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PRESENT STATE AND DEVELOPMENT OF ENGINEERING BLASTING TECHNOLOGY IN CHINA

Wang Xuguang
Beijing General Research Institute of Mining and Metallurgy(BGRIMM), People's Republic of China

ABSTRACT: This paper outlines the research, application and development of engineering blasting technology(such as chamber blasting, deep-hole blasting, underground mining blasting, underwater blasting, and urban demolition controlled blasting), blasting materials and blasting fundamentals in china.

Engineering blasting, as a branch of science and technology, has been attracting wide attention and playing an important role in China. Under the guidance of the policy of "Reform and Opening to the Outside World" in recent ten and more years engineering blasting technology has rapidly developed in China, reaching an unprecedented level and providing extremely marked economic benefits. Its progress represents mainly in such respects as increasingly wider application to various branches of the national economy with techniques gradually improved (Feng Shuyu, 1991); uninterrupted emerging of various new types of high efficiency and safe commercial explosives and initiating materials to adequately meet and prompote the modification and development of blasting technology (Wang Xuguang, 1991,1995); fruitful results seen in research work on such topics as blasting fundamentals, methology for classification of rock blastability, blasting optimization design and mathematic modelling, safety and measuring techniques, capable of controlling blasting practice Moreover, elaboration and implementation of safety regulations, and young generation of blasting experts and their practical work have also laid down a solid foundation for further advance of China's blasting technology

The above mentioned aspects will be reviewed in this paper with outlook on the development in the years to come.

1. INCREASING WTDE APPLICATION OF DIFFERENT ENGINEERING BLASTING TECHNIQUES TO VARIOUS BRANCHES OF NATIONAL ECONOMY

1.1. Chamber Blasting

Practice has shown that Chamber Blasting is a less investment, higher efficiency and faster realization technique, being widely used in China's mountainous areas to remove large volumes of rock. As early as in 1956 it was introduced to mine capital stripping. For instance, that year the largest then in the world chamber blasting project was realized at the open pit mine of Baryon Nonferrous Metals Corp., Gansu Province, with a total explosive charge for three blasts amounting to 15,573t, total rock mass blasted 9.07 Mm^3, of which 2 27 Mm^3 thrown out of the pit outlines, enabling the mine put into operation two years ahead of schedule. Again in 1964, enforced loosening chamber blasting technology was adopted at the open pit mine of Jinchuan Nonferrous Metal Corp. to level off several hills, with total explosive charge 16SS t and 2.18 Mm^3 rock mass blasted, also ennabling this mine to enter operation one year ahead of schedule. This method has Widely been used to stripping projects at a number of open pit mines attached to metallurgy, building materials, chemical engineering, coal and other industries. For example, in the initial capital construction at the limestone pit of Shunchang Cement Plant a hilllevelling off chamber blasting was carried out with multi-row quasi-plane charge pattern of 1708 t explosives, resulting in 1.22 Mm^3 rock mass blasted, 66% of which thrown into the waste dump.

Since 1958 the directional blasting techniques for dam building have been used in China. Up to now over 60 various kinds of stone dam, such as water reservoir dam, tailing dam, mud-rock flow protective dam, lime storage dam, etc. have been built with quite rich experience accumulated and calculating methods elaborated. For instance, at nanshui Hydroelectric Power Station a tatol of 1394 3 t explosives was consumed by directional blasting for dam building, resulting in 2.26 Mm^3 rock mass blasted and 62.5 M high dam formed by one blast, this initial dam was then upheld to 81.8 m and upgraded, which has been running quite well. During the Seventh Five Year Plan period frontier research work was done on piling up over 100 m high dams by directional blasting, providing theoretical and technological results. Again, at Jinshiyu Gold Mine, Hebei Province, a tailings dam was initially raised by directional blasting with equivalent and symmetrical charges on both sides of different altitude under unfavourable relief conditions. Its construction was completed nine months ahead of schedule and investment reduced by 55% compared with conventional dam building technology, and the stability of pioneer dam has been proved satisfactory.

