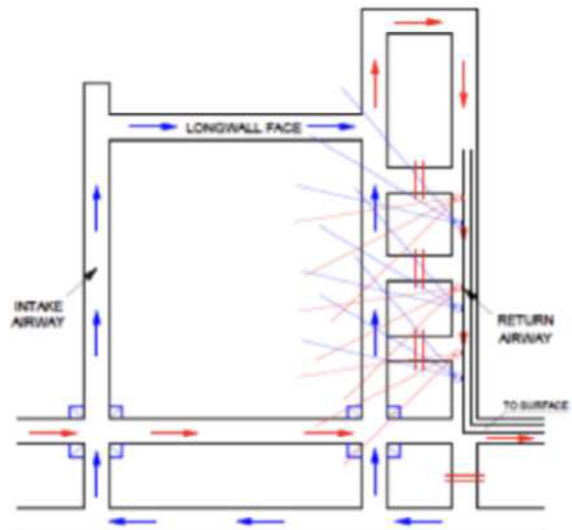

Figure 9 : Alternate Ventilation System with additional Gate Road Entry

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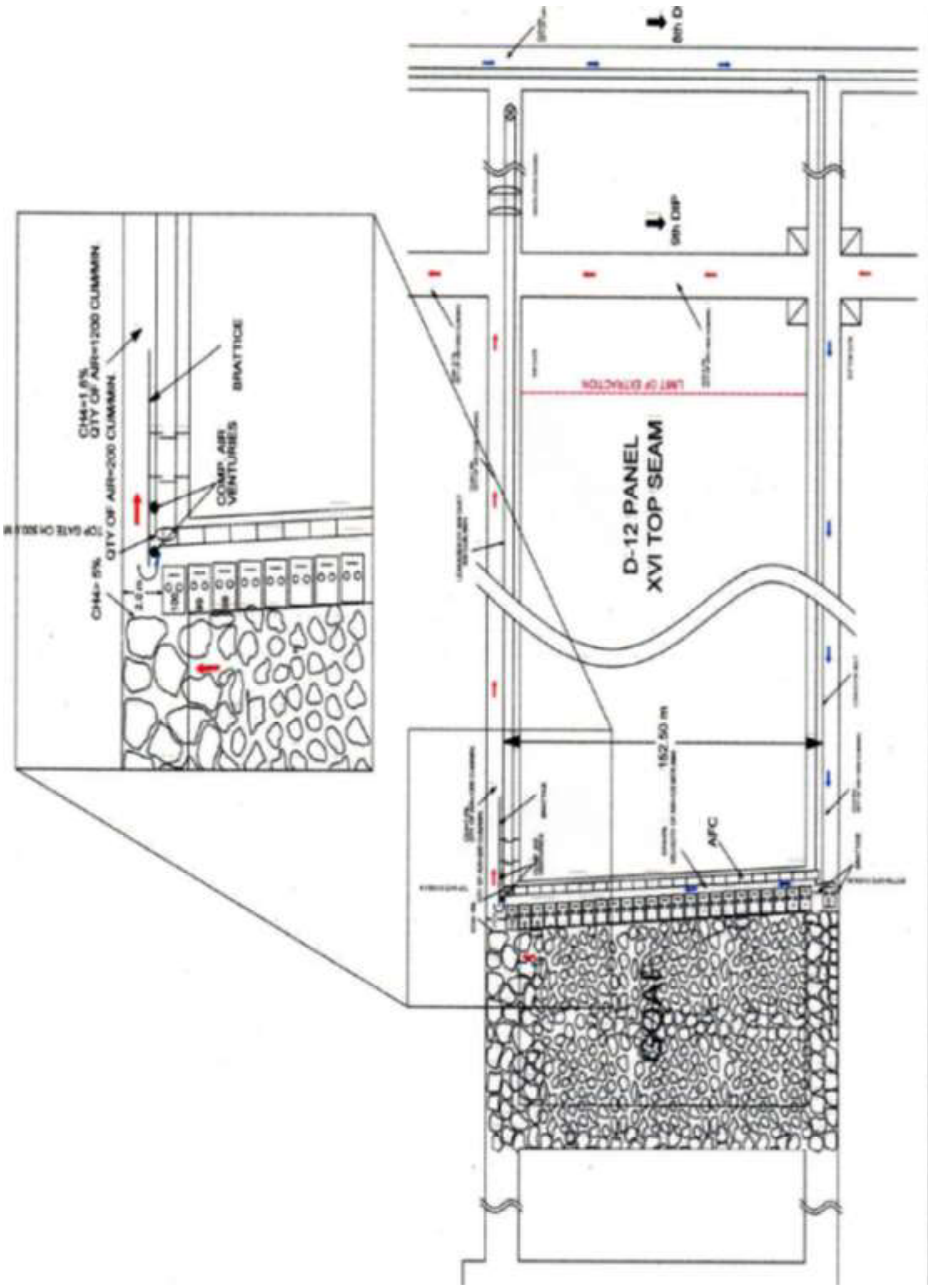


Figure 7 : Final Arrangement at Tail Gate

Stability Enhancement of Dump Slopes using Geosynthetic Materials

Manthan Chauhan*

INTRODUCTION

The stability of an overburden dump slope is a major concern for safe and smooth mining operations. The implementation of geosynthetics in a dump slope can enhance the factor of safety and help in preventing slope movement.

Geosynthetic is a product, at least one of whose components is made from a synthetic or natural polymer, in the form of a sheet, a strip, or a three-dimensional structure, used in contact with soil or other materials in geotechnical and civil engineering applications. Geosynthetics are manufactured from polymeric material used with soil, rock, earth or other geotechnical engineering related material as an integral part of a human-made project, structure, or system (ASTM D4439). The geosynthetic products are made from synthetic polymerssuch as polypropylene, polyester, polyethylene, polyamide,PVC, etc. These materials are highly resistant to biologicaland chemical degradation. Natural fibers, such as cotton, jute, bamboo, etc., could be used as geotextiles andgeogrids, especially for temporary applications.

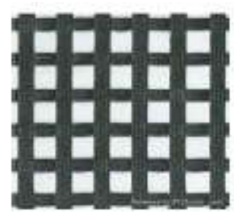
The application of geosynthetic is vast as they are used for separation, filtration, reinforcement, protection, waterproofing, erosion control, drainage etc. The most used geosynthetics are geo-composite drainage, geogrids, geotextile and geomembranes.

GEOGRIDS

Geogrids are planar, polymeric structure consisting of a regular open network of integrally connected, tensile elements, which may be linked by extrusion, bonding, or interlooping or interlacing, whose openings are larger than the constituents.It has a grid-like configuration that has a large aperture between individual ribs. The main function of geogrid is to provide reinforcement to the pavements, soil slopes,overburden dumps and retaining walls.

Woven Geogrid

Extruded Geogrid



Bonded Geogrid

GEOCOMPOSITE DRAINS

Geocomposite drains, consists of a geonet bonded with non-woven geotextile layer (s) on one or both sides, are used for drainage in both horizontal & vertical situations.

Typical Geocomposite Drains

MECHANISM OF STRESS DISTRIBUTION

The outward movement reinforced soil mass can be restricted by placing the geogrids layers horizontally within a dump slope.TheGeogrid strips interact with the dump mass by adding a tensileforce and this tensile force is transferred to the dump massthrough geogrid–soil interaction mechanisms. The interactionbetween geogrids and soil depends on the particlesize distribution of dump material and aperture size of geogrids.

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Geogrids have large apertures that allow the soil or dump material to be continuous through the inclusion. The stresses are transferred to the soil through passive soil resistance ontransverse members of the grid. However, in geotextile, the stresses are transferred through the friction created acrossits entire surface area (Montanelli 2008).The friction between geogrid and dump particles plays a crucial role as the dump particles trap between the geogrid apertures. Therefore, slope movement is prevented, as the geogrids come in tensionduring slope failure.A suitable geogrid is selected based on its strength and aperture size that depends on the particle size distribution of dump material. The dump particles trapped into the geogrid aperture thus increase the interface properties between geogrid and overburden dump, which increasesthe stability of dump slopes.

ROCKFALL HAZARD MITIGATION IN OPEN CAST MINES

Maintaining stability of slopes in mines and also in the dumps has become an integral part of any mine. Proper design and protection of slopes not only ensures safety but also maximizes profit through increase in volume of extraction, minimization of space to store obverburden dump material etc. Maccaferri offers high-tensile steel cable meshes and drapery mesh to contain rocks and provide surface stabilisation. Steelgrid HR is available in tensile strengths greater than 160kN/m, and HEA cable panels for demanding loads up to 200kN/m. Maccaferri's range of flexible rock fall protection barriers are available certified by ETAG up to 5,000kJ (MEL) energy absorption. Attached to the rock slope, above critical infrastructure (haul roads, conveyors, tips and crushers), these barriers progressively deform under impact, absorbing loads. Attenuator and hybrid barriers are also available.

MINE ACCESS/ENTRY AND MATERIALS HANDLING INFRASTRUCTURE

By using Maccaferri geogrids the raised hopper platform area near the crusher is stabilized. With geogrid strengths up to 1,600kN/m, even the heaviest dumpers/vehicles can be accommodated, and many crusher walls of over 20m height have been constructed. Maccaferri's soil reinforcement structures are available with a variety of face-finishes, including:

- Green Terramesh, Paragrid or MacGrid geogrid reinforcement for sloped vegetating face
- Terramesh soil reinforcement system for gabion faced structures
- MacRES for vertical faced concrete panel walls

TAILINGS DAM LINING SYSTEMS, HEAP LEACH PADS

MacLine impermeable membranes make the tailings dam and leach pads impermeable and leak proof . Thus it helps in avoiding infiltration of discharge/leakages into the natural ground water. Combined with MacDrain drainage geocomposites, leachates can be collected efficiently and reliably. Also, containment dykes often feature Maccaferri MacGrid reinforced soil, or gabion retaining structures and major dump zones can be supported on basal reinforced platforms. These platforms are reinforced with Paralink or MacTex W2, at the heart of which is polyester reinforcement providing long-term high strength and low strain to minimise differential settlements. MacTube geotextile tubes are used for dewatering mine tailings, sludge ponds or slurries. Slurry is pumped into the MacTube, which is designed to retain the solid particles while the filtrate fluids are released through the filter fabric of the tube walls. Once drained, the solid residue is left to dry before being disposed of in a controlled manner.

SHOTCRETE AND ROOF SUPPORT IN UNDERGROUND MINES

Maccaferri's Pararib tunnel reinforcement mesh contains loose and falling debris from shafts and excavations. Pararib is lightweight, white and flame retardant, making it ideal for use underground. Wirand fibres are added to shotcrete to reinforce it and provide stabilisation of shafts, excavations and access tunnels and it can even replace traditional steel reinforcement mesh.

USE OF GEOSYNTHETICS IN OTHER MAJOR INFRASTRUCTURE SECTORS IN INDIA

Even New Technical codes for using Geosynthetics for different applications in Railways & Road Projects have already been published and such Technologies along-with proper design (using below mentioned Indian Standards/ codes & International Indian Standards/codes) are already being used in many significant Railways & Road Projects.

- RDSO 2020 / GE : IRS 0004 – Comprehensive Guidelines and Specifications for Railway Formation.
- Indian Roads Congress, 2019 : IRC:SP:59-2019 : Guidelines for Use of Geosythetics in Road Pavements and Associated Works(First Revision) had stipulated its use and Figure, presents the Pavement Sections with and without Reinforcement.

CONCLUSION

Maccaferri through its field study and continuous up-gradation of the technology by detailed field data collection and testing services had made significant presence in mining sector to provide safe and stable solution for excavations, slopes, tailings dams etc.

Multispectral Imaging, REE & Isotope Studies and Dual Genetic models for more Meaningful Iron Ore Exploration in India

Dr.Abhijeet Mukherjee*

ABSTRACT

Exploration of iron ore is guided by systematic and effective search models developed by geologists based on genetic concepts and objective criteria. Most of the iron ores produced (mined) in the world result from the enrichment of Precambrian Banded Iron Formations(BIF's), but the processes responsible for this enrichment are still unclear and constitute a source of debate. India does possess the methodology for modern day iron ore exploration; but proper structuring is called for coordinating the work progressing in isolation in many areas. Programming, planning, execution, data synthesis and evaluation are necessary. This paper deals with suggestions for analyzing genetic mode, ore morphology and ore quality of iron ore deposits in the country; planning of proper drilling method that has to be proposed after proper understanding of the genetic mode for inferring proper solid model of the iron ore deposits; usage of continuous core logger can generate qualitative and quantitative mineralogical results. High resolution visual images that facilitate grade characterization and ore body delineation during exploration and mining. Geochemistry can be clubbed together with the recent remote sensing techniques-hyperspectral imaging. These techniques could be used in the green field projects iron ore exploration could be done using limited exploration geochemistry and hyperspectral imaging. Oxygen isotope studies help in establishing ore beneath ore. Centre for Exploration Targeting (CET), Australia has reported recent advances in BIF-related Iron ore Models and exploration strategies. These diverse exploration strategies have also been adopted in the Greenfield areas elsewhere in other countries and the same are discussed in this paper for a better understanding of the concepts .

INTRODUCTION

Iron ore in India has been classified based on the genetic mode, ore morphology and ore quality. Proper drilling method has to be proposed after proper understanding of the genetic mode for inferring proper solid model of the iron ore deposit. Most important factor of exploration strategy is fixation of optimum drilling grid. The statistical methods based on geological considerations will fix the optimum drilling grids required for a deposit.

Nowadays, with the dwindling reserves of high-grade ore bodies, delivering iron ore with dependable composition, mineralogy and metallurgical quality is becoming progressively more difficult as steel mills requirements become more stringent. Shortage of skilled geologists has been a problem in the iron ore industry in the last four years and a system that could speed up the logging process will be welcoming by the industry. To tackle this problem an original spectral system has been developed by CSIRO Exploration and Mining: a continuous core logging system (Ramanaidou, 2008).

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Geochemistry can be clubbed together with the recent remote sensing techniques-hyperspectral imaging. These techniques could be used in the green field projects iron ore exploration could be done using limited exploration geochemistry and hyperspectral imaging.

Oxygen isotope studies help in establishing ore beneath ore. Centre for Exploration Targeting (CET), Australiahas reported recent advances in BIF-related Iron ore Models and exploration strategies. Extensive regions of BIF and iron-rich metasomatite, which lie beneath a cover of younger sediments and are potential hosts to deposits of massive hematite. Gravity survey on ground successfully discovered a new prospect where a large gravity anomaly some 2000m long by 150-400m wide was outlined.

Iron ore industry would be beneficiated through inter-

-institutional collaborative projects along with the mining companies which would augment the resource of iron ore of the country to a greater extent. Collaborative projects with leading countries like Australia, China, and Japan etc. could be taken up by the Indian agencies.

Tectonic framework of iron ore deposits in India: Iron ore deposit is an enigmatic rock of the Precambrian period. Many paradigm have been put forth on the genetic aspect in India and still continued (Acharya 2000; Chakraborthy and Majumdar 1986; Mukhopadhay 1988 and Mukhopadhyay et al., 2008).

One such study, if technostructural frame work for genesis which would help us in understanding the basin initiation is the study on BGS belt (Badampahar Gorumahisani-Suleipat) by Beura (2002). According to Beura (2002) and Beura and Singh(2005b) thedeposited basin of BGS belt has probably been originated due to progressive tectonic activities in different stages: (i) Initial stage: cratonic massif witnessed spreading and extension along its margin (ii) Subsequent period: Thinning of cratonic margin resulted that led to rifting on further extension (iii) Post rifting: Grabenisation could develop the BGS intracratonic basin and (iv) Deposition: the intracratonic basin becomes the depository for iron formation and in many instances supracrustal rocks including BIF were laid down in early Proterozoic rift basins (Radhakrishna al., 1988). Stretching of the sialic crust gave rise to thinning and fracturing near the margins of the ancient continental block this led to subsidence troughs and on further spreading led to volcanism accompanied by deposition of chemical precipitates e.g. Eastern Iron Ore Group(EIOG),Southern Iron Ore Group(SIOG) and Western Iron Ore Group(WIOG) in Singhbhum craton (Mukhopadhyay, 1989).

