CRACKED MIXTURE SEPARATION - A CLOSER LOOK

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INTRODUCTION

Palm oil mills in Sabah are experiencing painfully low kernel extraction ratios. The main reason appears to be inefficient pollination of female inflorescence arising from reduced percentage of male inflorescence produced by the palm. This in turn seems to be related to the survival system of the palms. Leaving the biological aspect out, let us look at what the mill can do to improve kernel extraction ratio by having a closer look at the processing plant and try to understand the principles involved.

Palm oil mills in Malaysia use a combination of dry and wet separation systems to recover kernel from the cracked mixture. The dry separation known generally as Low Tension Dry Separation (LTDS) makes use of winnowing velocities ranging from 8 m/s to 16 m/s to give reasonably acceptable separation of light particles. If the velocity is kept below 10 m/s it is possible to get kernel losses below 0.5% at the expense of a slight reduction in separation efficiency.

In two-stage separation, which offers greater flexibility of operation the velocity ranges from 8 m/s to 12 m/s at the first stage and 13 m/s to 16 m/s at the second stage respectively. In the first stage the winnowing velocity is kept at a low value of about 8 m/s to reduce the kernel loss to a minimum. In the second stage the aim is to recover as much clean kernel as possible by separating all the thick shell and some kernel. The winnowing velocity may be raised up to 16 m/s to ensure clean kernel separation. In first stage most of the shell separation take place followed by clean kernel separation in the second stage. So what is left is low volume cracked mixture. This way the loading on the wet separation system is considerably reduced. One more stage may be added to this at winnowing velocity of 20 m/s to 24 m/s to remove stones and other undesirable objects. As part of the kernel is recovered in dry form less heat is required to evaporate the recovered kernel surface moisture than if they are subjected to wet separation process.

WET SEPARATION

The two popular wet separation systems popular in Malaysia are (a) Hydro-clay bath and (b) Hydro-cyclone, the former fast gaining popularity in new mills.

Hydro-clay bath Separation

This is a very ancient system of separation using the principle of density difference of fractions in a mixture for separation and usually gives good results as far as separation is concerned. The present day systems for clay-bath separation uses continuous separation equipment. The cracked mixture is fed into a conical tank containing the clay bath. The level of the bath is maintained by bending the underflow discharge pipe upwards to the required level followed by another downward bend to discharge it into a perforated rotary drum for collection.

The specific gravity of the bath is the key factor in determining separation efficiency in hydro-bath separation systems. For kernel-shell separation the specific gravity of the bath is maintained between 1.16 to 1.20. If nuts are found to escape in shell a second hydro-bath separator can be set up with specific gravity between 1.25 to 1.45 to separate the nuts for eventual recycling. As the investment cost for a hydro-bath separator is in the vicinity of RM 25 000 the mills having high loss of nuts in wet shell should evaluate the economic viability of installing one unit of hydro-bath separator irrespective of what the first stage separator is (*viz*: hydro-bath or hydro-cyclone).

In hydro-bath the kernels will float and overflow into an annular space at the outer edge of the cone, from where they are discharged into perforated rotary washing drum for collection. Both the shell and kernel washing drums are situated side by side. After de-watering the separated fractions are transported to their respective destinations. The washing liquid also joins the clay bath stream and is collected in the bottom slurry tank. Specific gravity corrections are made from time to time by adding kaolin or suitable salts like calcium carbonate. If kernel loss in shell is high the specific gravity of the bath has to be increased to enable the kernel to float. Likewise if the shell in kernel is high the specific gravity of the bath is in excess and water dilution is necessary. Periodic drainage of the slurry tank is necessary to remove accumulated sand and other contaminants. The clay be ing mildly acidic, addition of alkaline solution like sodium hydroxide or soda ash would raise the pH level to favourable alkaline range.

The consumption of kaolin is reported to be 1.14 kg per tonne FFB or 16.23 kg per tonne kernel produced (Oh, 1988). In terms of cost this works out to be 20 cts per tonne FFB or RM 2.84 per tonne kernel produced (West Malaysia).

Hydro-cyclone

The first hydrocyclone was patented in 1891 but failed to make any impact in the industry till after the second world war. It started off in mineral processing and mining industry followed later by chemical industry, power generation, petrochemicals, textile industry, metal working industry as well as a host of other industry. Hydro-cyclones have wide applications and varying configurations for different applications but the separation principle remains the same.

It is a static machine, where the tangential entry into the con-cylindrical body causes centrifugal separation in a vortex created at the centre of the cylinder. The feed undergoes division of fraction and are drawn towards specific locations.

(a) The course and dense underflow fraction, which move towards the periphery and discharge through the bottom orifice together with some of the liquid medium and,
(b) The light and fine particles which are drawn towards the centre and discharged through the overflow together with most of the liquid medium.

The separation is dependant on size and the characteristic size of the separation is called cut size. Cut size is defined as particle size at 50% on the grade efficiency curve, which is identical in all geometrically similar cyclones. In simple terms this is the particle size which has a 50% chance of being separated in a cyclone.

