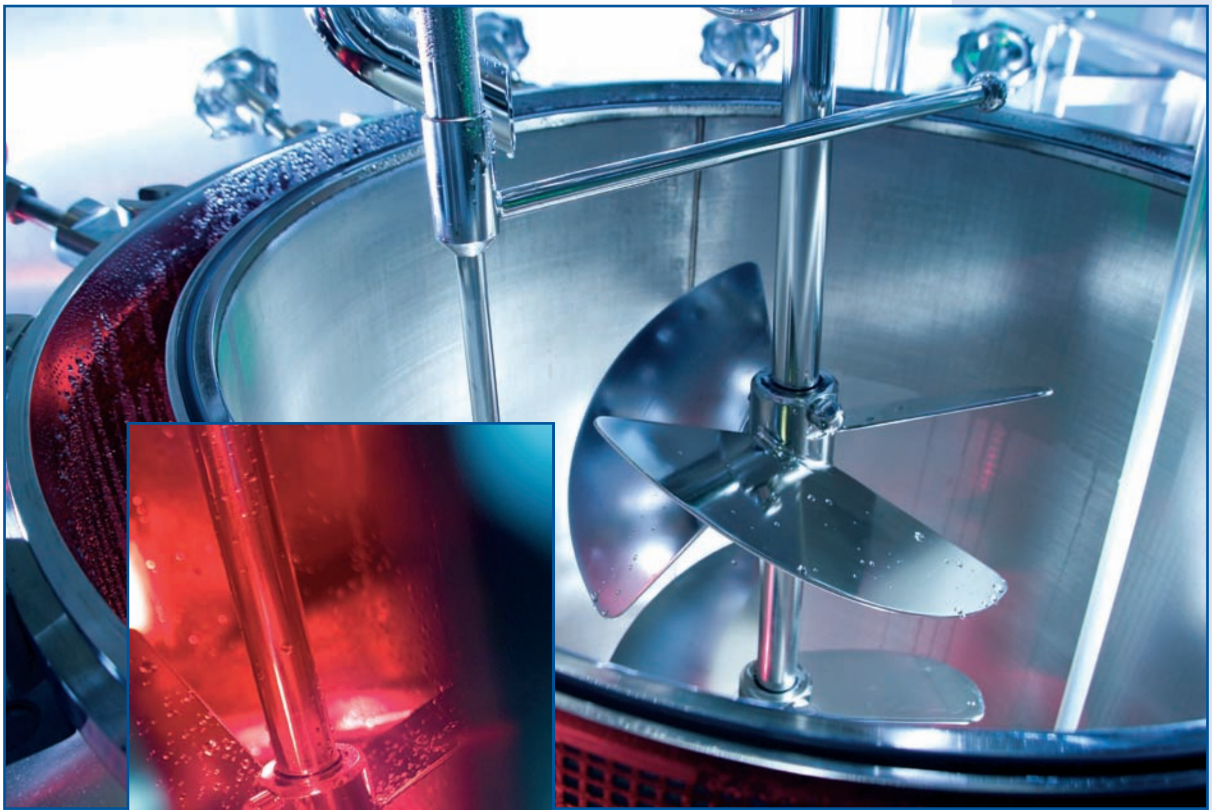
bio-m® Agitators

general information on Agitator sizing

- process lay-out
- mechanical design



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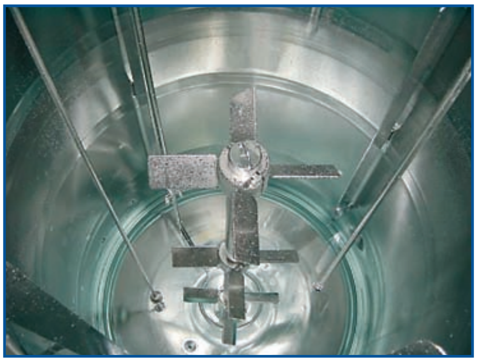
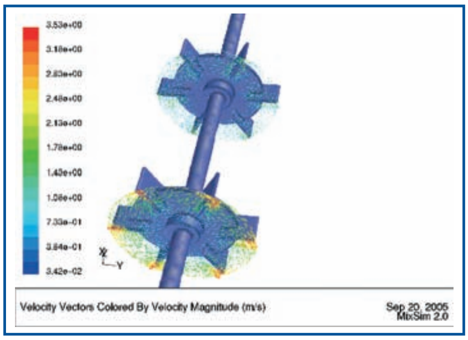
Introduction:





There are calculations available for sizing an agitator, with regard to the process layout as well as the mechanical features. The calculations are similar for magnetically coupled and mechanically sealed agitators.