The iron ore basins of Karnatka have been developed as “intra-cratonic” fringed by volcanics that erupt along fracture zones (Radhakrishna, 1983). Ultimately it led to block rifting causing zone of depression and subsequent deposition of sediments.

The sedimentary setting of Proterozoic iron formation of Canadian Shield (Goodwin, 1983 Dimorth 1996) Hamersley group (Morris and Horwitz, 1983) and Transvaal Super Group (Beukes, 1973, 1984) has also undergone tectonic system of basin development. The intra-cratonic basin received sediments from sea water through transgression and aggression, terrestrial source through continental denudation, deep circulation of marine or meteoric water and volcanic exhalation process inside the basin.

Taking into consideration the tectonic frame work of iron ore deposits, the exploration for iron ores could be confined to the cratonic margins i.e., by using Remote Sensing ,hyperspectral & GIS where the outlines of aerial extent of the BIF’s could be marked.

CURRENT IRON ORE EXPLORATION SCENARIO IN INDIA:

Total geologically potential area for iron ore is approximately 8000 sq km. It includes 7000 sq km in Peninsular India and 1000 sq km in Extra Peninsular India. Total explored area (includes LSM and DM) is approximately 7000 sq km which includes nearly 900 sq km lease hold areas. Total freehold unexplored area is around 1200 sq km and explored area for reassessment is around 4000 sq km.

The area covered for iron ore in various states of the country requires detailing and it would take several years to demarcate the areas for further mapping in 1:5000 or 1:2000 scale. The data provided by CGPB- Committee-I on Iron Ore, GSI, Ministry of Mines would indicate 334 UNFC code. The base document of CGPB- Committee-I on Iron Ore is silent on the upgradation of the UNFC code in terms of the Geological Axis. The base document on Ferrous Minerals; CGPB-Committee-I on Iron Ore, MoM, GOI can include areas that are to be prioritized for UNFC G-Axis upgradation.

SEARCH MODELS BASED ON GENETIC CONCEPTS IN IRON ORE

Exploration is guided by systematic and effective search models developed by geologists based on genetic concepts and objective criteria. Most of the iron ores produced (mined) in the world result from the enrichment of Precambrian BIF‘s, but the processes responsible for this enrichment are still unclear and constitute a source of debate. Two end member genetic models have been proposed: supergene versus hypogene enrichment of a BIF Protore. Supergene iron ores are the most abundant type of iron ores be it be Quadrilatro Ferrifero, Brazil, and Hamersley basin, Australia or India. Supergene ore arises by the selective leaching of gangue minerals from BIF by ground water and the residual accumulation of the iron oxides. Hypogene ores form the richest, high grade Fe ore bodies. Their genesis is ascribed to the interaction of the BIF's with the hydrothermal fluids(basinal), which dissolved chert (quartz), leaving pores spaces, which were partly filled by a new generation of iron oxides associated with carbonates, iron silicates and apatite. In Hamersley basin, Australia, new evidence indicates that the ore bodies are structurally controlled along old normal fault systems that formed during a period of major uplift and extension in Proterozoic times. Hematite ores are always hosted by the Brockman Iron Formation, and ore formation resulted from a multistage, sequential removal of gangue minerals from the host, giving rise to residual concentration of iron. A two-stage hypogene alteration during the evolution of the basin followed much later in recent times by supergene enrichment producing the rich hematite ore (Taylor et.al, 2001). Geologic mapping, basin analysis, and calculated fluid compositions indicate that giant ore bodies of microplaty hematite, and possibly martite-goethite, in the Hamersley province of Western Australia, were formed by heated fluids driven by early Paleoproterozoic orogenesis. Regional circulation of hydrothermal fluids, including heated surface water, through reduced banded iron formations occurred during or soon after the orogeny. It has been speculated that martite-goethite ore bodies, previously considered Mesozoic-Cenozoic, could also be related to heated Paleoproterozoic meteoric fluids migrating northward away from the fold belt.

On the other hand there is a hypogene-supergene modified model .This comprises an initial hypogene stage with either leaching of all the chert from the BIF protore leaving pore spaces or with metasomatic replacement of those minerals by carbonates, followed by a supergene stage that leached the hydrothermal minerals formed in the previous stage.

Classification of iron ore in India based on ore morphology, genetic mode and ore quality:
The iron ores of eastern India show different morphological set up with respect to their genetic and structural manifestation (i) Ore body associated with Canga horizon – the Detrital Iron ore Deposits (DID) of varying thickness are associated with the recent lateritization process and are often controlled by tectonic weak planes (ii) Blanket type of ore body – it broadly obeys to topography of the area, it is capped by a laterite profile and the thickness of the ore body generally varies irregularly to the bottom line of pre-existing ground water level, it gradually grades over to BIF and probably fits to supergene enrichment model (iii) Sheet or slab-like iron ore body - generally found with hypogene model of hydrothermal origin. It is controlled either by shear zone or multi-dimensional fault / fracture system (iv) Plannar ore body - follows the bedding planes and schistosity plane of the underlying rocks (BHJ, BHQ & BMQ), related with syn -sedimentary depositional process (v) Isolated ore bodies of domal or basinal configuration – mostly controlled by related fold geometry and subsequent erosional process (vi) Ore bodies of irregular shape are generally related to igneous origin.

a) Syngenetic sedimentary type deposits

These models were the first proposed models for high grade iron ore formation according to which iron enrichment is either a primary depositional features or a digenetic modification of iron ore. This concept was later abandoned in favor of syndiagenetic supergene concept (King 1989, Lascelles, 2006). Lascelles (2006) advocates deposition of "chert from BIF" during the diagenetic stage of BIF formation which subsequently were oxidized and further leached to present depth.

These are ore bodies following bedding plane of underlying BIF. The BIF's are associated with schists and banded cherts and shows complex refolded fold structures .The ore is massive and hard laminated ore containing mainly magnetic and martitised hematite. Goethite is rarely present. The ore has 54-59 % Fe, 5-11% SiO2 &1-2% $_{Al203}$ e.g., Ghutung – Pongaposi - Madhyapur area, Odisha.

b) Supergene enrichment deposits:

In most simple supergene models, enrichment of iron formation to ore as a straightforward leaching process in which entire BIF gangue is removed by ground water. This simple model could not explain the large depth.

c) Possibly Hypogene type deposit

Many of the early hypogene model proposed mineralizing fluids were post metamorphic possibly originating from intrusion at depth and is major ore forming process (Dorr, 1965; Machamer, 1968). Introduction of iron ore to ore site by hydrothermal solution raises many problems as a major ore forming process (Morris, 1980) and wide spread discovery of hydrothermal alteration of iron ore formation underneath ore and intrusion of dikes resulted in a modified "hypogene" ore genesis concept for deposit. This model propose sequential removal of gangue, first by hypogene process followed by supergene process as complex geometry of most high grade hematite deposits. Morris (1980) presented the supergene – metamorphic model to overcome above problems according to him, iron ore is formed initially at depth and underwent successive stage of diagenesis and metamorphism, uplift & erosion, again reburial and exposure & leaching of ores to form hematite. These are blanket type of ore deposits following topography of the area, one can observe gradational and other inter fringing relationship between different ore zones and transition of ore to BIF both laterally and vertically down the depth.

The BIF is underlain by volcanics and overlain by upper shale. Structural model explain occurrence of ore in antiformal syncline of the BIF.

The iron ore is massive, hard & soft laminated powdery ores and blue dust. The ore is mostly hematite rich ore occasionally associated with martite. Goethite is conspicuously present. The ore has 55-69% Fe, 0.2 to 6% SiO2 and 0.2% to 3% $_{Al203}$ in Bailadila Deposit No.14 and 55-68% Fe, 2 to 6% SiO2 and 2.5% to 7.5% Al203 in Noamundi (see Figure.7a)a responsible for ore forming process (Barley et al., 1999; Taylor et al., 2001 and Thorne et al., 2004).This model is applicable to most of the Australian deposits, however modified hypogene concept are now being proposed for high grade Hematite worldwide (Dalstra and Guedes, 2004 and Hagemann et. al., 2005). These are sheets or slab like deposits. The ore zone occurs at the bottom part of the BIF& occurs as isolated deposit underlain by volcanics within the surrounding Singhbhum granites and are affected by major fault and related fracture system (Figure.8). Ore is generally hard,massive and bouldary type. Magnetite is recrystallised to martite and hematite leading to highly porous lumpy hematite ore. The grade of ore is around 67% Fe with low silica and alumina e.g. Gandhamardhan.

d) Supergene modified hydrothermal

The iron ore bodies in Donimalai Iron Ore Mine (DIOM) are intensely associated with BIF in the field. Some of the laminated ores contain pockets of unreplaced quartz. Cavities are present between adjoining ore laminae in the banded ores and these cavities represent original quartz banding. All these attribute to supergene enrichment process. These features are mostly predominantly in the North Block of DIOM. The ore banding in the North Block are shallow in depth and this ore grades to BIF (Protolith) through a transition zone which also supports super gene enrichment.

The South Bock of DIOM shows syntectonic leaching of silica with introduction of new iron in the deep ore body in South Block, through the heated circulating solutions. In some cross sections of the South Block the ore body is very deep (Cross Section 4) whereas the ore bodies in CS-3, CS-2 and CS-1 are shallow in nature (Murthy and Chatterjee, 1995). In the North Block the ore is shallow and is represented mostly by soft laminated ore, friable ore, lateritic recemented ore and little hard laminated ore and this shows supergene signature. Shallow drilling was proposed in the North Block. Whereas, in the South Block deeper vertical and inclined holes were envisaged to delineate the ore body that go beyond 200 meters in depth as there was enrichment of BIF at deeper levels by water from deep magmatic source which was responsible for enriching the already leached formation by meteoric waters (Roberts and Bailey, 1943).

DRILLING STRATEGY FOR INDIAN IRON ORE DEPOSITS

***(a)* Sedimentary deposits**

Exploration module is decided on the basis of geological set-up of ore related with BIF and associated litho sequence. The bedded type iron ore shows repetition of steeply digging beds . Angular boreholes are planned from the hanging wall side of the ore zone depending on size and shape of the ore body e.g.Ghutang-Pongapoasi-Madhapur area, Odisha.

***(b)* Supergene ore deposits**

The ore begins with lateritic ore at the top with massive, hard and soft laminated, biscuity ore, powdery ore and bluedust showing interfringing relation below the cover. Such ore zones show blanket type of ore morphology obeying to the topography of the area. Vertical boreholes are usually planned in such type of deposits considering the length and surface width of the ore body.

Interfringing relationship of various ore types and occurrence of remnant Protolith of BIF within the ore zone may need execution of some inclined boreholes and exploratory adits for proper evaluation of sub-surface ore geometry e.g. Bailadila Deposit No.14, Chhattisgarh and Noamundi, Jharkhand.

(c) Hypo gene type ore deposits

The regional prospecting for these deposits is highly interpretative as the ore body remains covered below the BIF topped by lateritic capping . The exploratory deep pit and the scout boreholes are considered to be the fundamental requirements for such deposits. After delineation of the ore body, vertical boreholes are planned for these deposits e.g. Gandhamardhan.

SUPERGENE MODIFIED HYDROTHERMAL DEPOSITS

In the North Block the ore is shallow and is represented mostly by soft laminated ore, friable ore, lateritic recemented ore and little hard laminated ore and this shows supergene signature. Shallow drilling was proposed in the North Block. Whereas, in the South Block deeper vertical and inclined holes were envisaged to delineate the ore body that go beyond 200 meters in depth as there was enrichment of BIF at deeper levels by water from deep magmatic source which was responsible for enriching the already leached formation by meteoric waters.

OXYGEN-ISOTOPES FOR ORE BENEATH ORE IN CASE OF IRON ORE BASED ON GENETIC MODE

Roughly fifteen isotopes of oxygen are known to exist. These are Oxygen-12 through Oxygen-26. Of these fifteen, however, only Oxygen-16, Oxygen-17, and Oxygen-18 are stable isotopes. Furthermore, Oxygen-16 is the most abundant, constituting 99.762‰ of the Earth's oxygen (Firestone, 2000; Gibson, 2005). Known as "light" oxygen, Oxygen-16 is composed of 8 protons and 8 neutrons (Herring, 2006). Applying the definition of "isotopes" above, it is reasonable to conclude that Oxygen-17 and Oxygen-18 have 8 protons/9 neutrons and 8 protons/10 neutrons, respectively. Of these latter two oxygen-isotopes, though, only Oxygen-18 is found in sufficient quantities to be of use to science. Known as "heavy" oxygen—because its mass is approximately 12.5‰ more than the mass of Oxygen-16 and having an abundance of around 0.20‰, Oxygen-18 can be used along with Oxygen-16 to determine ancient climate. This is because the ratio of Oxygen-18 to Oxygen-16 in water changes with the climate (Herring, 2006).

The oxygen-isotope concentration ($\delta^{18}O$) of a water sample is determined with respect to a datum known as standard mean ocean water (SMOW). SMOW is a sample of well-mixed ocean water that contains a precisely known $^{18}O/^{16}O$ concentration and is currently stored at the International Atomic Energy Agency in Vienna, Austria (Groning & Frohlich, 2006). Oxygen-isotope concentrations are typically expressed in parts per thousand (‰) using the following mathematical equation:

$$\delta^{18}O = [(\delta^{18}O/\delta^{16}O) \text{ sample - SMOW / SMOW] X1000}$$

Where, $\delta^{18}O = 0.0‰$ for SMOW (Aber, 2006; Kennett, 1982). Presently, the world ocean has a $\delta^{18}O = 0.0‰$, and glacial ice sheets exhibit ä¹⁸O values ranging from -20‰ to -30‰ (Aber, 2006).

High-grade BIF-hosted iron ore deposits are widely believed to have formed by epigenetic residual enrichment of hematite at the expense of other constituents, most notably chert. Processes responsible for the enrichment to high-grade iron ores are, however, only poorly understood and a range of metallogenetic models have been proposed. Field relationships have been used to distinguish three major groups of BIF -hosted high-grade iron ore deposits, namely deposits of ancient supergene, hydrothermal, and supergene- modified hydrothermal origin. Iron ores from all three deposit types are essentially composed of hematite; among different morphological types of hematite, microcystalline platy hematite and martite predominate.

OXYGEN ISOTOPE STUDIES IN HEMATITE

The oxygen isotope composition of hematite is useful in indicating the origin i.e. hydrothermal or supergene nature. In general there is an enrichment of the heavier isotope in case of supergene deposits of whereas the hydrothermal deposits depleted in the heavier isotope i.e. have lighter oxygen isotope values (see also Perry and Ahmed, 1983) It is observed that the values ($\delta^{18}O$ SMOW) range between -3 to +4 in case of iron ore deposits related to supergene enrichment. The ($\delta^{18}O$ SMOW) values for the hydrothermal deposits are in the range of +1 and -7. The field evidences; in favour of early hydrothermal stage are disconcordant mode of occurrence, unreplaced BIF corestones. Oxygen isotope studies help in establishing ore beneath ore.

What India can do for iron exploration?

Centre for exploration targeting (CET), Australia has reported recent advances in BIF-related Iron ore Models and exploration strategies. A new genetic model has emphasized structurally controlled hypogene alteration and upgradation of BIF to high grade (>65% Fe) iron ore. Conventional structural and stratigraphic mapping and reconstruction of the tectonic history of iron district, in combination with high-tech geochemical analyses such as laser ICP-MS analyses of in situ oxides and fluid inclusions, stable(C-O-H) and radiogenic (Sr) isotopes, provide the iron explorationists with an invaluable set of tools to discover concealed iron orebodies, deposits and districts e.g. Gandhamardhan in Odhisa and Bailadila deposit no.10 in Chhattisgarh.

Extensive regions of BIF and iron-rich metasomatite which lie beneath a cover of younger sediments and are potential hosts to deposits of massive hematite. Gravity survey on ground successfully discovered a new prospect where a large gravity anomaly some 2000m long by 150-400m wide was outlined. Initial drilling identified earthy hematite breccias eg. Bonai horse shoe in Odhisa and Jharkhand States.

In Pilbara Craton, Australia, mapping and sampling indicated the potential for large and high quality iron ore deposits. In addition, the airborne survey highlights prominent magnetic anomalies coincident with iron formation that extend to areas of poor exposure.

