A. K. DASH
R. M. BHATTACHARJEE
A. AHMAD
K M. R. SAGESH
and
C. S. SINGH

Mine accident investigation in India: a system approach

Mining has been observed as a high-risk industry for a long time. Accident statistics of Indian mines still shows very high rate of injuries and fatalities. The current death rate per 1000 person employed in coal and non-coal mines is 0.27 and 0.40 respectively. The serious injury rate in the current year is also very high and unacceptable. More disturbing is the fact that a few causes are repeated for fatal, non-fatal and serious accidents. Even though all the accidents are being investigated by different agencies and recommendations are made against them in each cases but still similar accidents are repeated. Therefore question mark is automatically put against the effectiveness of present-day investigation methodology. In this paper a few recent fatal accidents in Indian mines have been reviewed and identified causes and recommendations analyzed. The review highlights certain deficiencies in the current investigation methodology of India. The aim of this study is to analyse the investigation report to identify the gaps in the current investigation procedure (i.e. where are we?) and suggest for changing the focus of investigation from human error to system deficiency i.e. where do we go from here?

Keywords: *Accident; accident investigation; coal mine; gap analysis; system error.*

1. Introduction

These days, workplace accident occur every day and it became worst and known to be a major matter of concerned in almost all types of industry (Rahman et. al, 2014). Mining industry is one of the high risk based industry due to its dynamic nature. Generally same types of accidents repeat because of ineffective accident analysis. Learning from past events is one of the central characteristics for achieving a more resilient system (Cook and Woods, 2006). All of us know that most of the workplace accidents result from unsafe act and unsafe conditions (Dash et. al., 2015-a, 2015-b). The ineffective management system led to unsafe act and unsafe condition at the workplace. But the question is that "what are the root causes for unsafe act and or unsafe conditions"? Is there any other latent cause or weakness in the safety management system that has led to the unsafe act and or unsafe conditions? Hence to identify the system weakness we need to examine the system which might have led to into the accident and this can be done through analytical method like Root Cause Analysis (IAEA, 1999), Swiss Cheese Model (Reason, 1990), Human Factors Analysis and Classification System (HFACS) (Shappell, 2000), Systems Theoretic Accident Model and Processes (STAMP) (Leveson, 2004), Functional Resonance Accident Model (FRAM) (Hollnagel, 2004) etc.

Traditional approaches on the prevention of accident/ injuries in mines reached its limit of effectiveness in improving safety performance and a fresh approach is utmost required (Paul and Maiti, 2007; 2008). So far, most of the Indian mining accidents causing fatal or serious injuries had been investigated mainly to comply with the statutory requirements. Though principally, the purpose of accident investigation is fact finding to prevent recurrence, neither blame fixing nor merely identifying contravention of statute (Bhattcharjee et al., 2014).

In most of the accident investigations, including accidents in Indian mines, only the surface causes or direct causes are identified and responsibilities are fixed against those who are directly involved in those direct causes. Perhaps, that is why similar causes are repeated for most of the accidents and are not prevented as the latent or root causes are not addressed and corrected. It is high time to review the accident investigation methodology and to evolve a suitable guideline to conduct investigation with primary focus on identification of root causes and make suitable recommendations to address the system deficiencies, instead of focusing only at human error, to make the system inherently safe and thus reduce the potential of accidents.

2. Analysis of responsibility for fatal accidents in Indian coal mines

The coal mine fatal accident investigation report from 2007-2009 (DGMS, 2010) are collected and analyzed, to identify the

Messrs. A. K. Dash, Asst. Professor, Department of Mining Engineering, National Institute of Technology, Raipur, R. M. Bhattacharjee, Professor, Department of Mining Engineering, IIT (Indian School of Mines), Dhanbad, A. Ahmad and K M. R. Sagesh, Dy. Directors of Mine Safety, DGMS and C. S. Singh, Senior Manager, Coal India Limited, India. Corresponding author, e-mail: ashishdash1991@gmail.com

