



离心机的选择

Choosing a centrifuge

Thomas Broadbent & Co公司的John Wright说道，为某一具体分离任务选择合适的离心机应基于经济和技术两方面的考虑，同时还需要充分了解各种不同的选择

Selecting an appropriate centrifuge for a specific duty is based on economic and technical considerations, and requires a thorough understanding of the various options, says John Wright of Thomas Broadbent & Co

与各种可供选择的固液分离方法相比，离心分离具有很多独特的好处，这取决于所选分离系统的类型。离心机具体的优点有：占地面积相对较小；洗涤能力高；产生的滤饼含水量低；生产能力高；能为用户提供一个全密闭处理设备。离心过滤同时也被看作是一种最为有效的杂质去除方法。

然而，为某一具体应用选择恰当的离心机应基于两个关键考虑——经济预期和技术要求。

When compared with alternative methods of separating solids and liquids, centrifugal processing – depending on the type of system selected – provides a number of unique benefits. Centrifuges can be installed in a relatively small footprint; have a high washing capability; produce low cake moisture; achieve a high capacity throughput; and can provide the user with a totally enclosed and vapour-tight

技术考虑

在考虑各种可能的选择之前，重要的是要清楚地界定分离过程。由于离心机究竟能够实现什么样的结果并不很确定，第一步往往容易被未来的离心机用户忽视。准确界定分离过程在最初向离心机供应商简要介绍工艺需求时也是至关重要的，因为供应商需要将筛选试验和可行性研究建立在有关数据资料基础上，以避免将宝贵时间和精力浪费在模糊且误导的假设上。

一旦清楚地界定了分离过程，就能够更容易地确定出影响工艺包选择的变量。这些变量包括：悬浮固体物的百分含量、料浆体积通过量、固体物通过量和所要求的排出产品一致性。从离心机排出的物料通常是粉末或者粒状形态，但是也有一些情况排出的是糊状物。产品一致性将在一定程度上决定物料的处理和运输方法。

未来的离心机用户应当明确地界定离心工艺需要实现的目标。物料是否需要澄清、分级、除砂、浓缩、脱水、洗涤、分离或碎浆？分离工艺是固液、液液还是液液固三相？

其他需要考虑的重要因素包括：期望的“G”力，容许滤饼干燥度，排出液中容许固体物含量，产品的温度、粘度、比重与pH值，以及离心工艺应该是间歇过程还是连续过程。如果离心机是用于制药或者精细化工行业，则必须根据GMP规范设计制造，配备整合在线洗涤(CIP)系统。

选择间歇式离心机还是连续式离心机取决于许多因素。间歇式离心机对洗涤操作限制很少，而连续式离心机通常限于约10%的液固比，而且在完成操作之前分配到洗涤区的时间不超过数秒钟。例如，如果待处理物料中残留杂质含量低且对洗涤要求高，间歇处理具有的更高灵活性可允许进行必要的调整来满足个别需要，例如：延长洗涤时间；使停留时间更长。

在确定分离性能，以及判断某种间歇式分离机或连续式分离机是否是最佳选择时，粒度分布和颗粒物形状也是需要考虑的重要因素。一般说来，粒径大于45微米的物料与相对松散的物料非常适合用过滤设备分离。然而，更微细或者松散的物料则更适合用沉降方



processing facility. Centrifugal filtration is also considered to be one of the most effective methods of removing impurities.

Correct selection of a centrifuge for a specific application, however, is based on two key concerns – economic expectations and technical requirements.

Technical considerations

Before considering the various options, it is important to define clearly the process. This first step is often overlooked by prospective centrifuge users due to uncertainty as to what exactly a centrifuge is capable of achieving. An accurate definition of the process is also of vital importance at initial briefings with the centrifuge supplier, who needs to base screening tests and feasibility studies on relevant data and not waste valuable time and effort on vague and often misleading assumptions.

Once the process is clearly defined, it is much easier to identify variables which affect the choice of process package. Such variables can include the percentage of suspended solids, volumetric slurry throughput, solids throughput, and the required product consistency at discharge. Materials usually exit the centrifuge in a powdered or granular form, but there are some instances in which it can also be discharged as a paste. Product consistency will to some extent dictate the method of materials handling and transportation.