Most of the resource estimates of iron ore deposits were made at least 3 decades ago by Union or state exploration agencies except the resource and reserve base of NMDC. Later exploration by others has modified these assessments marginally.

These earlier exploration schemes and the final estimates were dictated by the then purpose of exploration, the stage of exploration, the desired category of reserve/resource to be established at the stipulated level of accuracy, size and type of the deposit etc.

Deeper level of exploration (beyond 50m. vertical depth) has been advocated by many. The present UNFC classification of resource amply demonstrates the urgent need to launch exploration of the inferred category. Reconnaissance, Prospecting, General Exploration data along G-axis and Geologic Study along F-axis of UNFC need to be consolidated for identification of prospects for Pre-feasibility, Feasibility studies(F-axis) in order to evaluate economic viability(Economic axis). Identification of large deposits should be attempted both by model-driven approach and inductive techniques. There is need for high degree of confidence in a geological assessment of any project's worth.

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Predicting Industrial Machine Tool Component Surface Defect Using ML and AL Techniques

Jeush Benjamin*

AN OVERVIEW OF SURFACE DEFECT DETECTION OF INDUSTRIAL MACHINE TOOL

In industries, quality control is considered to be the at most priority since it is important to maintain the quality level of the product in order to avoid the added repair [1]. Traditional methods typically deal with macro sized or sometimes regular sized surface defects. In general, artificial visual defect detection targets to identify the limitations and categorize them intended for advanced processing.

Industrial applications are in need of a well-designed data base (DB) in order to detect the type of defect for proper classification of the defect occurred in the surface of the machine tool [2]. But establishment of universal and complete DB for a classifier is considered to a challenging process due to occurrence of unique and random defects in operation scenarios. Figure 1.1 shows the presence of different types of defects present on the surface which are major issues of a denied smooth surface which includes scratches, dust, damage spot etc.

These defects make a machine tool to be devoid from a smoother performance with many deviations, making the product or the production cycle to be slower and with less efficiency.

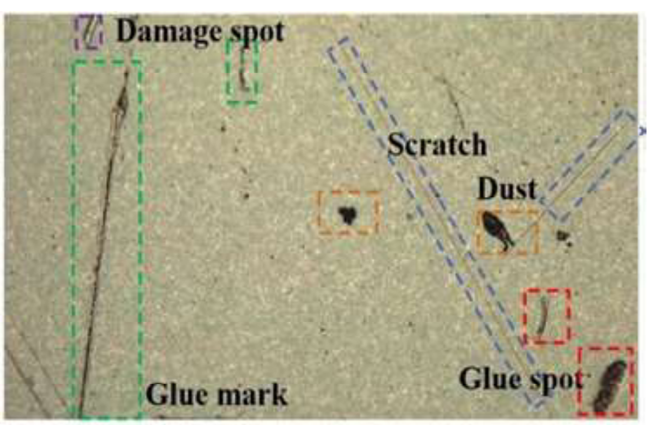

Figure 1.1: Defect present on the surface

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The defects such as cracks, scratches, dusts can make the surface of the tool to result in a poor performance while adapting in manufacturing process. This actually results in the less efficient and less quality of the product manufacturing. These deviations can be avoided through certain Material based defect classifier is employed in every application since general classification approach is considered to be in high demand. Surface defects can be categorized in two vital groups which includes palpable and visible defects.

Durable and dependable classification can be done with the help of artificial intelligence system. Judgement regarding detection of the surface defect is highly depended on human supervisor. The decision is mainly based on threshold and rational representation of the defect. Hence the taxonomy is primarily categorized in terms of spatial features and magnitude of the ratio components.

SIGNIFICANCE OF SURFACE DEFECT DETECTION

In order to detect the quality of the materials, surface defect detection is used in specific defect inspection. The steps involves capturing the images of the surface of the material with the help of industrial camera then methods like identifying, localizing and categorising the defects are implemented which helps to resolve the causes of the defects. These process can be time consuming as well as unreliable if it is performed manually. Massive economic problem can arise for manufactures due to undependable quality control.

Hence computer vision methods are implemented instead of using manual detection. The steps involve classification of defect type from the given image and identifying the location of the defect in the image. In earlier days, Handcrafted features were used in order to categorise the defect in the images. But there are few drawbacks while employing these methods. Hence AVI (Automatic Visual Inspection) is used. This method is one of an ML approach used in the precise defect detection which actually performs as End to End performance. It has been identified that Deep Learning (DL) method had outperformed traditional method DL and ML methods.

In order to identify the defects, textural defect detection is implemented as it is considered to be one of the important approaches used to detect the defects [3]. Vital information regarding recognition and interpolation can be gained by textural defect detection. The tasks relied in identifying the surface defect of the machine or the industrial tool are widely seen as textural analysis issue. In order to fetch the needed and useful texture features of the machine tool surface defect, great efforts are required [4].

There are few techniques which are used to demonstrate the texture analysis for the given image. The techniques includes structural, model based, filter based and statistical approach. From the above approaches, statistical approaches are considered to be the widely used and dominated approach than all other mode of surface defect detection methods in case of analysing the results with higher precision and quality [5].

It is important to sustain the tonality consistency of ceramic tiles which is considered as tonality inspection. Visual perception is also done in order to inspect the consistency of the products. Even though the tonality variations can be delicate, sometimes they can be visible if the surfaces come together. This is considered to be a major quality factor. Tonality detection can be performed on both randomly textured surface as well as uniform pattern surface but cannot be implemented using manual detection since manual detection is cumbersome and a tedious process. Issues like temporal variations and spatial variation can make tonality grading problematic [6].

Lastly colour texture analysis is used in order to increase the computational power and accessibility of the camera since demand to employ colour in surface defect detection is raising. In surface inspection, lot of work related to colour texture analysis has been applied. Methods used for colour texture analysis are mostly taken from grey level images which includes co- occurrence matrix and LBP.

When in case of an automobile industry, and other main modelling engineering fields such as mechanical and civil sectors, make use of hot rolled steel plates as a main source of machinery manufacturing process. As rolling steel plates play a vital role in the manufacturing systems, in a larger quantity and in hence several defects can be identified using hot rolled steel plates which includes holes, cracks, crust roll marks etc.

These defects are considered to have huge impact on both performance as well as appearance of the product. Hence it is very important to identify the surface defect present on the plate either it is of steel, ceramic or a wood surface impacted in rolling, drilling or in cutting process.

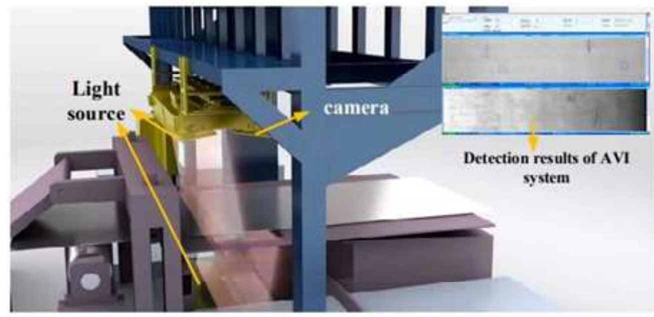

Figure 1.2: Industrial strip surface defect detection

Figure 1.2 shows the surface defect detection methodology used in industries with the help of AVI system as the main defect detection process.

RECENT TRENDS IN SURFACE DEFECT DETECTION

In earlier days multiple defects cannot be identified using surface defect detection. Scratches, holes, dents and many forms of defects are present on the surface. There are possibilities of multiple defects present on the surface, which cannot be identified using surface anomaly detection since classification of defects is not possible using this method. Hence Target Defect Detection approach is used in order to perform on multiple defect [7]. It has been demonstrated that TDD method is not effective since independently trained DL model is required for every dataset. Communication between the defects can lead to failure of the method. It is important to identify the multiple defects.

Parallel identification of multiple defect detection uses single DL architecture in order to find the type of defect exist on the surface [8]. This method can be performed in two steps. Firstly, identification of defect on the surface. Secondly classification of type of defect. Defects identified can be labelled either automatically or manually. Only supervised and semi supervised approach provides labels to the known categories. DL models are trained in order to detect the defects. Training process must comprise of surface samples along with multiple defects and defect connections in order to forecast the defects in parallel.

MAJOR PITFALLS IN SURFACE DEFECT DETECTION

Surface defect detection faces various challenges which includes HRF (High surface reflectance) in which high surface reflectively is considered to be responsible in order to fetch high light and surface of the materials such as aluminium, steel are very smooth. PDI (pseudo defect interference) is also implemented.

During the course of laminar cooling, several defects like water cloth, water mist and other defects were produced which can lead to incorrect alarms of AVI equipment. Continuous rolling equipment (CRE), rolling speed fluctuation (RSF), roll speed differential (RSD) and other effects are caused by random elastic deformation (RED). This RED provides random image distortion on CCD camera side [9].

Rapid change of coil, detection of defect in hot rolling mill can generate massive image data and speed as high as 5.12 Gbps. Hence detection algorithm is required in order to accomplish decent stability between consistency, calculation and detection accuracy. A descent and a well classified algorithm is needed to establish the relationship between the defect occurred in the surface of the machine tool and the type of defect occurred on the product obtained as a resultant from that particular machine as a manufacturing tool.

ML (Machine Learning) AND AL (Artificial Learning) ALGORITHMS FOR INDUSTRIAL MACHINE TOOL COMPONENT SURFACE DEFECT PREDICTION

In order to carry a proper classification and the type of defect occurred on the surface of the machine tool can be achieved by incorporating a proper study or an analysis over the defect occurred in the machine tool. A proper defect detection can be done by using the appropriate algorithm which is ore in a viable need of producing defect less product as result.to deal with this major issues there are lots of approaches carried out tin the surface defect detection.

Most of the approaches make use of ML and AL techniques employed in the surface defect detection mechanism. Initially the surface defect detection is done using the AI techniques in all the sectors of the manufacturing process lines. ML defect detection technique used in the defect detection in the manufacturing industries especially in the Machine tools such as mechanical and automobile industries make use of the ML techniques which are further categorized into three sub-categories as

- Supervised Learning,
- Unsupervised Learning and Reinforcement Learning (RL).

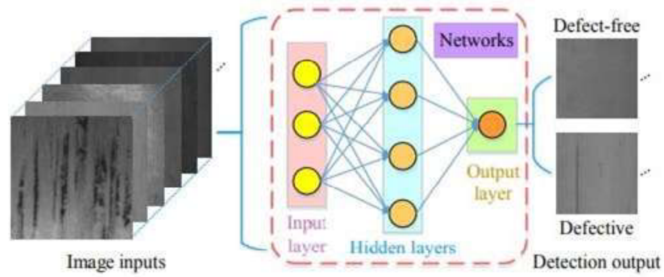

Figure 1.3: Flow of machine learning method

SVM (Support Vector Machine), NN (Neural Networks) and Decision Tree (DT) are the three common algorithms which comes under Supervised Learning of the ML methods. SVM algorithm is considered to be more appropriate for noisy datasets than other algorithms such as naive Bayes, neural networks. This provides better accuracy and improved computational complexity in terms of minimizing the generalization error present in the upper bound, SVM algorithm is used instead of ANN since it does not minimize the generalization error instead they reduce the empirical training error. It has been said that SVM helps achieving high generalization performance [10].

Multiple defects which are observed in the surface of the machine tool at a time which can be of grease, hole, scratches, cracks can be detected using Faster R-CNN which is also again an DL method used in the surface defect detection. Weak scratches which are found at milder rates present on the metal surface can be detected precisely using Deep CNN method.

In real time applications including the industrial scenarios, an approach called YOLO (You Only Look Once) is implemented. An improved YOLO algorithm is most commonly used approach using the CNN which is one of the reputed and widely used DL methods employed forth defect detection in all kinds of the industrial machine tools which actually does cutting, adjoining and in laser cutting also.

The Improved YOLO provides about 99% accuracy in terms of detection rate in surfaced defect detection along with the speed of 93 FPS. The considerable situations include that these algorithms are reliable and dependable according to the machine tool they are employed. But on the other hand the drawback indicates that when it is employed to detect the defected samples for the surface defect detection, the algorithm doesn't perform well in any of the cases on any of the machine tool employed in manufacturing process [11].

But in case of unsupervised learning which is an another domain of the ML learning method, Automatic defect detection of the surface of machine tool is considered to a daunting task to put forward and to consider. The CNN cannot be only employed in case of supervised learning but also for unsupervised learning as well. For the surface defect detection process, the DCGAN (Deep Convolutional Generative Adversarial Network) which comes under by unsupervised learning is also used.

In case of determining the texture of the machine tools surface is detected by combining both the GAN along with Auto-Encoder process and LBP. The Auto Encoder is one the most common and widely used techniques employed in the defect detection methods in case of all kinds of the machine tools employed in the industries. The main motive of using the Auto- Encoder in the algorithms in the learning method is to obtain a clear and a classified data which are free form noise and are easy to employ in the algorithm methods, used in the classification or in identification of the surface defects. The main advantage of using this process is that they are not in need of any labelled sample for them to function. But the drawback is that they are poor in performance when they are employed to higher vulnerable noise data. Even though supervised and unsupervised learning approaches provide shift in terms of advancement with in use of SDD, Reinforcement Learning (RL) is quite different from these approaches as they have the ability to deal with the small datasets also.

Convolutional Auto-encoder (*CAE*) and Generative Adversarial Network (*SGAN*) (CAE- SGAN) is a one more method used in surface defect detection [12]. The main advantage of using this process in the defect detection mechanism is that it is need of only min8imum number of labelled samples for this that data base for detecting the defect whereas the drawback lies as the algorithm needs lots of interaction process during the phase of training than the normal count of the interaction process which actually results in lowering the efficiency and the accuracy of the prediction process.

The methods apart from using the algorithm in the process of the surface defect detection can be carried out using proper and an efficient Machine vision which is more capable of performing a proper defect detection mechanism in case of all kinds of the machine tools, which are used in testing and determining the quality of the production process which is mainly employed in case of mainly in classification of shape deformity in the surface and other inspections of the defect occurred as well. In earlier days, the process of surface defect detection is introduced inly to detect the defects present on non-texture surfaces without any much of the variations occurred in the surface of the machine tool used.

But with the increasing terms of productivity technologies and in productivity count as per the developed technical need, surface defect detection process are also used in detecting more on complicate and complex defects found on the surfaces and in the texture over the surface of the machine tool as well. These include Challenging defects such as Tiny and blurred defects which are difficult to mark can also be rectified using the detection method called SDD systems.

Defects present on complicated texture other than the machine tools or the industrial tools some other tools surface which can be employed in the defect detection of the surface to enhance the quality and the performance of the tool also includes fabrics, woods can also be employed in case of examining the surface background using a method called, Wavelet Transform (WT). Support vector machine algorithm is established based on statistical pattern recognition [13].

The one more method employed in the surface defect detection of the machine tool which are commonly employed in the manufacturing industries which includes drilling and shaping tools includes the method called Faster RCNN [14]. This methodology has been implemented in the surface defect detection as the accuracy rate of this method is comparatively provides more stability than single shot detector in the defect detection process. Many methods are combined together for the better performance of the FCNN these include RCNN (Regional Convolution Neural Network), FEN (Feature Extraction Network) and RPN (Region Proposal Network).

PROBLEM IDENTIFICATION

In case of the mechanical and the other domains, the need of productivity plays an important role. Surface defect detection serves as an indispensable part of an intelligent production. So there is an optimal need of doing a certain investigation on the defect detection of the surface of the machine tool used in the industry for the production of desired outcome of the product with expected quality. This is easily affected by both the manpower and by the machines opted in using if it is of in defect or absence.

This needs a thorough revision over the working and the precise performance over production, which increases the development of both growth and count of productivity. So in order to ensure the quality and sufficient product production needs to implement proper productivity tools to enhance the cost of revenue and scalability. Using a tool with a defect in any of the domain affects the reliability and the manifestation of the particular product. The defect detection over the tools implemented in respective domains can decrease the rate of key issues regarding the product delivery and processing standards.

The defect tool producing the product can result in the lesser ability, durability and endurance along with some embossment or any kind of disorientation of the product. This inspection needs a clear vision in both the internal and the external (surface) of the opted machine tool. A defect detection in the surface of the machine tool can help in fixing the bug which is found in the system, which is more optimal in need of making the product to be more efficient in terms of both appearance and in basis of performance.