In construction of railways and highways chamber blasting is used primarily for rock work with maximum charge for one blast reaching over 400 t For example, in construction of such railway lines as Baoji-Chengdu, Yingtan-Xiamen, Chengdu-Kunming and Datong-Qinghuangdao chamber blasting techniques were employed to considerable extent with rock volume blasted 10.54 Mm^3 Especially in the past years single charge sequential millisecond blasting technology has successfully realized, thus ensuring safe operations under complicated circumstances In addition, directional blasting has been playing favourable role in dealing with slipping slopes.building of flood-diverting canals and levelling off industrial sites, etc

It should be noted that replacing of concentrated charges by cylindrical or guasi-slabconcentrated charges has made marked progress in Chamber Blasting. Especially, sectional millisecond delay detonation techniques have been successfully applied, resulting in larger throwing distance and throw rate, more concentrated rock-pile and lower blasting vibration effect. For instance , in December 1985 at an asbestos mine in Sichuan Province the millisecond detonating system with multiple cylindrical charges at both sides of low and high altitude was successfully used to pile up a over 40 m high mud-rock flow protective dam of good shape, the effective throw rate reaching 63.5% and specific chargé for upper dam rock only 0.7 Kg/m^3. Again in 1990 at Huizhou Port, Guangdong Province, directional blasting succeeded in building up a berth by filling the sea hannel with blasted rock. Adopting small plane slab charges in this blasting succeeded in the remote throw in slopping areas and in the refilling of a 230 m region between the beach and the island with throwing rocks. The throw efficiency was 63%. Rocks largely penetrated the silt with the maximum settlement up to 6 mm.

1.2 Deep-hole Blasting

Deep-hole Blasting techniques have been , widely adopted in the stripping engineering of open pit mines, deep-hole caving at underground mines, excavation of railway roads, levelling off industrial sites in mountainous areas, and excavating caves for hydroelectric power stations, etc. in China.

Deep-hole blasting for open pits includes large-scale multi-row millisecond delay blasting, tight-face blasting and small-burden large-spacing blasting, etc. However , in the adjacent slope areas, presplitting and smooth blasting techniques have been used to keep the stability of slope areas . The large-scale multi-row millisecond delay blasting technique has been spread and utilized in the large-scale open pits, such as Nanfen Iron Mine, Shuichang Iron Mine, Dexing Copper Mine, Open Pit of Jinduicheng Mo Industry Corp. Its bore-hole_ layout parameters, explosive loading structure, matching of the explosive for the properties of rock mass, initiation sequence and delay time, etc. have been thoroughly studied The blasting quality has been noticeably improved with fine techno-ecnomic performances For instance, comprehensive study has been undertaken at Nanfen Open Pit in the past years, which use <j)250,310,380 mm drilling head with the coordination of large-scale electric shovels and

electric-wheel trucks. The delay blasting scale was 500,000-800,000 t. The maximum scale 810,000 t was the first of its kind in the preloading charge by loading truck in China. At that time, SOS blasting holes were drilled, 270 t explosives preloaded, 104 sections divided, the unit consumption of explosives 0.9 Kg/m^3, large block ratio 0.035% without pillars, The efficiency of electric shovel reached 1921 t/h Economic benefit was considerable. In addition, at this mine the program of blasting parameter optimization system was designed to calculate and predict the optimal parameters and blasting effect under different blasting conditions, then an optimization diagraph was elaborated for blasting engineering design work. It also adopted anisynchronous and sectional interference-vibration blasting, cutting down the vibration rate to 20-30%.

Deep-hole Blasting has been also widely adopted in other fields. For instance , deep-hole sectional delay blasting, preslitting blasting, protective layer single blasting and non-protective layer blasting, etc. have been adopted in the base course excavation of hydroelectric power stations, e.g. Gezhouba, Dongjiang, Chaishuitan, Dongfeng Power Stations. Especially, at Dongjiang and Dongfeng hydroelectric power stations horizontal presplitting blasting and horizontal presplitting plus deep-hole sectional delay sequence blasting have succeeded, demonstrating a new level of deep-hole blasting.

