GASSED BIOCHEMICAL REACTOR

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RESUMEN. Reactor bioquímico gaseado llamado (*Reactor gaseado)* de ahora en adelante se equipa por dispositivo de mezclar neumático por sustitución de los motores eléctricos y conductores magnéticos o el sello mecánico aséptico para garantizar condiciones de asepsia y aislamiento en aplicaciones bioquímicas; en particular *Reactor gaseado* es distinguido por proporciones de transferencia de masa más altas en procesos bioquímicos aeróbicos que tienen lugar bajo la atmósfera de gas enriquecida de la cámara del reactor. Un flujo de gas de trabajo máximo se expande a los niveles admisibles establecidos de turbulencia líquida de la cámara del reactor por pruebas experimentales y la escala de reactor máxima al valor admisible establecido es encontrada por simulación matemática. El software y la entre-cara de usuario son concebidos para realizar el diseño del reactor y estimar la ejecución técnica a los procesos de mezclar en sistemas de gas-líquido. *Reactor gaseado* soporta proporciones geométricas diferentes al reactor estándar con impelente único a los recipientes esbeltos mostrando los planes de impulsores de tamaños diferentes; el gas estéril para la operación del reactor es producido a la propia unidad de compresión por sustitución de los procedimientos de esterilización regulares. *Reactor gaseado* es distinguido por ruptura mecánica de espumas indeseadas para evitar el uso de productos químicos, la extracción segura de muestras y productos presurizando la cámara del reactor y el suministro de suspensiones en la corriente de gas de trabajo; el reactor constituye una nueva alternativa tecnológica de bajo costo para producciones farmacéuticas pequeñas, los trabajos en laboratorios y propósitos de investigación; beneficios técnicos y económicos significativos en esquemas de reactores se prevén

ABSTRACT. Gassed biochemical reactor called *Gassed reactor* from now on is equipped by pneumatic mixing device per substitution of the electric motors and magnetic drivers or the aseptic mechanical seal to warrant asepsis and isolation conditions in biochemical applications; in particular, *Gassed reactor* is distinguished by higher mass-transfer rates in aerobic biochemical processes that take place under the enriched gas atmosphere of the reactor's chamber. A maximum working gas-flow expands to the set allowable levels of liquid turbulence of the reactor's chamber by experimental tests and the maximum reactor-scale to the set allowable value is found by mathematical simulation. The software and the user-interface are conceived to accomplish the reactor's design and estimate the technical performance to the mixing processes on gas-liquid systems. *Gassed reactor* supports different geometrical rates to the standard reactor with single impeller at the slender vessels showing arrangements of impellers of different sizes; the sterile gas for the reactor's operation is produced to the compression unit itself per substitution of the regular sterilization procedures. *Gassed reactor* is distinguished by mechanical breaking of the unwanted foams to avoiding the use of chemicals, the safe extraction of samplings and yields pressurizing the reactor's chamber and the supply of suspensions on the working gas-stream; the reactor constitutes a new technological alternative of low-cost for small pharmaceutical productions, the works on labs and research purposes; significant technical and economical profits at reactors layouts are foreseen.

REACTOR DESIGN-OVERVIEW

Gas-liquid systems are present to a number of industrial applications; a common application involves the mass-transfer of a sparingly soluble gas into a liquid where a reaction may occur, for example the fermentation under aerobic conditions for productions as antibiotics, steroids and single-cell proteins;[1] at this role the biochemical reactors take part.

The biochemical processes impose the challenges to the design and construction of biochemical reactors, among them the asepsis and isolation conditions, the transfer operations of mass and heat, the mixing operations by proper flow-patterns and shear-stress, the oxygen supply, taking of samplings and supplies, measure and control of variables, welds and materials, power consumption, valves and fittings, scale-up, yields and the process's economy, etc.

Gassed reactor follows the standards on design and construction of conventional analogous reactors though it constitutes a new reactor design subject to future technical tests. Menendez AJ. Biochemical reactor of pneumatic energy, Solicitude of patent: 085, 2014.

This work shows a new biochemical reactor distinguished by the following technical features.

Gassed reactor recognizes both gas-flow controls at the operation, i.e. the flow-control to the power generation and the sparged aeration rates to the culture broth respectively.