The one more problem relied with using the defect presence tool will reduce the objective of the product obtained from the manufacturing process. The existing basic and under relied algorithm do not perform up to the expected level in maintaining the endurance and the efficiency of the machine tool. So a reliable data fulfilling the algorithm requirement has to be opted for and efficient manufacturing process. Lowering the optimal behaviour of the machine tool due to any of the defect present in the surface of the particular tool results in production of the product with a lower durability, efficiency along with its efficacy. The proper functioning of the product is also failed here. This automatically reduces the market count and the production lane of the particular product. This in hand brings the reduced profit values and the reputation of the particular production sector along with their share market values.

Non-Traditional Machining of Metal Matrix Compound: Multi-Objective Optimization

Jay Kumar Soni*

ABSTRACT

Al, SiCp MMCs have wide range of applications in aerospace, automotive and electronics engineering due to its excellent properties compared to other conventional materials. Conventional machining process shows difficulties in machining of these advanced materials due to several reasons like high tool wear, poor surface roughness, high machining cost etc. Therefore, different researchers have utilized several advanced machining methods like electro discharge machining, electrochemical machining, ultrasonic machining etc. for effective machining of these composites. In this present work, ECM and EDM have been selected for machining of MMCs towards obtaining high product quality and satisfactory process performance yield. It is utmost important that several process parameters of ECM and EDM need to be precisely controlled as well as optimized. Taguchi method is generally used only for optimizing single response. As these processes are involved with multiple response characteristics; exploration of an appropriate multi-objective optimization technique is indeed essential. Therefore, this thesis work represents case study on selection of optimal machining parameters in ECM of Al/15%SiC composites using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) integrated with Taguchi method and further utilizing another hybrid method Grey-Fuzzy Logic coupled with Taguchi's optimization philosophy. The performance characteristics: Material Removal Rate (MRR) and surface roughness have been considered for optimizing the machining parameters (feed rate, voltage and electrolytic concentration). Experimental results have been validated to illustrate the effectiveness of this approach. Similarly, for obtaining the optimal parameter setting of EDM of Al/10%SiC composites, another hybrid optimization technique utilizing Principal Component Analysis (PCA) and TOPSIS combined with Taguchi method has been proposed to take care of correlation between various response features (performance parameters) of EDM. Further another advanced optimization technique Multi-objective Optimization by Ratio Analysis (MOORA) with Taguchi method has been employed for evaluating the optimal setting of process parameters of EDM. The response characteristics: Material Removal Rate (MRR), tool wear rate, surface roughness and overcut has been considered for optimizing process parameters: voltage, pulse on current, pulse on time and duty cycle.

Keywords—metal matrix composites, electro discharge machining, electrochemical machining, Taguchi method, Grey-Fuzzy approach, PCA, TOPSIS method, MOORA.

INTRODUCTION

A compound material comprises of two or further chemically and/ or physically apparent phases. Composite accoutrements , also nominated as composition accoutrements or known as mixes, are naturally or finagled appearing accoutrements produced from two or further composing accoutrements with vastly different chemical or physical parcels which persist distinct and separate within the finished structure. The constituent rudiments, substantially comprises of a buttressing rudiments, paddings, and a compound matrix binder which differ in composition or form on a macro-scale. The constituent rudiments save their own characters means they don't combine or dissolve fully into one another although they act in musicale. typically, the ingredients parade an interface between one another and can be physically linked. mixes which are of miscellaneous structures accommodate the musts of specific function and design, invested with ambitious parcels which limit the compass for bracket. still, this mistake is made up for, by the reality new kinds of mixes are being constructed, each with their own specific characteristics and purpose like the particulate, flake, laminar and filled mixes. patches or filaments rooted in matrix of another material are the most suitable illustration of ultramodern- day compound accoutrements , which are substantially structural. The present study deals with machining and machinability aspects of Metal Matrix mixes(MMCs)(mongrel mixes) emphasizing parametric appraisal and multi-objective optimization in relation to

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machining performance features. The ensuing sections accumulate introductory knowledge on MMCs.

STATE OF ART AND PROBLEM STATEMENT

The main end of this chapter is to give the background information about the proposed study from an expansive literature check. From this literature review a planning and understanding of present work has been achieved. Selection of material, their ultramodern day's operations, brief information about the processes involved in fabrication of essence matrix mixes, recent advancements in processing and machining, elaboration and effective employment of different optimization fashion have been surveyed through this chapter A lot of inquiries and examinations have been carried out to dissect the effective way for fabrication and effective machining of Al, SiCp corroborated compound.

A. Al,SiCp Metal Matrix Composite

Composite material consists of two or further accoutrements (the matrix binder and the underpinning or padding rudiments), altering in composition or form on a macro-scale. For essence matrix compound the matrix material is a essence. bandied that essence matrix mixes have a number of profitable parcels as compared to monolithic essence including advanced specific strength, advanced specific modulus, and resistance to elevated temperatures, better wear and tear resistance and lower portions of thermal expansion. Also MMCs have several superior mechanical parcels over polymer matrix mixes which include lesser transverse stiffness and strength, better temperature capabilities, lesser compressive and shear strengths. There also numerous devisee physical parcels of MMCs like resistance to utmost radiations, noninflammability, no significant humidity immersion parcels and high thermal and electrical conductivities. showed that in once two decades, essence matrix mixes have been generating broad range of exploration fraternity in material wisdom. Major of the operations and workshop have been demanding aluminium and other light matrices for purposes asking high strength and stiffness along with light weight. thus, the major elevation has been on the development of lighter MMCs using aluminum and other light blends. It's indeed essential to find utmost effective system for processing and machining of this advanced compound material.

B. State of Art on EDM & ECM

EDM : One of the most simply employed advanced material junking processes is Electro discharge machining(EDM). English physicist Joseph Priestley in 1970 first fulfilled the erosive effect of electrical discharges. EDM is especially used for machining of hard metals and advanced accoutrements or those that would be veritably delicate to machine with conventional machining methods. EDM, generally also nominated as spark eroding, spark machining, die sinking or lineerosion. Its exclusive aspect of exercising thermal energy to machine electrically conductive corridor disregarding the hardness has been its unique advantage in the manufacture of bones, mould, aerospace, automotive and surgical factors. In addition to these, in EDM there's no direct contact between the electrode and the work piece removing the mechanical stresses, vibration and chatter problems during machining.

ECM : *Gussef* in 1929 first patented the process resembling ECM. Significant advances during the 1950sand 1960s emerged ECM as an efficient technology in the aerospace and aircraft industries. Electrochemical machining is also another advanced machining technology which offers a better alternative or sometimes the only alternative in achieving precise 3-D complex shaped features and components of difficult to machine materials. The advantages of ECM over other traditional machining processes include its applicability disregarding the material hardness, comparable high material removal rate, no tool wear, and achievement of fine surface features and the production of components of complex geometry with crack-free and stress-free surfaces. Therefore, ECM has been utilized in many industrial applications including engine casings, turbine blades, gears, bearing cages, molds and dies and surgical implants.

***State of Art on EDM* :** During EDM, material is removed from the work piece by a series of fleetly recreating spark discharges between two electrodes(tool electrode as cathode and work piece as anode), separated by a dielectric fluid and subordinated to an electric voltage. When a suitable voltage in range of is applied, the dielectric breaks down and electrons are emitted from the cathode and the gap gets ionized when a suitable voltage and inter electrode gap is applied. In fact, a small ionized fluid column is created leading advancing an avalanche of electrons in the spark gap. When fluxes of electrons are collected in the gap it results in resistance drop causing electric spark to jump from tool to work piece face. The generation of contraction shock swells due to spark develops a original rise in temperature which is sufficient to melt a part of essence. The tensile force produced by electric and glamorous fields caused by the spark gash off patches of molten and soften essence from work piece. Once the current inflow stops, new dielectric fluid is generally flushed into the inter-electrode volume enabling the debris to be carried down and the separating parcels of the dielectric to be restored generally known as flushing. Chen and Mahdivian showed that sparks are generated by electrical circuits of several types and of different surge form of current and voltage of its own and the material junking is a function of discharge energy. illustrated that the high temperature grade generated at the inter electrode gap results in large localized stress which lead to junking of material. linked that there's three types of material junking medium i.e. melting or evaporation, spalling and oxidation or corruption.

State of Art on ECM **:** ECM is frequently nominated as ' rear electroplating ', in which it removes material in place of adding it. This is completely grounded on Faradays law of electrolysis. explained that a D.C. voltage (generally about 10to 25 volts) is applied across the interelectrode gap between an anode work piece and pre-shaped cathode tool. The electrolyte(e.g. NaCl, NaNO3aqueous result etc.) flows at a high speed through the inter electrode gap(about0.1 to0.6 mm). According to Faraday's law, the anode work piece is dissolved with current density of 20 to 200 A/cm2.The electrolyte inflow takes down the dissolved material generally essence hydroxide) and other by products generated in the process similar as cathodic gas from the gap. The final shape of the work piece is nearly negative glass image of the tool electrode. proposed a computational model to prognosticate the corrosion profile in the use of a simple flat end electrode during ECM process and also bandied that the material junking increases with adding electric voltage, molar attention of electrolyte, machining time and reduced original gap. presented a computer simulation of cut and try procedure for designing tool shape in the ECM of prescribed work figure and showed that an optimum value of the feed-reverse factor for iterative revision of the tool shape exists. studied on the intermediating variables in electrochemical machining of SAE- XEV- F stopcock sword and concluded that irregular junking of material is more likely to do at low feed rates whereas face roughness decreases with feed rate. employed slate relational analysis combined with ANN and multiple retrogression model for multi-objective optimization of MRR and face roughness as objects and current, voltage, inflow rate and gap rate as machining parameter in ECM of hardened sword and eventually used ANOVA to identify the significance of the proposed model. Tang and Yang used orthogonal array trial and slate relational analysis system to find the optimal setting of process parameters electrolyte attention, electrolyte pressure and the feed speed for material junking rate, side gap and face roughness in ECM of a special pristine sword.

Problem Statement **:** Essence slice is one of the most widely and important employed manufacturing processes in engineering diligence. The study of essence slice focuses substantially on the input work accoutrements , parcels and features of tools, and machine parameter settings affecting affair quality characteristics and process effectiveness. A great enhancement in process effectiveness can be achieved by process parameter optimization that determines and identifies the regions of critical process control factors leading to responses or asked quality characteristics with respectable variations promising a lower cost of manufacturing. The technology of essence slice has advanced mainly over time with a common thing of achieving advanced machining process effectiveness. Selection of optimal machining condition(s) is the essential factor in achieving this thing. In any advanced essence cutting operation, the manufacturer wants to set the process- related controllable variable(s) at their optimal operating conditions with minimal variability in the affair(s) and effect of willful variables on the situations. To design and apply an effective process control for essence cutting operation by parameter optimization, a manufacturer seeks to balance between cost and quality at each stage of operation. The Taguchi system is a methodical methodology of design and analysis of trials for the intention of designing and perfecting product quality.

EXPERIMENTATION

This chapter contains the details of experimental work done for present design work. The characteristics, composition of the raw accoutrements needed for manufacturing of MMC work instance is handed. The details of each step for fabrication of Al, SiCp MMC with specific composition is described with. The images of each process involved in fabrication system are handed for detail study. also different on-conventional machining operations are carried out on the fabricated MMC samples for farther trial and analysis. The details of nontraditional machining styles and their performance characteristics are explained herewith.

Raw Materials **:** Al alloy powders (A2265), Sic powder were purchased from RFCL Limited, New Delhi, India. The composition and specification are described below:

1. Al Powder **:** The Al alloy powder contains 99.7% Al, 0.1% Cu, 0.17% Fe, and 0.03% Zn. The atomic weight of Al powder is 26.88 and particle size is 110 meshes.

2. SiC Powder **:** Fine powder of SiC is purchased from open market with 99% metal. The particle size is of 325 meshes.

Work piece Fabrication **:** The fabrication fashion for mixes is an important consideration. By the processing fashion, the essential link between needed parcels and cost estimation is estimated for a given set of rudiments. In general, fabrication is concerned with the prelude of underpinning into the matrix essence with an invariant distribution. The main end is to achieve proper cling between the matrix and the underpinning with enhanced mechanical and physical parcels. Now a days, the primary artificial processing routes available for the fabrication of Al grounded essence matrix mixes comprises of theorizing, spot deposit, casting and greasepaint metallurgy ways. Spray deposit processes similar as the code position styles have been set up to fabricate flyspeck corroborated Al grounded essence matrix mixes with good material and low isolation parcels. But this system has limitations like the expensive atmospheric conditions, difficulties involved in product of net shape and in achieving repetition for underpinning amounts, which restricts the use of this forthcoming fashion. The specialized difficulties like poor interfacial cling, high localized residual porosity underpinning clustering and isolation are more frequently seen in conventional casting styles and theorizing which circumscribe the utility of these fabrication styles. The greasepaint metallurgy processing fashion is chancing magnet due to several reasons.

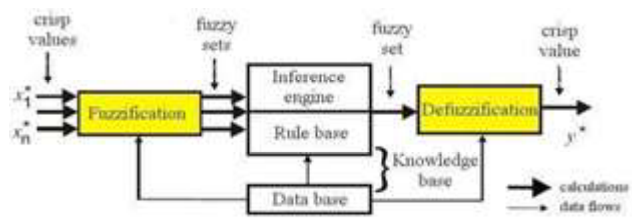
The Al, SiCp MMCs are fabricated using greasepaint metallurgical cold uniaxial pressing and sintering technology. The factual consistence of the samples is attained through
water absorption system and the average factual viscosity was set up to be0.00238 g/ mm3.

Design of Experiment **:** Design Of trials(DOE) is an important statistical tool to study the effect of multiple variables contemporaneously introduced by RA. Fisher in England in the 1920’s. DOE can be effectively employed to optimize product and process designs, study the goods of multiple factors(i.e., parameters, variables, constituent.) on the performance, and break product problems by courteously laying out the investigative trials. DOE has advantages of lower number of trials needed for closeness in effect estimation, enhancement quality of a product or process, thickness of performance. In ECM and EDM it’s delicate to find a single optimal combination of process parameters for multiple performance characteristics since process parameters impact them else. For the present disquisition, Taguchi’s Orthogonal Array has been employed for design of trial for nonstop enhancement of quality and productivity.

METHODOLOGIES FOR DATA ANALYSIS

The term optimization is carried from Latin word “ optime “, which means the stylish. Optimization is the achievement of the stylish result subordinated to given situations constraints. Depending on the circumstances, the word „ optimum may be taken as „ minimal or „ maximum . In product, design, planning, construction, and conservation of any manufacturing or engineering system, masterminds or experimenters have to draw numerous directorial and technological opinions at different phases. All similar opinions primarily aim moreover or to maximize the asked benefit or to minimize the trouble needed. As the benefit needed or trouble asked in any practical circumstance can be articulated as a function of numerous decision variables. Optimization can be defined as maximizing or minimizing an objective function by constantly opting input values under given constraints. While designing products and systems needs a profound interpretation of goods that negotiate desirable performance, the demand for a methodical and effective decision- making approach initiates the substance for optimization strategies. The need of objective functions to contribute a scalar quantitative performance measure which requires be maximizing or minimizing. The objective function can be the system s profit, product cost yield etc. For illustration of gets of the system a prophetic model is demanded. This modulates into a number of equations and inequalities that’s known constraints in optimization problem. In the prophetic model the variables must be accorded to satisfy the constraints. This can substantially be achieved with different situation of variable values, prevailing to a doable region which is attained by a subspace of these variables. The process of optimizing contemporaneously and totally set of objective functions are nominated as multi-objective Optimization(MOO) or vector optimization. Since the late 1940s, an ample of trouble has been done into generating algorithms for interpretation of different types of optimization problems and perpetration of good software prosecutions. In case of advanced machining styles like ECM and EDM is delicate to find a single optimal combination of process parameters for multiple response characteristics since process parameters impact them else/ laterally. In order to gain the stylish productivity and quality characteristics; the control parameters affecting the machining process bear to be optimized. So, there's a substance for a multiple objective optimization system to gain the results to this problem. In this discussion, the challenge is to land a model, from a group of promising models, which impeccably suits the experimental data. The parameters of machining are considered as variables and the performance parameters are considered as objective functions which need to be optimized. For ECM a most popular multi-objective optimization fashion, fashion for Order Preference by Similarity to Ideal Solution(TOPSIS) combined with Taguchi is employed for getting the optimal setting of the process parameters. also, another mongrel optimization fashion slate-fuzzy combined with Taguchi system is employed for farther analysis and comparison. In EDM the parameters are set up to be identified. thus, a mongrel optimization fashion combined star element Analysis(PCA)- TOPSIS with Taguchi system is employed for getting the optimal result. also, again another effective multi-objective optimization fashion MOORA combined with Taguchi system is employed for farther analysis.