1.3. Underground Mining Blasting

Since early 1950's deep-hole blasting has been used for caving ores at underground mines in China Those mines adopting caving method generally use vertical or horizontal fan-like holes of <j>60-100 mm and 10-60 m deep for caving. The explosive loading for one blasting is from several tons to tens of tons even hundreds of tons with the maximum over 200 tons. The blasting at the underground metal mines has been widely carried out by loading porous prilled ANFO and heavy ANFO by loaders, in conjunction with plastic detonating tube non-electric initiating system. While the reasonable bore-hole layout parameters, explosive loading structure and initiation sequence are selected, attention should be paid to the application of tight-face blasting, combination of high-density and bottom loading of high-strength explosives in the vertical fanlike deep-hole blasting in order to improve the blasting quality Since the beginning of 1980's, VCR mining with spherical charge blasting has been studied and applied in a numder of nonferrous mines, such as Fankou Lead-Zinc Mine and Shizishan Copper Mine of Tongling Nonferrous Metals Industry Corp., and furter developed into a combined blasting method in which the spherical charge is used for cut-off stoping and column charge for ore breaking-up. This is a high efficiency safe mining method whicg has attracted attention of mining community. In addition, air isolation loading and interval initiation in holes, controlling of edge holes energy and reaction direction have been considered to reduce the break-up to sidewall. Work on mathematic modelling and parameter optimization for this mining system has made considerable progress.

In the tunnel digging engineering, especially in the large-section tunnel digging blasting, horizontal deephole (5m in depth) blasting and uncoupling loading dmooth blasting in conjection with grouted bolting have been adopted widely to increase the digging efficiency and reduce excavation volume

1.4 Underwater Blasting

In the early 1970's the underwater blasting, the largest in that time, near the docks of Huangpu Port, Guangzhou, China was successfully carried out, making an underwater passageway with a width of 80 m and a depth of 9 m, through which ships of 10,000 tons can pass The total rocks crushed in 300, 000 m^3 Along with the gradual increase of construction projects of port docks and channel buildings, the scale and technique of underwater blasting have deen progressing continuously

Underwater soft base treatment is a difficult problem in port construction in China Since 1979, a series of underwater blasting has been undertaken successfully in the construction of Nanhai, Donghai and Qingdao Ports in China, and the blasting technique for some soft base treatment has been formed In 1987 on the basis *of* modelling and mechanism research, a complete set of new methods for underwater soft base treatment including explosion desludging and packing stones, explosion ramming, and underdyke explosion desludging, was successfully fulfilled in Lianyungang port and a great deal of systematic data and research achievements were obtained The practice shows that these new methods are adaptable to various underwater sludging base treatment, having the advantages of simple construction and low cost

In 1986, a 800 m long underwater concrete cofferdam wall was successfully removed by blasting method at Gezhouba Hydroelectric power Station on the Yantze River, China The total explosive loading in this blast was 47.76 t, more than 3000 holes blasted sequentially in 324 intervals of millisecond by adoption of double intersection connecting plastic tube non-electric initiation network to ensure 100% safe accurate blasting with satisfactory results.

The newly constructed No 3 water source of Zhengzhou Aluminum Industry Corp., Henan Province is at the beach of Yellow River. The distance from cofferdam wall to pump station is only 4 meters. Under such a circumstance, a three-row underwater deep holes in 16 intervals of millisecond blasting operation was fulfilled to break the waer intake dam and very good results were got.

In addition, when water diverting tunnels are constructed around reservoirs or natural lakes, rock filling blasting method can be used at the water intakes to get fine techno-economic results. For instance, 4075.6 Kg explosives were used for the construction of Fengman Hydroelectric Power Station with a water storage of 30 m^3, rock filling of 411 x 185 m.

1:5 Urban Demolition Controlled Blasting

In 1950's, blasting was tried in the urban demolition engineering in China. In recent years,, along with the rapid development of urban construction and continuous technical reform of enterprises, more and more abolished buildings, constructions (e.g. chimneys, water towers, bridges, abolished defence works, oil towers, industrial workshop bases, road bases, etc.) needed demolition. Meanwhile gradual perfection and popularization of controlled blasting provide technical and material base for the demolition work. At present, tens of engineering blasting companies distributed across China are undertaking various urban demolition blasting and a great amount of earth blasting. It is demonstrated that applying controlled blasting under complicated conditions to demolition of abolished buildings and constructions is a safe, simple, rapid and economic method which can control the collapse direction, stone flying, vibration and noise of the structure being demolished effectively to reduce the effect on the surrounding environment.

