IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN: 2278-487X, p-ISSN: 2319-7668
PP 39-49
www.iosrjournals.org

Optimization of Air Pollution Due To Coal Dust at Open Cast Mines

M. Pradeep Kumar[1], Dr. N.V.S. Raju[2], A. Rameshwar Reddy[3] & Srija Nataraj[4]
[1]*Research Scholar, JNTUH Kukatpally, Hyderabad TS – India*
[2]*Professor of Mechanical Engineering, JNTUH CEJ, Karimnagar, TS – India*
[3]*M.Tech Scholar, JNTUH, Kukatpally, TS – India*
[4]*M.Tech Scholar, Sreedattha Engg. College, Ranga Reddy, TS- India*

Abstract: *Coal mining is one of the major activities causing an increase in pollution and exerts a tremendous long lasting impact on the environment. Mining activities have been found to pollute the atmosphere which affects the human health, flora and fauna, increasing the atmospheric temperature. Mining of coal is done in two ways, open cast mining and underground mining. To maintain the energy demand, opencast mining has been growing at a phenomenon rate in India. Among all the operations performed in open cast mines, blasting is one of the most prominent and common operations which carried out in almost every mine that have a significant effect on environment. The dust grains emitted during blasting are of major concern for the mining operators and local communities. The presence of this dust in air is abnormally high. There are several being presently existed to control the dust yet they are insufficient. It is intended to put effort in this direction to evaluate various methods in controlling the dust and hence the air pollution in the coal mines through this project.*

This work was done in view and observations made at Singareni Collieries Company Limited (SCCL) located in Telangana state, is the major source in producing the coal in the state. A designing strategy is implemented using the concepts of moulding, blasting and weight analysis to optimize the coal dust generated due to blasting in opencast mining. In practice, the explosives are placed vertically to the ground surface which increases the coal dust during the blasting. This paper deals with the experimentation of explosives in different angles to decrease the dust which is generated during the blasting in opencast mining. The optimal angle is calculated by analyzing the results of all the experimentations for each and every angle. Also to know the quality level of the process, the experimentation results were graphed using the concept of control charts.

Keywords: *Pollution, Optimizing coal dust, Open Cast Mines, Optimal angle*

I. Introduction

Coal is the quite riotous fossil fuel on the earth. Its predominant use had always been for producing heat energy. From the early days to the present time, most of the power plants generate electricity with the use of coal by extracting it from the earth's surface by the process of coal mining. Mining is the process of extracting minerals and other deposits from the parent ores that are present in the earth's crust. Coal mining involves drilling, blasting, mucking (material removal), and the various operations on the surface necessary to remove the ore and to transport the miners. Drilling shot holes and blasting the ore is a standard process. Mining of coal is done in two ways, open cast mining and underground mining. In the early days, there were only underground coalmines. Where workers only but not machines can do work. This was very dangerous particularly, while workers working under ground. In order to overcome these dangers, the Open Cast Projects have been developed. In addition to the advantage of safety, the manpower requirement in these projects is also less as compared to that for the underground mines. Machines only in Open Cast Mines carry out almost total work.

The most vital operation in open cast coal mining is blasting. Mostly, in all types of mining, rocks are broken by drilling and blasting. The process of cracking and fracturing the material is done by the use of explosives and this process is called as blasting technology. In olden days, blasting was done with the black powder, but today an enormous advancement and changes was observed in explosive materials, blasting techniques and understanding of the mechanics of rock breakage by explosives. A successful mining operation is determined by efficient and effective blasting design and its execution. Improper blasting design and poor practices may lead to a negative impact, also excessive explosives at a mine result in caving and damage to internal structure of rocks.

This work was done in view and observations made at Singareni Collieries Company Limited (SCCL) located in Telangana state, is the major source in producing the coal in the state. Totally, there are 30 underground mines and 16 Open Cast Projects in this belt with a man power of 58,837. In general, the explosives are placed vertically to the ground surface which results in high amount of coal dust during the blasting. This paper deals with the experimentation of explosives in different angles to decrease the dust which is generated during the blasting in opencast mines. The optimal angle is calculated by analyzing the results of all the experimentations for many angles, repeated five times for each angle.