TABLE 1: RESPONSIBILITY FOR FATAL ACCIDENTS IN INDIAN COAL MINES

	Responsibility	No. of accidents in the year		
		2007	2008	2009
1.	Misadventure	3	4	2
2.	Management	6	9	11
3.	Management and subordinate supervisory staff (SSS)	13	15	12
4.	Management, SSS and co-worker	3	4	1
5.	Management, SSS, co-worker and deceased	-Nil-	-Nil-	2
6.	Management, SSS, co-worker, deceased and injured	-Nil-	-Nil-	2
7.	Management, SSS and deceased	2	6	6
8.	Management, SSS and injured	1	-Nil-	1
9.	Management, shot-firer, co-worker and deceased	1	-Nil-	1
10.	Management, co-worker and deceased	-Nil-	-Nil-	2
11.	Management and deceased	4	3	2
12.	Management and co-worker	5	7	-Nil-
13.	Management and shot-firer	-Nil-	1	-Nil-
14.	Subordinate supervisory staff (SSS)	7	3	7
15.	SSS and co-worker	2	5	-Nil-
16.	SSS, co-worker and deceased	-Nil-	5	3
17.	SSS and deceased	4	2	5
18.	SSS and short-firer	1	-Nil-	-Nil-
19.	Co-worker	8	8	5
20.	Co-worker and deceased	4	5	7
21.	Deceased	13	7	12
22.	Others	-Nil-	1	2
	Total	77	86	83

Source: Directorate General of Mines Safety, Dhanbad, India (DGMS, 2012)

TABLE 2: ANALYSIS OF RESPONSIBILITY FOR FATAL ACCIDENTS IN INDIAN COAL MINES

Group	Groups responsibility	Year		
		2007	2008	2009
1	Only deceased	17% (13)	8% (7)	14% (12)
2	Only management	8% (6)	10% (9)	13% (11)
3	Combination of one or more human entities from SSS, co-worker and deceased	51 % (39)	41% (35)	47% (39)
4	Combination of management error and human error	38% (29)	42% (36)	35% (29)

(Note: In the above table the parenthesis show the number of cases investigation)

contribution of human behaviour in such accident. The responsibility column is subdivided into different categories of management, deceased, subordinate supervisory staff (SSS) and co-worker etc. and also in combination of groups. Table 1 provides the year-wise number of accidents in which different category/groups of entity are responsible for the fatal accidents in Indian coal mines from 2007-2009.

The data of the Table 1 are analyzed to give a clear picture of the percentage of different groups of people involved in the accidents during 2007-2009. Table 2 shows the percentage of different human entity groups like “only deceased” or “only management” or “combination of one or more human entities from subordinate supervisory staff (SSS), co-worker and deceased” or “combination of management error and human error” responsible for the fatal accidents during the said period.

From the analysis of Tables 1 and 2, it is observed that deceased themselves are held responsible for the accident in 17%, 8% and 14% cases in the year 2007, 2008 and 2009 respectively. Whereas management alone or management fault is responsible in 8%, 10% and 13% cases during the same period. In Table 2, group 3 represents combination of one or more human entities from SSS, co-worker and deceased, which accounted for 51%, 41% and 47% of the total fatal accidents, during 2007, 2008 and 2009 respectively whereas combination of individual human error and management lapses contributed to 38%, 42% and 35% of the total fatal accident. This shows that in a large number of accidents, human errors are held responsible. It is mainly because the accident investigation methodology used is highly inclined towards fault finding.

In most of the accident investigations, only the direct causes are identified as main contributory factors for such accidents and the individuals responsible for such contraventions are held responsible for the accident (Bhattcharjee et al., 2014; Bhattcharjee, 2015). Hence, the recommendations are also mainly inclined towards elimination of human error by administrative actions, training, awareness and supervision. Improvement of the safety management system covering the organizational faults, task environment, task conditions and safe work procedure are not given due thrust in the recommendations.

In view of the above observations, it is imperative that the accident investigation methodology should include identification of latent factors or root causes to highlight the weaknesses or gaps in the system and the recommendations should be focused towards improvement of the system, not merely eliminating the human error (Bhattcharjee et al., 2014; Bhattcharjee, 2015).

3. Case studies

In this paper, mine accident investigation reports are obtained from Directorate General of Mines Safety (DGMS), India (DGMS, 2013) and few recent accident investigation reports of Indian mines have been reviewed to examine the nature of causes leading to the accident. Brief description of the accidents and the identified causes including responsibilities are described in the following pages.

3.1 Case study-1

3.1.1 Brief description

In an opencast coal mine "While two trip man were going on a motor cycle after booking their attendance to their place of work, a dumper coming from behind hit the motor cycle, due to which the rider received serious bodily injuries and died on way to the hospital while the pillion rider escaped with minor injuries."

3.1.2 Identified causes

Following causes are identified at the time of accident investigation:

(1) Absence of suitable code traffic rule for separation of heavy vehicle and light vehicle movement in active work place.

(2) Failure of manager and supervisor to ensure compliance of statutory condition.

3.1.3 Responsibility

The manager, agent and technical advisor-cum-contactor's representative are held responsible for the accident.