The current demolition controlled blasting involves borehole blasting, hydraulicpressure blasting, outside blasting, static breaking by expanding agent and static pulling method. The first three methods are based on the selection of different explosives for blasting demolition. The later two adopt static stability-losing principle to fulfil demolition. In wide engineering practices, a lot of precious experience has been accumulated on the hole layout pattern, loading structure and dosage calculation, selection of explosives, determination of blasting instruments and sequence and safety protective techniques for various demolitions. At the same time, the mechanical process and stability-losing conditions of decomposing, crushing and collapsing have been studied mechanically and survey and analysis of harmful effect such as noise and earthquake of blasting have also made.

Engineering practice shows that most of the engineering blasting companies can control collapse sequence, direction and range accurately in demolition work even under a complicated environmental and strict requirement. For instance, the old building of Huaqiao Hotel in the business region of Beijing had a total demolition volume of over 3000 m . Its main building had 8 floors of 34 m high totally. The two wing buildings had 7 floors of 28 m high totally. This was an extremely difficult demolition with very bad outer conditions. More than 6000 holes were drilled for blasting and more than 600 Kg explosives loaded for 9 intervals of millisecond sequence blasting. The whole building collapsed according to predetermined direction and range so safety was ensured and designed blasting results were obtained.

2 CONSTANT EMERGING OF SAFETY, HIGH-EFFICIENCY COMMERCIAL EXPLOSIVES AND BLASTING ACCESSORIES WELL MATCHING THE DEVELOPMENT OF BLASTING TECHNIQUES.

2.1 Commercial Explosives

At present, the annual consumption of commercial explosives in China amounts to 1, 000, 000 t. The main development of the commercial explosives in China can be displayed in three aspects, water-bearing explosives, powder and granulated explosives and relay detonating column.

Generally speaking, water-bearing explosives are the general name of slurry explosives, water-gel explosives and emulsion explosives, the representatives of different developing periods. Since 1959, slurry explosives have deen developed in China. In the mid 1960's, they were popularized and utilized widely at some mines in Northeast China. In 1970's, its further development was recorded, but most of them were used for large-diameter(<j>250mm) hole blasting at open pits.

Water-gel explosives were developed later. Until mid 1970's, China made water-gel exploives were unavailable. At that time, Huaidei Mines Bureau imported the production technology and equipment water-gel explosives from Du Port Corp., U.S.A. It promoted the development and application of water-gel explosives in China. Generally, the production of emulsion expliosves can be divided into continuous arid intermittent processes. Since later 1970's. the technology and equipment for intermittent production of emulsion explosives have been developed primarily due to the practical situaion of equipment level and plenty and low cost of labour in China. The intermittent production equipment and process control formed have met the demand of development of emulsion explosives in China satisfactorily and have its own characteristics. At the same time, contiunos production process annd equipment of capacity of 5000 t/y and 10, 000 t/y emulsion explosives annually were also successfully developed and put into commercial production. The series of emulsion explosives in China are various. Regarding the appearance, there are not only conventional soft grease but also non-adhering to the container elastic type. Regarding density, there are not only general density explosives (1.05-1. 25 g/cm^3) but also high density, high detonating velocity annd high strength explosives. Regarding utilization conditions, there are not only metallic and nonmetallic mine blasting explosives but also coal permissible explosives for mines with gas and coal dust explosion risk and petroleum exploration seismic focus column and low cost heavy ANFO explosives. The current explosives in China can meet the need of various engineering blasting. The future task is to establish sedation and standardization so that the clients can select the most suitable one according to different rock conditions, biasting methofs and temperatures, etc.

Experience has show that the effective measure to get more obvious economic profit from the blasting operation by water-bearing explosives is mechanization of loading. Although the slurry explosives were widely utilized in China in the mid 1960s, the first set of slurry explosives pump truck and pumpable slurry explosives were available in the mid 1970's. However, emulsion explosive pump loading trucks and pumpable emulsion explosives, emulsion explosive mixing trucks and truck-made emulsion explosives have been developed in succession and put into application.

