To meet rising Coal demand Industry has to initiate required R& D and explore look-ahead technology for introduction in mine

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Abstract:
Coal is conventional and key source of energy. Nearly fifty-five percent of the India's total energy requirements are met from coal which play an important role in the development of India To meet the growing requirement, production of coal is increasing day by day. It is being used as major resource in Power plants, steel and cement industry. Coal Mining in India has been going on effectively for over last 200 years. Working environment of coal mines are generally hazardous due to causes like flooding, subsidence, roofcollapse, leakage of noxious gases, explosion etc. For this reason mine related accidentsoften take place. Many miners had lost their lives due to accidents. In order to meet up country's rising coal demand there has been major shift in the method of coal production Specially after nationalization of coal Mines ,coal production has been mainly done from opencast with deployment of heavy machineries. Thishowever has led to increase in productiontogether with enhancement of production cost, wages of employees and price of coal to large extent Simultaneously there has been sharp decrease in the manpower strength .closure of number of underground mines.There has been a positive aspect of decline in the rate of accidents yet the rate of occupational diseases remain almost same.The technologies that have been introduced in phases in coal mines are sophisticated and modern., which include control of operation by computer , GPS, improved underground communication system and robot.Though much costly but in a restricted cases robotic technologies are in the process of introduction specially for safety purpose. In fact coal mining industry has been gradually adopting mechanization leading to automation.

Key Word: Key source of energy, hazardous, Opencast, Technology. Automation

Introduction:

Coal is the most abundant fuel resource in India which continues to be the major source of primary commercial energy worldwide. It is perhaps the largest contributor to the industrial growth of India. It is not only a crucial but enduring element in a modern, balanced energy portfolio, providing a bridge to the future as an important low cost and secure energy solution to sustainability challenges.
Out of the four major fuel resources in the country, viz. oil, natural gas, coal and uranium, coal has the largest domestic reserves. A far large percentage of coal demand in the country is met by domestic production as compared to other major fuels like oil and natural gas. The scenario is expected to remain the same in the foreseeable future unless alternative energy sources occupy centre stage.

After nationalization of coal mines the coal production gradually shifted from underground mines to opencast mining. Earlier 80% of coal production was coming from underground mines and 20% from opencast projects. Gradually the trend got reversed and underground production reduced to 20% while contribution of open cast projects is almost 80%.With the passage of time the cost of production from underground mining has been increasing at regular interval due to employees wages, input cost and power consumption with chances of mine accidents. The opencast projects using Heavy Machineries where production is dependent largely on mechanization and, has less number of employees. Due to limited number of manpower deployment in open cast, accident rates are generally low. The disadvantages in opencast mining are :-1) deployment of costly Machines, 2)cost of coal production increases due to fluctuation in fuel price 3) high cost in store items and 4)enhanced power tariff. Open cast mining has impact on land due to degradation of huge areas which creates miseries and eviction of villagers.

While coal is poised for enormous growth specially from open cast projects , it faces significant and mounting social and environmental challenges. Under this situation it has diluted attention on underground mines with the result despiteinfusion of heavy investment the underground production kept on going down.

Coal Reserve

In fact, over the last few years, the coal reserves have increased by on Geological Resources of Coal (In BT) in the country to 33 BT as could be seen from the following table whichaccounts for coal reserves up to 1,200 m depth have been established in the country (Table 1).

Table 1: Coal Reserve:

YEAR	PROVED	INDICATED	INFERRED	TOTAL
1.1.2006	95,866	119,769	37,666	253,301
1.4.2008	101,829	124,216	38,490	264,535
1.4.2010	109,798	130,654	36,358	276,810
1.4.2011	114,002	137,471	34,390	285,863
1.4.2017	143,058	139.311	32.779	314,158*

(*Including Sikkim)

Of the total reserves, the share of prime-coking coal is 5.313 billion tonnes, medium-coking & semi-coking is 29.221 billion tonnes and non-coking coal, including high sulphur is 280.615 billion tonnes. (1)

In comparison to other fossil fuels, coal is less energy efficient but pollutes more. The primary concerns at the regional levels is with the environmental impacts on air, water, land, forest, biodiversity, climate and the costs of mitigating these.