On the following pages, zeta has put together basic information on these topics:

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If there are any questions don‘t hesitate to contact us

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Agitator Sizing

1. BASIC INFORMATION
about the process, vessel dimensions, operating conditions etc.

2. INFORMATION ABOUT THE PRODUCT
at least: S.G., Viscosity (refer to data sheet)

3. AGITATION TASK
- Blending
- Suspending of Solids
- Heat Transfer
- Gas Dispersion etc.

4. SIZING TO THE PROCESS REQUIREMENTS
(by experience, CFD, lab-scale tests, scale up)
Result: Definition of impeller design, - diameter, -speed

5. CALCULATION OF THE POWER REQUIREMENT / TORQUE
Equations: $P \sim s.g. \times n^3 \times d^5$, $Mt = P / (2 \times \pi \times n)$

6. MECHANICAL DESIGN
i.e. type of shaft bearing, shaft diameter, critical speed, lantern, type and size of drive system, magnetic coupling etc.

7. FURTHER CHARACTERISTICS
for instance size of vessel flange, m.o.c., surface finish etc.

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Viscosity

Viscosity is a characteristic measure for the internal friction of a fluid.

Usually the dynamic viscosity η is given, which correlates to the kinetic viscosity υ and the specific gravity ρ : $\eta = \rho \times \upsilon$

Standard dimension of the dynamic viscosity: mPa s
(milli Pascal Sekond) = 1mPa s= 1Pa s/1000, 1 Pa s = 1 N s / m^2

Old dimension (should not be used any longer):
cP (centi Poise), 1 cP = 1 mPa s

The viscosity strongly depends on the temperature; a viscosity therefore should always be given together with the temperature, at which the measurement was done.

With **Newtonian** fluids, the viscosity depends on the temperature only. With **non-Newtonian** fluids there are more influences, especially shear forces (shear thinning) and/or duration of the shear stress (thixotrope)

EXAMPLES:

Product	Temperature	Viscosity
	°C	mPa s
Solvents (Aceton, Toluol etc.)	20	< 1
Water	20	≈ 1
Liqueur	20	12
Sugar solution 50%	20	15
Salad oil	20	85
Sugar solution 64%	20	120
Egg liqueur	20	620
Glycerin 100%	30	624
Glycerin 100%	25	945
Glycerin 100%	20	1500
Yoghurt	20	≈ 1000
Honey	45	≈ 2000
Apple puree	20	≈ 10000

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Agitating task:
Blending / Homogenisation

1. DEFINITION

Blending of miscible liquids, within a certain, given or required mixing time, to a certain, given or required degree/quality.

2. MIXING TIME DIAGRAM

This diagram is produced in a lab- or pilot scale test procedure and is valid for a certain impeller type and mounting situation - in any vessel size provided there is geometric similarity (impeller shape, d/D ratio, H/D-ratio etc.)
In this test procedure the mixing time θ is measured which it takes to achive a certain mixing quality (usually 95 % of pH value, of temperature etc.), with different speeds of rotation **n** of the impeller.

The diagram shows the product **n x** θ over Reynolds No. Re

3. MEASURING METHODS

There are different methods to determin the mixing time which may deliver slightly differetn results.

In the lab scale, the de-colouring method is used frequently: A blue iodine-starch solution is added to the liquid. Then a sodiumthiosulfate solution is added and the time is measured how long it takes the agitator to decolour the liquid.

Alternative methods can be to measure the time it takes to achive an even conductivity or temperature.