Since mid 1950's, low-price ANFO explosives have spread and used in China. But before that time, the used ANFO explosives were mainly powder ANFO explosives(i.e. using crystal ammonium nitrate, diesel oil, wood powfer as raw materials) and Ammonia Rosin-Wax explosives (using crystal ammonium nitrate, rosin and paraffin as raw materials). Along with the continuous increase of porous granulated ammonim nitrate and rapid development of emulsion explosive techniques, the meshanization of loading porous granulated ANFO and beavy ANFO as well as blasting holes have been spread and used. At present, ANFO explosives and Ammonia Rosin-Wax explosives used in China's metallic mines make up 75-80% of the total output.

The specific historical conditions make the powder ammonium TNT explosives (using crystal ammonium nitrate, TNT, wood powder as raw materials) still occupy a larger part in the commercial explosives in China. The main shortcomings of these explosives are noxious, easy to absorb moisture to form agglomerate, and lack of water resistance. In recent years complex oil phase materials and doudle surface active reagents, etc. with comprehensive sensibilizing and moisture protective properties are used to reduce the TNT content in ammonium TNT explosives and effectively solve the problem of moisture adsorption and blockage of powder ammonium nitrate explosives. Now a new Non-TNT powder explosives for rock blasting which can be compatible to No 2 rock ammomium TNT explosives has come into being. On the other hand, several new types of low density, low detonating velocity, low strength powder explosives for smooth blasting have also been developed.

Before 1978, thr blasting of slurry explosives in China was carried out by site-made RDX-TNT (1:1) primer, while ANFO in large diameter holes was usually blasted by about 1 Kg of No 2 rock explosive cartridges. The results were not very satisfactory. Recently, the relay blasting cartridges have been produced in special factories. There are various types such as PETN-, RDX-, and TNT Primer. Its appearance, weight, blasting power and predetermined middle holes, etc. can match the same kind products outside China. Additionally, some specific blasting instruments have been developed too, e.g. crushing bomb for flowing sand layer gravel, solving the problem of gravel crushing in sand drilling exploration.

2.2 Blasting Accessories

There are more than 40 commercial detonator manufauring plants in China, which manufacture

1,400 million pieces of commercial detonators per year, among which fire detonators account for about 35- 40%, instantaneous electric detonators 35- 40%, millisecond delay electric detonators 15%, 1/4, 1/2 and one second delay electric detonators 5%, non-electric detonators 5%. there are usually 30 intervals in millisecond delay electric detonators and non-electric detonators. The high accuravy millisecond delay non-electric detonators have isointervals. nominal secnd of the largest 30 interval is 1350 milliseconds. In the last the years, several new products bave been developed.

(1). Non-priming Explosive Detonator

It is based on the principle of explosive burning changed into explosion. The first explosive loading of detonators was cancelled owing to the reinforced inside constrained conditions The first non -priming explosive detonator production line was assembled in Dongchuan Mines Bureau in Yunnan Province, China. Its Products included both electric and non-electric detonators. The millisecond detonators are 1-20 intervals, the second delay detonators are 1-7 intervals and a series of products are available.

(2). Safety Electric Detonators

The safety is based on inserting a safety electric circuit between the legs and bridges of electric detonators. Its working principle is as follows.

When the legs of electric detonators receive any outside electric energy signals, the signals are identified in the electric circuit. The electric circuit can identify static current, direct current or alterative current with a frequency lower than 1000Hz and refuses to transmit such signals to its bridges so the electric harm can be avoided. Only when the electric signal input matches the predetermined blasting signals, the electric current can go through the curcuit to its bridge easily and initiate the detonators. So the exotic electric harm is avoided and theh safety problems in blasting operation are solved. In addition, millisecond delay transmission instruments, relay blasters have also been produced in No 12 factory of Fuxin Mines Bureau. Its products can be divided into single or double directional They usually have 6 intervals