The prospective user should clearly define what the centrifugal process is required to achieve. Does the material require clarification, classification, degritting, thickening, dewatering, washing or separating and repulping, and is the process a solid-liquid, liquid-liquid or a three phase liquid-liquid-solid duty?

Other important considerations include: the expected 'G' force, allowable cake dryness, allowable solids in the discharge liquors, product temperature, viscosity, specific gravity, pH and whether the process should be batch or continuous. If the centrifuge is to be used within the pharmaceutical or fine chemical industry, it may have to be manufactured to a GMP design with an integral CIP system.

The decision to use a batch or continuous machine can depend on many factors. Batch centrifuges place very little limitation on the wash function, whilst continuous machines are mostly limited to a wash-solids ratio of approximately 10 per cent, with no more than a few seconds allocated to the wash zone before completing the operation. If, for example, the materials to be processed have low residual impurities and a high washing requirement, the greater flexibility of the batch processing will allow the necessary adjustment to satisfy individual needs such as extended washes and longer residence times.

Particle size distribution and shape are also important factors when determining separation capabilities and whether



法进行分离。经验表明，在一些情况下，不管粒径或颗粒物形状如何，物料用间歇方法和连续方法处理可能都合适。

特殊要求

如果需要确保各批物料之间不产生交叉污染，则可以在离心机上安装可预编程且经认证的在线洗涤(CIP)系统，这同时也消除了清洗和维修期间打开机壳的需要。这样的离心机特别适用于制药和精细化工行业。

最近几年，流程行业中强制实行了非常严厉的实施规范。一些药品管制局的建议对这些规范的制定实施影响很大，包括美国食品和药品管理局。这引起了行业对认证分离机产品的需求，同时为开发符合良好生产规范(GMP)的核心要求、并引入最先进的可编程逻辑控制系统的离心机提供了根本推动力。这类离心机符合GAMP标准，能够满足过程与环境完整性的要求。在需要使用离心机处理具有潜在爆炸性或可燃性产品的情况下，可以为其安装惰性气体吹扫系统，以确保彻底的操作完整性。此外，还能够为离心机配备耐压密闭系统。

具体选择

在明确地界定了分离工艺、目标和所需变量之后，就可以开始为工艺过程选择一种既能满足规定标准，同时又具有最佳性能和最高性价比的离心机。

如果需要的操作是过滤——包括滤水、滤饼洗涤或者分级，立式篮筐离心机、锥篮式离心机、刮刀卸料离心机、推料式离心

or not a batch or continuous centrifuge is the best option. Generally speaking, materials that are at least 45 microns in diameter and relatively incompactable are highly suitable for separation by filtration equipment. Finer or compactable materials, however, lend themselves more to separation by sedimentation. Experience has shown, however, that in some instances material compositions can be suitable for both batch and continuous processing, irrespective of size or shape.

Special requirements

In circumstances where it is necessary to ensure that there is no cross-contamination between batches, machines can be installed with pre-programmable, validated clean-in-place (CIP) washing systems, which also eliminate the need to open the casing between cycles for cleaning and maintenance. These machines are particularly suitable for use on applications within the pharmaceutical and fine chemical industries.

Over the years, stringent codes of practice have been rigidly enforced across the process industries and have been greatly influenced by the recommendations of pharmaceutical authorities, including the US Food and Drug Administration. Such codes have created a need for validatable centrifuge designs, and have provided the basic initiative for the development of machines which combine the very best of good manufacturing practice (GMP) and state-of-the-art programmable logic control. These centrifuges are GAMP compliant with the ability to satisfy the requirements of process and environmental integrity. In situations where centrifuges are required to handle



机、螺旋过滤离心机、沉降过滤离心机和翻袋式离心机与振动式离心机都适合。但是，如果需要的操作是沉降——包括分离、澄清、分级、除砂或者浓缩，沉降式离心机、篮式无孔转鼓离心机、盘式离心机、管式离心机则更为适合。初步筛选试验将能很快地确定出最佳选择。