Underground coal mining:

Underground coal mining in India has been confronting serious techno-economical challenge at the time of depillaring of developed coal seams standing on pillars. If timely extraction is not done from these locked-up pillars, it will lead to loss of huge coal and there may be spontaneous heating, accumulation of poisonous gases, creation of unsafe working environment endangering the health of inhabitants. Inherited geo-technical problems for underground exploitation of a thick coal seam become even worse under Indian geo-mining conditions mainly due to the massiveness of the coal seam itself, and huge overlying roof strata and shallow depth cover .

The problems of a deep seated coal seams make underground coal mining more challenging. Conventional depillaring frequently encounters strata control problems and not economically viable due to low production and productivity, Generally, the strata control problems and poor rate of production are interlinked . Underground coal pillar extraction with competitive productivity and safety is of strategic importance for the coal mining industry. It is now time to adopt highly mechanized and much production oriented technologies wherever possible for sustainable development of underground coal mining .
While Environmental concerns will be the key to the coal industry's future ,coal from underground mine is considered to be a part of clean coal technology compare to opencast mining. In fact Coal seams having scope for adequate coal production and higher productivity need to be identified for future coal extraction with safety for workers which is of prime importance

With a view to have coal operation economically favorable .proper Research & Development (R&D) initiatives should be taken to overcome the technological vacuum for extraction of coal from below ground.
Even with its major hurdles, coal will continue to dominate the energy sector in the country for some years and will occupy in future a foundation and a fundamental source of our economy Considering the limited reserve potentiality of petroleum and natural gas, eco-conservation restriction on hydelprojects and geo-political perception of nuclear power, coal will continue to occupy the centre stage of India's energy scenario.

The coal production in India has risen after nationalization from 73 Mt in 1972 to about 382 Mt in 2004-05.and 598.61 Mt in 2016-17 . However coal demand that has been projected as 1061 Mt by the end of 2024-25(2)

The Methods of Coal Mining:

The life cycle of mining begins with exploration, continues through production, and ends with closure and post mining land use. New technologies can benefit the mining industry and consumers in all stages of this life cycle .

Two types of coal mining is in practice 1) Underground by opening Pit or driving drift for incline and 2) Surface Mining.

Underground coal mining today is basically done by two methods: Bord /Room and Pillar in conventional coal mines and mining with continuous miners, long wall mining with shearers in advanced mines.. The former is essential for developing large blocks of coal for long wall extraction.

Conventional Mining:

Conventional mining employs miners who use explosives and drills to extract coal, which is then loaded onto coal tubs for transport to the surface. This method presents higher risks to miners because of the use of explosives. The coal dust generated by the drilling and explosives is also a health hazard when continuously inhaled. This is the oldest method of coal mining.

Conventional bord and pillar underground mining methods provide poor production, productivity, due to slow recovery of coal and safety. There is no doubt that mechanization is the only way for sustainability of underground coal mining .In this process 70% coal is mined mainly by deployment of workers and rest through the coal cutting machines.

In advanced coal mines abroad,coal mining depends heavily on mechanical, motor-driven machinery for almost every aspect of the process, from initial extraction to transport to processing. Improving the performance of machinery (thus reducing down time), increasing the efficiency of operation, and lowering maintenance costs would greatly increase productivity. The development and application of better maintenance strategies and more advanced automation methods are two means of improving machine performance.

All of the repetitive and dangerous tasks are now considered for automation, though the critical decisions are still to be made by workers.

Continuous Miner

More than two-thirds of coal extracted underground is done by a "continuous miner," a tractor with a mounted cylindrical grinder that breaks coal away from the seam. The continuous miner leaves undisturbed pillars of rock and coal in the working area to create natural supports for the roof. This is known as "room and pillar" mining. When most of the coal seam has been extracted, the pillars then are mined one by one, allowing the roof to naturally cave in.
Depending on the geo mining conditions of India, for mass production of coal from underground the possible options for application of highly mechanized mining technologies include Continuous Miner based method of mining, Short wall Mining, High wall Mining, Long wall mining and Long wall Top Coal Caving method of mining(4).
List of some of coal mines where continuous miner has been introduced in various coal companies of India (Table 2) :

Table2. Engagement of continuous Coal Miners:

Name of Mine	Name of Coal Company
Anjan Hill mine, NCPH, Pinoura, Sheetaldhara, Rani Atari	South Eastern Coal Company
Jhanjra Project, Sarpi underground project	Eastern Coalfields Ltd
Tandsi colliery, Kumbharkhani	Western Coal fields Ltd
VK-7 incline and GDK-11 incline	Singereni Coal Company Ltd

Roof Bolters

Roof bolters are large, hydraulically-powered machines used to force bolts into roofs. Miners use roof bolters to support tunnel roofs and prevent underground collapses.