Fuzzy Conclusion is the system in which the mapping from a given input to an affair is formulated exercising fuzzy sense. also opinions can be drawn, or patterns discerned on the base of mapping. Fuzzy sense can potentially acquire mortal decision timber, firm logic, and other perspectives of mortal apprehension. The fuzzy- rule grounded methodology is a core logic process where experts experience and subject knowledge can conceivably be enforced and restated into the machine language. The ensuing rudiments involve the process of fuzzy conclusion Class Functions, If- also Rules and Logical Operations. Generally, two kinds of fuzzy conclusion systems can be employed Mamdani type and Sugeno type. Depending on the way in which labors are determined, these two types of conclusion systems are varied. The most generally employed fuzzy methodology is Mamdani's fuzzy conclusion system. This was developed by Ebrahim Mamdani in 1975 as a trouble to control a boiler and stem machine combination by incorporating a set of verbal control rules penetrated from mortal drivers gests . Mamdani fuzzy model is developed on the base of the combinations of IF- also rules taking account both consequent predicts and fuzzy antecedent. In this model, the rule base is generally developed by an expert and thus, it's gauzelike to study and understand is the advantage of this model. Because of its ease perpetration, for sorting out a multitudinous real- world problem, Mamdani model is still most primarily employed. A fuzzy system generally consists of four factors i.e., fuzzifier, a conclusion machine, a knowledge base and a Defuzzifier. The class functions are first employed by fuzzifier to convert the crisp inputs into fuzzy sets. also, the fuzzy values are generated by the action of conclusion machine on fuzzy rules performing fuzzy logic. After that the Defuzzifier these fuzzy values into crisp labors.



Taguchi's Rule of Manufacturing **:** Taguchi restrained that the stylish chance to remove variation is at the time of design of a product and its manufacturing process. Hence, he developed a strategy for quality engineering that can be employed in both circumstances. The process has three stages:

1. System design
2. Parameter design
3. Tolerance design

For this present effort, parameter design is used.

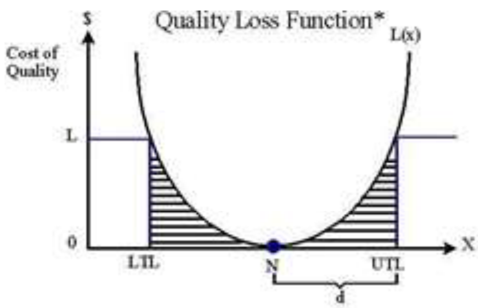
Taguchi Method **:** In the late 1940 Dr. Genichi Taguchi fulfilled numerous satisfying explorations with optimization ways as an experimenter in Electronic Control Laboratory in Japan. Taguchi system, which is also popular as the Robust Design eminently, enhances engineering productivity. The Robust Design system assists assure client satisfaction, by premeditative taking in to account the noise factors(manufacturing variation, environmental variation during product's operation and element deterioration) and the cost of failure in the field. Robust Design aims at enhancing the introductory action of the product or process, therefore expediting flexible design and concurrent engineering. really, it's the most dynamic methodology usable enhanced quality and to lower product cost, contemporaneously also dwindle development interval.

Highlights of Taguchi Philosophy

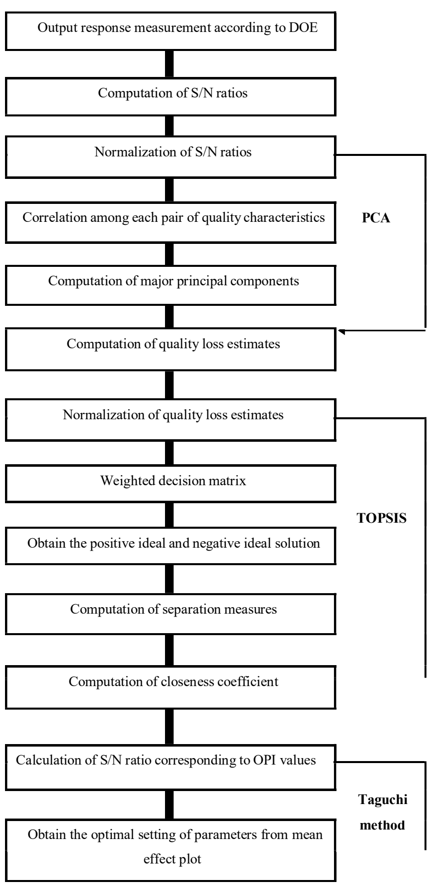
A. Robust Design – a structured, analytical and methodical process.

B. Quantify design consistently in greatly less time and resources

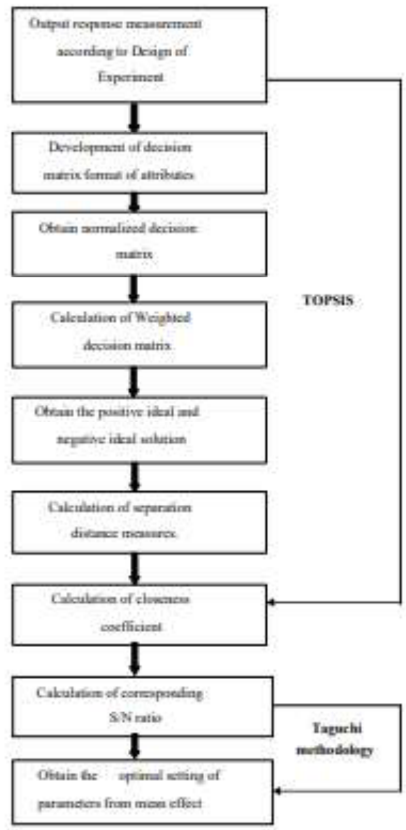
C. Develop supreme products at remarkably lower cost in lesser time



Proposed Methodology for Analysis of EDM Data :



Proposed Methodology for Analysis of ECM Data :



DATA ANALYSIS

This chapter contains the analysis of experimental data by different optimization ways bandied in Chapter 4. Optimal parameter settings are calculated by different mongrel and multi objective optimization approaches.

Electrochemical Machining Data Analysis : The three machining parameters feed(F), voltage(V), electrolyte attention(C) is varied at four different levels for getting the optimal parameter setting for electro chemical machining TOPSIS integrated Taguchi system has been employed. farther slate-fuzzy approach has also been employed. The position values of each process parameter corresponding to L16 orthogonal array are shown below.

L16 OA for ECM process parameters

Run No.	F	V	C	F(mm/min)	V(volt)	C(%)
1	1	1	1	0.10	8	10
2	1	2	2	0.10	10	15
3	1	3	3	0.10	12	20
4	1	4	4	0.10	14	25
5	2	1	2	0.20	8	15
6	2	2	1	0.20	10	10
7	2	3	4	0.20	12	25
8	2	4	3	0.20	14	20
9	3	1	3	0.30	8	20
10	3	2	4	0.30	10	25
11	3	3	1	0.30	12	10
12	3	4	2	0.30	14	15
13	4	1	4	0.40	8	25
14	4	2	3	0.40	10	20
15	4	3	2	0.40	12	15
16	4	4	2	0.40	14	15

The remarked values of presentation parameters according to order of parameters of each round is measured and presented in Table.

Experimental data

Run No.	F	V	C	MRR (mm^3/min)	R_a (µm)
1	0.1	8	10	11.46155	15.06668
2	0.1	10	15	2.538463	10.13334
3	0.1	12	20	10.53847	9.066668
4	0.1	14	25	14.69232	5
5	0.2	8	15	13.38463	9.2
6	0.2	10	10	21.76930	8.2
7	0.2	12	25	18.07693	9.933334
8	0.2	14	20	9.538463	11.8
9	0.3	8	20	15.07693	10
10	0.3	10	25	17.46155	15.8
11	0.3	12	10	18.92309	8.666668
12	0.3	14	15	16.76924	5.4
13	0.4	8	25	30.38463	22.6
14	0.4	10	20	9.384616	10.8
15	0.4	12	15	3.076924	8.933335
16	0.4	14	15	20.15387	7.6

Electro Discharge Machining Data Analysis : The four machining parameters voltage(V), palpitation on current(Ip), palpitation on time(Ton), duty cycle(ô) is varied at four different situations. For getting the optimal parameter setting for electro discharge machining a mongrel optimization fashion combined PCA- TOPSIS integrated Taguchi system has been employed. also, further MOORA system has also been employed for farther optimization analysis and comparison. The values of each indispensable corresponding to each position values in L16 orthogonal array(OA) as shown below.

L16 OA for EDM process parameters

Run No.	V	Ip	Ton	τ	V	Ip	Ton	τ
1	1	1	1	1	42	3	40.00	70.0
2	1	2	2	2	42	4	70.00	75.0
3	1	3	3	3	42	5	100.00	8.0
4	1	4	4	4	42	6	130.00	85.0
5	2	1	2	3	44	3	70.00	80.0
6	2	2	1	4	44	4	40.00	85.0
7	2	3	4	1	44	5	130.00	70.0
8	2	4	3	2	44	6	100.00	75.0
9	3	1	3	4	46	3	100.00	85.0
10	3	2	4	3	46	4	130.00	80.0
11	3	3	1	2	46	5	40.00	75.0
12	3	4	2	1	46	6	70.00	70.0
13	4	1	4	2	48	3	130.00	75.0
14	4	2	3	1	48	4	100.00	70.0
15	4	3	2	4	48	5	70.00	85.0
16	4	4	1	3	48	6	40.00	80.0

The observed values of performance parameters Material junking Rate(MRR), face roughness(Ra), Tool wear and tear rate(TWR), overcut(Z) according to setting of parameters for each run are measured and shown in Table.

Experimental data

Run No.	V	Ip	T_{on}	τ	MRR (mm^3/min)	TWR (mm^3/min)	Ra (µm)	Z (mm)
1	42	3	40	70	1.344539	0.04857998	5.81	0.0946
2	42	4	70	75	0.483194	0.028026907	7.333334	0.1496
3	42	5	100	80	0.168068	0.016816144	6.81	0.0956
4	42	6	130	85	1.848741	0.028026906	7.933334	0.2096
5	44	3	70	80	1.533614	0.039237669	7.133334	0.1726
6	44	4	40	85	1.764707	0.033632288	9.22	0.019
7	44	5	130	70	8.865547	0.022421526	8.61	0.168
8	44	6	100	75	4.222691	0.044843051	8.133334	0.1966
9	46	3	100	85	0.882354	0.05044844	7.61	0.104
10	46	4	130	80	1.97481	0.022421526	8.866668	0.0746
11	46	5	40	75	1.44959	0.011210763	6.933334	0.0056
12	46	6	70	70	10.13026	0.056053813	5.466668	0.2896
13	48	3	130	75	6.953783	0.033632289	8.466668	0.137
14	48	4	100	70	0.798321	0.016816144	8.43	0.033
15	48	5	70	85	2.184875	0.061659194	9.81	0.1296
16	48	6	40	80	12.4917	0.151345293	6.466668	0.246

CONCLUSIONS AND FUTURE SCOPE

In this study, TOPSIS combined with Taguchi gospel and slate proposition combined with fuzzy rule grounded model have been developed towards optimizing roughness normal and MRR in machining Al, 15SiC mixes. It has been set up that both the styles concluded with same result. So, the optimal setting for ECM is set up to be most beneficent. The proposed procedures are simple, effective in developing a robust, protean and flexible mass product process. In the environment of slate-fuzzy grounded Taguchi system there's no need for checking the correlation among responses as no individual weight has been assigned to responses. FIS can efficiently take care of these aspects into its internal scale thereby prostrating colorful limitations of being optimization approaches. This approach can be recommended for nonstop quality enhancement and off-line quality control of a process of manufacturing assiduity. In order to achieve stylish quality characteristics and satisfactory process performance yield; the machining parameters in EDM of workpiece material Al, 10SiCp MMCs need to be optimized. Taguchi's gospel is primarily concerned with the optimization of single response only. thus, in this study a multi-objective mongrel optimization fashion combining PCA, TOPSIS integrated with Taguchi system; and another effective fashion MOORA combined with Taguchi system have been employed successfully for optimizing performance parameters of EDM reaching to an optimal parameter setting for machining of advanced accoutrements like Al, SiCp MMCs. These intertwined approaches can be applied for product quality and process performance enhancement in any product processes which involve multiple response features and can be considered as an effective tool for nonstop process enhancement and off- line quality control. forenamed work can be extended in the following directions Different material parameters like of SiC, temperature of sintering, snare size of maquillages can also be considered for experimental analysis and farther quality enhancement. Other machining parameters of ECM like inflow rate, different electrolytes. can be taken into account for analysis. also other machining parameters like palpitation on energy, flushing pressure of dielectric fluid etc. can also be taken into account. Machine tool vibration, cryogenic effect on tool sets can be espoused for analysis. Different fine models can be developed for productivity and quality enhancement program as well as for optimization of process parameters of EDM, ECM on MMCs.

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Influence of Ground Water on Stability of Pit Slope in Opencast Coal Mine-Numerical Model Analyses Under two Different Approaches

Pritiranjan Singh* Dr Singam Jayanthu*

ABSTRACT

Coal has been the major source of production of power in India. Electricity production in India is mostly based on coal powered thermal power plants. Hence it is essential to maintain a continuous supply of coal to thermal plants for uninterrupted power supply. Coal mining in India has always been a tedious affair. Due to the socio-political scenario in the second populated nation, grabbing a piece of land for mining purpose is an onerous activity. Difficulty in acquiring land and the growing demand for coal forces mining companies to go down deeper and steeper to achieve maximum productivity. This in return compromises with safety aspects. It is a dynamic process to keep a balance between the productivity and stable slope geometry. Presence of groundwater decreases the stability of pit. In this paper a sensitivity analysis is performed in two different methods namely Finite Difference Method (FDM) and Limit Equilibrium Method.(LEM). FDM is relies upon shear strength reduction (SSR) technique to estimate factor of safety (FoS). LEM method calculates the critical failure surface to estimate FoS. This research aims to investigate output of sensitivity analysis in both methods. In un-drained condition the estimated FOS in FDM model showed higher values than LEM Model.
Keywords: FDM, LEM, SSR, FoS,

INTRODUCTION

In a country like India mining has always been a difficult task due to the problems faced by coal companies in acquiring land. Increase demand for coal, compels the mines to go to steeper and deeper. Considering the situation it is prudent to carry out stability of slopes for safe operation along with maintaining productivity. India has witnessed many slope failure incident with recent past seeing catastrophic failure at Rajmahal OCP at Lalmatia of M/s Eastern coal fields limited in the year 2017. The tragic accident has claimed twenty three human lives. This incident had send tremor across the mining fraternity of India. This forced the mine safety watchdog DGMS to come up with stricter circulars and guidelines to address the issue of slope stability in mines .Table 1 shows list of major slope failure incidents in India.

Amongst the many factors, water plays a devils role towards stability of mine slopes. Presence of water decreases the shear strength of material, thereby decreasing the stabilizing forces. To inhibit the effect of water coal mines adopts various dewatering and depressurization technique. Groundwater in form of aquifers is a major source of water in mines. Detail study of hydrogeology prior to mining and during excavation is essential to access impact of ground water towards stability of pit slopes. In this research a sensitivity analysis was done to investigate the effect of ground water on the stability of pit slopes. The analyses were carried out by

Table 1: Major Slope Stability Failures In Indian Coal Mines (Source: Internet)

1	August, 1995	Hindustan Lalpeth (WCL)
2	June, 2000	Kawadi Opencast Coal Mines (WCL)
3	December, 2008	Jayant opencast coal mines (NCL)
4	January, 2009	Jayant opencast coal mines (NCL)
5	June, 2009	Sasti opencast coal mine (WCL)
6	October, 2002	Lignite mines (NLC)
7	May, 2005	Lignite mines (NLC)
8	August, 2013	Basundhara coal mines (MCL)
9	April, 2013	Bharatpur OCP, (MCL)
10	July, 2014	Dhanpuri Opencast mine, (SECL)
11	May, 2015	Khadia OCP, (NCL)
12	March, 2016	Amalgamated Konar Khasmahal OCP (CCL)
13	December, 2016	Lalmatia coal mines (ECL)
14	Tuesday, July 23,	Bharatpur OCP, (MCL)

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two software based on Finite Difference Method and Limit Equilibrium Method of slices.