沉降式离心机的类型

卧式无孔转鼓沉降离心机

沉降式离心机包括两个装在固定机壳中的水平同心转动部件：转鼓和螺旋输送机。外转动部件/转鼓是锥形的，这样固体物能从比液体小的半径位置处排出。内转动部件是一个空心轴螺旋输送机，具有与转鼓轮廓紧密配合的叶尖。

料浆通过泵送或者重力送料的方式被引入输送机空心轴。料浆自动加速到离心机的转速，在离心力作用下经由出料口被送到转鼓中。固体物通过液池沉淀，沉积在转鼓内壁。

转鼓和螺旋输送机之间存在微小的转速差，这能使固体物沿转鼓壁被连续地送出液池，向上经过锥形干燥区到达固体物出料口。澄清液以相反方向从可调溢流口连续地排出。无孔转鼓沉降式离心机也可以作为分级器使用，能够显著地降低悬浮液中的固体物含量；可处理的物料粒径可以粗至50微米，也可以细至1微米。

无孔转鼓篮式离心机

近年来，间歇有孔篮式离心机被认为已经过时。其他类型的离

potentially explosive or flammable products, they can be installed with inert gas purging systems to ensure complete operational integrity. Machines can also be supplied with pressure tight systems.

Individual selection

Having clearly defined the process, the objective and required variables, it is now possible to proceed with selecting a specific type of centrifuge which will not only meet the specified criteria but will combine optimum performance with maximum cost-effectiveness.

If the requirement is for filtration - including drainage, cake washing or classification - a vertical basket, conical basket, peeler, pusher, screen scroll, screen bowl, inverting bag or vibratory centrifuge is suitable. But where the requirement is sedimentation - including separation, clarification, classification, degrading or thickening - decanter, solid bowl basket, disk bowl and tubular centrifuges are more appropriate. Preliminary screening tests will quickly indicate the best option.

Types of sedimenting centrifuge

Horizontal solid bowl decanters

Decanter centrifuges consist of two horizontal concentric rotating elements contained in a stationary casing. The outer rotating bowl/element is tapered so that solids discharge from a smaller radius than the liquor. The inner element is a hollow hub screw conveyor with blade tips shaped to fit closely to the contour of the bowl.

Feed slurry is introduced into the conveyor hub by pump or gravity feed and, as this automatically accelerates to machine speed, the slurry is delivered by centrifugal force into the rotating bowl via discharge ports, where solids settle through the liquor pool formed on the wall of the bowl. There is a slight differential speed between the rotation of the bowl and that of the conveyor, which permits the solids to be conveyed continuously along the bowl wall, out of the pool, and up the tapered drying beach to solids discharge ports. The clarified

离心机，尤其是无孔转鼓沉降式离心机开始更受青睐，这主要是由于在处理难以输送的固体物的输送器设计上取得了进步。然而，这也存在一些例外，尤其是对于待处理物料体积相对较小，且循环次数不是一个重要因素的应用场合。

盘式离心机

盘式离心机的运转速度高，产生的离心力是重力的3,000-20,000倍。这种离心机具有一个连续澄清系统，适用于物料中固体物含量低于1-2%的应用。盘式离心机设计用于固液或者液液两相的连续分离。分离过程中，固体物沉积在转鼓内壁上，并能通过转鼓的间歇开启手动或者自动地排出。盘片堆叠大大地增加了有效的沉淀或澄清区面积，液固两相流经盘片的上表面或下表面。液体通过一个或者多个配水盘流出。

管式离心机

管式离心机主体部分为一两端封闭的无孔管。通常由底部进料口加入两种不同比重的液体。其中较重的液相聚集在管壁上，较轻的液相浮于其上。两液相通过挡板进行分离，并将它们排到两个不同的液流中。如果所处理的固体物料是液固或液液固形态，就必须

liquor discharges continuously in the opposite direction from adjustable overflow ports. Employed as a classifier, the solid bowl decanter centrifuge effects sharp cuts of solids in liquor suspension, with materials as coarse as 50 micron, or as fine as one micron.