Long wall Miners

In contrast to continuous miners, longwall miners remove large, rectangular sections of coal instead of scraping coal from a bed bit-by-bit. According to Kentucky Coal Education, continuous miners consist of a series of large cutting shearers and a self-raising hydraulic system that supports the mineshaft ceiling as sections of coal are removed.

Rock Duster

Rock dusters are pressurized pieces of equipment that coal miners use to spray inert mineral dust over highly flammable coal dust. The inert dust helps prevent accidental fires and explosions.

Shuttle Cars

In a few advanced coal mines in Raniganj coalminers use electric-powered shuttle cars to transport coal from the coal bed to safer points in the mine. From there, miners can use standard scoops, or haulage vehicles, to drive their loads completely out of the mine. Miners of all types use haulage vehicles for various tasks.

R&D Support:

Indigenous R&D efforts are needed to overcome the problems of underground mining for sustainable underground extraction of coal.

R&D support isthe basic requirement to adopt any type of mining technology developed elsewhere, especially for underground mining. In the years to come Automation in underground coal mining would seem unavoidable and beginning of which is already in sight .These are:
1) Introduction of integrated realonline information system for underground activities may transform the Indian underground coal mining industry.
2)An appropriate and reliable remoteoperated system is a vital requirement for designing, developing or introducing of advanced systems in underground coal mines for enhanced production, productivity and safety.

3) Development and application of robot and remote operation technologies will empower Indian coal industries for efficient exploitation of underground coal seams.

Efforts are on at Central Scientific Institute of Research (CSIR) -Central Institute of Min (CIMFR) to develop suitable underground mining methods indigenously as well as to evalua technologies, stepping in due to changing economical policy of the country(5).

Figure 1. Long wall

The production and productivity of individual, continuous, and long wall production units have increased consistently over the years.

All functions of the machine are hydraulically operated from an in-built hydraulic power pack run by a flame proof electric motor. The overall dimensions of the machine are suitable for the available head-room and gallery width.

The automation of the shearer loader technology starting with the reasons for automation: These are firstly required for the increase of production by way of rationalizationand secondly the gentle material handling associated with health protection and safety at work. Consecutive the development of the automation concept is being presented which commenced in 1986 with the introduction of the Memory Cut at DSK and successfully continued in 1993 with the first-time utilization of the Defined Face Opening (DFO) in Australia.

Highly mechanized underground mining technologies:

Highly mechanized underground mining technologies can meet the challenges of Indian underground coal mining industry. Butadoption of highly mechanized foreign technology is also not easy due to a variety of reasons. One of the major reasons in mining technology is generally site specific and required to modify as per the site and based on the geomining conditions of the mine

Surface Mining:
Presently, country'smajor coal production comes from open cast mining duetolarge scale mechanization and automation of opencast mines.

For extracting coal which lies close tothe surface, huge drag-line shovel machines remove the topmost layers of soil and rock, exposing the coal, which is then removed by smaller machines. Surface mining may involve removing sections of hills or top layers of a flat surface area. The layers of rock and earth covering the coal are reserved till the coal is removed.

Surface mining equipment is similar to construction equipment (e.g., scrapers, bulldozers, drills, shovels, front-end loaders, trucks, cranes, draglines). Surface mining today is characterized by very large equipment (e.g., trucks that can haul more than 300 tons of rock, loading shovels with buckets greater than 36 cubic meters, draglines with buckets greater than 120 cubic meters), and modern technology for planning, designing, monitoring, and controlling operations (Table 3).