LITERATURE REVIEW

Sensitivity analysis is performed to evaluate the results of a dependent parameter with change in values of an independent variable. In this research factor of safety of pit slope is considered as the dependent variable whereas ground water table is regarded as independent parameter. Factor of safety estimation was carried out in FDM and LEM based Software.

FINITE DIFFERENCE METHOD

Finite difference method is used for various geotechnical studies. Alike finite element method (FEM) , FDM approach adopts shear strength reduction(SSR) technique to evaluate factor of safety. In this technique the shear strength parameters (cohesion and angle of repose) are reduced by factor till the solution converge to attain the failure environment. Equation 1 shows the Mohr Columb failure equation used for SSR technique.

$$\tau = C + \sigma_n \tan\phi \qquad (1)$$

Where C is cohesion of material, τ is shear stress being applied of material and σ_n is normal stress acting upon the failing material. ϕ is the angle of repose of failing material. Considering SF being the safety factor at the instant of failure the residual Cohesion and angle of repose can be expressed as (equations 1 and 2)

$$C_{res} = \frac{C}{SF} \qquad (2)$$

$$\phi_{res} = \tan^{-1}\left(\frac{\tan\phi}{SF}\right) \qquad (3)$$

LIMIT EQUILIBRIUM METHOD

Limit Equilibrium Method of slices also uses Mohr-Columb failure equation to determine the slip surface with least safety factor. In this research the method of slices i.e Morgenstern–Price method is used to determine factor of safety. Morgenstern-Price is based on general method of slices satisfying limit equilibrium. It represents a condition of equilibrium among forces and moments acting on the blocks. These blocks are created by creating slices of equal length in the sliding zone.(27). Figure 1 shows Forces acting on individual blocks.

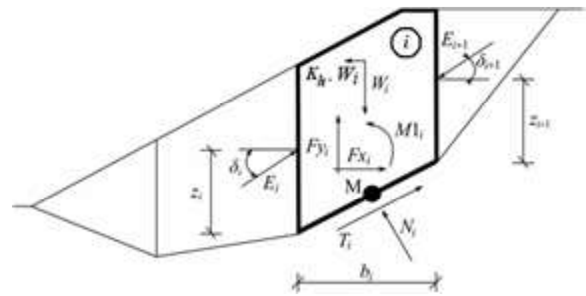


Fig 1 Static diagram of a schematic slope in Morgenstern–Price method (Finesoftware 2010)

The following assumptions are introduced in the Morgenstern-Price method to calculate the limit equilibrium of forces and moment on individual blocks(28):

- dividing planes between blocks are always vertical
- the line of action of the weight of block Wi passes through the center of the ith segment of slip surface represented by point M
- the normal force Ni is acting in the center of the ith segment of slip surface, at point M
- inclination of forces Ei acting between blocks is different on each block (δi) at slip surface endpoints is $\delta = 0$

SITE OF INVESTIGATION

Mine A is located in the Jagannathpur block of Bishrampur Coalfield under the control of M/s South Eastern Coalfields Limited. The Coal Block is having an area of excavation of about 532.03 Ha at surface.. At preset the mine has gone up to a depth of about 40m with about seven number of benches. Two segregated dumps of 48m and 43 m are active for top soil and hard strata stacking. Figure 2 shows the present mine layout as on September 2021. The photograph shows present mine working along with spoil dumps and working face.

Fig 2: Layout of Mine A as on Sept 2021

There are total 10 no of seams (fig 3). Among these The top nine seams are considered for quarrying with L-8 seam as base seam. Top most seam X- is lying at a depth of 55 m. OB benches overlying the x seam consists of ten benches with maximum height of 6 m. Underlying seams with thickness varies from 0.3 to 5 m upto 110 m maximum depth.

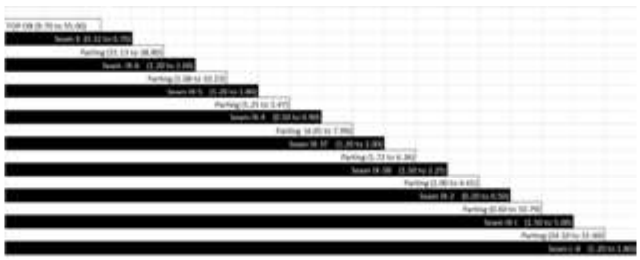


Fig 3: Seam orientation of Mine A

Presently the mine pit is about 40m deep. The mine is planned to go deep up to a depth of 110m. Table 2 shows the working bench parameters for the mine pit adopted in practice.

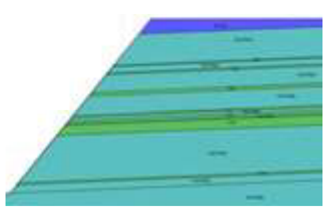
Table 2 Bench Parameter for working Pit

Sl. No.	Particulars	Remarks
1.	Bench height OB Coal	Upto 6 m or equal to parting thickness. Upto 5m or equal to coal seam thickness.
2.	Bench width	25 m
3.	Slope of coal bench	70°
4.	Gradient of haul road	1 in 16
5.	Gradient of ramps	Usually 1:16, sometimes upto 1:10

NUMERICAL MODELING

Mine A is planned to be excavated upto a depth of 110m towards its dip side(fig 4 a) with a strike length of 2.4 km. Maximum length along dip is 2.7 km. Towards the dip side the quarry will attain a maximum slope angle of 46 degree. Fig 4(b) shows a representative cross section of final pit slope.

(a)



(b)

Fig 4: Final Pit ; a) Pit Layout, b) Cross Section of final pit slope showing seam orientation

Numerical simulations were performed by FDM and LEM software. Field condition of varying ground water table with depth of 5m, 10m, 15m and 20m were modeled in both software. With assumption dewatered scenario a dry condition was also simulated. IN FDM software after drawing the geometry the material properties were assigned to the model. Meshing was done by adopting medium size mesh. Standard earth gravity was assigned to it prior to simulation. In LEM based software Slip circle was defined from right to left by providing adequate freedom for movement of slip surface. Critical failure surface was determined with the slip surface displaying least value of factor of safety. The material properties were assumed by physic-mechanical bore hole data of mine and field conditions. Table 3 shows the material properties assumed for numerical modeling.

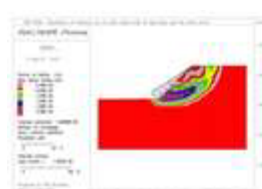
Table 3: Assumed material strength properties

Material	Density (in gm/cc)	Cohesion (in Kpa)	Angle of Repose (in degree)
Soil Layer	1750	40	20
Coal	1450	300	25
Hard Strata/Inter burden	2200	400	30

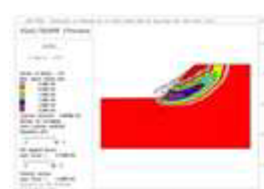
RESULTS

Results from FDM Approach

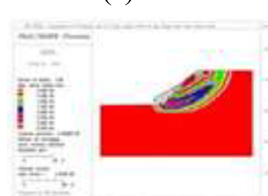
Five no of model geometries were drawn assuming dry condition and phreatic surface depth of 5m,10m,15m and 20m from the ground surface. The simulation results were obtained by SSR technique. Fig 5 shows Factor of safety estimated in un-drained condition of pit slope.



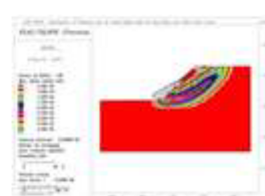
(a)



(b)



(c)



(d)

Fig. 5: Sensitivity analysis of Final Pit Slope with ground water levels of
a)5m , b)10m , c)15m , and d)20m in FDM

In dry condition due to absence of hydrostatic pressure the safety factor obtained is highest. Fig 6 shows the simulation result of dry model.

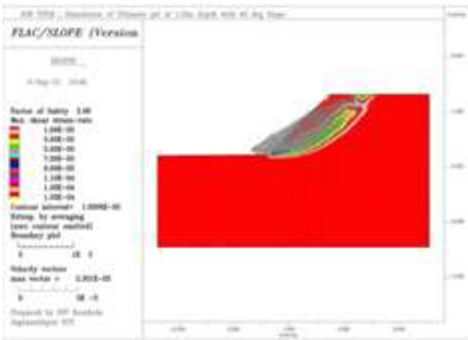
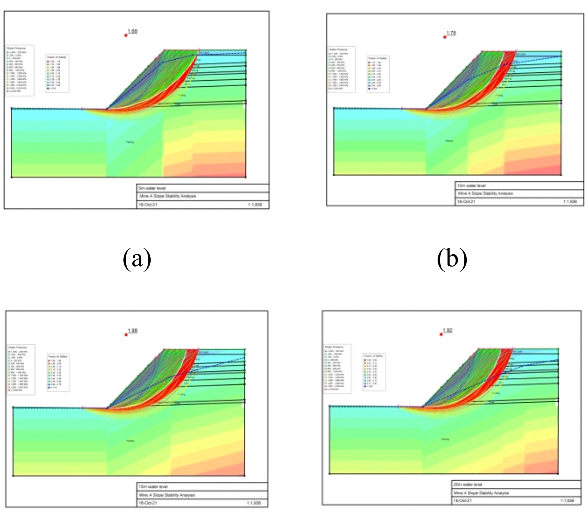


Fig 6 Factor of safety Analysis in dry condition in FDM

Results from LEM Approach

As per analysis performed in FDM approach, similar models were analyzed in LEM software. Fig 7 shows the safety factor outcome for un-drained conditions in LEM method.



(a) (b)

(c) (d)

Fig. 7 Sensitivity analysis of Final Pit Slope with ground water levels of a)5m , b)10m , c)15m , and d)20m in LEM

Similar to FDM analysis fully drained condition of pit slope showed highest safety factor in LEM method. Fig 8 shows the analysis result.

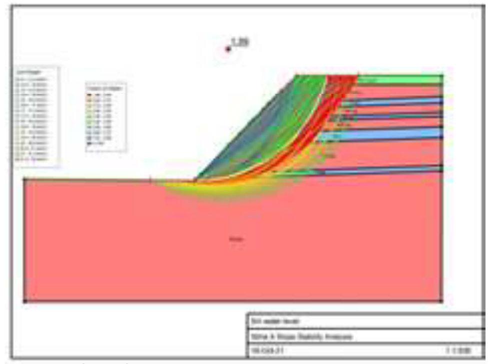


Fig 8 Factor of safety Analysis in dry condition in LEM

The safety factors obtained under various ways in both FDM and LEM analysis are tabulated in table no 4 as follows

Table 4 Results of FoS analysis with different ground water level in FDM and LEM

Ground water Level	FoS obtained from FDM	FoS obtained from LEM
5m	1.61	1.68
10m	1.75	1.78
15m	1.82	1.88
20m	1.90	1.92
Drained Condition	2.08	1.99

CONCLUSION

Sensitivity analysis was performed with Finite Difference Method and Limit Equilibrium Method on a 110m deep coal mine pit. In the analysis phreatic surface was assumed to be at a depth of 5m, 10m, 15m and 20m from ground level. With change in ground water level from 5m to 20m the output factor of safety varied from 1.61 to 1.90 in FDM Model and 1.68 to 1.92 in LEM Model. In drained condition FDM method showed higher safety factor than the LEM method.

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Deep Mining: Time for A Deeper Look

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ABSTRACT

Mineral consumption is increasing rapidly as more consumers enter the market for minerals and as the global standard of living increases. As mining is the source of mineral extraction it needs to be accelerated. Although mining operations are going on we should continue underground mining operations to progress to deeper levels in order to tackle the mineral supply crisis in the 21st century. However, the deep mining has lot of difficulties to deal with and deep mining occurs in a very technical and challenging environment, in which significant innovative solutions and best practice are required and additional safety standards must be implemented in order to overcome the challenges and reap huge economic gains. The major challenges that are associated with deep mining are rock bursts, gas outbursts, high in situ and redistributed stresses, large deformation, squeezing and creeping rocks, and high temperature. This paper presents the current global status of deep mining and highlights some of the newest technological achievements and opportunities associated with rock mechanics and geotechnical engineering in deep mining. Of the various technical achievements, unmanned working faces and unmanned mines based on fully automated mining and mineral extraction processes have become important fields in the 21st century.

INTRODUCTION

Since the exploitation of the earth's resources has a long history, coal and mineral resources at shallow depths have gradually become exhausted, and the exploitation of coal and mineral resources continues ever deeper into the earth. At present, deep mining at 1000 m is normal; the depth of coal mines has reached 1500 m, the depth of geothermal exploitation has reached more than 5000 m, the depth of non-ferrous metal mines has reached around 4500 m, and the depth of oil and gas exploitation has reached around 7500 m. Deep mining will become common in the future.

Deep rock mass is characterized by high in situ stress, high temperature, and high water pressure. Compared with shallow resource extraction, deep mining may be associated with disasters such as rockbursts, large-scale caving, and large inrush of mixed coal, gas, and water. These events are often complex in nature and difficult to forecast and control. The characteristics of the rock mass and the boundary conditions in deep mines are the primary causes of disasters in deep mining. For example, when the mining depth reaches about 1000 m, the in-situ stress caused by the overburden, tectonic features, and mining activities can cause stress concentration, resulting in damage to and failure of the surrounding rock masses. Under high stress, as the accumulated deformation energy is more prominent, accidents may occur more frequently. Under conditions of high stress, high temperature, and high water pressure, the disturbance generated by mining activities can lead to the sudden and unpredictable destruction of the rock mass, which is manifested by a large range of instability and collapse. In addition, the deformation and failure characteristics of rock masses at great depths often exhibit strong time-dependent characteristics. The disturbed stress- and time-dependence of deep mining engineering can result in the occurrence of disasters that are very difficult to forecast. Emerging problems of rock mechanics and mining engineering have been studied for deep mining. Moreover, new theories and techniques for deep mining are necessary, taking in situ and mining-induced characteristics into account.

PROBLEMS IN DEEP MINING

We can categorize the problems associated with deep mining as follows: -

(1) High in situ state of stress

High stress is a decisive factor resulting in severe damages and accidents in deep mines. In mining beyond 1000 m, in situ stress often exceeds the rock mass compressive strength. For example, the maximum in situ principal stress at depth between 1000m and 5000m can be 50–250 MPa, respectively, according to the results of in situ stress measurements.

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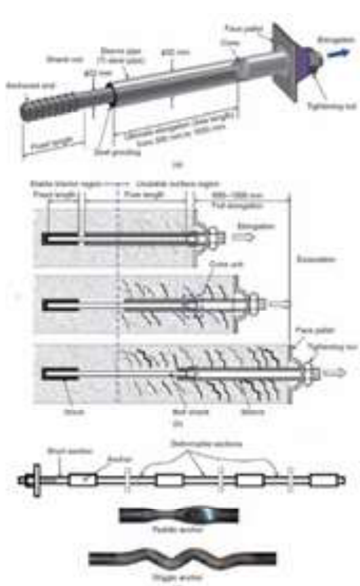
(2) High earth temperature and pore water pressure:

High earth temperature and high pore/joint water pressure increase the possibility of damage or violent disturbance. The geothermal gradient is 30–50 °C/km and the rock temperature can be greater than 40 °C at about 1000 m depth. High water/pore pressure will not only cause technical problems and impact the working conditions, but also influence the rock properties. At 1000 m depth, the hydraulic pressure is 10 MPa, which can result in hydraulic fracturing or water inrush accidents.

(3) Significant time dependent stress:
Along with the great in-situ stress and the rock is subjected to further stress conditions in case it has to withstand for long time without extraction.

ROCK SUPPORT FOR DEEP MINES
In situ stress is the dominant factor influencing underground deformation and failure in mining and other underground engineering. As the mining depth increases, the influence of in situ stress on the stability and failure of the surrounding rock mass becomes more obvious, and the selection of rock support techniques becomes more vital. He et al. developed asymmetric coupling support technology for roadways in soft rocks, including controlling technologies for floor heave, double controls on the crossing points for large roadway sections with anchors, and intensive design technology for pumping station chambers. These technologies have been successfully applied to site support works.