Solid bowl basket centrifuges

Batch perforated basket centrifuges have, in recent times, been considered to be obsolete technology. Other machines, especially solid bowl decanters, have become more favourable mainly due to advances in conveyor designs for difficult to convey solids. There are exceptions to this, however, especially where relatively small volume materials have to be processed, and cycle times are not a significant factor.

Disc bowl centrifuges

The disc bowl type centrifuge operates at high speeds of 3,000 to 20,000 times gravity, providing a continuous clarification system which is suitable for use where materials have a solids

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定期清洗设备。但是，如果不存在固体悬浮物，处理过程就可以连续进行。

过滤离心机的类型

立式篮筐离心机

在液压驱动器和电流逆变器的控制下，新型篮式过滤离心机的进料、洗涤、旋转和刮刀速度选择范围很宽，因此在各种浆料和化学品的处理上具有很强的适应性。这种间歇式离心机产生的滤饼异常干燥，这使其具备两个主要优点：使用最少量的洗涤液便能够对滤饼进行很有效的洗涤；能够以低的篮筐转速卸出分离的固体物——这确保对脆弱晶体的破坏可以忽略。提取出的母液和废液能够容易地在单独的间歇循环期间被分离。

假若进料条件、进料速度和滤布选择恰当，篮式离心机便能够对粒径在1-10,000微米的固体物进行脱水处理。为了实现全自动安全运行，并使所需的操作员干预最小化，也可以对离心机进行完全的密封与清洗。工艺过程是完全密闭的，因此操作员不会身体接触产品。

在离心机的运行过程中，料浆从篮筐的上部开口加入，正常情况下篮筐减速转动。进料经由一个切线管或者360度的锥形分布器直接加到篮筐中，具体取决于处理中的料浆类型和离心机种类。进料速度和篮筐转速被调节，这样当料浆覆盖了整个篮筐壁时，进料速度与过滤速度之间实现理想匹配，形成厚度均匀分布的滤饼。

content of less than one to two per cent. Designed to separate either a solid-liquid or two liquid phases on a continuous basis, solids settle on the wall of the bowl and can be discharged manually or automatically by intermittent opening of the bowl. The disc stack greatly increases the effective settling or clarification area, and the liquid and solid phases travel up or down the disc surfaces. The liquid discharges through one or more paring discs.

Tubular centrifuges

Designed as a solid tube which is capped at both ends, the tubular centrifuge is usually fed through a bottom inlet with two liquids of different specific gravities. Of the two liquids, the heavier phase is concentrated against the wall of the cylinder, whilst the lighter phase floats against it. The two phases are separated by means of a baffle, which discharges them into two distinct flows. Where solid feeds are processed in a liquid-solid or liquid-liquid-solid state, regular cleaning is necessary, but if there are no suspended solids, the process can be continuous.

Types of filtering centrifuge

Vertical basket centrifuges

Due to the wide selection of feed, wash, spin and plough speeds available, either by electrical inverter or hydraulic drives, modern basket filtering centrifuges are very adaptable in the processing of an extensive range of slurries and chemical compositions. Producing an exceptionally dry cake, these batch machines have two major advantages: A capability to give cake solids a very efficient wash, using minimum wash fluids, and an ability to discharge the separated solids at low basket speed – thus ensuring negligible breakage of delicate crystals. The extracted mother liquor and wash liquor are easily segregated at separate stages of the batch cycle.

Given the correct feed conditions, feed speed and filter cloth, basket centrifuges are able to dewater solids from one to 10,000 microns. They can also be fully sealed and purged for safe operation



离心机的正确选择基于两个关键考虑：经济预期和技术要求

在洗涤周期之后，篮筐开始以高得多的速度转动，来对滤饼进行脱水干燥处理。在干燥过程结束时，篮筐转速回降到一个较低的速度，通过横移刮刀手动或者自动地将滤饼卸出。

卧式篮筐刮刀卸料离心机

这种离心机产品现有两种类型：化工业用重型刮刀卸料离心机和制药业用GMP刮刀卸料离心机。刮刀卸料离心机兼具过滤和脱水两种性能，特别适用于在制药和精细化工行业超洁净环境条件下处理多种多样的物料。该型离心机配备有多孔滤篮和滤筛膜以及脱水用无孔转鼓。刮刀卸料离心机的前面配备有一个全开式机壳，这能使操作员安全地对内部情况进行检查。顾名思义，这种离心机还带有一个用于卸出滤饼的自动刮刀机构。另外，还附带有一个有效的尾料移除系统，

and on fully automatic operation, minimum operator attention is required. As the process is totally contained, the operator has no physical contact with the product.