Table3:Complex Surface Mining Equipment(5)

Complex mining equipment is used directlyor as supportin the mineral extraction process:

Draglines	High wall miner
Shovels	Blast hole Drills
Loaders	Dozers
Haul Trucks	Graders

Mining Transportation & The Tools of Coal Preparation

Device related to the transport of coal from the mine to processing facilities to railloading and finally to the consumer:

Conveyors, underground and overland . Rail road
barrage/ship trucks

Excavators

Miners traditionally use shovels and steam shovels to break and remove earth, but today's miners rely on excavators. An excavator is a mobile vehicle that moves on tracks or with standard wheels. It features a rotating platform, off of which comes a hinged arm with a bucket or scoop attached to its end for digging.

Draglines

Draglines are enormous earth moving machines that Operators use to drag away dirt and expose underlying coal or mineral deposits. Draglines are some of the largest machines on the planet, and can remove several hundred tons of material in a single pass, according to Kentucky Coal Education.

Drills

Miners who extract natural gas and oil commonly rely on drills to reach underground deposits before piping into the resources to the surface. Coal and mineral miners also use drills to create extensive series of holes, which they then fill with explosive charges to blast away chunks of earth.

With the introduction of Heavy Machines in the next decade, the mining industry may lose more than half of its jobs to automation, That's not based on future technologies, but on automated equipment being deployed today.

The mining industry is primed for automation. It's capital intensive, buys expensive equipment and pays relatively well. The technologies are getting advanced and Robotic Technology has been knocking the door of Coal industry specially for the purpose of ensuring safety.

Back ground for introducing Robotic Technology in coal mines:

To the problem of coal mine accidents which results in the death of several people per year is a cause for concern. For example, on February 2, 2001 around 16 million gallons of water from a nearby tank gushed into the Bagdigi coalmine (India) trapping at least 45 miners. Much similar type of accidents have also been reported earlier. On September 27, 1995, 74 miners were killed in four different accidents in four collieries in Dhanbad mines (India). The Chasnala Mine Disaster of Indian Iron and Steel Company Limited in the 1975 was perhaps the most gruesome tragedy of this kind killing 375 miners. (6)

It is found out that the rate of fatality in the coal mine industry is nearly six times than the rate for all private industry. And most of these accidents are due to toxic gasses, fires and lack of rescuesystem. By implementing a Coal Mine Surveillance robot, which can move around unmanned in the mine and detect the level of different toxic gases and temperature level and report them live to the control room, this level of fatality can be considerable reduced.

Introduction of Sensor:

From a technical aspect it requires very specific types of sensors, and innovative methods in transmitting and receiving data because a conventional approach will not do much good from an industrial point of view.The technology can be considered valid if it can detect different sorts of gases, the temperature and give a warning to the miners inside the mine in case of a danger, at the same time transmitting all the data to the control panel. The data send to the control panel can make a lot of difference, setting up and giving strategies to a rescue team for rescue will make the rescue very efficient. (7)

Therefore, using mobile robots in the search and rescue operations not only enhances the personal safety but also shortens the operation duration. There are several robots designed for this type of application in the literature

Methane gas explosions are one of the most common causes of underground coal mine disasters. Methane is an odourless, colourless and highly combustible gas that leaks out during mining of coal seams and, if left undetected and uncontrolled, can explode violently with a small spark. Therefore, it is of paramount importance to control the methane through adequate ventilation when it is present in small amount in the air(8).

For detecting methane gas level, the coal mining equipments are fitted with methane monitors in order to enable the machines as well as the electricity to be automatically shut off once the methane level reaches 1.5%. Recently developed sensor-based methane detectors utilising radio frequency identification (RFID) technology can be deployed in any part of a deep underground coal mine transmitting methane concentration readings wirelessly to the surface. US-based Tunnel Radio, for instance, has developed a wireless detection system for monitoring methane gas and carbon dioxide (CO_2). It comprises of an easy-to-install gas sensing module suitable for battery-powered application. The device can send precise gas-level readings to the surface computer system on a continuous basis.