Gassed reactor is distinguished by higher mass-transfer rates in aerobic biochemical applications that take place under the enriched atmosphere of gas (air) to small gauge-pressure values of the reactor's chamber supported by the two-film theory,[2] namely the higher rates of oxygen-transfer are expected to the incremented values of the partial pressures of gas into the liquid-phase in order to improving the cellular growth and respiration at higher concentrations of dissolved oxygen with significant repercussion to the yields, etc.; to this aim the automatic process control or an estimated gauge-pressure value may be assumed to the course of aerobic biochemical applications.

Gassed reactor is distinguished by a simple and compact pneumatic mixer of variable speed, the optional direct readings of speed and easy sterilization by steam, immersion in hot-water, etc. *Gassed reactor* does not require the electric motors and magnetic drivers or the aseptic mechanical seal; the reactor constitute a new technological alternative of low-cost for small pharmaceutical productions, the works on labs and research purposes; preliminary analysis of costs illustrates significant technical and economical profits at reactors layouts by concept of equipments substitution.

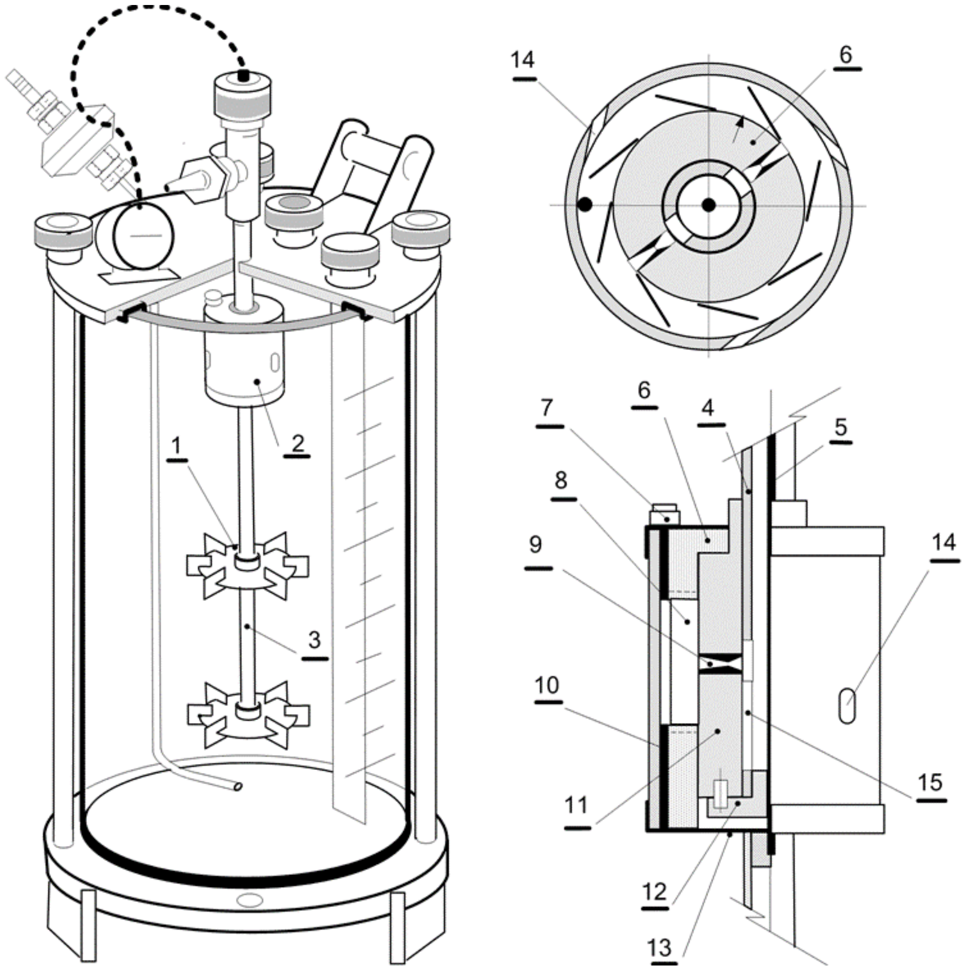

Fig.1. *Gassed biochemical reactor (Vliq=50lit; Dves/dag=2.5).*

Gassed reactor-Description

Gassed reactor is represented to the isometric view; the drawings at cross sections illustrate the reactor's design in addition. (Fig.1)