In operation, slurry is fed through the top opening of the basket which normally operates at reduced speed. Depending on the type of slurry being treated and machine type, the feed is either introduced directly into the basket via a tangential pipe or 360 degree distributor cone. The feed rate or basket speed is adjusted so that ideally the feed rate matches the filtration rate as the slurry covers the basket wall, top to bottom, forming an evenly distributed cake.

Following the washing cycle, dry spinning commences at a much higher speed, at the end of which, the cake is discharged either manually or automatically by use of a traversing plough back at a lower rotational speed.

Horizontal basket peeler centrifuges

Two types of peeler centrifuge are available: A heavy duty chemical design and a GMP design. The peeler centrifuge offers

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both a filtering and decanting capability, and is particularly suitable for processing a wide range of materials in the ultra clean environmental conditions of the pharmaceutical and finechemical industries. Machines have perforated baskets and screened membranes for filtering processes or solid bowls for decanting. The peeler centrifuge has a fully opening front-end casing, which allows operators to inspect the interior safely and, as its name implies, has an automatic peeler

knife mechanism for cake discharge and the additional benefit of an effective heel removal system – a feature that provides complete batch-to-batch containment and dramatically reduces the operating cycle by removing separated solids at high speed.

Due to high 'G' forces and increased discharge speeds, the Peeler utilises short cycle times, which can be adjusted to ensure a range of washing capabilities, and can be used for applications where the feed slurry has either a low or fluctuating solids concentration. GMP design centrifuges are built to comply with international validation standards for modern plant and equipment with no 'dead' areas, inside or out. Peelers can be fitted with CIP systems to ensure that there is no contamination between batches and to ensure total cleanliness during product change-over. They are also built to a "through the wall" design which allows the centrifuge to be more easily serviced in a completely separate area of a factory. This feature totally eliminates the risk of contamination to the front end process side of the system.

其好处在于使批次物料之间被完全隔离。刮刀卸料离心机能够高速地卸出分离出的固体物，因此极大地缩短了操作周期。

刮刀卸料离心机的“G”力大且卸料速度高，故其操作周期短。可以对其进行调节以确保不同的洗涤性能。这种离心机能用于浆料中固体物浓度较低或存在波动的应用。GMP离心机的设计制造符合新型内外部无死区工厂设备的国际认证标准。刮刀卸料离心机可以配备CIP系统以确保各批产品之间不发生污染，并确保产品转换过程中的完全洁净。这种离心机还采用了穿墙设计，这可以使它们能更容易地用在工厂完全独立的区域。这一特点完全消除了系统前端工艺侧的污染风险。

螺旋/筛网式离心机

螺旋/筛网式离心机包括一个水平驱动螺旋输送机，输送机在锥形转篮中以最适宜的差速旋转。固体物在离心力的作用下从母液中分离出，分离过程在高“G”力下进行，同时，通过筛篮的倾斜和其与螺旋输送机之间的转速差将产品卸出。在分离点位置，螺旋输送机将固体物继续向前输送到过滤篮宽开口端的出口口排出，滤出液则可直接通过筛网。

螺旋筛/网式离心机能够配备一个自动螺旋速度调节器来适应不断变化的工艺需要。这一特征完全消除了操作员的干预和过程停机时间。螺旋/筛网式离心机具有优异的洗涤性能，可用于各种进料粒

Scroll/screen centrifuges

The scroll/screen consists of a horizontally driven scroll conveyor, which revolves at an optimum differential speed within a rotating conical basket. Solids separation from the mother liquor is achieved by the action of centrifugal force, operating at high 'G' force, whilst discharge takes place by the inclination of the basket and the differential speed of the scroll. At the point of separation, solids are conveyed forwards by the



