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THE PRESENT STATUS AND TRENDS OF MINERAL PROCESSING TECHNOLOGY IN CHINA

(DRAFT)

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I.Crushing & Screening and grinding & Classification

1. Equipment developments

A large number of research work has been performed to develop the crushing and crushing and grinding technology in medium-and small-sized mines for the realization of more crushing and less grinding and reduction of the particle size of grinding feed. The Machinery Engineering department of Central South University of Technology (CSUT) has developed a kind of gyratory crusher with a variable nip angle [1,2] . Compared to a conventional jaw crusher ,thus the throughput is in one time increased with 50% energy reduction and steel consumption repectively.Beijing General Research Institute of Mining & Metallurgy (BGRIMM) [3] has coined a new term of work nip angle,and has consequently developed a new type of single-toggle jaw crusher . Compared to conventional jaw crushers,it makes 20-50% increase of throughput and one time increase of liner life. The PEX series fine jaw crushers were proposed by a Shanghai company [4,5] .There are three specifications at present time .Its discharge opening can be adjusted at the ranges af 10-40mm and 15-50mm,and the unit capacity in terms of discharge width is 0.8-1.2t/mm.h. In normal cases, for a nonferrous concentrator of 500t/d, two-stage one-closed crushing circuit flowsheet is adopted with substitution of PEX fine jaw crushers for commonly used standard cone crushers,which can reduce the energy consumption of equipment and promote the safety level of production keeping the discharge opening being not easily choked. A mine machinery factory has invented a kind of powerful fine jaw crushers,suitable for crushing hard materials with compressive resistance up

to 250MPa.

An institute of metallurgical construction in Xian has developed a kind of high - efficiency vibratory mill of MGZ - 1 model with a specification of Φ200X1320mm [6,7] . In comparison with Φ200X1320mm Palla-20U model(Germany) and Φ200X1320mm CH-20 model(Japan),the vibratory strength of the three are 8g, 10g and 15g respectively for Germany's ,Japan's and China's;the capacities are respectively 0.05t/h, 0-0.25t/h and 1.5-4t/h; the installation power are respectively 4kw,5.5kw and 5.5kw; the specific power are respectively 80kw.h/t, 22-55kw.h/t and 13.75-36.7kw.h/t and the size reduction ratio are repectively 50,50 and 200-300.

Changsha Research Instituteof Mining & Metallurgy has developed a kind of GPS-900-3 model high-fequency vibratory fine screen [8] .Its characteristics are:

1) using the motion with a high frequency and a low amplitude; 2) the screen surface consists of screen net knitted by overlapped stainless steel; 3) adopting the floating bearing screen body with rubber and spring; 4) the operation and maintenance are convient,and the power required is low. By use of it in an iron mine,it was indicated that the screening efficiency was 60-70% ,and the grinding size composition was ameliorated due to the increase of screening efficiency.By use of the equipment in combination with other technical arrangement,the capacity can be increase by 27.45%.

2. Study on wearability of grinding media

The developments of wearproof materials are focused on multi-element Cr series alloys. A kind of Cr series alloy was developed.In the regrinding operation by Φ2700X3600mm overflow mills in Dagushan Mill, the Φ25X35mm special-shaped low-Cr alloy cast grinding media were used instead of Φ30mm forged low carbon steel pellets with the unit consumption of steel balls is decreased from 0.794 to 0.353kg per ton of run of mine ore. After Zhang Jiawa Mine Company altered the B$_2$F steel balls used previously to Cr steel balls,the con-

sumption of steel balls decreased from 0.794 to 0.353kg per ton of ore. in the case of a certain grinding fineness,the mills using Cr-steel balls can increase the unit capacity from 38.95 to 95.48 ton per hour per set.

A kind of self-fastening combination boltless high-Cr liner was designed by a certain printing & dyeing industry mill [9] ,which used riveting plate to fasten the liners to the shells of mills .Use of the low-flexibility high-Cr cast galvanized iron liner makes its wearability exceed high-mangenese steel liners.With it installed in a fertilizer factory,the output increased by about 20% at near 20% decrease of energy consumption and 3-6 times increase of liner life. An engineering college has invented a kind of Mo-series high rare-earths Cr-alloy cast grinding ball and grinding segment.It is gained through direct smelting by a vertical furnance with raw Mo ores, which provides a new way to utilize raw Mo-ores comprehensively. Tests indicated that the wearability of Mo-series high rare-earths Cr-alloy was 5-10 times as that of bearing steel balls.