Dust monitoring and control technologies:

Dust build-up in the underground mining area is another major cause of coal mine explosions. The inhalation of silica and coal dust also poses serious health hazards for the miners. The use of air ventilators and water sprays, and the regular cleaning of coal dust lying on the surface are some of the basic techniques to prevent coal dust explosions. An array of dust-buster agents including binders, foams and antioxidants are also being developed to mitigate the chances of coal dust related disasters. GE's newly launched CoalPlus technology, for example, can reduce coal dust by up to 90% in different coal mining operations(9).

The coal dust explosivility meter (CDEM), a portable and handheld instrument for instant monitoring of the ratio between coal dust and rock dust levels in the underground mine, is currently available in the market. The device originally developed by USA's National Institute for Occupational Safety and Health (NIOSH) is being commercialized by Sensidyne. Personal dust monitors (PDM) have also been developed to give miners a tool to track exposure to respirable coal dust in real-time.

Research and development conducted by CSIR-Mining Technology South Africa in the areas of active continuous miner based coal dust/methane explosion suppression systems, passive 'bag based' stone dust barriers systems, design and positioning of refuge bays, integrated escape and rescue strategies, and neural network based coal dust/methane explosion risk assessment has been introduced.

The suppression of dust or suspended participate matter was trued by water spraying from the loading or transfer points. In the subsequent years water infusion in the seams and water jet mounting on the
cutting edges was tried to minimize dust menace during cutting of the coal.

The environment of underground mines has been a subject of serious concern to the mine operators because of the liberation of methane with coal cutting, heat and humidity and generation of fumes with the blasting of coal. The opening of the seams with interconnecting galleries, coursing for intake and return air, creation of air draught and deployment of auxiliary or forcing fans were some of the conventional means adopted to improve the environment of underground..

The auto oxidation of the coal; a slow process is aggravated when large surface area of the fine coal particles come in come in contact of air. The oxidation of pyrite adds a new dimension to the problem and being

The coal mine safety decision systems, such as ventilation safety monitoring system, underground water inrush monitoring system, underground coal and gas emission monitoring system, have been established in many large and medium-sized coal mines. A large amount of original data had accumulated in these systems. How to transform data into information for scientific decision was a problem worth to consider for coal mine safety production.

Finally, data mining system based on rough set was designed, which was applied to data mining analysis of underground gas emission,

Proximity detection and collisionwarning

Collision between machinery or between machinery and personnel is one of the common causes of accidents in underground as well as open pit mines. Proximity detection technology can be installed on mobile machinery to detect the presence of personnel or machinery within a certain distance of the machine.

NIOSH developed an active proximity warning system, called the Hazardous Area Signalling and Ranging Device (HASARD), for warning workers through visual, audible and vibratory indicators as they approach dangerous areas around heavy mining equipment.

Caterpillar has also developed detection technology called Cat Detect Personnel that features as one of the five sub-modules of its integrated mining management suite Cat MineStar. The technology involving RFID tags worn by the workers and the detectors mounted over the machines to warn operators with audio and visual indications of possible collisions, speeding or rollovers.

Computerized permit-to-work system

The effective management of a permit-to-work system is critical to mine safety as it tracks the authorizations and competencies of employees while identifying the key risks involved with a particular job.

A computerized permit-to-work system collating all required documentation for specific types of work, taking into account the specific identified hazards and the precautions needed to be taken by workers, is helpful in ensuring mine safety at the work authorization level. (10)

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Air conditioning of the atmosphere in some of the deep underground mines has been realized in theinterest of efficiency. In the safety risks, ill health and likely injuries and accidents could be minimized. In this exercise, optimization of the man, machines, and environment system- physical environment in terms of heat, humidity, air movement, illumination noise, vibration, toxic agent, dust and fumes are to be lookedinto. Working under poor light in the past caused miners low vision and poor eye sight is practically unknown now because of the improved lighting. Presently a few equipments have been deployed (Table 4)

Table4: The following apparatus and equipment purchased :

Sl. No.	Details	Numbers purchased
1	Multi-gas Detector	2
2	Purity of oxygen testing device	4
3	Portable gas chromatograph for analyzing the Mine air sample	1
4	Inflatable portable lighting system	2

Single Board Computer (SBC) for control and operation. Some of the instruments communicate with the SBC through analog signal and some through digital signal. The command/control signal from the On-shore command/control station is transmitted to the SBC through acoustic modem/RF Modem using acoustic communication/ RF communication methodology. Various data and signals from the SBC are also transmitted back using the same path and subsequently processed on-line or logged for post processing.

