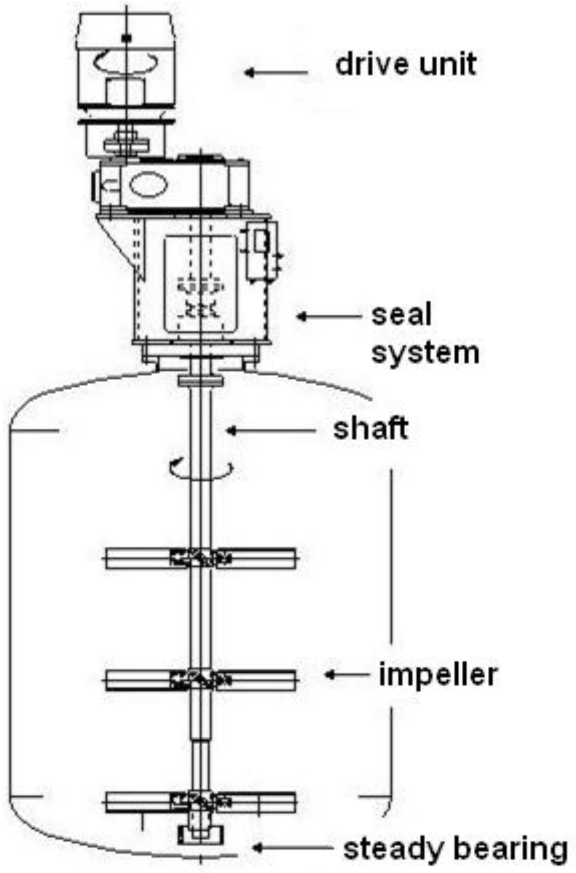
1- INTRODUCTION TO THE SELECTION OF MIXERS

GENERAL INFORMATION

The mixer is a machine that transfers energy into a liquid, obtaining flow rate, head and shear in proportions that depend on the speed of rotation and the type, diameter and number of impellers used.
The flow rate increases the speed of the fluid as quickly as possible, the head ensures motion reaches even points that are far from the impellers while the shear helps to overcome the surface tension between different phases to facilitate mixing/dispersion.
Various components make up a mixer.



Control unit: this consists of a motor to provide energy, which may be electric, pneumatic or hydraulic, and possibly a reduction gear to achieve the required speed.
Sealing system: present only when the mixer is used on a closed tank.

Shaft: this is the mechanical device that transfers energy to the impellers. It may be composed of a solid bar or a tube.
Impellers: these are the components which, rotating in the liquid, transform the energy transmitted by the drive unit in order to achieve the set objectives. They may be of different shapes and sizes.
Base guide: It is possible to add this in larger mixers or where a mechanical seal is present in order to reduce shaft waving and limit the loads on the control unit. It nevertheless represents a system subject to wear present in the tank with maintenance problems, so it is preferable to use it only when strictly necessary.

SELECTION

Choosing a mixer is a complicated job as the effects of this machine cannot be quantified with specific parameters, either by the client or by the manufacturer.
A user is often unaware of how the mixing feature of an existing machine can be improved.
The experience of the manufacturer is the main factor for making the best selection.
Many manufacturers are only experts in specific applications. Others, the most qualified, have a huge database of experience and draw selection procedures for all major industrial processes from this.
GREC technicians are able to ensure process selections for a large number of applications, thanks to the experience gained since the company was founded in 1903.
In fields that our experience does not stretch to, we rely on international partners with high reputations with which we have exclusive relationships.

When the customer provides all necessary data, GREC Srl makes the selection with a PROCESS GUARANTEE, meaning that if the mixer does not produce the required results, GREC Srl will make any changes necessary to achieve them, free of charge, even taking back an unsatisfactory mixer.
The presence of this guarantee makes it possible for the customer to rely on our technicians.

Mixer uses fall into two broad categories, depending on whether the more important parameter is the flow rate or the shear generated.