The electrochemical inverstigation on grinding process has been carried out for further enhancement of wearability of grinding media. it is indicated that about one-third of steel balls are corroded away in grinding process.The reasons are: 1) corrosion caused by the differences of standard electrode potential in metalls; 2) wear corrosion resulted from the impact action of steel balls and feed materials.The pulp potential variation in the process of grinding lead-zinc ores of Fankou Mine was studied at CSUT [10,11] .In the range of studied conditions, the pulp potential decreased with increase of grinding time and grinding fineness, and the pulp pH value had a great effect on pulp potential.The pulp potential increased with the dosage of lime added in mills.Before flotation,the pulp potencial was influenced by the addition points and the quantity distribution of lime, and the difference between the two pulp potential values in the two cases of adding all lime in mills and in conditioners was about 400mV.The pulp potential decreased by the addition of Xanthate and dithiophosphate in mills.On the basis of the testing results,

corresponding measures were taken to prevent the grinding media from being corrded with respect to the variation of pulp potential.

3. Study of comminution theory

Professor Xu X.H. and his graduates in Northeast University of Technology measured work index starting with the comminution properties of materials bed (12) .They used an experimental method to crush and impact the materials bed and gained the corresponding coefficients, which were called crush and impact work index respectively. In the meantime, Bond work index was measured by a standard mill to make a paralled comparision. The results indicated that the crush work index showed a good agreement with Bond's and could simply be measure, which could be taken into consideration as a substitution of Bond work index.

The study of the comminution mechanism of materials beds has spurred the development of high-compression roll mills.Prof. Hwang S.S.,et al. (13,14) , have consistantly been focusing on the study of the materials beds comminution technology on high-compression roll mills in CSUT.It is demonstrated that high-compression roll mills should utilize pure compressive stress, which has much better effects in contrast with impingement and shearing force. In addition, they have studied the role of the impingement comminution of materials beds, and found that the crush probability of impingement crush of materials beds exist a limitation value of saturation crush porbability either in a single or multiple repeated impingement. Therefore, in the design of the crush equipment with impingement comminution of materials beds as its main comminution mode, the determination of mechanical parameters should make the saturation-comminution probability optimum, by which the specific energy consumption of comminution can be effectively decreased.

4. Prospects

Because of high energy consumption in grinding process, the technology of

" More crushing and less grinding " and subtitution of crushing for grinding will be further promoted. There will be various crushing equipments to meet a technological urgent need, such as the high-compression roll mills ,wil being constantly emerged.

The demand of uitrafine materials is increasing day after day in various industries,so the ultrafine crushing equipments and ultrafine screening equipments will be gradually taken seriously.With the development of the technology ofmaterials beds comminution and ultrafine comminution, theoretical approaches on the materials beds comminution and the ultrafine comminution will being developed in depth constantly.

II. Gravitation Concentration

1. Technology and equipments of gravitation concentration

(1) heavy medium separation(HMS)

HMS is applied more extensively in China. A research institute adopted two-stage three-flow separators to treat the raw ores in the Concentrator of Dongfong Fluorite Corporation [15] . With feed size 2-15mm and feed grade 39.77% CaF_2,29.16% tailings to raw ores were discarded at a tailing grade of 8.05% CaF_2,which was lower than that of floation tailings in 15%. A 52.82% average grade of the concentrate in combination with minus 2mm fraction unseparated was recovered, which had about 13% increase than feed grade with overall recovery up to 94.1%. A research institute in Hunan [16] adoted heavy medium cyclones to process the lean calcic-silliciou colloidal phosphoric ores in Hunan Xiqi Phosphorite Mine.After two-stage separation of one roughing and one cleaning, three products of concentrate, middlings and tailings were yield. With a feed grade of 14.4% P_2O_5, the concentrate contained 24.44-25.16% P_2O_5 at a recovery of 66.66%, which could be used to produce phosphoric acid by wet method; the middlings contained 14.27% P_2O_5 at a recovery of 15.59%, which could be used to yield calcic-magniferous phophoric fertilizers after

classificationand deslime: and the tailings had a yield of 33.76% with 6.71% P_2O_5 content, which could either be mixed with raw ores to compoud calcic-magnferous phosphoric fertilizers,or be used as building materials.