According to the site test results, Niu et al. suggested the adoption of a rigidity- and flexibility-coupled dynamic reinforcement technique by applying initial flexible support to stabilize the broken surrounding rocks in the early stage, using reserved deformation for the unloading of high stresses in the middle stage, and adopting a high-strength and high-stiffness support for the whole section in the late stage, in order to resist creep deformation. He et al. further developed a designated experimental system for rockburst in deep mining. In order to resolve the failure of conventional support materials in large-deformational surrounding rock, an energy-absorbing bolt with large elongation and constant resistance was developed, as shown in Fig. 1(a) and Fig. 1(b). The bolt can resist the large squeeze of rock by counter acting the shock-produced deformation energy through the large deformation of the bolt. The pull-out force constantly ranges from 120kN to 200kN, and the deformation capacity is 0.5–1 m. Li et al. developed an energy-absorbing rock-support device, the D-bolt (Fig. 1(c)), for burst-prone and squeezed surrounding rocks. The average impact load is 200–300kN for a 200 mm D-bolt, and the cumulative dynamic energy absorption of the bolt is 47 kJ·m”1.

TEMPERATURE CONTROL IN DEEP MINES

As mine workings reach ever-greater depths, the rock temperature increases and working conditions become less sustainable, new, innovative cooling technologies are now required. The cooling system followed by the worlds largest mine “MPONENG GOLD MINE” is as follows:

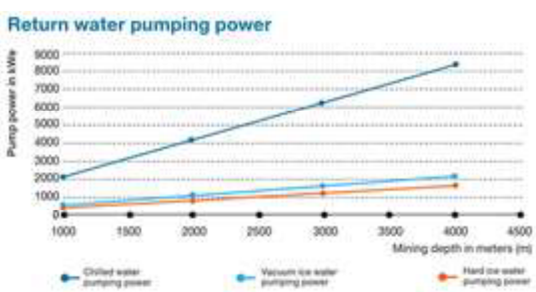
Mponeng is one of South Africa’s deepest mines, with virgin rock temperatures reaching up to 54.5ÚC at 3.5 km below surface. For miners to be able to work at acceptable temperatures, the ambient air has to be cooled down to 28ÚC Wet bulb temperature.

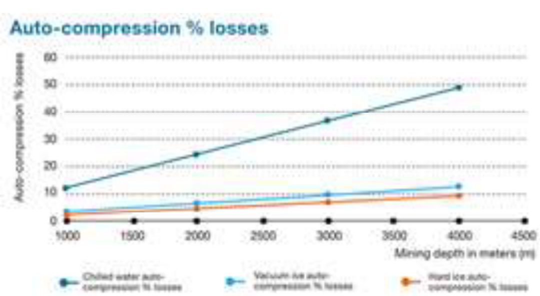
Hard ice advantages and energy efficiency Making ice on the surface in ice-making machines, sending it down the mine into a dam, then circulating the cold melt water through air coolers is more energy efficient than a conventional chilled water refrigeration system, because the latent heat capacity of a kilogram of ice means it can take up far more heat than a kilogram of cold water. This accounts for significant savings in operational costs. Once the ice melts, the water still has to be pumped back up to the surface, but the quantities are much smaller and pumping costs are reduced to less than a quarter of the costs of a chilled water refrigeration system. In general, the ratio of mass flow rate for hard ice compared to water would be 1:5.

The proportion of water turned to ice is also important. Vacuum ice only achieves ice mass fractions of 60%, while hard ice is in the range 93% to 98% depending on the water quality. A lower ice mass fraction means more ice needs to be sent underground to achieve the same cooling duty, thus increasing the quantity and pumping costs of the return water. In general, the ratio of mass flow rate for hard ice compared to vacuum ice would be 1:1.35. Although ice plants are slightly more expensive in capital outlay than conventional refrigeration plants, the initial investment is offset by lower operating costs, in particular the reduced pumping costs of smaller volumes of water and the more effective low temperature underground cooling.

THE BENEFITS OF HARD ICE COMPARED WITH CHILLED WATER

Hard ice systems compared to conventional water chiller plant brings savings of US$ 4.46 Million) per year in pumping power consumption. The percentage cooling loss due to auto-compression effects is orders of magnitude higher in water systems than in hard ice systems (50% of cooling load at 4000m). This clearly demonstrates that, if available cooling at shaft bottom is used as the criterion, ice systems are economically attractive for shallow hot mines as well as deep mines.

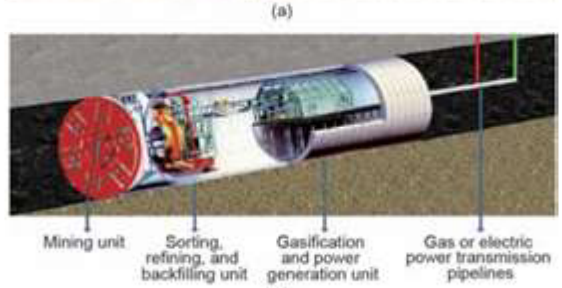




FLUIDIZED MINING

Xie et al. proposed that there exists a theoretical limit on mining depth by traditional methods. It is estimated theoretically that all the currently available mining methods will become obsolete once the depth of underground solid mineral resources exceeds 6000 m. Therefore, to realize the development and utilization of mineral resources at great depths, disruptive innovations in development theory and technology must be made. For this purpose, xie et al. proposed a theoretical and technical conceptualization of the fluidized mining of deep underground solid mineral resources (Fig. 2). Based on a mining mode similar to a TBM, the idea is to achieve in situ, real-time, and integrated utilization of deep underground solid mineral resources through mining, sorting, refining, backfilling, power generation, and gasification of solid resources, thus converting the resources into gas, liquid, or a mixture of gas/ liquid/solid substances. As a result, future coal mines will no longer have workers going down into the mines, coal being mined up, coal refuse being piled up into mountains, or dust obscuring the air; rather, power and energy transmission will be clean, safe, intelligent, environmentally compatible, and eco-friendly.

(a)



(b)

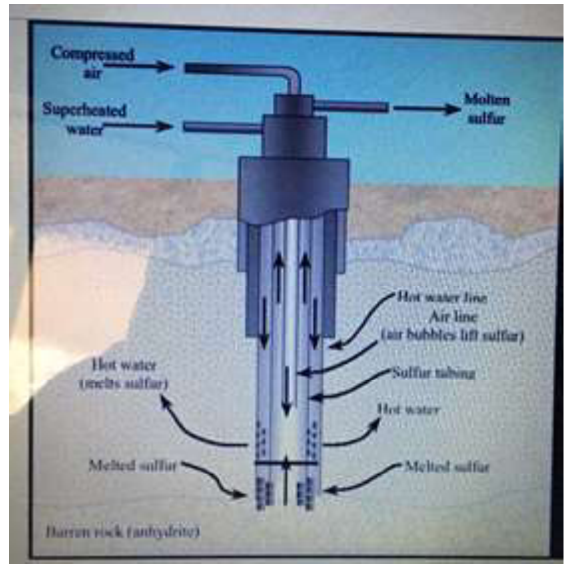
For coal mining, the fluidized mining concept includes the following five main procedures: '(1) unmanned mining, (2) automated sorting, (3) fluidized conversion of solid mineral resources, (4) controlled backfilling, and (5) power transmission, intelligent electricity control, and electricity storage. For metal mining, the fluidized mining concept includes the following three steps: (1) unmanned mining, (2) fluidized conversion of solid mineral resources, and (3) controlled backfilling [24]. There are four technologies to achieve the fluidized mining of deep underground solid mineral resources (1) the conversion of solid mineral resources into gases, such as the underground gasification of coal; (2) the conversion of solid mineral resources into liquid fuels, such as the underground liquefaction of coal and the high-temperature biological and chemical transformation of coal; (3) the conversion of .solid mineral resources into mixtures, such as explosive coal dust and water-coal slurry; and (4) the in situ conversion of solid mineral resources into electrical power, such as the in situ underground electrification of coal. Fluidized mining is indeed a disruptive innovation in mining technologies, particularly in regards to future deep mining.

SOLUTION MINING

As conventional ore production methods have become more costly and difficult, the mining industry has increasingly turned to the category of methods known as solution mining. S*olution mining is* defined as the subclass of aqueous surface mining methods in which minerals are recovered by leaching, dissolution, melting, or slurrying processes. However, the following can be considered distinct categories:

1. Borehole extraction systems
2. Leaching methods
3. Evaporite/evaporative procedures

Melting, dissolution, and slurrying are normally conducted using single-well procedures in which each well is a producing entity. A good example is the Frasch process. In this single-well method, the wellbore contains three concentric pipes. The outer pipe is used to inject superheated water into the deposit to melt the sulfur. The inner pipe allows compressed air to flow to the bottom of the well, where it flows upward through the annulus between the inner and middle pipes, taking the melted sulfur with it. The flow is produced primarily by the difference in densities between the water and the aerated sulfur. This is often referred to as an airlift system.



Seabed mining is coming — bringing mineral riches and fears of epic extinctions

Seabed mining is a method of extracting metals and minerals from the seafloor. It's used to describe both deep sea, and shallower mining techniques, although the former tends to be referred to as Deep Sea Mining (DSM).

- Recently, the Indian government cleared a deep ocean mission to explore deep seabed mining and encourage marine biodiversity research.
- The government aims to develop an integrated seabed mining system for mining polymetallic nodules from 6,000-metre depth in the central Indian Ocean.
- The Union Ministry of Earth Sciences, which is the nodal department for the project, said that they are looking at maintaining a balance between marine ecology and energy security of the country.
- Environmentalists argue that this quest for deep-sea minerals is without evidence and could damage the marine environment.

This will help us to meet the future demands.

CONCLUSION

This short review paper presents the current status of deep mining in the world, and highlights some of the newest technological achievements and opportunities. It also addresses some technical geo-mechanical issues associated with deep mining. Some of the current challenges, advances, and prospective issues in deep mining can be summarized as follows: (1) Deep mining will become common in the future as coal and mineral resources at shallow depths gradually become exhausted. Progress is restricted and influenced by the advancement of rock mechanics and machine technologies. New theories and techniques are therefore necessary for deep mining, particularly considering the high in situ and mining-induced stresses and other boundary conditions that are found at great depths. (2) Some control measures have been developed and applied for deep mining disasters such as surrounding rock deformation, rockburst, and the inrush of mixed coal-gas and water. However, the development of critical techniques for deep mining, such as monitoring and control techniques for mining-induced rock deformation, safety, the green mining of deep coal mines, and the collaborative mining of deep metal mines, is still in progress. (3) With the rapid development of modern technologies, many critical problems restricting the progress of deep mining will be conquered, either independently or by the combination of intelligent mining, enhanced continuous mining for metal mines, and fluidized mining of deep coal resources, all of which represent the dominant approaches to deep mining in the future. Deep mining is transitioning toward being fully automated, intelligent, and mechanized. (4) Novel mining technologies are being developed to identify and exploit previously unattainable resources in order to meet the rising global demand. Seabed mining that specifically targets seafloor massive sulfide deposits, iron-manganese crusts, and metallic nodules requires new approaches to material recovery.

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Digitization in Drill and Blast: On Going Optimization in Drill and Blast Using Digital Technologies - Examples, Challenges and Success Factors

Sanjay Purohit* Pankaj Goyal**

ABSTRACT

Drilling and Blasting are the core operations in a mine. It impacts all the downstream operations and their costs. Optimizing drill and blast operations reduces the overall mine to mill cost. Innovation through digitization and technology is a key focus area for Mining companies. Digital technologies exist for optimizing both drilling and blasting for many years. However, these technologies have largely been non-integrated and non-real time. This gap results in sub-optimal drilling and blasting operations. Also traditionally, focus has been on optimizing individual areas (drilling or blasting and subsequent subsystems). Industry has largely lacked the availability of real time or near real time integration available to the user in the field. Digitization in drill and blast is often talked about but large companies find it very hard to implement this successfully. This paper talks about implementation examples in coal mining companies, digital strategy for drill and blast, implementation effort and some key innovations. "Also, examples of digitization at multiple India based mines (Coal, Rock phosphate etc.) are provided where digital platform for drill and blast was adopted. Details are provided as how digital tools can help in simulation, designing and better drill and blast analysis. Predicting the blast results on actual topography obtained from survey at design stage can significantly help the mines to obtain the targeted blast results - this is carried out using a 3D blast designer on any survey file. Point of view is also presented about key considerations for a mining company where determining the digital strategy in drill and blast.

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Prevention of Dump and Highwall Failure in the Indian Opencast Coal Mines, A Conceptual Note

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ABSTRACT

Opencast Coal Mining is the dominant methodology in the present Coal Mining Industry. Failure or collapse of in-situ high walls and ribs in opencast coal mines is a profound contributor for mine accidents and loss of lives in the current scenario. Post failure management is a treacherous task, due to which preventive action is preferable. This is a conceptual note, enumerating preventive actions against accidents or incidences due to failure of highwall or dump slope failure. The perspective preventive actions are survey with theodolite and prism combination, survey with total station and prism combination, monitoring of induced stress in the highwall or slope, monitoring of ground movement along highwall or slope using drone technology, monitoring of ground movement along-side the highwall or slope using slope monitoring radars, etc. The preventive actions cannot be tailor made owing to situation specific issues of slope and highwall stability.

Key words : Highwall, Dump Slope, Stress and Opencast coal mining

INTRODUCTION

Super incumbent strata of coal bearing zone remains in equilibrium in the pre-mining state. Mining tends to hamper the state of equilibrium of natural forces or stress in such in super incumbent leading to further strata instability. Opencast coal mining is subjected to such strata instability, principally in two different mining situations, (i) During Highwall formations of in-situ stratum, (ii) Dump instability. Failure of in-situ rock or coal highwalls and dumps, especially OB dumps have caused great concern in Indian opencast coal mining in different geo-mining situations since years.

Post management of any failure remains critical and complicated with situation specific issues. This necessitates preventive actions against the failure of highwall and dump slopes. Numerous technical issues remain behind such ground failure in OC mining.

The study is aimed at conceptualising few situation specific suggestive measures for prevention of ground failures of in-situ highwall and dumps in Indian opencast coal mining.

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MECHANISM OF HIGHWALL AND SLOPE FAILURE

Earth is spinning around the Sun and as well as around its own axis. Stability of the Earth is dictated by the dual equilibrium of centrifugal and centripetal forces, resulting from both of the spinning actions. This dual equilibrium of forces give birth to tremendous static energy inside the crust. So, rock mass, a part of the crust in its virgin state is in equilibrium all along its cross section. Once any opening in the crust is made, such as mining, the void created initiates disturbances in equilibrium in the rocks around with possibilities of release of Earth Energy, in turn failure of rock mass around the openings. In case of opencast mines, such dis-equilibrium is noticed in the form of failure of in-situ highwalls and operational ground failures, such as failure of dump slope. Apart from the disturbance of such geo-equilibrium, lack of physical confinement also contributes in a larger way for failure of in-situ highwalls and dump slopes in opencast mines. The causative factors of ground instability in opencast mining are enumerated as under.

(i) Dis-equilibrium of geo-stress field
(ii) Lack of confinement
(iii) Banded strata structure leading to highwall failures
(iv) Presence of geological disturbances leading to highwall failures
(v) improper highwall geometry
(vi) Weathering effect on highwalls and dump slopes
(vii) Hydrostatic content of strata
(viii) Induced mining effects, such as transportation roads nearby, blasting effects etc.

(ix) Improper ground condition for siting dumps
(x) presence of water body at or near the base of the dump
(xi) Improper dump sequencing, such as presence of fines at the base of the dump leading to gravitational disbalance.
(xii) Lack of artificial protection including base ramp, drainage etc., to the base of the dumps.
(xiii) Lack of scientific design of dumps
(xiv) Lack of arrangement for release of hydrostatic pressure from the dumps
(xv) Improper dump compaction
(xvi) Improper slope angle & dump height
(xvii) Improper soil regeneration / lack of green belt development

HIGHWALL AND SLOPE FAILURE, FEW INDIAN OCCURENCES

Number of incidences or accidents have already taken place in different Indian opencast coal mines either due to highwall failures or due to dump slope failures. Few of such happenings are enumerated as follows.