CONTROLLED BY THE FLOW RATE

This category includes applications where the liquid inside the container must be at a certain speed in order to guarantee the outcome of the process.

a) Blending - namely mixing miscible liquids: pH control, storage tanks, preparing mixtures, flocculation.
b) Suspended solids - collection or storage tanks where solids must not be deposited on the bottom. Uniform distribution of solids in the liquid mass before a later stage (chemical reaction, cooling), sludge treatment.
c) Heat exchange: it is necessary to maximise the speed of the liquid along the walls in order to increase the exchange coefficient.

For this type of application, a mixing scale is normally established from 0 to 10 which, according to the volume of liquid to be mixed, determines the flow rate required from the mixer.
The installed power is not a parameter to be considered and remains only a consequence of mechanical sizing.

CONTROLLED BY THE POWER

This category includes applications where it is necessary to overcome surface tension between different stages of the process in order to achieve the desired outcome.

a) Dissolving solids (preparation of solutions, such as sugar solutions or chemicals for water treatment).
b) Dispersion of solids (preparation of dispersions such as paints or loaded bitumens).
c) Mixing immiscible fluids (preparation of emulsions such as mayonnaise or ecological diesel).
d) Gas dispersion (fermentations, oxygenation of primary sludge).

For this type of application, a specific minimum power to be applied is defined, without which the phenomenon required does not take place and/or does not remain stable over time.
The flow rate generated must be verified, but is often well above what is required.

MIXED APPLICATIONS

In the chemical industry in particular, liquids in reactors can go through different stages that require different mixer functions.
For example, it may first be necessary to obtain a solution for the dispersion of powders (high shear required), then a phase with heat exchange (high flow rate required) and then obtain the finished product through crystallisation (it is necessary to distribute the product in a uniform manner but insert little energy into the liquid).
In cases like this, it is possible to design special mixers where the rotation speed is controlled by an inverter and various types of impellers, active at different levels.

IMPELLER TECHNOLOGY

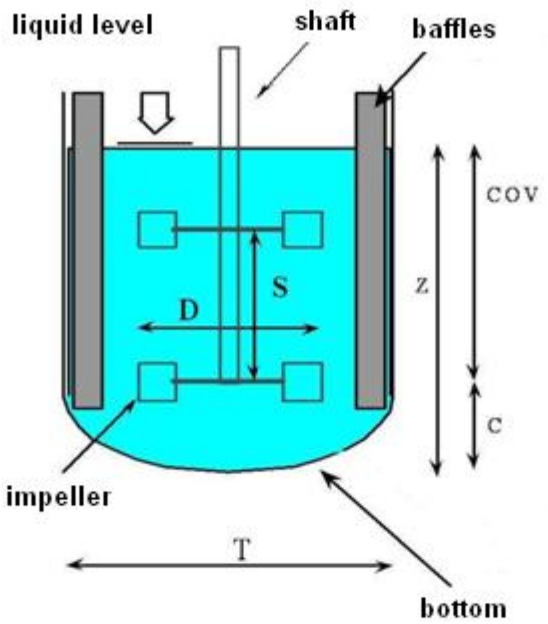
Awareness of the behaviour of impellers depending on the geometry of the container and the characteristics of the fluid is an asset belonging to each individual manufacturer.
The greater the knowledge, the greater the confidence with which selections will be made, and, ultimately, the greater the ability to offer competitive machines.
Impellers can be divided into two categories:
AXIAL – these push the product toward the bottom, from where it then rises back up along the walls. They provide high flow rates and different doses of shear or head depending on the shape and total surface area.
RADIAL - these provide high shear and a low flow rate, pushing the liquid onto the side walls of the container, then making it go up and down.

PARAMETERS

The parameters necessary for sizing a mixer and the symbols used in this publication are listed below.