Gassed reactor is made up by three main elements, i.e. the standard impeller for liquid agitation (1), the turbine-type driving-core (2) and the connecting tube to both elements (3). The driving-core (2) is constituted basically by the arrangement of flat paddles or vanes (8) at both grooved elements (6) providing a simple assembling job and easy sterilization by steam, immersion in hot water, etc.; the residuals liquids from the sterilization are drained through the narrow groove (15). A welded thin rod (10) to both endings of the driving-core (2) constitutes the element for the torque transmission at the rotational motion. An inert wear-resistance polymer may be employed to the construction of the steady bearing (11), for instance PTFE; two Laval nozzles (9) accelerate the gas-flow at the ejection increasing the mechanical power of the pneumatic device. The weight of the set is supported by the screw cap (12); both covers (13) and the threaded nut (7) close the pneumatic device to enabling the disassembly of the unit at the maintenance periods.

Optionally, the thin steel rod (5) or the mechanical counter of turns is screwed inside the feeding tube (4) in order to take direct readings of the rotational speed by means of a flexible connection to the speed-meter or employing electromechanical transducers.

Gassed reactor-Operation

The pneumatic device develops the mechanical power when the gas-stream is forced to ejection through both Laval-nozzles (9); the gas-flow shows an increment to the ejection speed and the momentum to the set of paddles (8) take place. The gas expands to the reactor's chamber through the orifices or the slots (14) and it should be treated per prophylaxis before release to the atmosphere as usual; a relief valve may control the gauge-pressure of the chamber.

The continuous gas-flow prevents the entry of fluids to the driving-core (2), thus the proper aseptic performance of the unit is expected provided that the working gas-flow is clean or contaminants-free. The reactor's speed is fitted by the gas-flow control and to over-loadings the pneumatic device stops functioning with no further damages.

A maximum working gas-flow expands to the set allowable levels of liquid turbulence of the reactor's chamber by visual tests at simulated experience using a one-inch single pipe with three orifices in five-liters glass vessel (Fig.1); a rough value equal to 20m ^{3}/hr (Normal) is measured and accepted to the experience for all the reactor sizes.

Gassed reactor produce the sterile gas to the compression unit itself for the operation and supply of aerobic biochemical applications; the outlet temperature of the air on single-stage and adiabatic compressors to the operating value of 3 kg/cm^2 gauge rises above 150 ºC and 220 ºC, starting from the inlet air temperatures of 20 ºC and 70 ºC respectively.[2] Decker et al. found that bacterial spores suspended in air may be killed at 218 ºC in 24 sec.[3]

A considerable reduction of the power requirements for agitation at the immersed impellers in gassed systems (Pg) take place (Pg/Pow=0.3-1.0),[2] therefore the *Gassed reactor* may improve the technical performance considerably by virtual power increments close to the seventy percent higher (1.70Pow) when higher power requirements are involved; similar virtual increments to reduced values of power number, Np from 6.20 to 1.80 are found on case of turbine impellers, six flat-blades and the un-baffled mixing conditions.[4]

Gassed reactor supports different geometrical rates to the standard reactor with a single impeller,[2,5] i.e. the rate of the vessel diameter versus the impeller diameter different than 3.0 (Dves/dag ≠ 3.0) and the liquid height versus the vessel diameter higher than 1.0 (H/Dves >1.0) at the slender vessels showing arrangements of impellers of different sizes; larger impellers at geometrical rates Dves/dag=2.5 are shown for illustration (Fig. 1); worthy of mention the proper selection of geometrical rates obeys to the process's performance, scale-up and power consumption, etc.

The technical performance of *Gassed reactor* to the mixing processes on gas-liquid systems is estimated by mathematical simulation; [6] the software in C++ language and the user-interface are conceived to accomplish the reactor's design; four standard impellers are employed to the model, i.e. the six-blade turbine impeller, radial disk turbine impeller, paddle impeller and the pitch-blade impeller; [7, 8] the mathematical algorithm is discussed on details to a solved example.

