РЕЗЮМЕТА НА ПУБЛИКАЦИИТЕ

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за участие в конкурса за доцент по научната специалност "Процеси и апарати в химичната и биохимична технология", шифър 02.10.09, обявен в Държавен вестник бр. 87/ 05.11.2010 г

I. Публикации към дисертацията - 5

1. Публикации в списания с импакт фактор - 4

1. Hadjiev, D., D. Dimitrov, **M. Martinov**, O. Sire, **(2007),** "Enhancement of the biofilm formation on polymeric supports by surface conditioning", Enzyme and Microbial Technology, **40**, (4), 840-848. **IF = 2.375. Намерени цитати : 21**

Abstract: The aim of this study is to determine the influence of the surface properties on the microbial adhesion to different substratum. Six polymer supports have been selected. Further, the possibility to improve the biofilm growth on the carriers using a conditioning film of PMMA/PAC was proposed. The role of the hydrophobic/hydrophilic interactions between bacterial and support surfaces was determined using contact angle measurements. Scanning electron microscopy was used to compare biofilm morphology on different supports. Mid-infrared microspectroscopy has allowed analyzing *in situ* the attached biomolecules at various periods of the biofilm development. The infrared attenuated total reflectance method was found to be convenient for surface analysis. Epifluorescence microscopy after DAPI labeling was used to reveal the biofilm structure and the cell density. Indigenous microorganisms from an industrial wastewater-recycling unit were used. The monitoring of the biofilm formation showed the advantages of the coated materials, which allowed faster colonization and higher cell densities. Optimal colonization was observed when the difference between the surface free energies of the support and the bacteria was maximized. Tests on the biodegradation of wastewater exhibiting high COD concentrations attest the biofilm potential in fast COD decay

2. Martinov, M., D. Hadjiev, S.D. Vlaev, (**2009),** "Gas-liquid mass transfer in fibrous bed reactor with counter-current liquid recycle", *Chemical Engineering Technology*. 32 (6), 932-938. **IF = 1.223. Намерени цитати : 3**

Abstract: In this work, the gas-liquid mass transfer in a lab-scale fibrous bed reactor with liquid recycle was studied. The volumetric gas-liquid mass transfer coefficient, $k_L a$, is determined over a range of the superficial liquid velocity (0.0042–0.0126 $m.s^{-1}$), gas velocity (0.006–0.021 $m.s^{-1}$), surface tension (35–72 mN/m), and viscosity (1–6 mPa.s). Increasing fluid velocities and viscosity, and decreasing interfacial tension, the volumetric oxygen transfer coefficient increased. In contrast to the case of co-current flow, the effect of gas superficial velocity was found to be more significant than the liquid superficial velocity. This behavior is explained by variation of the coalescing gas fraction and the reduction in bubble size. A correlation for $k_L a$ is proposed. The predicted values deviate within ± 15 % from the experimental values, thus, implying that the equation can be used to predict gas-liquid mass transfer rates in fibrous bed recycle bioreactors.

3. Martinov, M., D. Hadjiev, S.D. Vlaev, (**2010),** "Liquid Flow Residence Time in a Fibrous Fixed Bed Reactor with Recycle", Bioresource Technology, 101(4), 1300-1304, **IF = 4.453. Намерени цитати : 1**

Abstract: Waste removal efficiency of gas–liquid biofilter reactors for waste water treatment depends on its flow regime and residence time distribution (RTD) as key parameters of bio-reactor performance. The present study reports RTD regime in a fibrous fixed bed biofilm reactor related to a fluid velocity range appropriate for biofilm operation. The data from tracer experiments are correlated in terms of the one-parameter ‘‘tanks-in-series” model. The aerated fibrous bed reactor RTD function is found to be dependent on net liquid and gas phase superficial velocity UL and UG. Liquid internal recirculation exhibited small effect comparable with the effect of net liquid flow. A power law relationship relating the number of perfectly mixed cells with liquid and gas superficial velocity is elaborated. Assuming similarity of the prototype and real vessels' flow fields, the equation as well as its corresponding range of fluid velocity can be used for bio-reactor design and scale-up. Comparison over the model parameters obtained in fixed bed bubble columns at low fluid velocity shows the results of this study to be comparable with previous data of mesh wire packing.

4. Martinov, M., D. Hadjiev, S.D. Vlaev., **(2010),** “Gas-Liquid Dispersion in a Fibrous Fixed Bed Biofilm Reactor at Growth and non-Growth Conditions”, Process Biochemistry, 45 (7), 1023-1029. **IF = 2.414.**

Abstract: There is limited data on gas dispersion characteristics of fixed bed biofilm reactors under growth and non-growth conditions. In this paper, the gas–liquid dispersion of a bubble bed packed with a fibrous structured packing for biofilm application is studied. The reactor is operated with Pseudomonas putida aimed at aniline degradation in wastewater. Gas hold-up and bubble size distribution are determined. Running gas–liquid reaction conditions as well as non-reactive flow gas hold-up and bubble size distribution in the presence of surface-active and viscous components were measured. The properties of the gas dispersion proved to be stabilized by the fibrous bed presence and showed improvement of the dispersion parameter by the packing. Gas hold-up was found to increase monotonously with the rise of gas superficial velocity and viscosity and with surface tension fall. Liquid superficial velocity showed marginal effect. Apart from showing high gas hold-up and low bubble size due to surface-active and viscous dissolved elements, the biochemical reaction did not pose any significant additional effect. In agreement with the expected lack of bubble coalescence and break-up in the highly ionic solution practiced, the population size distribution and average bubble size were found to vary with the major operation factors opposite to their gas hold-up contribution. Gas hold-up was correlated with the specific bubble-to-channel size ratio and further with the variables considered. An empirical equation is proposed that relates gas hold-up with all studied variables. Assuming geometric similarity of the prototype and the real vessels, the equation as well as its corresponding range of fluid velocities can be used for bioreactor design and scale-up. The results concerning the gas hold-up are shown to be comparable with previous studies of mesh wire packing.