Objectives of the present work

- To study the environmental impact of coal dust in open cast mining
- To identify the blasting designs used in coal mines
- To design a strategy for minimizing the dust that is generated during the blasting in open cast mines

Figure 1: Blasting in Open cast mine

II. Literature Review

Partha Das Sharma deals with environmental pollution due to coal mines and its control measures. In this paper he predicted air pollution due to emission of methane, sulfur dioxide and oxides of nitrogen, water pollution, land degradation, noise pollution, solid waste and deforestation. He also deals with some of the control measures like subsidence, abandoned mines, external overburden dump, mine fire and water and air pollution control.

M.K Ghosh advocated that open cast mining creates more air pollution in respect of dust. His investigation was conducted to evaluate the impacts on air quality and the sources of pollution were identified. It was found that particulates are more respirable in nature were found to be very high. This study revealed that more stringent air quality standards should be set for coal mining areas which will not make harmful to the human health and vegetation.

Ratnesh Trivedi examines different sources of dust generation and quantifies dust emission rates from different point, area and line sources considering background dust concentration. Air quality modeling using Fugitive Dust Model (FDM) reveals that dust generated due to mining activities does not contribute to ambient air quality significantly in surrounding areas beyond 500m in normal meteorological conditions. Predicted values of total suspended particulate matter using FDM are 68-92% of observed values. A management strategy is formulated for effective control of air pollution at source and other mitigative measures including green belt design have also been recommended.

A. Alia & M. Souli came up with an air- blast simulation which is described using Eulerian multi-material formulation. In order to validate the numerical approach and prove its ability for high pressure wave propagation, comparison of two examples with experimental results is performed. Both simulations lead to the same prediction for the pressure time history. Good agreement between the test results and the predicted pressure response is achieved.

John M. Veranth & Gauri sesahadri studies that vehicle-generated road dust was measured under stable atmospheric conditions at a flat site in the Utah west desert, and the horizontal flux of the dust was calculated by integration of interpolation functions that are fit to wind speed and dust concentration measurements at discrete heights.

M. R. Kolhe studied the impact of coal industry on environment. At a glance he reviewed the disasters in coal mining, oil & gas exploration. Further he stated the advantages and disadvantages of coals as a fuel in power plants. He concluded that land impacts of coal production and use are regulated primarily under the various Acts and Laws. He felt that the coal mining operations should be conducted with a proper planning and design strategy in order to protect the communities and environment where coal is being mined.

A.M. Neale pointed various reasons for the incorrect blasting which includes inaccurate and improper drilling, pre-stripping, lack of experience, highwall damage. Further he analyzed the different methods that improve the effectiveness of blasting. These methods are, change in blasting design, good control over blasting, implementation. Finally, a model blast design and results were programed and simulated. By modelling changes in pattern, explosives and drill bits, it was shown how this simulator can be used as a tool to make more informed decisions about design changes.

Ting Ren summarized the use of CFD modeling in coal mining industry. Computational fluid dynamics or CFD has become a powerful tool to assist mining engineers and find solutions to these problems. The use of CFD modeling in gas management and drainage, heating control, and longwall dust control strategies have been studies. CFD modeling results must be validated against field data and engineering judgements and used as a tool of integrated system combining other computing and experimental methods

Greg Black presented a report to evaluate a hydro code, which is a type of computer program, called AUTODYN for the use of modeling blast loads on bridge sections. Blast modeling is necessary due to the threats posed by terrorist attack and current technology makes computer simulations cheaper than experimental testing. It discusses various options presented by AUTODYN which set it apart from other hydro codes and other available software.