C = Distance of the impeller from the bottom (mm)
D = Impeller diameter (mm)
d = Shaft diameter (mm)
S = Distance between impellers (mm)
T = Tank diameter (mm)
Te = Equivalent diameter (mm)
A = Base surface area (m^2)
V = Volume to be mixed (m^3)
Z = Level of liquid (mm)
Cov = Level of liquid above the impeller (mm)
L = Shaft length (mm)
ρ = Density of the liquid (kg/m^3)
μ = Viscosity of the liquid (cps)
N = Speed of rotation (RPM)
P = Power (kW)
Q = Impeller flow rate (m^3/h)
Mt = Torque (Nm)
Mf = Bending moment (mm)
Fr = Radial force (N)
Fa = Axial force (N)

i = Reduction ratio
Np = Impeller power number
Nq = Impeller flow rate number
Re = Reynolds number
Vf = Viscosity factor
Pf = Proximity factor



GEOMETRIC FORMULAS AND RATIOS

In order to size a mixer, it is necessary to provide the geometric diameters of the tank or container in which it is to be inserted.
In the case of tanks with a rectangular base, the equivalent diameter is defined as

$$Te = 1000 \times \sqrt{\frac{A \times 4}{\pi}} \quad (1)$$

For mixers with a reduction gear, the diameter of the impeller depends on the diameter of the tank, according to the ratio D/T. This typically varies from a minimum of 0.2 for simple applications to a maximum of 0.6 for those which are more difficult or with high viscosity.

$$0{,}2 < \frac{D}{T} < 0{,}6 \quad (2)$$

The positioning of the impellers also depends on the difficulty of the application and the viscosity. The normal situation is:

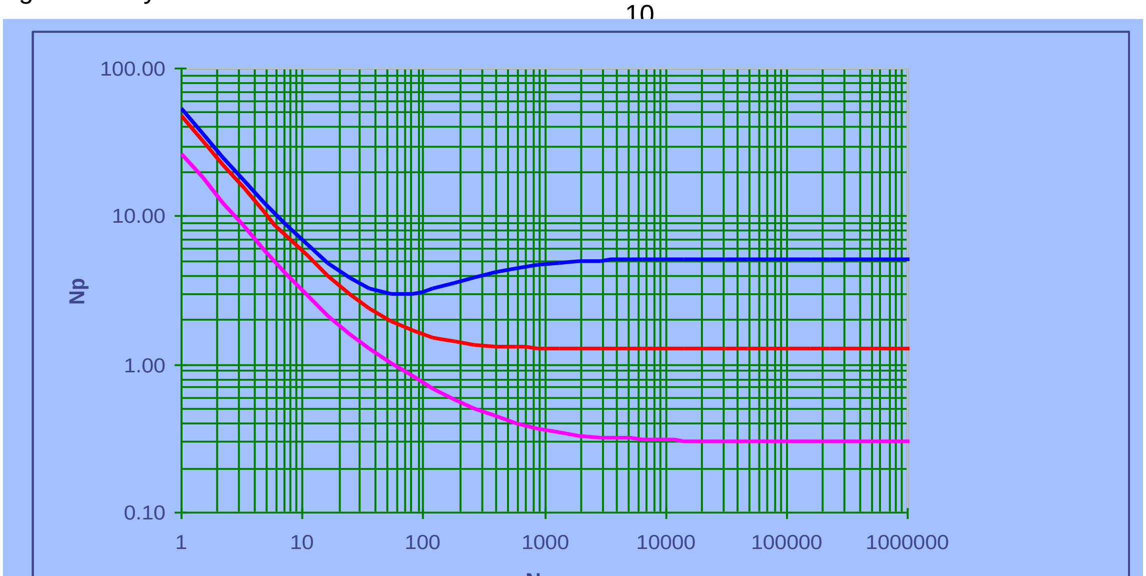
$$0{,}3 < C < 1{,}5 \quad (3)$$

$$0{,}8 < S < 2 \quad (4)$$

Each impeller is defined by two dimensionless numbers obtained through laboratory experiments, Np and Nq. These are considered constant at first approximation, when in fact they also depend on geometric factors (proximity to the walls) and the viscosity of the product. As the viscosity and the proximity to the wall increase, the Np value increases (the impeller absorbs more power) and the Nq value decreases (the impeller generates less flow).
The proximity factor (Pf) and the viscosity factor (Vf) are thereby defined, and these are normally unitary.
The parameter that affects the performance of the mixer is not so much the viscosity as the Reynolds number.