4. EXAMPLE

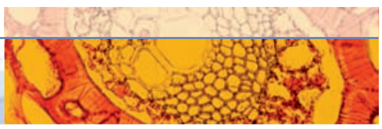
Marine type propeller, speed n = 200 1/min

Re > 10 000 (turbulent flow)

n x θ = 100 (from Mixing time diagram)

Therefor:
θ = (100 / 200) min, mixing time is 30 sec

(provided there is gometric similarity to the test scale)



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Agitating task: Suspending of solids

1. CALCULATION OF THE SETTLING RATE OF A PARTICLE (SIZE d_P):

$$v_S = f\,(\Delta\rho, \eta, d_P)$$

(with the help of the Reynolds-, Archimedes- und Nusselt-Number)

2. CALCULATION OF THE SETTLING RATE OF A PARTICLE SWARM:

$$v_{SS} = v_S\,(1 - c_V)^X \quad (c_V = \text{solids content})$$

3. CALCULATION OF THE SPECIFIC SETTLING POWER:

$$E_{SS} = (\Delta\rho / \rho_{liquid}) \times c_V \times g \times v_{SS}$$

4. CALCULATION OF THE NECESSARY AGITATION POWER P:

- $P > E_{SS}$
- $P/V = f$ (tank diameter d_1, expected suspension quality)
  (P/V = specific power input, power input per m^3)
- Interrelationship between P/V and d_1 is not linear;
  (The curve P/V over d_1 has been determined by Zehner, Kipke et alt.)

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Agitating task: Heat Transfer

1. FLOW OF HEAT Q:

Q is proportional to the heat transfer area A and to the difference in temperature:

$$Q = k \times A \times \Delta T$$

2. HEAT TRANSFER COEFFICIENT K:

$$1/k = 1/\alpha_i + s/\lambda_w + 1/\alpha_a$$

α_i = Internal heat transfer coefficient (Product -> Vessel wall)

s = Thickness of vessel wall [m]

λ_w = Heat conductivity of the vessel wall [W / mK]

α_a = External heat transfer coefficient [W / m²K]

3. CALCULATION OF α_i:

3.1 Prandtl-No. (viscosity, heat capacity and -conductivity of the product) :

$$Pr = \eta_R \times c_p / \lambda_R$$

3.2 Nusselt-No.

$$Nu = C \times Re^{2/3} \times Pr^{1/3}$$

(if Re >200 ; neglecting the difference in viscosity near the tank wall)

C = f (typ of impeller, mounting)
C = 0.4 .....0.9

3.3 Internal heat transfer coefficient

$$\alpha_i = Nu \times \lambda_R / d_1 , \qquad \alpha_i \sim P^{2/9}$$

(d_1 = Tank Diamater, P = agitator power)

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Agitating task: gassing

1. PURPOSE OF MIXING

to intensify mass transfer by means of

- Magnification of the specific mass transfer surface a / minimizeation of the bubble size
- max. concentration grade Δc by high turbulence
- Magnification of gas hold up time
- short mixing time

2. CHARACTERISTIC FIGURES

gassing rate:	gas input (volume)per minute/ vessel working volume vvm = q / V[1/min]
Gas velocity:	gas input (volume) per minute / cross sectional area of the tank $v_L = q \times 4 / d_1^2 \times \pi$
specific gas throughput:	$Q = q / n_2 \times d_2^3$
Froude-No.:	$Fr = n_2^2 \times d_2 / g$

3. CALCULATION

the calculation has to be done by the iteration method:

1. Specification of impeller-type, -quantity, -diameter
2. Specification of the impeller speed of rotation (by experience or looking for a certain P/V value)
3. Determination of the Power No. „Ne“ from the diagram „Ne over Q“, Froud No. as parameter
4. Check: the impeller must not be flooded by the amount of gas (diagram, specific for each impeller type)
5. Depending on 4., a new calculation may be necessary, taking a different impeller diameter, different speed; Optimization of the process lay out
6. Calculation of the power requirement and spec. power P/V
7. Calculation of the mass transfer:

   $k_L a = C \times (P/V)^A \times (vL)^B$

   coefficents

   A = 0,3 ... 0,8 (depending on the viscosity)

   B = 0,5 ... 0,3 (coalescenc .... no coalescence)

   proportional factor

   C = f (impeller) (e.g. Rushton turbine: C = 0.41)

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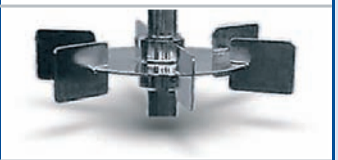
Typical impellers:

Type	Typical agitation task, characteristics	Viscosity range	Diameter ratio	
		mPas	d/D	
Marine type propeller	Homogenise Suspend solids circulate; Axial flow pattern, High rpm	1 - 1000	0,15 - 0,35	
Pitched blade Impeller	Homogenise Suspend solids Improve heat transfer; Axial flow pattern, with a radial component; medium rpm	1 - 2500	0,2 - 0,4	
Rushton Turbine	Gassing; Radiale flow pattern; Usually multi stage; High speed (rpm) / high power input	1 - 1000	0,3 - 0,45	
Segment Impeller	Gentle homogenisation, improve heat transfer; Axial flow pattern, with a radial component; Usually multi stage Low speed	1 - 1000	0,4 - 0,5	
Cross beam Impeller	Homogenise Suspend solids Improve heat transfer; Axial flow pattern; Usually multi stage	100 - 50000	0,4 - 0,8	
Counterflow Impeller	Homogenise, gassing, Suspend solids, Improve heat transfer; Axial counter flow (inside down, outside up); Always multi stage	100 - 50000	0,5 - 0,9	
U/Z - Impeller	Homogenise Improve heat transfer; Always multi stage; Often used in food industry	100 - 10000	0,4 - 0,6	

You may also refer to our brochure and to DIN 28131

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Calculation of the required Motor Power

1. PRODUCT CHARACTERISTICS

at least: specific gravity ρ [kg/m^3], viscosity $\eta = f (T)$ [Pa s]

2. DESIGN FEATURES ACCORDING TO THE PROCESS:

Type and number of impellers
Impeller diameter d2 [m]
Rotational speed n2 [1/s]

3. CALCULATION OF THE RYNOLDS NUMBER RE:

$$Re = \frac{n_2 \times d_2^{\,2} \times \rho}{\eta}$$

4. DETERMINATION OF THE POWER NO. NE (NEWTON-NO.):

Ne = f (Re, Impeller Type, diameter ratio etc.)
to be taken from the relevant diagram Power No. vs Reynolds No.

5. CALCULATION OF THE POWER REQUIRED BY THE IMPELLER:

$$P_V = Ne \times \rho \times n_2^{\,3} \times d_2^{\,5}$$

6. CALCULATION OF THE TORQUE:

$$M_t = \frac{P}{2 \times \pi \times n2}$$

7. FACTOR FOR ANY LOSSES, SAFETY ETC.

$$P_{Motor} = 1{,}1 \ldots 1{,}3 \times P$$

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Calculation of the necessary shaft diameter

1. DETERMINATON OF THE RADIAL FORCE AT THE IMPELLER

(turbulent flow pattern)

$F_R = c_R \times \rho \times n_2^2 \times d_2^4$

n_2 = speeed of rotation, d2 = impeller diameter
c_R is specific for the impelelr type, has to be measured,
c_R = f (impeller, mounting position, first critical speed)
ρ = density

2. CALCULTATION OF THE BENDING MOMENT

$M_b = F_R \times l$, l = shaft length

3. CHECK: DOES THE IMPELLER RUN DURING FILLING/ EMPTYING OF THE TANK

if yes: $M_{b, D} > M_b$

4. CALCULATION OF THE MOMENT OF COMPARISON

(Hypothesis of the maximum shape changing work)