3.1.4 Gaps in current investigation methodology

The investigation did not reveal the following and raised the following questions:

(1) Whether the management system does provide for establishing different safe operating procedure including the traffic rule?

(2) Why the system failed to identify the non-compliance of statutory conditions before the accident?

(3) Whether the role and responsibility of the manager, agent, and technical adviser and other officials with regard to development of safe operating procedure (code of traffic rule) where clearly defined in the management system?

(4) What is the usual practice of transportation of work person to the work place?

(5) Whether any risk assessment was conducted to identify the hazards and control for transportation of work persons to work place?

(6) Whether there was any control against the hazards due to un-authorized entry into the place of work?

(7) Whether the active work place is isolated by providing suitable fencing, gates, and sentry etc. to prevent unauthorized or uncontrolled movement in the active work place?

In absence of a risk assessment and implementation of effective control against such hazards, probability of such accident remains very high.

3.2 Case study-2

3.2.1 Brief description

In an opencast coal mine "While a dozer was being reversed during preparation of a road at a slurry pond being evacuated, it hit the engine cover of a breakdown excavator lying on the floor causing serious bodily injury to two persons sleeping over it, one of whom succumbed to injuries on the way to hospital after about four and half hour."

3.2.2 Identified causes

Following are the causes of the accident as per the investigation:

(1) The persons were sleeping at the working place while on duty.

(2) The dozer operator failed to ensure that no object or persons were present within its range of travel while reversing the dozer.

(3) The persons, whose presence were not required at the workplace, were present.

(4) The dozer was not having any audio-visual alarm for reversing.

3.2.3 Responsibility

The investigator held the workers (including the deceased) and the dozer operator to responsible for the accident.

3.2.4 Gaps in current investigation methodology

The investigation did not reveal the following and raised the following questions:

(1) Why the workers were sleeping there?

(2) Did they know where the rest shelter was?

(3) What were their jobs on that day?

(4) Were they physically fit for work on that day? Were they under influence of drug or alcohol? Were they fatigued?

(5) Were they trained and properly inducted into the work place?

(6) What was the level of skill, competency and experience of the dozer operator?

(7) Was there any other source of distraction for the dozer operator?

(8) Was there any audio-visual warning system provided in the dozer for reversing? Was it working properly?

(9) What was the operating condition of the dozer?

(10) Is there any procedure to check the dozer condition before starting it?

(11) How was the weather or visibility condition?

(12) Whether this was a routine type work?

(13) Whether a risk assessment was conducted before undertaking such non-routine work?

(14) Whether there was any other assistance to the operator like a spotter etc. for such job?

(15) Whether there was adequate supervision for the job?

(16) Whether task condition like work pressure, last hour of work, last day of roster etc. led to such unsafe act?

Without investigating into these issues, perhaps the investigation outcome cannot be effective to prevent re-occurrence.

3.3 Case study-3

3.3.1 Brief description

In an opencast mine "While a mine worker was crossing a stationary belt conveyor in a coal handling plant, the conveyor started suddenly causing the worker to fall over the conveyor and he got carried away along four belt conveyors and three transfer points and finally fell into a RCC bunker from a height of about 28m over loose coal, the worker succumbed to the injuries on the way to hospital after about four hours."

3.3.2 Identified causes

The identified causes of the accident are:

(1) The worker (deceased) attempted to cross the belt from the place where he was not supposed to cross it.

(2) The supervisor of coal handling plant was not able to remove the person's presence in the vicinity of the belt conveyor before informing the control room to start it.

(3) The site supervisor and the contractor employee fail to ensure that the person under his charge understood and carried out their duties properly in a safe way or not.

3.3.3 Responsibility

The worker (deceased), supervisor, site supervisor of the contractor were held responsible for the accident during the investigation.

3.3.4 Gaps in current investigation methodology

The investigation did not reveal the following and raised the following questions:

(1) Was there any suitable cross over bridge or any other arrangements for crossing the belt? What was the interval between such cross over bridges?

(2) Why the worker tried to cross the belt without using the cross over bridge?

(3) What was the level of skill, competency and experience of the worker?

(4) Whether contractor's workers had any safety induction training and were aware of the hazards of working around a moving belt or crossing over running belt?

(5) Was it the usual practice or culture of the mine to cross over belt at any place? Had anybody ever been punished for such unsafe act?

(6) Whether the worker was in a hurry to complete the job?

(7) Was there any system to lock out belt conveyor from any point?

(8) Was there any pre-start warning system in the belt conveyor?

(9) Was it working properly?

(10) Was there any procedure to check it regularly?