$$Re = \frac{N \times D^2 \times \rho}{\mu} \quad (5)$$

The graph shows the typical behaviour of the Np value as Re varies.
Series 1 is a four-blade PBT turbine, suitable for up to Re > 50
Series 2 is a three-blade impeller with a high efficiency wing profile, suitable for up to Re > 1000
Series 3 is a radial impeller, suitable for up to Re > 10



Three motion regimes can be defined:
Re > 2000 → Turbulent regime, the threads go in any direction, selection is not affected by differences in viscosity. On the chart on the next page, the Np value is constant.
2000 > Re > 20 → Transitional regime, the threads have limited opportunities for motion, the Np value starts to vary, although not significantly.
Re < 20 → Laminar or viscous regime, the threads follow one direction. It is important to know the exact rheology of the fluid, or even the viscosity at different levels of stress suffered by the product. The Np value increases in line with the decrease of Re.

The results of mixing are defined in particular by the flow generated, according to the formula

$$\boxed{Q = Nq \times N^3 \times \left(\frac{D}{1000}\right)^3} \qquad (6)$$

Shear and head cannot be defined by a mathematical formula but are obtained indirectly, based on experience, from the input power value. The latter is obtained from the formula (7):

$$\boxed{P = Np \times Vf \times Pf \times \rho \times \left(\frac{N}{60}\right)^3 \times \left(\frac{D}{1000}\right)^5}$$

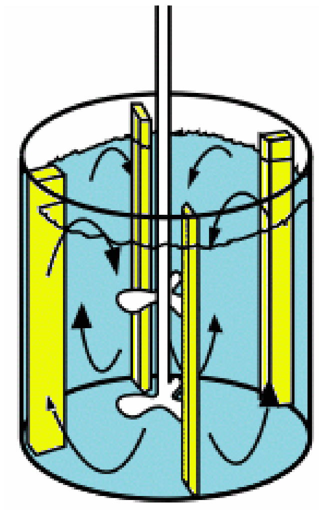
The parameters necessary for the mechanical sizing of the mixer are the torque and the bending moment.

$$\boxed{Mt = \frac{P \times 9550}{N}} \qquad (8)$$

$$\boxed{Mf = \frac{Fr \times L}{1000}} \qquad (9)$$

The Fr value and Fa value (which is usually negligible) can be obtained instead through formulas dictated by the individual experience of the manufacturer and type of impeller.

