Planex System

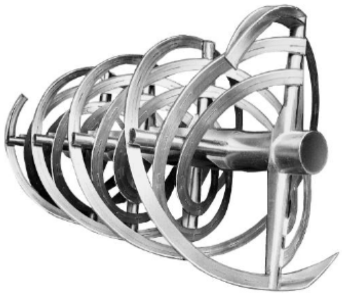
TECHNICAL REPORT

Contribution to the realization of a new concept paddle vacuum dryer

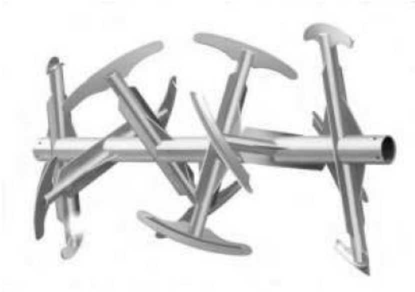
This is a summary description of a study by Dr. M. Garbero and Prof. M. Vanni of the “Politecnico di Torino” [1] on the configuration and construction of Planex System® the new horizontal paddle vacuum dryer designed and patented by Italvacuum (Patent No. US 5.857.264).

Type of Impeller

Ribbon or *Paddle* agitators are used in industrial practice to ensure adequate mixing of solid product in cylindrical horizontal dryers.



(1a) - Ribbon



(1b) - Paddle

Figure 1 - Impeller types

The *Ribbon* impeller shown in Fig. 1a offers a high degree of mixing both radially and axially without undue product heating. However, the impeller is difficult to clean, and the paddles can not be easily removed for servicing.

The *Paddle* type, Fig. 1b, is less sensitive to these problems but mixing is proportionally less efficient, it being good radially but less so axially.

In vacuum drying of powders, thorough mixing is less important than consistently bringing the solid particles to the surface of the granular bed for optimum solvent evaporation. Continuous surface regeneration is assured by both impellers. However, the paddle appears to be more suitable, as pharmaceutical and chemical-pharmaceutical applications demand frequent equipment cleaning. The energy consumption of the two impellers is comparable, even though dependent on the number of blades and paddles used.

In view of the above and considering the advantages of a simple construction, easy maintenance and quick cleaning, Italvacuum opted for the *paddle* configuration.

Product Mixing

To enhance stirring and for effective regeneration of solid particles at the bed surface, it was decided to impart a *planetary motion* in addition to the rotary motion. Planetary motion consists in a slow rotation of a small diameter impeller around the the dryer axis which does not coincide with the agitator axis (see Figure 2).

The dryer was designed for a ratio between impeller and chamber diameter of little more than 0.5. This solution was adopted because the impeller swept diameter must be able to effectively mix the solid product throughout the dryer during the planetary motion of the agitator, which means that it must be larger than $D/2$.

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On the other hand, impeller size must be restricted to permit operation at higher rotational speeds.

The agitator consists of four easily disassembled blocks, each carrying a single mixing paddle.

The reduced number of paddles (4 in all) ensures that the impeller shaft stress, generated by paddles movement in the solid mass, is kept to a minimum, such stress being a major contributor to power consumption at the drive shaft.

This configuration necessitates a bigger shaft to prevent flagging and vibration during the planetary motion, but the trade-off is energy saving. In fact, doubling the number of paddles (from 4 to 8) power consumption is estimated to increase by about 30%.

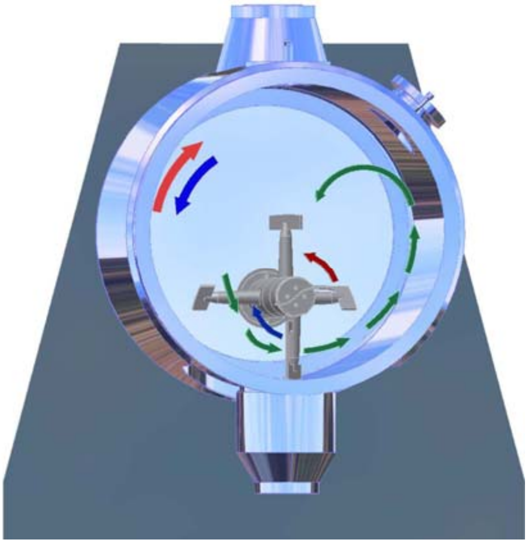

Figure 2 - Four-paddle agitator

Paddle outline minimizes the gap between agitator profile and dryer shell to facilitate the removal of lumps of material. Paddle angle offsets axial thrust on the impeller to a certain extent, although by precisely how much was not possible to calculate, as it depends on the friction between granular components and paddle, as well as between types of solids, and varies greatly depending on process conditions.