(2) Jigging

There are some recent developments on extending the feed size range of jigs and using coarse jigs in preconcentration for discarding waste, which is mainly attributed to the successful applications of the movable sieve jigs. A kind of TJD-75 model movable sieve jig with a non-symmetric cycle has been developed by Northeast University of Technology,et al. (17) . it was used to preconcentrate the 12-120mm sized ores after primary crushing in an iron mine. The yield of the tailings disposed was 16%, and the ore grade was increased by 4% with recovery up to 95%, which was pronouncedly superior to the preconcentration result yielded by fixed sieve jigs with a sine cysle.

Zigzag wave jigs have extended their possible applications as high-efficiency fine jigging equipments. The DYTA-7750 model hydraulic radial jig series produced by a machinery plant have ten specifications with 3 to 12 chambers, the jigging area is 9.9-39.6m^2,and the throughput is 30-180t/h.

(3) Shaking tables

The Research Institute of Yunnan Tin industry Company has made some recent achievments on structure improvements of table head and deck. In view of the disadvantages of Yunxi-type table head: the storke adjustment by moving the pull rod position up and down and a narrow range of stroke adjustment, a new type of YX-1 model table head has been developed (18) ,which preserves the advantages of Yunxi table head in motion performance. The stoke adjustment need not move the pull rod position, and the stroke has a wide adjustment range from 6 to 26mm. the Research institute has also design two new types of grooved decks (19) , one of which is YXK-74 model deck for the separation of 37-150 microns fraction and the other is YXK-37 model deck for 19-74 microns fraction. Their characteristics are as follows: 1) adding small shallow ditch stripes to the concentration zone on the deck to avoid heavy

minerals being flushed directly by eashing water; and 2) increasing the crawling distance of the ditches bottom in die-out zone to enhance the separation of heavy and medium density minerals. It was confirmed in production practice that this deck had a great capacity, a little consumption of washing water, about 10% increase of recovery and up to 15% reduction of oprating cost. A kind of TY500 model variable arm type bech table with an eccentric rocker mechanism has been developed by an institute [20] . Its stroke is 0-7mm and speed 0-1000rpm, which can all be successively adjusted in operation.

(4) Spiral concentrators (Spirals)

A kind of GL-600 model double-head spiral concentrator has been developed by Guangzhou Research Institute of Non-ferrous Metals [21] . The spiral trough diameter is 600mm, the spiral pitch is variable, and the spiral trough cross-section consists of the compond diagrams of cubic parabola, line, circle and parabola. The GL-600 series have three products, i.e. GL-1A and GL-1B, which have 4 and 6 circles of spirals for roughing and scavenging respectively; and Gl-2, which has 7 circles of spirals for cleaning. The feed size range is 0.03-2.5mm. The contrast experiments indicated that its throughput, concentration ratio and separation efficiency are all higher than those of normal spirals. A kind of DL-2000 model spiral sluice has been developed by BGRIMM [22] . Its spiral trough diameter is 2m, and the cross-section appears to be compound curves shape, which has a satisfactory response on wide size range materials separation. Feed size being 0.04-4mm, the capacity for a single spiral is up to 5-10t/h. Production practice confirmed that the facility could be used to concentrate free cassiterite before table floatation instead of shaking tables, which solved the problems resulting from tables, such as a large occupation area and a high consumption of electricity and water.

2. Fine particle gravitation concentration new technology in a composed-forces field

(1) Centrifugal concentration

A kind of continuous efflux centrifugal concentrator developed by BGRIMM [23] can feed and discharge successively, which uses the compound forces of strong impulsive force from high-compression water efflux; strong centrifugal precipitation force and Biganold's force to join in separation. Its centrifugal separation efficiency is up to 660,belonging to strong centrifugal force, and the high-compression efflux pressure is 1.5-2MPa.This equipment can handle ultrafine materials of minus 10 microns, and can recover cassiterite particles down to 3 microns.The SL-600 model drum of the equipment is 600mm in diameter and 240mm in length with a capacity of 250-430kg/h. With it uesd in Guangxi Changpo Mill to process -10 microns tin slimes, for the feed containing 0.40-0.53% Sn, the concentration ratio was 6.57-8.81 at an operation recovery of 51.25-53.95% after one roughing operation, and the cassiterite recovery was 83.3-85.76% for +5 microns fraction and 50.71-59.56% for the fraction of -5 to +3 microns.