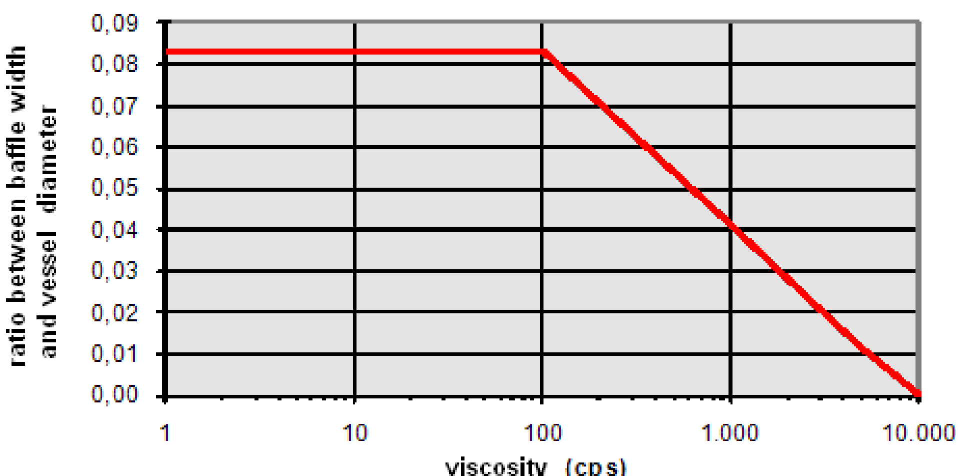
ANTIROTATIONAL BAFFLES



The aim of the axial impeller is to push the fluid towards the bottom, from where it then rises back up along the walls When the movement along the walls reaches the free surface, it heads back down along the shaft axis.

If the mixer is placed centrally in a cylindrical tank, this aim is not achieved because the motion tends to remain rotary, creating a vortex.

To eliminate this phenomenon, which wastes energy and generates additional load on the shaft, seven fixed seats on the walls, known as baffles, are used. When coming up against the breakwaters, the rotary motion is broken, and deviates in a vertical direction.



The same aim is accomplished in other ways:
-Using a tank with a rectangular base: the edges of the tank act as baffles.
-Installing the mixer offset and tilted.
-Installing the mixer offset. In the latter case, a vortex is created, therefore energy is dissipated, but this acts outside the mixer axis, therefore does not exert extra loads.
The width of the baffle, according to the diameter of the container, depends on the viscosity of the fluid in the table below.

MECHANICAL SIZING

The process sizing consists of determining the number, type and diameter of the impellers to use and the speed of rotation which enables the required flow or power to be achieved.
There are several possible combinations, the best being the one that yields the most flexible and inexpensive solution.
By going faster, it is possible to use smaller and therefore less expensive impellers and reduce the torque acting on the shaft at the same power.
The rotation speed has a maximum limit beyond which it is necessary to increase the diameter of the shaft, and hence the cost.
There is, therefore, an optimum speed for each application.

Each impeller that rotates within a liquid and transfers energy to it receives a reaction in terms of torque absorbed (Mt), axial load (Fa) and radial load (Fr), which contribute to establishing the following dimensional parameters:
-Thickness of the blades and the impeller hub
-Shaft diameter
-Size of the reduction gear to be used

The diameter of the shaft also depends on that fact that this is a thin rod subjected to loads - the thinner it is, the lower its vibration frequency meaning it can come close to the rotation frequency.
The overlapping of the frequency of a mechanical element with that to which it is subjected may cause catastrophic situations with vibrations and breakage.

When sizing a mixer, this phenomenon must be taken into consideration, therefore the following rule is in place:

$$\boxed{N < 0{,}8 \times Nc} \qquad (10)$$

The critical speed essentially depends on the thinness (d/L) of the shaft and, to a lesser extent, on the weight of the impellers installed and the distance between the reduction gear bearings.

Once the required length of the shaft has been defined, it is possible to determine a maximum speed for each shaft diameter in a quite precise manner which cannot be exceeded.

Depending on the installation, it is necessary to consider service factors on the critical speed and the radial load.
The factors to consider, and for which GREC Srl has adequate service factors, are:
-Offset installation without breakwater.
-Offset, tilted installation without breakwater.
-Liquid surface less than one impeller diameter above the same.
-Impeller crossed by liquid weight.
-Impeller very near the bottom.

Depending on the stiffness of the casing, the type and diameter of the bearings used and the type and diameter of the driving gears, each reduction gear has a maximum bending moment (Mf), torque (Mt) and axial load (Fa).
The reduction gears used by GREC Srl are suitably optimised for use with the most common impellers, and in all cases have cast iron casings, service factor on the torque > 2 and the expected life of the bearings is over 20,000 hours in continuous at the maximum expected load. This sizing normally allows a minimum of 3-5 years of operation without requiring any maintenance. The only precaution is to follow the lubricant change table.