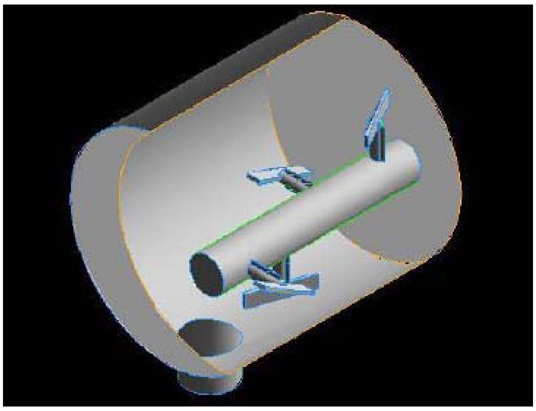

Figure 3 – Drain port

Figure 3 shows the version with low drain port on the cylindrical surface of the vessel between first and second paddle, which ensures that the product is discharged each time the agitator reaches the bottom of the cylinder.

A specific drain cycle featuring agitator swing with alternating rotary motion and minimum gap between agitator and dryer chamber wall ensures that the product is discharged completely.

Power Consumption and Product Overheating

Overall consumption of the machine considered depends on the combined effect of rotary and planetary motion of impeller shaft in the solid mass.

Power consumption for the planetary motion alone during processing is slightly higher than that needed to drive the mechanical parts with an empty machine. This is because the solid is moved mainly by the impeller rotation around its axis, planetary motion being rather slow. Consequently, power consumption due to planetary motion depends mainly on the weight of the mechanical parts and on the friction generated during motion.

Conversely, energy consumption due to impeller rotation about its axis is not easily quantifiable. In addition to paddle geometry, it depends on type of solid dryed, grain size, humidity, agitator speed and extent of filling. Hence, an advantage of the planetary motion, i.e. the **possibility of using a significantly smaller impeller diameter**. The planetary motion ensures thorough mixing of the material throughout the chamber, whilst **reduced impeller diameter saves energy because of reduced friction between solid particles**.

Power consumption at the shaft may be extrapolated from the following formula[2]:

$$P = L \times g \times \lambda \times \varphi \times \rho \times \frac{\pi \times D_g^2}{4} \times S \times N$$

Where:
P = Power at shaft, kW
g = Gravitational speed, 9.81 m/s²
λ = Coefficient of resistance for material displacement (3-4)
φ = Filling fraction
ρ = Apparent density of material, kg/m³
D_g = Impeller dia., m
S = Pitch, m
L = Agitator length, m
N = Speed, rps

Thus, the power consumption at the Planex drier impeller shaft, and therefore the energy lost through friction between solid particles in these types of machines, is about a third of that of conventional dryers with concentric agitator.

Filling

Power consumption due to impeller rotation about its axis depends also on filling. In conventional machines with concentric agitator, the volume of solid material moved depends on the extent of filling of the entire equipment, as the impeller swept volume coincides with total volume, whereas in the machine considered the impeller handles only part of the solid, the volume of which varies during the planetary motion. Therefore, for the same extent of filling, power consumption varies with time depending on the depth of the impeller in the solid mass.

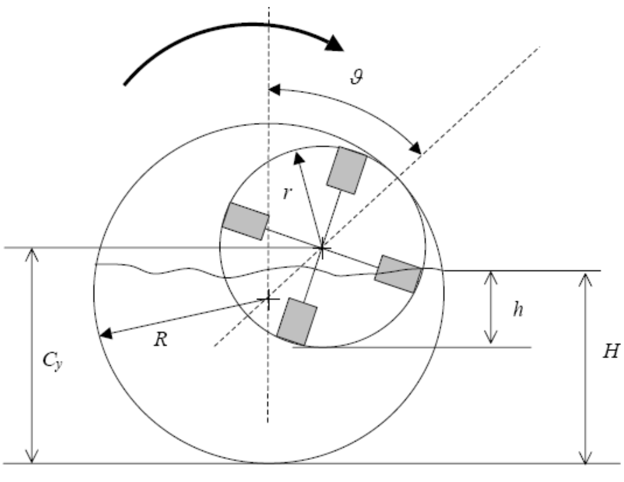

Figure 4 – Impeller planetary motion

Power consumption as a function of filling fraction φ and speed N (rpm) according to Masiuk[3]:

$$P = k \cdot N \cdot \exp[1.28(\ln\varphi + \varphi)] \quad (1)$$

yields the curve of Figure 5 showing power consumption versus angle of impeller rotation about dryer axis for different chamber filling conditions.

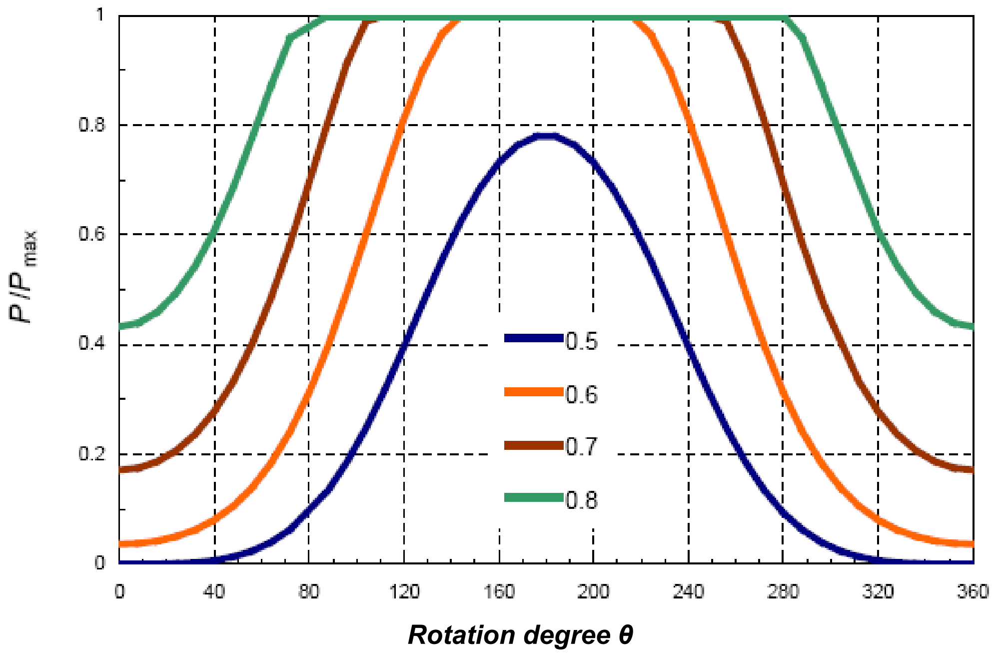

Figure 5 – Impeller power consumption as per equation (1) during planetary motion versus dryer chamber filling

For the best configuration, power consumption is less important than the regeneration of the gas-solid surface - a basic parameter for effective evaporation - and the renewal of the particle-to-wall contact – essential for efficient heat exchange. This depends on the combined impeller planetary and rotary motions. As well as on the equipment, optimum filling also depends on process conditions and product characteristics. In case of overfilling, the process becomes inefficient, as the impeller lies deep in the material almost continuously and is therefore unable to regenerate the surface. In case of underfilling, the combined rotary motion about the axis and the alternating planetary motion are extremely effective even with not much product.

An intermediate configuration represents the optimum solution, with nominal chamber filling at 0.5 to 0.8 of total volume. In these conditions the impeller moves at all times a certain volume of solid material , being at full depth only for short periods of time.

Additionally, agitator swing reduces chamber filling ratio to 0.2 without adversely affecting machine efficiency.

[1] Garbero, M., Vanni, M., 2004, “Contributo alla realizzazione di un essiccatore prototipo per brevetto IT1273100”.
[2] Dubbel, Beitz, Kuttner, “Dubbel’s Handbook of mechanical engineering”, CRC Press, (1994).
[3] Masiuk S., “Power consumption, Mixing Time and Attrition Action for Solid Mixing in a Ribbon Mixer”, Powder Technology, 217-229, 51, (1987).