The camber votex panning pan developed by CSUT [24] adds a votex part under a camber cyclone for cleaning, through which additional water is poured in for the second concentration of down-flow.

(2) Magneto-gravity separation

Magneto-agglomeration gravity concentration is to magnetize the feed materials in the light of a magnetic field, resulting in materials agglomeration, then the megnetic agglomerates are separated from gangue minerals under the action of gravitation.After its successful applications in two iron concentrators, a satisfactory result has again been obtained in the separation of vanadium and titanium magnetite at present [25] . For the feed of -0.3mm,size with 27.63% Fe content, a concentrate containing over 57% Fe was attained with over 69% recovery. Compared to previous low-intensity magnetic separation--sieving flowsheet, the concentrate grade increased by 1.44% ,and the capacity rose by 39% due to the coarse feed.

3. Theory of gravity concentration

The hindered settling velocity formula suiting for ultrafine uniform spheric particles group has been inferred in theory by Yang Y.J.and Yao X.D. with respect to the assumption of effective action zone [26] .It is confirmed in practice that the derived formula has a better coincidence with the objective role than previous ones, which possesses an industrial significence for the investigations on gravity concentration,classification and condensation of ultrafine materials.A kind of moving sieve jig cycle curve suitting for coarse particals separation has been designed by Sun C.B. and Sun Y.B. [22] ,using sampling experimental facilities and theoretical analysis.Its foundamental form is that the descent motion time of sieve frame is short with a high speed, and the ascent motion time is long with a low speed.During this kind of cycle, particals stratified according to the travel motion difference between light and heavy mineral particles in initial acceleration section in bed rather than according to the terminal velocity of motion. The experiment with real ore was carried out by use of the non-symmetrical jig cycle designed by this theoretical analysis,and the result was obviously superior to that gained by sine jig cycle.

According to the current motion characteristic along the length direction of spiral trough, the current of spiral sluice was divided into initial and stable section by Hwang S.A. [28] , and the distributions of the parameters in the initial current section were studied for the first time, such as inertial film thickness, average flow rate, Reynolds number, unit width of flow volume, accumulation volume and radial net volume. The current motion charateristics of various cross-sections in initial section are different, and this part is about 1.5 coil long. It plays a role to push light minerals to the edge and coarse heavy minerals to the intermediate zone, which is useful for the separation and distriction of light and heavy minerals.

4. Prospects

In consideration of ecnomy and enviromental protection, much attention has been paid on gravity concentration in recent years. Gravity concentration has somewhat extension in the applications of preconcentration for coarse partical ores and roughing for common ores, and the theoretical approaches and process simulation of gravity concentration have also made some achievements , but its future wil be dependent on the develoments of the new methods for finer particles recovery.In late years,the research of gravity concentration is focusing on the development of new technology and equipment for ultrafine materials separation, while the main prospective direction is to use the processing method of composed-forces field with centrifugal force in combination with various forces field (such as gravitation, centrifugal, magnetic and interface force).

III. Magnetic & Electrostatic Separation

1. Tehcnology and equipment of magnetic separation

(1) Low-intensity magnetic separation

The developments of low intensity magnetic separation principally invoves: (a) design of higher intensity drum magnetic separators with NdFeB magnets;(b) development of magnetic separattors for bulk materials separation;(c) strengthing low-intensity magnetic separation.

A kind of CT-1416 model permanent magnetic drum has been developed by BGRIMM [29] .Its magnet system is compounded by NdFeB and strontium ferrite magnets, and the average induced magnetic intensity is up to 0.56T at the pole surface. The assembly magnetization technique was adopted to magnetize NdFeB magnets. The magnetic drum shows a large bending strength and a great loading capacity .With it used in an iron mine, its yearly capacity was 1.215 million tons of raw ores, and 0.1395 million tons wast with grade 11.18% was prediscarded,making the grade of the feed entering the mill--separation system increase from 37.85% to 40.38% which had an apparent effect in energy saving.