III. Impact On Environment Due To Coal Mines

The mining is a most hazardous activity that has significant effect on environment. The impact of environment due to mining is more significant and long lasting because of poor management practices and rehabilitation of mined areas. The environmental effect is becoming an important issue for the industry and its workforce. Many issues are related with coal mines which includes waste management, air pollution, land use and water pollution. Apart from these, coal burning produces million tons of solid waste products annually. Coal mines being very hazardous, many disasters in the past were happen due to coal mines and the list is long. Some problems like roof collapse, suffocation, gas explosions and gas poising are associated with underground mining while mine wall failures, vehicle collisions are associated with open cast mines. Also mining operation like making holes with drill, explosions and transporting the coal from one place to other are the causes for air pollution.

In underground mining the coal is dig for deeper in depth, for which the amounts of rock are brought up from the bowels of earth. In this type of mining, unique dangers include the possibility of cave-in, mine fire, explosion, or exposure to harmful gases, in addition, dust generated by drilling in mines places miners at risk of developing serious lung diseases. In any system of mining there is potential environmental risks introduced. The amount of dust generated in open cast mining operations can be carried to nearby towns by the wind. These dust particles can cause all kinds of health problems for humans who are exposed to it. There are several causes for air pollution, out of all the dust particle released during the blasting operation of coal is found more serious issue. Coal dust inhalation can cause black lung disease. Miners and those who live in nearby towns are the most affected. Cardiopulmonary disease, hypertension, COPD, and kidney disease are found in higher than normal rates in people who live near coal mines.

IV. Effect Of Blasting And Blast Designs

There are many factors responsible for production and diffusion of mine dust particles, some of which occur during loading and transport of coal, and rock breakage. Among all the operations performed in open cast mines, blasting is one of the most prominent and common operations which carried out in almost every mine that have a significant effect on environment. The dust grains emitted during blasting are of major concern for the mining operators and local communities. The amount of dust generated and the impact of its diffusion depend substantially on geological, blasting and meteorological conditions. A cloud of dust grains can be raised to substantial heights depending on the blasting design and techniques. The dust grains which were exposed during blasting will disperse for long distances. Some of the dust settles in and around the mine area and this again may rise due to mining operations such and movement of machineries and transportation. Diffusion of this dust may affect the nearby regions and may cause several health problems which leads to a denial public impact on open cast mining. There were many blasting strategies developed in order to minimize the dust generated.

The most commonly used blasting technique is bench blasting in which blasting takes place in a vertical or sub-vertical hole or a row of holes towards a free vertical surface. Short-hole blasting is one of the type of bench blasting, where drilling is limited to 1.2 m to 5.0 m length and hole diameters up to 43 mm. INCO developed Crater blasting in the mid 1970's for primary stoping, pillar recovery and raising. In opencast mines both vertical and inclined holes parallel with bench face is practiced. Row of the holes may be in single or multiple. So there are mainly two types of blasting pattern followed in opencast mines. These are:

a) Single Row blasting pattern
b) Multi-row blasting pattern.