Cable Blasting accessories usually include commercial fire fuses, detonating cords, and plastic detonating tubes. Although the delay of the commercial fire fuses is not exact, it can be combined with fire detonators easily and simply. Its current annual consumption is about 500 million meters, including normal safety fuse and carbon fuse. The former has a combustion speed of 100-125 m/s, while the later 180-215 m/s. But the consumption of the later is no more than 1/10 of the former, the annual consumption of the commercial detonating cords is approximately 30 million meters, including normal detonating cords, seismic detonating cords, coal mine detonating cords and petroleum well detonating cords. The four kinds of detonating cords have a unit explosive loading of 11-12 g, 37-38 g, 12- 14 g and 30- 32 g or 18- 20 g respectively. The lead cover detonating cords are mainly used in the superdeep oil wells to initiate bombs. Plastic detonating tubes and non-electric detonators coordinate to form a non-electric detonating system. Because this system uses no electric energy to perform blasting operation and millisecond blasting can be carried out successfully as well as the production process of plastic detonating tubes are very simple, it has been widely applied in China and the application technique perfected continuously. Moreover, high temperature resistant (80-110) plastic detonating tubes have been developed recently to meet the demand of some special blasting operations.

It should be noticed that some specially used blasting materials have been developed greatly, e.g. oil well perforating bomb. Its annual consumption is about 2 million pieces in China including gun or non-gun types of various diameters. There are 24 models. The steel perforating bomb bas a inlet diameter of (j)50 mm and perforation depth of 520 mm. Static crushing agents and high energy combustion agents have been successfully used in the engineering balsting, especially urban demolition blasting operation.

3. GEAT SUCCESS HAS BEEN MADE IN THE FUNDAMENTAL STUDY ON BLASTING CAPABLE OF. GUIDING BLASTING PRACTICE

It should be abmitted that the selection of parameters and blasting methods in the past were based mainly on experiences in the design and calculation of engineering blastings. The reason is that there existed a certain gap between blasting theory and practive, But with the rapid development of modern technology and hard work of blasting engineers the basic theoretical study on blasting has achieved great success and can be used to guide blasting practices.

3.1. Blasting Measurement Techniques

Along with the developnent of electronic technology, blasting measurement instruments become more and more abvanced. With help of these abvanced measurement instruments, various physical and mechanical parameters concerned with blasting can be observed, then the reaction laws on pressure shock wave, seismic wave, stress, strain and crack development in the related blasting region can be obtained after computer processing. For instance, DSVM-IA Vibration Measuring Device is a kind of micro processor controlled vibrating measurement device based on calculation of the present values, having no signal transmission cables There channels of measurement and analysis results can be transmitted through several ex-parts or by numerical processing-information stored in the magnetic tape recorders. Then the quantative results are transmitted to a computer for analysis and processing . shock energy, bubble energy, total energy , pressure peak, shock value and energy density and other data of 34 kinds of commercial explosives in China can- be measured and compared by underwater blasting energy measurement method. On this basis, taking into overall consideration of density, detonating velocity and related performances of explosives and rock characteristics provide conditions for the design of blasting mathematic modelling.

Moreover, the development of blasting utensils in China has been very rapid, e.g. there are a series of products of electric initiating devices with different blasting power, blasting electric bridges, stray current measurement devices, storm predicting devices, sound and optical numerical detonator measurement devices, intelligent detonating velocity measurement devices and laser blasters, etc.

3.2.Theoretical Research on Blasting

In the theoretical stufy of blasting, fragmentation effect and cracking mechanics in rock blasting have been combined together and the fragmentation mechanism, movement laws and parameter optimization have been studied with the application of mathematical modelling The stress state of constructures can be analyzed by computer finite element method, especially the problem of dynamic and static stability losing of constructures when demolished by controlling blasting CAD of blasting has been achieved at Nanfen Open Pit Iron Mine, Shuichang Iron Mines and a lot of other metallic mines The research work on improving availability of blasting energy of explosives, controlling energy trasformation process and ensuring safety, quality and economic results of engineering blasting has got noticeable progress. On the basis of extensive tests, methodsand standards of classifying blastability of rocks have been formulated.