Hydro-cyclone operation is complicated and a number of research work is in progress to find out more about them. By no means their operation is completely understood due to lack of methods to investigate the behaviour of individual parameters which influence its performance. The separation efficiency of a cyclone is proportional to pressure drop within the cyclone up to a point after which the returns are negligible. The normal pressure range in a hydrocyclone is 1 to 2 bar-g in large units but may go up to 5 bar-g in small cyclones. Some of the useful things to remember in hydrocyclone separation are:

(a) Maintain optimum pressure drop.
(b) Increasing feed concentration reduces separation efficiency.
(c) Maintain dilute feeds, if high mass recovery is needed.
(d) Hydrocyclone separation efficiency can be improved by using multiple units either in series or parallel.
(e) The series configuration gives thick underflows and clear overflows.

One of the operating variable is the size of underflow orifice diameter, which can vary from as little as 10 mm to even 2 500 mm in large cyclones. There are many variations in design to cater for different applications. They are:

(a) Replaceable nozzles.
(b) Mechanically or pneumatically operated variable geometry orifices.
(c) Self adjusting constant underflow solid concentration.

Hydro-cyclones used in palm oil mills do not have adjustable orifices, which is a distinct set back as the mills are unable to optimise the right size orifice that can give the best results based on the characteristics of the cracked mixture peculiar to the mill.

As mentioned earlier research on hydro-cyclones is an on going process in several universities and is likely to continue till all the parameters are clearly known and correctly understood. The basic principle involved remains particle-fluid interaction. The separation is depended on particle inertia and stokes number. Other important factors are cut size and sharpness index, which constitute the measures of classification on cyclone performance.

For good division of component fractions the particles must have a finite density difference as in the case of hydro-bath separation and the flow must be steady. The centre air core must not be distorted by having bends immediately above the vortex tube. There are very steep velocity profiles in the flow causing high shearing force, which could break the flocs, agglomerates or drops in the flow. The discharge of the separated particles is mainly due to the flow itself and not by gravity except in the case of large cyclones when gravity will aid discharge. The radial settling velocity in a hydro-cyclone is due to centrifugal acceleration proportional to the square of the tangential velocity of the particle and inversely proportional to the radius of the location of the particle in the liquid media. The tangential velocity of the particle may be taken as the tangential component of the fluid velocity at the same location.

Secondary flow patterns moving across the layer adjacent to the top cover extending to the base of the vortex tube and along the outer wall of the tube are also generated in a hydro-cyclone. The cyclone cover and the outer wall of the vortex tube cause them to short-circuit there by reducing the spin velocity of the fluid and the particles in the region

When in operation, the hydro-cyclone generates a cylindrical surface approximately 0.43 of the cyclone diameter within the cyclone through which there is very little radial flow. The mantle so formed cuts off at a point, where it's diameter is 0.7 of the diameter of the cylindrical portion of the cyclone.

If a vortex finder diameter is increased to 0.43 of the cyclone diameter (*i.e.*equal to diameter of the mantle) the mantle disappears but triggers inward radial flow over the entire length. During separation most of the solids go through the outer vortex flow and are subjected to the influence of centrifugal force pushing them radially towards the wall. The centrifugal force proportional to the particle volume is opposed by drag forces, which are proportional to particle size. The settling velocity therefore depends on particle size. The fine particles may not reach the cyclone periphery by the time the outer vortex reaches the cone bottom. There is also the possibility of those reaching the periphery to mix back with the main stream. Overloading of the boundary layer caused by undersized discharge orifice can promote this re-mixing and be carried over with the overflow.

There is very little information available on the actual particle motion and their thermodynamics. The average residence time of water between the feed and the underflow was found to be about 7 seconds while that of feed and overflow 9.4 seconds. It is useful to know the following hydrocyclone design criteria.

1) Capacity can be increased by either of the following (1) increasing (a)cyclone diameter (b) outlet diameter (c) body length or (2) reducing vortex finder length.
2) Efficiency can be increased (by reducing cut size) by either (1) reducing (a) body diameter or (b) inlet diameter or (c) outlet diameter or (d) cone angle or (e)vortex finder length or (2) increase body length.
3) Classification sharpness can be improved by (1) increasing outlet diameter or (2) reducing vortex finder length.
4) Flow ratio can be increased by (1) increasing (a) underflow diameter or (b) body length or (2) reducing (a) overflow diameter or (b) vortex finder length.
5) Abrasion can be reduced by increasing (a) cyclone diameter or (b) inlet diameter

HYDRO-CYCLONE AND HYDRO-BATH SEPARATION -COMPARISON

	Areas considered	Hydro-clay bath	Hydro-cyclone
1	Capital cost	RM 25,000	RM 50,000
2	Power consumption	4.4 kW	25 kW
3	Kernel recovery	High	Lower
4	Variation in kernel size	Separation is unaffected	Separation is affected
5	Cracked mixture composition	Can handle any type DxD, DxP, mixture of the two	Limited to one type
6	Maintenance cost	Low	Higher
7	Design	Simple	More complicated
8	Kernel loss to wet shell	Broken kernel = 1.0% Whole kernel = 0.2 %	Broken kernel = 1.2 % Whole kernel = 0.5 %
9	Shell in kernel	2 % to 3 %	4 % to 5 %

CONCLUSION

It is hoped that the information presented in this paper will help the junior mill engineers to gain some insight into the working principles of the machines involved in the separation of the cracked mixture. This presentation is by no means comprehensive but sufficient as an introduction of the subject to the new engineers.

REFERENCE

Oh Lian Keng (1988). Claybath Versus Hydrocyclones for Cracked Mixture Separation. In *SLDB/PORIM Workshop on Palm Oil Milling Technology.* Hyatt Hotel, Kota Kinabalu, Sabah, 21-22 June 1988. p 138-158.