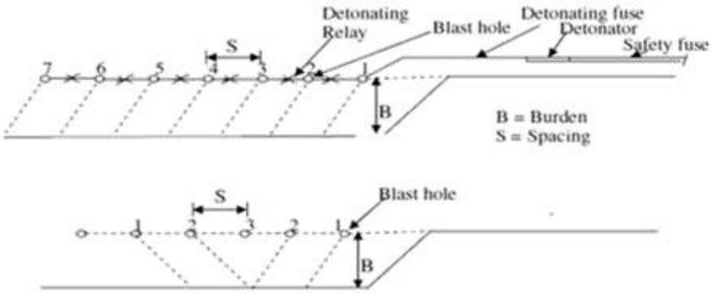

Figure 2: Single Row blasting pattern

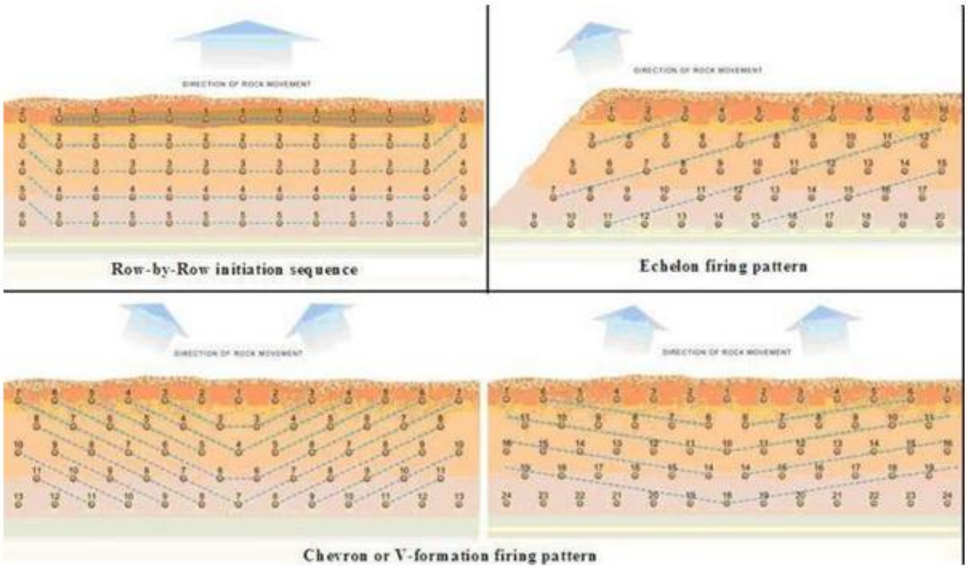

Figure 3: Multi-row blasting pattern

Apart from the geometry, the design of blasting depends on many variables. There are two variable in blasting design, controllable and uncontrollable. Controllable variables are those which we have control over that. Some of the controllable variables are listed below.

- Hole diameter
- Hole depth
- Sub-grade drilling
- Stemming distance
- Stemming material
- Burden and spacing
- Number of hole in the blast
- Direction or inclination of the explosives

On the other hand, uncontrollable variable are those which we do not have control such as geology, rock characteristics and regulations or local specification etc.

V. Proposed Method

According to a 2011 report in the journal science, Surface mining has caused numerous environmental problems which mitigation practices have not successfully addressed. For example, valley fills frequently bury headwater streams causing permanent loss of ecosystems. In addition, the destruction of large tracts of forests has threatened several endangered species and led to a loss of biodiversity. In order to overcome the problem causing damage to the environment a few alternate methods are proposed. Blasting design in open cast mining has a significant impact on environment. The correct design of blasting variable may considerably minimize the coal dust into atmosphere. Among all blasting variable, inclination of explosives has major contribution in diffusing the dust into atmosphere. It is proposed to modify the method by placing bombs at inclination. Various inclinations may be tried out to control the coal dust flying into the air directly. Some replicated models have been worked out to know the direction and height of the dust particle. In this model some small bombs such as the crackers used during Diwali festival, are placed in sand mould with inclination. The path by which sand is travelling into air is recorded by video-graphing through a digital camera. Scale is taken vertically along the direction of dust particle.

VI. Methodology And Experimentation

Various inclinations may be tried out to control the coal dust flying directly into the air. Some replicated models have been worked out to know the direction and height of the dust particle. In this model some small bombs such as the crackers used during Diwali festival, are placed in sand mould with inclination. The path by which sand is travelling into air is recorded by video-graphing through a digital camera. Scale is taken vertically along the direction of dust particle.

During experimentation, we have weighted the mould before and after blasting and collected the dust that fell in the experiment area and also weighed it. The sum of weight of mould after blasting and sand collected i.e., sand residue is calculated. The difference b/w the weight of mould before blasting and sum calculated just before gives the weight of amount of sand in to air. For considered angles we have done five experiments each done in the same manner as like as before.

Figure 4: Mould before blasting **Figure 5:** Mould after blasting

Casting of mould for inclined and vertical holes are made using sand casting. Mould is prepared using cope and drag initially pipes of same diameter are placed at different inclinations in different mould and then wet sand is poured on it. Ramming is done on sand to get stiffness to soil. The mold is left undisturbed for three days for drying. After the mold gets dried the pipe is removed carefully and bomb is placed in the slot. Bombs are lightened from the top of the mold. Scale is drawn in vertical direction to know the height of dust particle. The dust exploded outside is collected and weight analysis is done to know the quantity of dust entered in to the atmosphere.