An example of calculation

A maximum volumetric gas-flow of 20m^3/hr(N) arise to the allowable levels of liquid turbulence of the reactor's chamber, consequently the maximum reactor scale to the set allowable value is found at the scale-up by a trial and error procedure to the program runs; the main variables involved to the reactor's operation are found to the next example at gassed and un-gassed mixing conditions for comparisons using water as test-liquid and the basis for the general conclusions assuming similar conditions to the example, i.e. the higher powered impeller for dispersing gas into liquids of low viscosity and Newtonian behavior (power number, Np=6.2),[1,7] the reactor's geometrical rates etc.; rational and non-contradictory results are observed to the obtained variables by calculations assuming the overall energy loss-factor, k=0.60 on the author opinion; note that the set restriction is also fulfilled. **(Table 1)**

Table 1. Technical specifications-Gassed Reactor (Vliq=75lit, Vves=100lit).

	broth		water
	un-gassed	gassed	un-gassed
Working gas pressure, p1 (kg/cm^2)	4.31	3.15	4.30
Volumetric gas-flow, Q (m^3/hr)(N)	20.3	14.7	20.2
Impeller speed, n (rpm)	165	165	180
Power, Pow (W)	12.8	8.2	13.8
Energy consumption, Cpow (kW)	1.03	0.59	1.02
Power rate, Pow/Vliq (W/lit)	0.17	0.10	0.18
Reynolds number, NRe (-)	63700		69500

The technical performance of *Gassed reactor* is estimated at the specific process on vessel of standard geometrical rates and liquid volume, Vliq=75lit (vessel-volume, Vves=100lit); a single turbine impeller of diameter, dag=150mm, six flat blades, four baffles each 0.1Dves is employed; vessel diameter, Dves= 457mm; liquid height, H=457 mm; broth's viscosity μ=0.0012 kg/msec; pressure of reactor-chamber, p2=1.15 kg/cm^2; liquid density, ρliq=1200 kg/m^3; vanes number, pd=12; proper aeration rates, Q=15 lit/min are sparged to the culture broth for the cellular growth and respiration..

CONCLUSIONS

By taking into account the non-contradictory results to the program runs and the conservative energy loss-factor on the calculations, the author considers the model appropriate for the practical purposes of this job arriving to the following conclusions.

Gassed reactor is a reactor equipped by low powered pneumatic mixer appropriate for the mixing processes involving low-viscosity fluids and Newtonian behavior.

Gassed reactor is distinguished by higher mass-transfer rates in aerobic biochemical applications that take place under the enriched gas atmosphere of the reactor's chamber supported by the consistent physical theories.

Gassed reactor supports a maximum working volume close to 75lit (Vves=100lit) on processes of strong agitation to approximated power-rate values of 0.17W/lit and the un-gassed mixing conditions (turbine impellers, six flat blades, four baffles each 0.1Dves) and around 500lit using low powered impellers; obviously *Gassed reactor* shows higher power-rates to the smaller reactor sizes close to 30lit approximately.

Gassed reactor (Vliq=75lit) may improve the technical performance considerably at gassed systems or aerobic applications by virtual power increments from 0.17-0.19W/lit approximately and rotational speeds close to 200rpm; similar additional increments to un-baffled mixing conditions and the single-baffle vessels are found.

Gassed reactor shows maximum operational values of 20m^3/hr (N) and 5.0kg/cm^2 respectively for the small energy consumption to the gas compression lower than 1.0kW/hr.

Gassed reactor supports the heat-exchange by internal coils, the instrumentation for measure and control of processes and the sterilization by steam, immersion in hot water, etc.

Gassed reactor produces the sterile gas to the compression unit itself for the operation and supply of aerobic biochemical applications; the small further investment per substitution of regular sterilization procedures is foreseen.

Gassed reactor is useful as mechanical breaker of unwanted foams avoiding the chemicals.

Gassed reactor provides the safe extraction of samplings and yields pressurizing the reactor chamber and the supply of suspensions on the working gas stream at low contamination risks.

Gassed reactor is distinguished by a simple design without electric motors, magnetic drivers or the aseptic mechanical seal; preliminary analysis of costs illustrates significant technical and economical profits at reactors layouts by concept of equipments substitution.

Gassed reactor constitutes a new technological alternative of low cost for small pharmaceutical productions, the works on labs and research purposes; the conceived software provides the necessary technical support at the exploitation and design time.

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