(11) Whether the belt conveyor had any emergency stopping arrangement?

(12) How the person was carried away so long (four belts and three transfer points) without being noticed by other operators?

(13) Whether there was adequate supervision provided?

From the accident investigation, it could not be ascertained whether the above contributory factors were considered during the investigation. Rather, responsibilities were fixed based on their direct involvement, without investigating the root causes that led to the accident.

4. Summary of the finding of the gap analysis

The summary of the findings on the gap analysis of the case studies are as follows:

(1) The accidents are of very common and repetitive in nature.

(2) In most of the cases, human behavior or unsafe act

was identified as main cause and persons who were directly involved in the accidents, including the deceased, were held responsible for the accidents.

(3) The direct causes were identified to be the causes for accidents and no efforts were made to identify the latent, indirect or underlying causes

(4) The organizational factors like task condition, supervision, risk assessment, development of safe work procedure, ensuring competency for performing a job etc. were not examined while identifying causes of the accidents.

(5) The basic theory of causation of any accident as unplanned and uncontrolled energy was overlooked.

(6) Risk assessment was not carried out before all the routine or non-routine type of activities and adequate controls were not identified or in place before undertaking such job.

(7) Lack of skill, competency and fitness for duty of the operators or work persons was not examined.

(8) Human error or non-compliance of statutory provisions was identified as causes of accidents in most of the cases. But what led to human error or non-compliance were not examined.

(9) The real objective of accident investigation through identification of root causes and implementation of corrective measures could not be achieved through such superficial accident investigation.

(10) There is a strong need to review the effectiveness of current accident investigation methodology and introduce the concept of objective assessment of latent causes for unsafe act or behaviour.

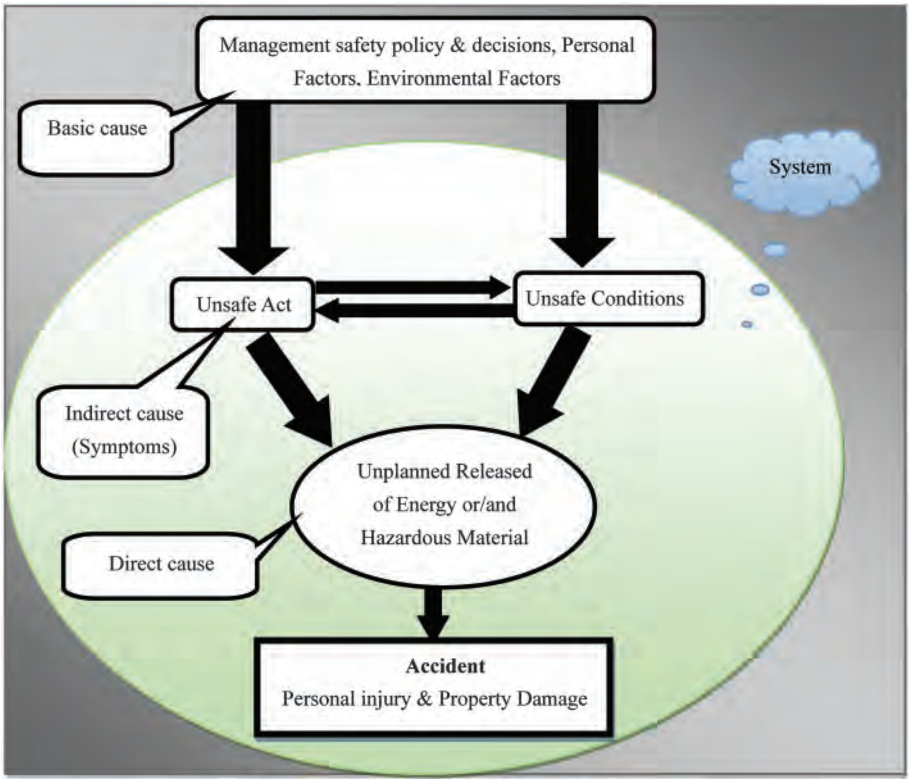

Fig.1 A conceptual accident causation model following Henrich's theory (1931)

5. Status of current investigation system in Indian mining industry

Accident investigations not only define what happened, but also why and how it take place. The information gained from these investigations can prevent recurrence of similar or perhaps more disastrous accidents. Accident investigators are interested in each event as well as in the sequence of events that led to an accident. It is equally important to define the level/type of accident to carry out the investigation. The recurrence of accidents with common causes show are as needing special accident prevention emphasis (Reese, 2011).The investigation system in Indian mining industry is mainly rule based not system or process based which is managed by generally reluctant compliers of safety statute (Dash et al., 2015-b, Bhattcharjee et al., 2014). Safety is not just someone's responsibility, it is everyone's responsibility to maintain safety. Safety management system is not an integral part of organizational management. In most of the cases it is observed that during investigation investigator identify the direct causes only and in few cases direct and indirect causes which are connected with human activities or failure (error/lapses/violation). But the basic cause (root cause) remain uncovered due to overlooking organizational factors.