径较大(通常在50微米以上)应用中的固液分离操作。这种离心机的一个特点是对悬浮固体和沉淀固体都能够进行分离。

卧式筛网转鼓沉降式离心机

卧式筛网转鼓沉降式离心机的工作原理与无孔转鼓沉降式离心机类似,但它是为涉及结晶性物料如对位二甲苯和煤粉的应用而设计,能提供更高的洗涤效率和脱水性能。这种离心机将无孔转鼓式离心机的澄清和沉淀优点以及附加筛网的脱水性能结合在了一起,运行过程分为两个阶段。

推料式离心机

这种类型的过滤离心机为连续式设备,能提供特别长的停留时间。固体物被在截留在楔型网篮上形成滤饼,由振动推料机构将滤饼从网篮运输到固体物出口。固体物料可以是粒状、结晶性或纤维状的,但是应该相对不易压缩。此外,它们还应该具有较小的长径比以使其能够自由穿流,平均粒径应为200微米。

振动式离心机

振动式离心机的生产能力高达350吨/小时。在振动式离心机中固体物被筛网截留,在筛篮轴向振动的作用下进行输送,筛篮振动速度高于离心机的转速。这种离心机非常适合用于处理通过量高的产品,它们能够很容易地脱水到所要求的含水量。

翻袋式离心机

翻袋式过滤离心机是一种全自动卧式离心机,其上采用了一个自动卸料滤袋。在液压活塞的作用下,篮筐前后壁前冲将固体物卸出。滤布被卷成圆筒形,其后缘固定在篮筐后壁,其前缘固定在篮筐前缘。在活塞前冲的同时滤袋里面被翻出,固体以块状形式被卸出到收集室中。

翻袋式过滤离心机主要用在制药行业,在每个工作循环之后能够将尾料移除,限于批产量较小情况下的应用。

scroll to discharge at the widest open end of the filter basket, whilst filtrate passes directly through the screen.

The scroll screen centrifuge can be equipped with an automatic scroll speed adjustment to accommodate changing process requirements. This feature completely eliminates operator intervention and process downtime. Scroll/screen machines have excellent washing capabilities and can be used for solids and liquids separation on a diverse range of applications where feed materials have high particle sizes – typically 50 microns and above. A unique feature is its ability to separate both floating and sedimenting solids.

Horizontal screen bowl decanters

Horizontal screen bowl decanters are operationally similar to solid bowl decanters, but are designed to provide additional washing efficiency and enhanced moisture removal for applications where crystalline materials such as paraxylene and coal fines are involved. The decanter operates in two stages, combining the clarification and sedimentation advantages of the solid bowl centrifuge with the dewatering benefits of an additional screen section.

Pusher centrifuges

This type of filtering centrifuge, which provides particularly long residence times, operates on a continuous basis, retaining solids as a cake on a wedge wire basket, from which it is transported by an oscillating pusher mechanism in the direction of the solids discharge. Feed solids, can be granular, crystalline or fibrous, but should be relatively incompressible. They should also be free-draining with a low aspect ratio and an average particle size of 200 microns.

Vibratory centrifuges

High throughputs of up to 350 tonnes/hour can be attained with this machine, in which solids are retained by a sieve and transported by axial vibrations greater than the rotational speed of the centrifuge. Vibratory centrifuges are highly suitable for processing high throughput products which can be easily dewatered to the required moisture content.

Inverting bag centrifuges

The inverting filter centrifuge is an automatic horizontal machine, incorporating an automatic unloading bag. The front and rear basket walls stroke forward by hydraulic piston to discharge solids. The filter cloth is arranged as a cylinder, with the rear edge secured to the rear basket wall and the front edge secured to the basket shell at the front rim. As the piston strokes forward, the cloth is turned inside out and the solid is discharged in clumps into the collection housing.

Primarily used in the pharmaceutical industry, the inverting filter centrifuge provides heel removal after each cycle and is limited to smaller sizes and capacities. ■