A kind of CTDY-1214 model mobile bulk dry magnetic separator has developed by BGRIMM [30] . Its magnet system consists of various compound materials.The induced magnetic intensity on the drum surface is about 0.4T, and the magnetic field has large action depth.The drum adopts non-magnetic cast iron instead of expensive stainless steel,cast copper or aluminium.The facility is moveable, and has a great flexibility of application .The CTDG-1516 model bulk magnectic separator developed by Maanshan Research Institute of Mine [31] has about 0.4T of induced magnetic intensity on the drum surface. Its drum diameter is longer than that of CT-1416 model.

A research institute in Baotu has developed a type of drum separator with NdFeB magnets [32] . Compared to tradictional drum separator with ferrite magnets, its drum surface intensity is higher up to 0.35T,the magnetic poles number reaches up to 8,and the magnetic field distribution is rational. It has formed NTC series with the specification of Φ750X1500mm. By use of the equipment in the concentrator of Baotu Iron & Steel Company,the industrial experimental results demonstrated that the grade and recovery of concentrate increased by 1.02% and 2.78% respectively in comparison to that gained by drum separators with ferrite magnets. The concentrators of Baotu Iron & Steel Company has developed a kind of CBN model Φ1050X1400mm permanent medium-intensity magnetic separator [33] .Its magnet system consists of compound materials. It adopts a complets reverse-current bottom cabinet.Water pipe are installed at the bottom of the feeder, and the pipe valve can be adjusted by necessity, resulting in pulp agitation dispersion under the action of compressing water and enhancement of effective separation.

(2) High-intensity magnetic separation

Wet high-intensity induced roll magnetic separators are extensively used for the separation of manganese ores. BGRIMM has developed a kind of induced double-roll high intensity magnetic separator(HIMS). The maximum induced magnetic intensity in the working zone of the upper roll is 1.4T, and the bottom one is 1.8T. A compound magnetic pole pairs is adopted, and the pole

heads and roll teeth are treated by coating a layer of wearproof alloy to improve the wearability. The coils are externally cooled by water.

Ring type HIMS mainly comprises two types--horizontal and vertical ring. The Z-shape plate matrix structure was proposed to separate hematie on the basis of the investigations on the plate matrices in horizental ring HIMS, the attained recovery was higher than that by use of conventional teeth plate materices.The main reason is that Z-shaped teeth plate has meandering triangle teeth, resulting in pulp redistribution, flow rate decrease, thin film formation and network distribution of magnetic intensity and gradient in the working zone, thus increasing the capture probability of mineral particles.Therefore,the recovery of magnetic mineral particles can be increased.

(3) High gradient magnetic separation

Conventional high gradient magnetic separators(HGMS) can be used for the purification of non-metallic ores,such as kaolin.However, it can not be effectively applied in metallic ores separation due to the mechanical entrainment easily occured in magnetic matriced. In view of the above-mentioned disadvantages,the investigations on reduction of mechanical tramp have been proceeding by CSUT from the begining of 1980's.The vibration,pulsation and vibro-pulsation HGMS have been developed one after another,which can effectively eliminate the mechanical entrainment of matrices and increase the separation efficiency.

For the Cu-Pb bulk concentrate in Henan containing 35% Pb and 3-5%Cu,after two stages of high gradient magnetic separation(one roughing and one scavening), a Cu-concentrate with 15-18%Cu content, less than 6%Pb content,and 84%Cu recovery,and a Pb-concentrate with over 41%Pb content less than 0.8%Cu content and 96-98%Pb recovery were gained [34] .

SLON-1500 model vertical ring pulsation HGMS was used to separate the overflow of Φ350mm hydrocyclones fed by the ground and classified jig middlings in Gushan Iron Mine. For the feed of 26.11%fe content, the concentrate grade was 56.78% with an operation recovery of 54.54% only one pass.

Various fine tailings discharged in the tailings dam were classified to separate, and the concentrate grade was 56.22%Fe at a recovery of 58.22% through one pass only.

A vibro-pulsation HGMS was used to process the tatalum and niobium slimes. In comparison to previous flowsheet (centrifugal separator—belt sluice), the recovery increased by about 20% with similar concentrate grade.

After the successful achievements on the investigations of the new technology of wet high gradient magnetic separation, the study of dry high gradient magnetic separation has again been proceeded by CSUT [35] .For the refractory kaoline with particle size less than 40 microns, the Fe_2O_3 content decreased from 2.2% to 0.82% with a yield of 86.3% concentrate after once dry vibration high gradient magnetic separation.