$M_v = \sqrt{M_{b, D}^2 + 0.37 \times M_t^2}$, M_t = max. drive torque

5. CALCULATION OF THE NECESSARY SECTION MODULUS AGAINST BENDING

$W_b = M_v / \sigma_v$, σ_v = max. equivalent stress

6. CALCULATION OF THE SECTION MODULUS OF A SHAFT

$W_{b, W} = (\pi \times d_W^3) / 32$, $W_{b, W}$ must be $> W_b$

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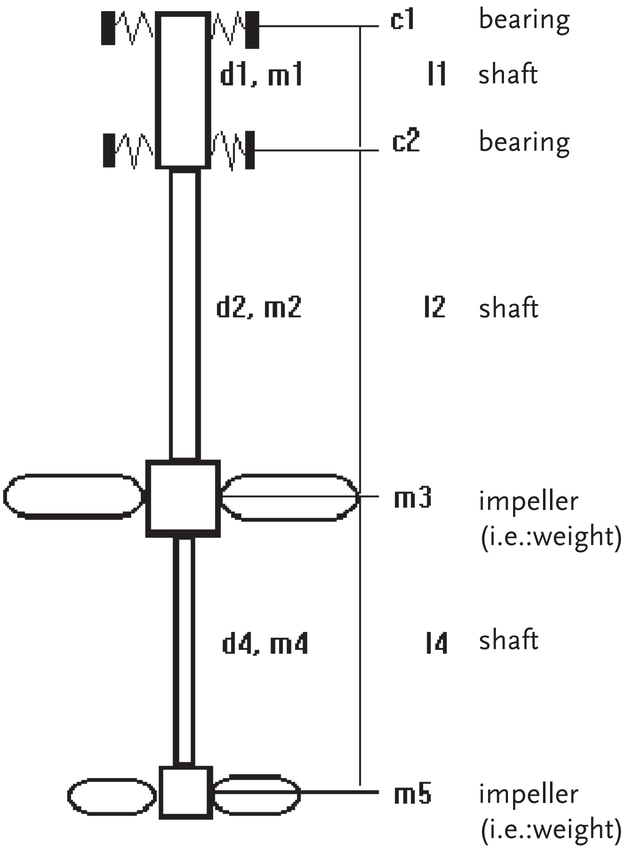
First critical speed

Any agitator is an oscillating system and therefore has a natural frequency or resonance frequency, called the first critical speed.

The agitator's speed of rotation must keep away (at least 25 %) from this frequency. This applies especially for speed controlled drives (VFD).

Otherwise, the shaft will vibrate more and more and finally will break down.

The first critical speed can be determined quite exactly by means of a field transfer matrix which contains all major agitator components:



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Questionnaire for Bio-M® Agitators

Inquiry from: ____________ Inquiry No: ____________

worked out by: ____________ Tel.: ____________ Fax.: ____________

Product	quantity	S.G.	Viscosity	Particlesize	Temp.
	kg	kg/m3	mPa s	µm	°C
Components					
Final Product					

PRODUCT CHARACTERISTICS:		
Flow behaviour:	❑ newtonian	❑ non-newtonian
agitation task:	❑ homogenize/mix	❑ suspend solids
	❑ heat transfer	❑ dissolve gas
	❑ disperse liquid-liquid	
intensity:		
Production process:	❑ batchwise	❑ continously
	flow rate [m³/h]:	

VESSEL:		
Please attach a vesssel drawing and a nozzle list, if necessary		
	❑ already existing	❑ to be supplied by zeta
	❑ to be supplied by others	
Design:	❑ cylindrical, vertical	❑ cylindrical, horizontal
	❑ rectangular	❑ with isolation
diameter/length [mm]:	height [mm] zyl.:	total:
kind of bottom:		kind of top:
filling volume [Ltr.] from:		to:
size of manhole:		
	❑ agitator runs during filling or emptying	
equipment inside the vessel (baffels, heating coils etc.):		
working pressure [bar] from:	to:	temperatur [°C] from: to:
external heat exchanging system:	❑ double jacket	❑ half pipe
	❑ others:	
agitator support:	DN	PN
	acc.to:	❑ nozzle length [mm]:

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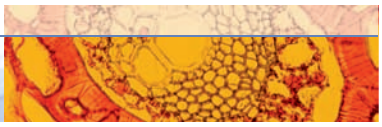

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material product wetted:	others	❑	surface finish inside:
	outside:		
Ex-Zone [0,1 or 2] inside vessel:	outside vessel:	Temperature class: T	
DRIVE:			
purchased by customer	❑ yes ❑ make preferred:	❑	no
fixed speed:	❑ Motor pole-changeable ❑ by means of	❑	variable speed
tension [V]:	frequency [Hz]: expl.-proof:	protection IP	
additional information:			
AGITATOR DESIGN:			
	❑ hygienic ❑ CIP	❑ ❑	sterile SIP
Is a foot steady bearing - to support the shaft - permitted?	❑ yes	❑	no
shaft sealing:	❑ not necessary ❑ mechanical seal	❑ ❑	seal ring magnetic coupling
material of O-rings:	❑ FDA conforming		
purchased by customer?	❑ yes ❑ make prefered:	❑	no
additional seal equipment required:			
Impeller:	❑ zeta's choice	❑	customer's experience:
Additional remark:			

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