3.3. Numerous Safety Regulations Have Been Worked out and Implemented to Guide Blasting Practice

Since 1978, the related responsible departments in China have organised the nationwide famous blasting experts to formulate and issue *Blasting Safety Regulations, Bulk Blasting Safety Regulations, Urban Demolition Blasting Safety Regulations, Regulations of Checking Blasting Personnel Safety Techniques*, etc. The related industrial departments have also worked out their own regulations, such as *Safety Regulations for Metallic Mine Blasting and Explosive Production* of the Ministry of Metallurgy, *Safety Regulations of Coal Mme Blasting* of the Ministry of Coal Industry. They have not only obeyed the national requirements but also specialized the professional specific situations. At same time, the related presses have edited and published many monographs, eg.'Ttocfc *Crushing Mechanics", "Emulsion Explosives", "Slurry Explosives: Theory and Practice", "Ammonium Nitrate Explosives", "Engineering Blasting", "Bulk Blasting", "Blasting Calculation Manual", "New Technology for Demolition Blasting"*, etc. The journals published are "Engineering Blasting", "Blasting" and "Blasting Material". Moreover , China Sosiety of Engineering Blasting holds one conference every four years and publishes its proceedings. Four proceedings have been published till now. The first International Engineering Blasting Conference was held in Beijing in 1991, its proceeding was published both in English and Chinese. The second International Engineering Blasting Conference will hold in Kumming in 1995. China Society of Engineering Blasting has coordinated with organizations of public security, metallurgy, coal industry, water supply and hydroelectric power and railways to hold;various specific workshops for training. It is shown practically that the trained technicians and workers are playing better part in various engineering blasting operations

4 FUTURE DEVELOPMENT

The author has discucced with a number of well known experts both in and outside China on the topic of further development of engineering blasting technology in China and got numerous instructive comments A summary of those comments is given as follows:

4 1 In respect of industrial explosives priority should be given to the R & D of porous prilled ANFO, emulsion (including permissible type for coal mines) and heavy ANFO explosives with uninterrupted expansion of their application scope and proportions. Especially, research works should be speeded up to develop new kinds of emulsion explosives with quality improved, and lighter, more compact equipment and higher efficiency technology for producing emulsion explosives Efforts should be made in order to by 2000 replace all toxic powdered AN-TNT explosives by the above-mentioned three types of mining explosives in ferrous, nonferrous, building materials and other non-coal mines.

Regarding initiating materials it is necessary to improve and widely use plastic detonating tube-nonelectric detonation system and enhance its reliability and flexibility. While increasing the number of intervals for electric detonators and their precision, we should develop the techniques and products of non-primary and safty electric detonators. In addition efforts should be made to develop the technique and equipment for site mixing-loading of explosives, especially emulsion and heavy ANFO explosives in both open pit and underground blasting . Such technique is preferred to use in combination with plastic tube-nonelectric detonation system so as to gain optimal blasting effect and safety.

4.2 As mentioned above, quite rich experience has been accumulated in such aspects as chamber, deep hole, underground and underwater blasting as well as demolition controlled blasting with satisfactory success in China . However , regarding the whole labour productivity China remains rather behind U.S.A., Canada and other developed countries. Therefore, efforts should be made in developing high efficiency drilling and blasting mechanics with more advanced mechnization. At the same time CAD should be widely applied in blasting design work in order to further improve its precision and reliability.

In addition , futher research must be done in such fields as fracture controlling blasting technology, theory on blasting crater and measuring techniques, and classification of rock blastability in order to put the research results to real application at earlier possible stage.

4.3 In respect of blasting fundamentals research it is a must to enhance the applied work on blasting mechanism and mathematic modelling on the basis of existing achievements. Regarding the former, it is necessary to use new measuring techniques such as moving optical bullet, moving cloud point, distance seismic wave measurement, X-ray pulse photography, high speed photography and computer programming, and further research on quantitative analysis of blasting dynamic charge and the complicated stress-strain field of blasting in heterogeneous medium, and put the research results to application. In respect of the later, it is preferable, on the basis of surveying the worldwide mathematical modles, to employ computer techniques, image analysis and fuzzy identification in order to search for regularities and shrink the gap between the mathematic modelling and blasting practice.

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