Figure 6: Working model **Figure 7:** Weighing arrangement

Table 1: Inclined vertically to surface

	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5
M-1	22	21.5	20.4	21	21.5
M-2	21.5	21	20	20.5	20.8
M-3	0.066	0.047	0.123	0.222	0.212
M-4	0.434	0.453	0.277	0.288	0.488
M-5	105	45	95	110	55

M-1	Weight of the mould before blasting (kg)
M-2	Weight of the mould after blasting (kg)
M-3	Sand residual (kg)
M-4	Amount of sand into the atmosphere (kg)
M-5	Height to which the dust raised (cm)

Figure 8: Inclined vertically to the surface **Figure 9:** Inclined at 80º to the surface

Average value of height and quantity of dust:

Average height to which the dust raised during blasting = (105+45+95+110+55)/5 = 81.66 cm Average amount of dust entered into atmosphere = (0.434+0.453+0.277+0.288+0.488)/5 = 0.388 Kg.

Table 2: Inclined at 80º to the surface

	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5
M-1	23	23.5	22.8	23	23.5
M-2	22.5	23	22.3	22.6	23
M-3	0.095	0.092	0.208	0.22	0.128
M-4	0.405	0.408	0.292	0.18	0.372
M-5	50	100	60	70	70

Average value of height and quantity of dust:
Average height to which the dust raised during blasting = (50+100+60+70+70)/5 = 70 cm
Average amount of dust entered into atmosphere = (0.405+0.408+0.292+0.18+0.372)/5 = 0.331 Kg

Table 3: Inclined at 70º to the surface

	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5
M-1	22	24	24.25	23.5	23
M-2	21.5	23.7	23.75	22.9	22.5
M-3	0.038	0.171	0.159	0.175	0.198
M-4	0.462	0.129	0.341	0.425	0.302
M-5	70	55	140	100	80

Figure 10: Inclined 70º to the surface

Figure 11: Inclined 60º to the surface

Average value of height and quantity of dust:
Average height to which the dust raised during blasting = (70+55+140+100+80)/5 = 88.33 cm. Average amount of dust entered into atmosphere = (0.462+0.129+0.341+0.425+0.302)/5 = 0.338 Kg.

Table 4: Inclined at 60º to the surface

	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5
M-1	23.6	24	24.1	23.6	24
M-2	23	23.3	23.3	22.9	23.3
M-3	0.213	0.201	0.39	0.311	0.25
M-4	0.397	0.499	0.41	0.389	0.45
M-5	140	125	100	110	130

Average value of height and quantity of dust:
Average height to which the dust raised during blasting = (140+125+100+110+130)/5 = 88.33 cm. Average amount of dust entered into atmosphere = (0.397+0.499+0.41+0.389+0.45)/5 = 0.429 Kg.

Table 5: Inclined at 50º to the surface

	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5
M-1	20	22	21	22	20
M-2	19.2	21	20.5	21.3	19.4
M-3	0.28	0.431	0.28	0.275	0.154
M-4	0.52	0.569	0.22	0.425	0.446
M-5	95	100	180	150	100

Average value of height and quantity of dust:
Average height to which the dust raised during blasting =(180+100+95+150+100)/5 = 125 cm. Average amount of dust entered into atmosphere =(0.52+0.569+0.22+0.425+0.446)/5 = 0.4363 Kg.