S.No	Name of the Mine	Date of Incidence/ Accident	Reason	Causality / Loss
1	Hindustan Lalpeth OC (WCL)	August, 1995	Overburden slope failure from a height of 25m due to rainfall	NA
2	Kawadi OC (WCL)	June, 2000	Slope failure of 31 m high over burden bench	10 persons killed
3	Jayant OC (NCL)	December, 2008	Dragline dump measuring 135m (length) x 70m(height) x 6 to 19 m (height across the slope) failed	5 person killed
4	Sasti OC (WCL)	June, 2009	Overburden dump of 73m height failed and collapsed down the pit	2 person killed
5	Lignite mines (NLC)	October, 2002	Around 4 lakh m3 of OB soil collapsed	Toe of the dump moved to a distance of around 530 m
6	Lignite mines (NLC)	May, 2005	Dump slide in the dump yard of bottom bench, mine-IA, NLC	An area of about 70m x 80m was moved down to 25m
7	Basundhara OC (MCL)	August, 2013	Dump failure due to rainfall	14 person killed
8	Bharatpur OCP (MCL)	April, 2013	55m high overburden dump side-casted by dragline against coal rib collapsed over a length of 150m causing fall of about 90,000 m3 OB material	1 fatally injured and 1 serious bodily injured
9	Dhanpuri OC (SECL)	July, 2014	Backfilled overburden measuring 54m (length) X 14 m (width) slided into sump	Two person killed
10	Khadia OC (NCL)	May, 2015	Internal dragline overburden dump failed over a length of 130m.	Burying of 2 dozers, 1 excavator & 1 rope shovel.
11	Amalgamated Konar Khasmahal OCP (CCL)	March, 2016	Overburden bench of 10m high × 35 m length collapsed from a height of 28 m	NA
12	Lalmatia Coal Mines (ECL)	December, 2016	Failure during removal of loose OB. A large area measuring 600 m x 110 m slide down by 30 m.	23 persons reportedly buried in OB dump slide
13	Bharatpur OCP (MCL)	23 July 2019	Failure possibly due to blast induced ground vibration. Debris of about 100 feet depth buried many person and equipment's.	4 miner dead, 10 injured in the landslide caused by OB dump failure.

CONCEPTUALISED PREVENTIVE ACTIONS

Following are few of the preventive measures against inequalities of the ground movements during opencast mining conceptualised based on Indian coal mining experiences.

Survey with theodolite and prism combination:

Surveying with theodolite and prism combination is the simplest form of monitoring ground movement along the highwalls and dump slope in opencast mining. With this methodology, relative movement of venerable ground position along the highwall sides and dump slope sides are identified and are monitored for subsequent prevention of untoward incidences in the nearby influence zone.

Survey with total station and prism combination

Surveying with total station in combination with prism is similar to theodolite with prism but, it is with more degree of precision in terms of monitoring ground movement of highwall and dump slope in even minute manner.

Monitoring of stress, induced in the highwall or slope

Relative movement inside highwalls and dump slopes cause change in rock stress. Such induced rock stress can be monitored for anticipation of highwall and slope failures in open cast coal mines. Following is a case study of stress monitoring in Highwall mining in a CIL mine.

The case study relates to monitoring of stress, induced upon high walls in Highwall mining, being practiced in Sharda opencast mine of SECL. Vibrating wire type of stress meters were installed in the horizontal bore holes drilled to the accessible location of stiff points of high wall. Purpose of the stress monitoring was to safe guard the operations in the trench, underneath from possible highwall failures. Following Fig 1 & 2 show the stress profile at two different stiff locations of high wall during the year 2015.

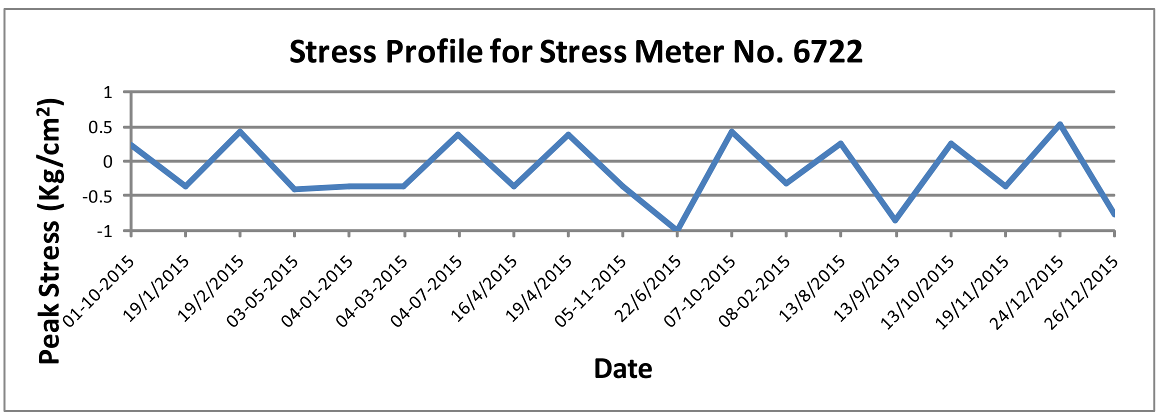

Fig. 1: Stress profile, Stress meter no. 6722

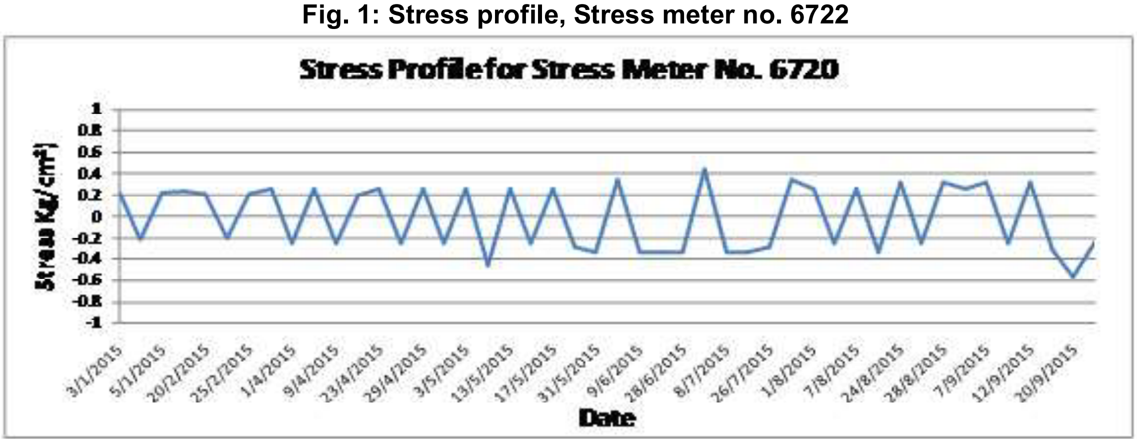

Fig. 2: Stress profile, Stress meter no. 6720

The summary of the analysis of the stress profiles drawn on the Fig. 1 & 2 says the following.

(i) Stress variation ranged from +0.52 Kg/cm^2 to -0.78 Kg/cm^2 at the location with Stress Meter no. 6722.

(ii) Stress variation ranged from +0.34 Kg/cm^2 to -0.46 Kg/cm^2 at the location with Stress Meter no. 6720.

(iii) Thresh-hold limit value (TLV) of peak stress (cumulative), established for the operation was 27 Kg/cm^2.

(iv) From the stress Profile, it was ascertained that, no appreciable change in stress except few minimal variations (both peaks and troughs) was observed round the year, round the station locations. Such variations were+0.52 Kg/cm^2 to -0.78 Kg/cm^2 (maximum) as the rate of change. The threshold limit value of cumulative stress in the workings at any place is 27 Kg/cm^2 with FOS=2. Cumulative profile of stress also exhibits smooth graph saying about no abnormal stress situation.

Monitoring of induced stress upon such high walls or ribs, installing stress meters may be very helpful for control measure decisions at right time with subsequent preventive actions. Stress meters are very low cost strata control equipment, easy to install and monitor. Monitoring is done remotely with wire extension ensuring safety of persons involved in the monitoring operation.

Following figure shows the pictorial view of a vibrating wire type stress meter.

Fig. 3: Stress meter

For further safety relating to ground control in all kinds of coal mining, stress monitoring may be very helpful with kinds of control measures projected as follows.

Monitoring of ground movement along the highwall or slope using drone technology:

Drones with high resolution optical or laser cameras have proved to be a boon in technological development for aerial monitoring of different operations with wide range of applicability in different sectors of society including industrial uses. Monitoring of relative movement along the high wall surfaces and dump slope surfaces is very possible with drone technology. It may result in prevention of accidents or incidences due to high wall or slope failures. Following is a pictorial illustration of slope monitoring with drone technology in coal mining

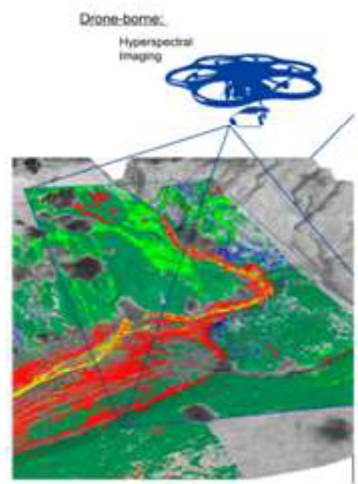

Fig.4 : Slope monitoring with drone technology

Monitoring of ground movement along highwall or slope using slope monitoring radars

Slope monitoring Radar technology has proved its effectiveness for prevention of accidents or incidences due to highwall or slope failure in the opencast coal mines around the globe. Slope monitoring radars are already in use in opencast mines of CIL, in the subsidiaries, WCL, SECL and NCL. Following is a pictorial illustration of slope monitoring radars

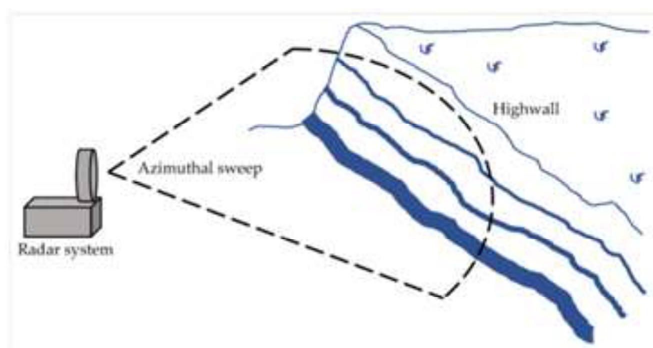

Fig.5 : Slope monitoring with radar technology

CONCLUSION

Opencast Coal Mining dominates the operation scenario in the present coal mining industry. Failure or collapse of in-situ high walls and ribs in opencast coal mines is a profound contributor for mine accidents and loss of lives in the current scenario. Such inequalities are highly situation specific. Preventive measures against accidents or incidences due to failure of highwalls or slope cannot be tailor made. Rather, it should be opted with orientation of the mining situation, for which few solutions or suggestions have been conceptualised in this paper.

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Identification of Strata Zones with Hidden Slips During Underground Coal Mining, A Strata Control Monitoring Approach

Dr. S. K. Jena*

INTRODUCTION

Presence of geological disturbances, either hidden or prominent influence Physico-Mechanical properties of host rock in under ground mining. Geological disturbances, especially hidden slips / dislocations attribute to most of the premature roof and side collapses. Pre- knowledge of presence of hidden slips in host rock geometry enhances awareness against strata failures and even raises scope for prevention. So, Govt. of India is in its best efforts through National Safety Conferences (since 7th Safety Conference) for Coal mining, for innovation of equipment to detect hidden slips well in advance of workings / failures. However, approaches of modern Strata Control Monitoring and instrumentation indirectly identify the presence of hidden geological discontinuities or slips within the host rock and become helpful for prevention of accidents or incidences due to strata failure. The paper is a conceptual one for anticipation of hidden slips during coal mining.

ENERGY MECHANISM OF THE EARTH

Earth is spinning around the Sun and as well as around its own axis. Stability of the Earth is dictated by dual equilibrium of centrifugal and centripetal forces, resulting from both of the spinning actions. This dual equilibrium of forces gives birth to tremendous static energy inside the crust. Rock mass, a part of the crust in its virgin state is in equilibrium all along its cross section. Once any opening in the crust is made for mining, the void created, initiates disturbances in equilibrium in the rocks around with possibilities of release of Earth Energy through weaker stratum or formations, in turn failure of rock mass around the openings.

STRATA MECHANISM AND ROCK FAILURE

Host rock geometry in coal mining is represented by stratified rock masses of relative weaker strength. Such stratifications are compound and unite in their virgin state before any kind of mining. Mining underneath (Both development and depillaring) tend to develop strain along weaker bedding planes generating bed separation, called as '**Dilation**'. Geological disturbances pose for potential weak planes causing easy and early release of geo-energy and subsequent dilation. Hidden geological disturbances, especially hidden slips are even dangerous formations, where dilation starts erratically and with irregular behavior pattern, generally causing premature collapses.

By the action of gravity, the dilated mass or stratums are supposed to sag along its span within the mining voids or openings, subsequently reducing the gap between the floor and roof of workings, called as '**Convergence**'.

Sagging of the stratums from the roof under the influence of dilation and subsequent convergence tend to exert certain '**Load**' on the support system and remaining pillar sides either static or dynamic.

In case of depillaring workings, layers of roof mass go on departing up ward with the increasing span of goaf width and subsequent strain or loading effect is revealed over working area as loading zone, requiring additional supports (advance supports). Proper assessment of extent and magnitude of dynamic loading effect becomes helpful for subsequent assessment of support resistance to ensure stability of roof at the face and within advance support area of depillaring workings. Presence of any hidden slip with in working limits may facilitate release of loading effect causing premature collapses. Early detection of the hidden slip may enable to create sufficient support resistance so that the premature collapse can be prevented and load may be diverted to goaf.

Dilation or Bed separation causes change in '**Stress**' from its in-situ state, which in turn is propagated in the rocks around. Such induced effect of stress can be revealed in

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the workings with the help of instrumentation, aiding anticipation of strata movement.

IDENTIFICATION OF STRATA ZONE WITH HIDDEN SLIPS

Bed separation or dilation of roof strata during mining can be identified and measured by installing instruments like, Tell Tales, Multi Point Bore Hole Extensometers, Magnasonic Extensometers, etc. Also effects of dead and dynamic loading in the under ground workings can be identified through instruments like Stress Meter, Load Cells and Remote Convergence Indicators etc. Usually, the instruments are installed in series at the strategic locations in the underground workings. Disturbances or voids created due to mining initiate bed separation or dilation in the strata horizons, further causing convergence, load and stress, which are identified through the strata monitoring instruments installed in series. In the initial stage of operation, the change in dilation, convergence, load and stress show a uniform and symmetrical trend irrespective of presence of minor geological disturbances or hidden slips. Any such disturbances with in roof mass exhibit behavior of compactness and there remains a continuity of strata pressure along bedding planes. As the workings progress further, there becomes a chance of relative movement along the hidden geological disturbances or slips due to continuous increase in induced mining effects. Any such relative movement or dynamism along the hidden disturbances or slips causes release of strata pressure disrupting the propagation of loading effect, further. As a result, readings from the strata control instruments in series exhibit sudden drop or reduction of values of dilation, convergence, load and stress beyond a particular zone of stratum. The zone or place beyond which the instrument readings get droped is identified as the zone with presence of hidden geological disturbances or slips. This phenomena is possible both during development and extraction operations. Such identification of hidden slips helps in planning preventive measures against anticipated strata failure and accidents.

CONCLUSION

Rock characteristic in its virgin state is quite unpredictable. Mining induces changes in several rock parameters including strata dilation, convergence, axial load, load on pillars, load on supports and stress etc. Such changes can be inculcated to assess strata dynamism during active mining. Geological disturbances are very sensitive to such changes, which become the source of release of geo – energy. Attribution of hidden slips for such energy releases, often lead to premature collapses. Exact location of a hidden slip is a very difficult task in terms of devising equipment. So sincere efforts of analytical strata control monitoring becomes a hope for identification of strata zone with hidden slips or anticipation of hidden slips, and subsequent prevention of uneventualities.

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