(4) Magnetic fluid separation

The centrifugal magnetic-fluid separator developed by Zhang Y.P.et al. [36] , is a vertical drum containing magnetic fluid with a circular magnet system installed around. The magnetic field is strong in outer part and weak in centre, as resulting in the formation of magnetic gradient along the radial direction. In separtion process, the drum and the magnet system rotate at a certain angular velocity or only the drum rotates with the magnet system fixed. The solid particles exsting in media are mainly subjected to the actions of centrifugal and magneto-floatation force. By adjusting the drum rotation speed, the magnetic fluid density and the magnetic field charateristics, the materials are gained separation dependent on the differences of density and magnetic permeabilities. This facility has a high separation speed, a high precision and a great capacity, especially suiting for fine materials separation.

2. Magnetic-flocculation, selective magnetic seeding and coating separation

The settling performance and its impact factors of magnetic particles in a uniform low-intensity magnetic field were studied and analized by Wei Y.H., et al. [37] . The concepts of moveable magnetic chains flow bed, immoveable

magnetic condensation state and unstable magnetic condensation state were proposed,and the magnetic flocculation of magnetite was considered to exsit a critical magnetic strength. With other factors fixed, the key is to determine a suitable magnetic strength and ascent water speed.

The main parameters and theoretical models of rheologic states of high-intensity magnetic suspensions were investigated by JiangC.L.,et al., and the shear-magnetic-agglomeration process and the physical properties of feeding materials were taken into consideration comprehensively which provided a theorectical criterion for separation by magneto-gravity principle (38) .

The investigations on selective seeding flocculation magnetic separation and selective seeding magnetic separation of lean ultrafine slime bearing siderite, limonite and specularite were carried out by Song Q.Y.,et al. (39) . Compared to the results from direct magnetic separation and selective flocculation magnetic separation, it was indicated that the selective seeding flocculation magnetic separation was the most effective method.

The study on hematite seeding agglomeration-high polymer flocculation-gravity concentration technology was carried out by Hu X.M.,et al. (40) . The results demonstrated that the technology had a good selectivity for hematite, and the obtained floccules were more compact, stronger and coarser than those gained by a single seeding agglomeration process or a single high-polymer flocculation process,which were suitable for gravity concentration.

Song Q.Y.,et al., studied the selective magnetic coating on specularite and its mixed ganguge (41) .The impact factors on the selective magnetic coating separation of specularite and gangue such as quartz, barite and dolomite were investigated,and the same investigations were carried out on the tailings of high-intensity magnetic separation in a mill .The testing results showed that the selective adhesion of magnetic seeds to the surfaces of weakly magnetic minerals could improve the recovery of weakly magnetic iron minerals.

3. theory of magnetic separation

The magnetic field charateristics around small wire matrixes in a magnetic field have significant impacts on high gradient magnetic separation.The magnetic field charateristics around the small wire matrices with a rectangular or a polygonal cross-section were studied in CSUT by use of finite difference and finite element method [41,42] ,and many important conclusions have been drawn.

4. Electrostatic separation

Promising results have been achieved on the separation of ultrafine rutile by use of self-made special high-tention drum electrostatic separation of 60,000 volts and special structure of electrodes in CSUT [42] with primary ore and beach sand as feed.

The primary ore feed contains 60% 0.04-0.074mm fraction, and 40%-0.04mm fraction,-0.02mm fraction occupies 15% in the sample. It can be seen that the sample size is finer.

When the feed for electrostatic separation contains 69.8% TiO_2, a final concentrate with a grade of 90.53% TiO_2 and 86.2% recovery can be derived from the cleaning concentrate of the mixture of the rough concentrate gained by one roughing and the concentrate of middlings reseparation.

Beach sand has a coarser feed size,the 0.074-0.12mm fraction contains most of them and the -0.074mm fraction contains 5-6%.While the feed for electrostatic separation contains 63.4% TiO_2 ,a concentate with 91.8% TiO_2 content can be yield at a recovery of 98% after one roughing and one cleaning. A satisfactory result has also been gained on beach sand separation with the sieve plate type electrostatic separator developed by Guangzhou Research Institute of Nonferrous Metals.

5. Prospects

The magnetic seperation of ultrafine weakly magnetic minerals and the electrostatic separation of ultrafine refractory minerals will be the principal research field in future, and the complex forces field HGMS and electrostatic

separator are the key facilities for these materials separation.

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