Figure 12: Inclined at 50º to the surface


Figure 13: Inclined at 45º to the surface

Table 6: Inclined at 45º to the surface

	Exp-1	**Exp-2**	**Exp-3**	**Exp-4**	**Exp-5**
M-1	20.4	21.25	20.8	20.5	21.6
M-2	19.7	20.5	20.3	19.9	21
M-3	0.361	0.257	0.244	0.255	0.213
M-4	0.339	0.443	0.256	0.345	0.387
M-5	120	100	130	105	130

Average value of height and quantity of dust:
Average height to which the dust raised during blasting = (120+100+130+105+130)/5 = 116.66 cm. Average amount of dust entered into atmosphere = (0.339+0.443+0.256+0.345+0.387)/5 = 0.354 Kg

VII. Observations

Data for the total of five variable have been tabulated, which includes the weight of the mould before and after blast, sand residual, amount of sand into atmosphere and height at with the dust has raised. Among all these variable, height raised by the dust and sand mixed into atmosphere are the critical factors that affect the atmosphere. This analysis majorly concentrates on these two parameters. As for each inclination, five experiments were tried out, data for dust flow and height raised have been show in the table no. 7 and 8. Again for each inclination, the average and range were calculated.

a. Dust Flow Analysis

Table 7: Data related to amount of sand in to the atmosphere with respect to each angle

Angle	W_1	W_2	W_3	W_4	W_5	Wavg	R_w
45º	0.339	0.443	0.256	0.345	0.387	0.354	0.187
50º	0.52	0.569	0.22	0.425	0.446	0.436	0.349
60º	0.397	0.499	0.41	0.389	0.45	0.429	0.11
70º	0.462	0.129	0.341	0.425	0.302	0.338	0.333
80º	0.405	0.408	0.292	0.18	0.372	0.331	0.228
90º	0.434	0.453	0.277	0.288	0.488	0.388	0.211
Avg						0.379 33	0.236

- W_1, W_2, W_3, W_4, W_5 are the amounts of sand in to the atmosphere in K.G.
- R_W is the range of amounts of sand in to the atmosphere. i.e., difference between max & min amounts

b. Height Analysis

Table 8: Data related to height during blasting with respect to each bomb inclination

Angle	H_1	H_2	H_3	H_4	H_5	Havg	R_H
45°	120	100	130	105	130	116.66	25
50°	95	100	180	150	100	125	85
60°	140	125	100	110	130	121	40
70°	70	55	140	100	80	88.33	85
80°	50	100	60	70	70	70	50
90°	105	45	95	110	55	81.66	65
Avg						100.44	58.33

- H_1, H_2 H_3, H_4, H_5 are the max heights to which the dust raised in cm.
- R_W is the range of heights to which the dust raised. i.e., difference between max & min heights

VIII. Results

Efforts are put on studying the proposed method to reduce the maximum height of the dust particles reached during blasting and the transport of dust particles to the surrounding areas and hence it has paved the way to minimize the presence of cold dust particles in the air. Experimentation has been done and the values of maximum height of the dust particles and also the dust released into the atmosphere have been taken. These values are tabulated in the table no 9. Also in order to know the acceptance level of the maximum height of dust flow and amount of sand into the atmosphere, control chart were used. Detailed description of control limits and its calculation is given below.

Table 9: Range of Average maximum height and amount of sand into the atmosphere

Angle	Avg Maximum Height (in cm)	Range (R_H)	Avg amount of sand into atm (in Kg)	Range (R_W)
45°	116.66	25	0.354	0.187
50°	125	85	0.436	0.349
60°	121	40	0.429	0.11
70°	88.33	85	0.338	0.333
80°	70	50	0.331	0.228
90°	81.66	65	0.388	0.211
Avg	100.44	58.33	0.37933	0.236

Control Limits

An insight into a process can be achieved through control charts. A control chart is used to compare graphically the process performance data with calculated statistical control limits which act as limiting lines on the chart. Control charts are the tools to check if the process is under control or not. The control charts focus on several aspects such as controlling and monitoring the process and performance; gaining insight into the process; identifying and reducing the variation; determining the process capability; and identifying the presence of trends, shifts, and other patterns in the process. The level of quality, characteristic and consistency of performance can be obtained by Mean-Range Charts. Mean-Range Charts are nothing but Quality Control Charts. The control limits for the charts can be calculated by the following formulae

Control limits For

For R-Chart, UCL= D_4 * and LCL= D_3 *

Where= =

A_2 = Control Chart Factor for - Chart

D_3 and D_4 Control Chart Factors for R-Chart

n	A_2	D_3	D_4
2	1.880	0	3.268
3	1.023	0	2.574
4	0.729	0	2.282
5	0.577	0	2.114
6	0.483	0	2.004
7	0.419	0.076	1.924
8	0.373	0.136	1.864
9	0.337	0.184	1.816
10	0.308	0.223	1.777

Sample calculations

For Bomb inclination Vs Average of max heights graph

UCL= A_2=0.483, for n=6 i.e., 6 different angles.