COMMUNICATION SYSTEM

Initially the communication system was set up using Acoustic Modem.)SR is controlled from the Remote Base Station where high data rate is required for transferring camera captured images, continuous flow of Sonar scan line data, motor data along with the controlled voltage, compass data. On the reverse command is sent from remote base station, for smooth operation of SR. During the initial trials, it has been found that data transfer rate of the Acoustic Modem was not enough in comparison to what system demands.(11) Also in confined environment, reflection and reverberation caused a big problem for communication. Acoustic modems need enough depth and wide area for successful continuous communication. The wise idea was to switch over the communication mode from the Acoustic to RF / WLAN enable data transmission. SR wasmodified to use a WLAN Protocol to communicate with the Base station. The communication in SR is bidirectional. WLAN uses spread-spectrum or OFDM modulation technology based on radio waves to enable communication between devices in a limited area, also known as the basic service set. This gives users the mobility to move around within a broad coverage area and still be connected to the network.(11a)

Laboratory level testing at CMERI: Objective of this testing was to test individual instruments, equipments, leak proof of the vehicle body, initial tuning of various equipments. As SR will work in underground coalmines wholly or partially logged with water, the system needs to be watertight. Several tests have been carried out on the main vehicle body in the shallow testing tank to detect any water leakage. Apart from the leakage test, floatation of the designed system has also been checked.

The CMERI Subterranean Robot (SR), Deployment of SR for exploring a submerged mine tunnel at Satgram Project under ECL (West Bengal), India.
The CMERI Designed SR with track wheel arrangement provides more bearing area which helps to move over loose soil, sand and gravel. It can also perform its work in very narrow passages due to its smaller size and light weight (nearly 41.5 Kg). Amphibian characteristic provides it better working ability in adverse condition of partially or fully flooded mine tunnels. Field trials at Coal mine: Actual field testing at underground coal mine was carried at Satgram Project under Eastern Coalfields Limited (ECL). The mine is approximately 211 m deep and a standard –2 mine. Project team identified two water-logged drifts, one of which is working as the main surface water collector sump for pumping(12).

E. CMERI Mine Robot

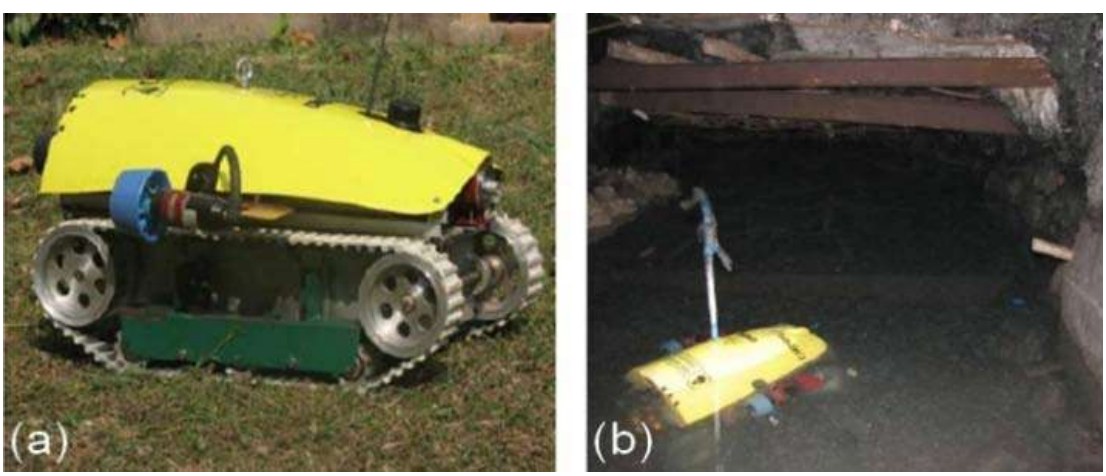

Fig 1 (Source CMERI)

This system will have capability of autonomous navigation, obstacle free path planning and intelligence to combat unforeseen situation together with fault tolerant architecture in system design.