Fig.1 is a conceptual accident causation model following Henrich's theory (1931) gives a clear view of gaps in ideal investigation system and actual accident investigation system in Indian mining industry which consider only the first and second level of causes (i.e. direct and indirect causes only) as shown in the Fig.1.

There are some gray area in Indian mining accident investigation system (identification of basic/root causes) which must be focus at time of investigation. To full-fill the primary objective of an accident investigation, it is important to identify all level of causes (direct, indirect and basic causes) accordingly corrective actions are made to prevent the similar accident.

6. Changing views of human error

Generally it is accepted by accident investigators that accidents are the result of a chain of events culminating with the unsafe acts and unsafe conditions. In the traditional view of accident causation, human error, is seen or treated to be the primary cause of incidents and accidents. The solution usually proposed is to do something about humans i.e. fire them, retrain them, discipline them etc. Alternatively, something can be done against humans (Dekker, 2007). This approach has never been very effective. Human error repeat over and over resulting the same type of accidents. All human actions are influenced by the environment in which they take place. Changing that workplace environment will be much more effective in changing behaviour than blame or punishment. Without changing the environment, human error cannot be reduced for long time (Leveson, 2009). Learning from own and other's past is important to reduce human error. Accidents are treated as the result of faulty processes involving interactions among people, social and organizational structures, engineering activities, and physical and software system components (Leveson 2004). As claimed by Rasmussen [Rasmussen, 1997] and others, doing better accident analyses needs shifting the emphasis from role of humans in accidents to system and or factors that shape human behaviour, that is, the context in which human actions take place and decisions are made [Rasmussen, 1997].

As an alternative, the systems thinking view of human error is that human error is a symptom, not a cause. All behaviour is affected by the system in which it occurs. To do something about error, we must look at the system in which people work (i.e. environmental conditions or workplace conditions like task planning, the design of the equipment, the suitability of work procedures, permit to work, abnormal operational situation etc.) (Leveson, et al., 2009).

7. Conclusion

Workplace accident in Indian mining sector is in moderate level which needs an efforts to control. It is essential to learn from the mistakes or from the accidents (Cook and Woods, 2006; Cooke and Rohleder, 2006; Hollnagel, 2004; Jacobsson et. al., 2010; Johnson, 2002; Johnson and Holloway, 2003; Jones et. al., 1999; Lindberg et. al. 2010; Stoop and Dekker, 2012; Reason, 1990). Accident investigation is the key tool used to identify the root causes of accidents (Jacinto and Aspinwall, 2003; Jacinto et al., 2009). It is necessary to line up with a suitable accident causation models (Katsakiori et al., 2009) to cover different levels of causes (Sklet, 2004; Khanzode et al., 2012) during an accident investigation (Jesus et al., 2013). From the above case studies analysis of the accidents, it is observed that the mines accident investigation in India is generally focused at human error or non-compliance of statutory provisions (Bhattcharjee et al., 2014; Bhattcharjee, 2015). In most of the cases only the direct causes have been identified to fix responsibilities and making recommendations (Dash et. al., 2014, 2016; Bhattcharjee et al., 2014; Bhattcharjee, 2015). This approach is proved to be grossly ineffective because of the fact the system deficiencies still remain unobserved and or undetected during such investigations and the recommended actions may not suitably address the root causes. That is why similar accidents are being repeated (Livingston et. al., 2001; HSE Book, 2004). Unfortunately, some investigators believe that the investigation ends when the blame has been established. The problem, here, is that once the unsafe act or unsafe behaviour (direct cause) is identified, analysis stops. Then investigators investigate to place blame.

It is time to focus on system approach instead of human error or unsafe act only. The system approach takes into account the dynamics of systems that interact within the whole safety programme. It concludes that accidents are considered defects in the system (OSHA, 2013), and people are only one part of a complex system. Accidents are the result of multiple failures or defects in the system. It becomes the investigator's job to uncover all the root causes (defects) in the system. Fixing the system, not the workers, should be the core of the investigation. To avoid accidents, the system must work more safely. This thinking results in long-term fixes that are actually less expensive to implement and maintain (OSHA, 2013).

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