LCL=

For Bomb inclination Vs Range of max heights graph

UCL= D_4 * = 2.004*58.33 = 116.89 D_4=2.004 for n=6

D_3=0 for n=6

Graphs are drawn between angles of holes, maximum height of the dust, and dust dispersion to know the level of quality, characteristic and consistency of performance. Initially the upper and lower control limits were calculated and then the graphs are drawn between the bomb inclination and range, mean of maximum height, dust flow which are shown below.

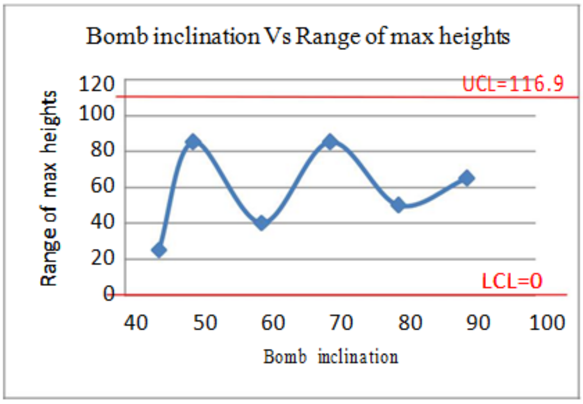

Figure 14: Range Chart for Bomb incl. and max height

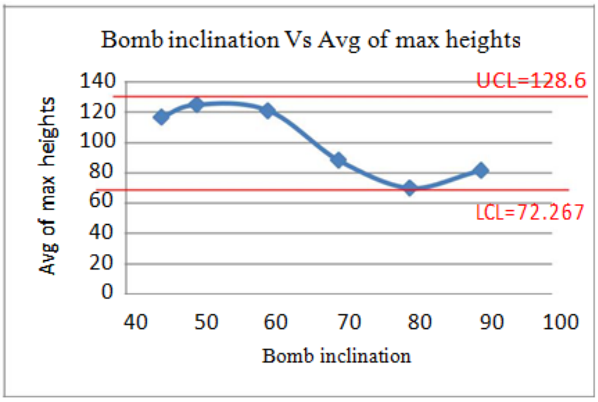

Figure 15: Mean Chart for Bomb incl. and max height

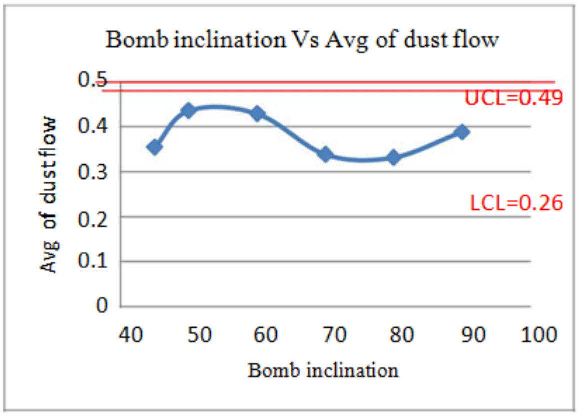

Figure 16: Range Chart for Bomb incl. and dust flow

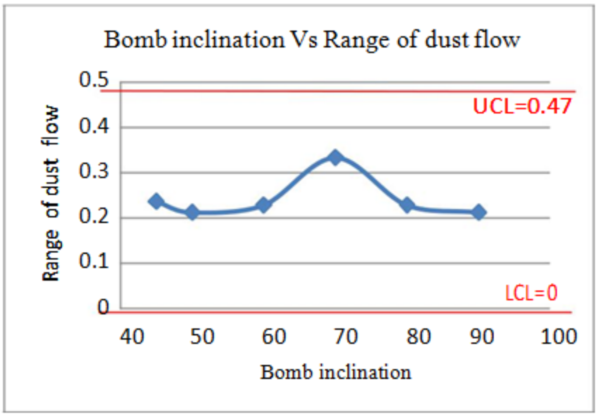

Figure 17: Mean Chart for Bomb incl. and dust flow

IX. Conclusion

From the table no. 9 it is clear that the optimum angle is 80º. The minimum height to which the dust is dispersed is at 80º and the optimum angle for dust flow into atmosphere is also 80º. From the graph Bomb inclination Vs Avg of max heights it is observed that the lower limit of the graph is exceeded. The shift is gradual shift and also it is positive. From the graph it is observed that the optimum angle is 80º i.e., the height to which the dust raises in to the atmosphere during blasting is minimum and the graph exceeds the lower limit at 80º. Hence the shift is positive (As per quality control charts: Mean-Range chart properties)

From the graph Bomb inclination Vs Avg of dust flow it is clear that the dust flow is optimum at 80º and the entire curve lies within the lower and upper limits. And also from the both graphs i.e., Bomb inclination Vs Avg of dust flow and Bomb inclination Vs Range of dust flow the curves lies between the lower and upper control limits. It is better to place the explosives at an inclination of **80º** for optimum dust flow and height to which the dust raises in order to reduce the air pollution due to coal dust in open cast mining.

References

[1]. Dr. N.V.S. Raju ―Reliability Centered Maintenance Models for Mining Machinery", Lambert Academic Publishing, 2012. ISBN: 978-6591-0809-9