The CMERI Mine Robot The robot has six wheels, mounted on rocker arm mechanism (fig.7). Six wheels provide it better terrainability and stability (static and dynamic) over four wheeled robots. The front and middle wheels are mounted on a Y-shaped rocker-arm. The configuration of the arms can be adjusted in an active fashion with the help of linear actuators connected to them. The rocker arm helps the robot to cross an obstacle and climb stairs. Three wheels of each side are driven by a single motor and steering is achieved by differential drive mechanism.
This robot has better terrainability, flexibility, and shock absorption capability on rough terrain due to its all-wheel drive mechanism and simple suspension system.

Robot of CMERI:

Verities of Robots now in use in the coal mines abroad
Now-a-days robots are being deployed in mines for rescue operation and to minimize such type of accidents by inspection of working environment, especially after blasting. However mine environment is extremely challenging and mine robots are specially designed to overcome such challenges. India will have to introduce such Robot for safety purpose ,

I. **UNDERGROUND MINE ROBOT (13)**

Groundhog Robot in Florence Coal Mine near Pittsburgh :
Several mine robots have been developed so far for various mine applications. Example of some underground mine robots have been discussed here from the point of view of their application and terrain ability.

A.**Groundhog Mine Robot**

It is a mine mapping four-wheeled drive explosion-proof autonomous mobile robot which was developed by Carnegie Mellon University The design of its chassis and steering system is such that, it can work on very rough terrain of mine. Its chassis consists of the front halves of two all terrain vehicles, allowing all four of its wheels to be both driven and steered. Two Ackerman steering columns which are linked in opposition, reduces its turning radius when it turns along a curve path.

***B.* Gemini-Scout Robot** (14)

Gemini-Scout is a remotely operated mine rescue robot, which was developed by Sandia robotics engineers at Sandia under National Institute New Maxico for Occupational Safety and Health (NIOSH) sponsored program

Gemini-Scout Robot in different terrain conditions (15)

It is a tracked wheel robot having good mobility to enable it to overcome stair-like obstacles, slopes, sand, gravel, pits which are commonly found in mines. The robot is constructed in two segments. Both segments are connected with a passive two DOF link which make it flexible. The robot is capable of navigating around tight corners due to its smaller size and compact design. Comparatively better terrainability of Gemini-Scout is achieved due to its segmented body design and tracked wheel configuration.

Detection and Rescue Robot: Detection and Rescue Robot (DAR) (16)

It is a mine rescue robot with six-track system, which was developed by 'School of Mecha-Electronic Engineering,' Beijing Institute of Technology Out of its six tracks two are drive tracks and two front and rear arms are used to cross obstacles. It is designed adaptive to mine conditions by making it explosion proof, water and dust proof. The design claims to have better terrainability with shock absorption capability. It can climb slope up to 300 by adjusting its arms and can move over rubbles.

Detection and Rescue Robot (DAR)

Apply IT, a South African software company, for example, has developed a permit-to-work authentication system called IntelliPERMIT that integrates all aspects of permits-to-work, access control and risk assessment, tracks the authorization levels of each employee at work, and ties permits into access controlwith biometric fingerprint identification. IntelliPERMIT has been installed at Newmont Mining Corporation's Boddington mine in Australia.

Recent development of drones, primarily by the U.S. military, has made more effective geophysical surveys possible. This technology is currently being explored by industry-government consortia in Australia

The robotic and automation methods all have the exact same goal: to reduce the danger involved in human jobs and to enhance productivity. By reducing the presence of humans, this reduces the different accidents that could occur in these hazardous working environments which is critical. Also, since the productivity can be enhanced at the same time(17)

Potential benefits arising from the application of mobile robots in underground mining are manifold. An improvement in occupational safety for people and equipment alike can be expected. Furthermore, robots are suitable for exploration, mapping and monitoring operations. Dangerous, potentially collapsing mine sites are better explored by robots as the loss of a machine attains no ethical and moral dimension compared to the loss of a human life. Robots that continuously monitor the environmental conditions (eg mine air measurements) could contribute to improving the safety of mining personnel working underground (18)

Robotic and automated applications are usually found in big industrial plants / mines that require repetitive human tasks. This automation is designed to increase human safety and enhance the general productivity of the plant/mines

At one point, venturing into a mine was quite dangerous and if a collapse occurred, the time to re-establish the underground tunnel to go get the worker was sometimes too long for their survival. Since the introduction of this kind of robot, the worker can be safely above ground and be more efficient. One of these robots was developed in Sudbury, Canada by Greg Baiden, the CEO of Penguin Automated Systems. The robot was tested in different mines around Canada and is now being used in Chilean mines.
Other robotic applications such as GPS guided robots are used for either mapping the mine tunnel or to detect the source of minerals or gas using a vision system.

Research on the development of specific sensors and sensor systems has focused on seismic methods. In underground mining the mining machine (if mining is continuous) can be used as a sound source, and receivers can be placed in arrays just behind the working face. For drilling and blasting operations, either on the surface or underground, blast pulses can be used to interrogate rock adjacent to the rock being moved. However, numerous difficulties have been encountered, even with this relatively straightforward approach. Current seismic systems are not designed to receive and process multiple signals or continuous-wave sources, such as those from the mining machine.

Recommendations:

Research in basic geological sciences, geophysical and geochemical methods, and drilling technologies could improve the effectiveness and productivity of mineral exploration. These fields sometimes overlap, and developments in one area are likely to cross-fertilize research and development in other areas

To increase productivity a truly continuous haulage system will have to advance with the advancing cutter-loader. If the strata conditions require regular support of the roof as mining advances, the support function must also be addressed simultaneously. Therefore, research should also focus on automated roof bolting and integration with the cutting and hauling functions.
The increasing size of loaders and haulers in both surface and underground mines has increased productivity. However, larger equipment is associated with several health and safety hazards from reduced operator visibility. Research should, therefore, focus on advanced technology development for integrating location sensors, obstacle-detection sensors, travel-protection devices, communication tools, and automatic controls.
Substantial research and development opportunities could be explored in support of both surface and underground mining. The entire mining system, including rock fracturing, material handling, ground support, equipment utilization, and maintenance, would benefit from research and development in four key areas:fracture, fragmentation, and cutting, with the goal of achieving truly continuous mining in hardrock as is done with coal
Small, inexpensive sensors and sensor systems for mechanical, chemical, and hydrological

applicationsdata processing and visualization methods (especially taking advantage of advanced, parallel-computing architecture and methods) that would provide real-time feedbackautomation and control systems (especially for mining equipment used in hazardous areas).
The above four areas represent a very broad summary of technology advances that would greatly enhance productivity and safety in mining.
Research should focus on equipment and methods specific to mining thick seams. Hydraulic mining may have potential applications for thick seams. The technical feasibility of hydraulic mining is well established, but equipment and systems that can operate in more diverse conditions will have to be developed
Mining adversely affects the eco-system as a whole. It is important to conduct suitable assessment studies to learn the potential adverse impact of mining or flora and fauna. The adverse impact should be identified at the planning stage itself so that corrective measures may be taken in advance.The adverse effects of subsidence fissures have made most of the subsided areas barren and unstable.

Conclusion:

Presently, majority of the coal production in India is coming from opencast mining specially which covers the reserve under shallow depth .. The reserve is fast exhausting due open cast mining method and future of Indian coal mining industry lies with underground mining only.
The conventional mining methods practicing majority of the coal mines in India yield less production with lower productivity. As well as safety aspect remains cause of concern. Technological development for extraction of coal from deep-seated coal seams and locked-up coal from developed pillars are vital requirement for the industry. Adoption of highly mechanised underground mining technologies may be vital to meet the challenges of Indian underground coal mining industry.
The scientific innovations in many industries are quite rapid. Conversely, the progress is not parallel to the other industries and still underground mining industry is forced to use the conventional methods/systems except a few in case of Indian underground coal mining industry. An appropriate and reliable remotely operated system is a vital requirement for designing, developing or introducing of advanced systems in underground coal mines for enhanced production, productivity and safety. Development of remote operation technologies including robotics will technologically empower Indian coal industries for efficient exploitation of underground coal seams. The remote operation technology enables continuous and on-line monitoring of real time strata control parameters like stress on pillars/stocks/ribs in underground openings including underground coal mines and tunnels wirelessly.

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