[2]. Dr. N.V.S. Raju "Total Quality Management" Cengage Learning India Pvt Ltd.

[3]. M.K Ghose "Air pollution due to opencast coal mining and the characteristics of air-borne dust – an Indian scenario" centre of mining environment, Indian school of mines, Dhanbad (2001)

[4]. Ratnesh Trivedi "Dust dispersion modelling using fugitive dust model at an open cast coal project of western coal fields, India" central institute of mining and fuel research, Dhanbad, India

[5]. P.C. Mishra and Shanbhu Jha "Dust dispersioin modelling in in open cast coal mines and control of dispersioin in Mahanadi coal fields of Orissa" ISSN: 0973-7049, December 10-12, 2010, sambalpur university.

[6]. A.M. Neale "Blast optimization at Kriel Colliery" /The Journal of the Southern African Institute of Mining and Metallurgy/ Volume 110/ April 2010
[7]. Daniel Thorn "Optimisation of Overburden Blasts at Glencore Ulan Surface Coal Operations" / Faculty of Engineering and Information Sciences/ Coal Operators' Conference
[8]. Manmit Rout & Chinmay Kumar Parida "Optimization Of Blasting Parameters In Opencast Mines" / Department of Mining Engineering/ National Institute of Technology/ 2007
[9]. Z. Song "A review of real-time optimization in underground mining production" / The Journal of The Southern African Institute of Mining and Metallurgy VOLUME 113 DECEMBER 2013
[10]. Partha Das Sharma - Coal Mining Pollution and its Control Measures", Lambert Academic publishing, Germany. ISBN: 978-8383-8651-5
[11]. Jinesh Vora "Dust Dispersion Modeling for Opencast Mines", Department of Mining Engineering, National Institute of Technology, Rourkela, 2010
[12]. http://technology.infomine.com/reviews/Blasting/welcome.asp?view=full
[13]. https://www.britannica.com/technology/coal-mining
[14]. https://www.worldcoal.org/coal/uses-coal/coal-electricity
[15]. https://www.duke-energy.com/energy-education/how-energy-works/electricity-from-coal
[16]. http://scclmines.com/scclnew/our-business_products-and-services_introduction.asp
[17]. http://scclmines.com/scclnew/company_about-us.asp
[18]. http://www.theworldcounts.com/stories/Negative-Effects-of-Coal-Mining
[19]. https://miningandblasting.wordpress.com/list-of-technical-papers/