2. Публикации в списания без импакт фактор - 1

5. Martinov, M., S.D.Vlaev, D.Hadjiev. **(2009),**”Oxygen transfer in a counter –current fibrous bed bioreactor: case of liquid recycle”, *Chemical Engineering Transactions*, 17, 543-548,

Abstract: In this work, the gas-liquid mass transfer in a lab-scale fibrous bed reactor with liquid recycle was studied. The volumetric gas-liquid mass transfer coefficient, $k_L a$, is determined over a range of the superficial liquid velocity (4.2–12.6 mm/s), gas velocity (6–21 mm/s), surface tension (35–72 mN/m) and viscosity (1–6 mPa.s). The effect of gas superficial gas and liquid velocity, surface tension and viscosity are examined. Increasing fluid velocities and viscosity, and decreasing interfacial tension, the volumetric oxygen transfer coefficient increased. In contrast to the case of co-current flow, the effect of gas superficial velocity was found to be more significant than the liquid

superficial velocity. This behavior is explained by variation of the coalescing gas fraction and the reduction in bubble size.

II. Публикации извън дисертацията - 17

1. Публикации в списания с импакт фактор - 5

6. Vlaev, S.D., **M. Martinov**, ***(1998)***, "Non–Uniformity of Gas Dispersion in Turbine-Generated Viscoelastic Circulation Flow", *Can. J. Chem. Eng., 76(3), 405-412,* IF=0.63, **Намерени цитати** 1.

Abstract : Gas dispersion has been analysed experimentally by measuring local gas hold-up in two lab-scale conventional turbine-agitated vessels loaded with viscoelastic fluids. The gas hold-up radial profiles obtained in various axial positions close and far from the impeller reveal high non-uniformity of gas dispersion. Non-uniformity is quantified and related to elasticity, shear dependent viscosity, shear rate, first normal stress difference coefficient and type of fluid. The low values of gas hold-up obtained for the vessel central area are interpreted as hindered gas dispersion caused by the flow pattern specific for the viscoelastic properties of the circulating fluid. The paper is complementary to the effort for collecting up data for benchmarking numerical CFD simulations (Kumar et al., 1997).

7. Sisak, Cs., T. Venyige, **M. Martinov**, S.D. Vlaev, **(2000),** "Small-Scale Liquid Mixing in a Bioreactor Column with Xanthan-Gum Simulated Filamentous Media", *Bioprocess Engineering, 22*, 253-256, IF = 1.115, **Намерени цитати** 1.

Abstract: Using the heat pulse technique, the local mean flow liquid velocity and the mixing conditions for two-phase flow in the riser of an airlift bioreactor have been measured and analyzed Xanthan-gum solutions were used as the physical model to some filamentous broths reported in the literature. A two-fold decrease of liquid velocity and diffusional mixing regime are predicted for the course of a fermentation process proceeding in a non-Newtonian biomass growth circulation system.

8. Martinov, M., S. Vlaev, **(2002),** "Increasing Gas-Liquid Mass Transfer in Stirred Power Law Fluids by Using a New Energy Saving Impeller", *Chem. Biochem. Eng. Q*. 16(1), 1-6, IF = 0.156, **Намерени цитати :** 5

Abstract: The gas-liquid mass transfer performance of a stirred vessel equipped with a novel impeller, has been studied. The device is presented as means to increase gas-liquid mass transfer rate in stirred non-Newtonian media of fermentation vessels. The impeller is of the fluid foil type that is suitable for power law fluids. Mass transfer rates for power law liquids are determined by measuring *KLa* in model pseudoplastic CMC and xanthan gum solutions at moderate shear. The effects of geometry, gas flow rate, rheology, and impeller speed are illustrated. The results are compared with similar data reported for the disc-style flat blade Rushton (RT) turbine, used conventionally in industrial vessels. The mass transfer coefficient is correlated with gas linear velocity and specific mixing power. An equation for *KLa* is proposed. In comparison with the conventional case, significant energy saving is demonstrated.

9. Vlaev, S.D., I Nikov, **M. Martinov, (2006),** "Shear and skin fraction on particles in power –law fluids agitated by flat – blade and fluid foil impellers", *Chemical Engineering Science,* 61, (16), 5455-5467, IF = 1.884, **Намерени цитати :**1.

Abstract: The shear rates that exert angular deformation on spherical particles have been measured. The particles are mimiced by a spherical probe. The probe has been immersed in various impeller-agitated power law fluids. The fluids are aqueous dispersions of polymers, e.g. CMC, xanthan gum

and starch. The probe has been positioned in various points of a stirred vessel and at various angles. Angle-averaged shear rate distributions were produced. The distributions obtained are characteristic for the specific impeller flow patterns. The flow patterns have been identified by computational fluid dynamics (CFD). Two types of impellers representative for the flat and the fluid-foil blade design, i.e., a Rushton flat-blade turbine (RT) and a Narcissus impeller (NS) are studied. The effects of rheological properties and blade design on the 'shear-rate-on-particles' distribution are examined. The local shear field non-uniformity has been uncovered and compared in terms of the CFD-generated time-averaged velocity and deformation rate profiles. The 'shear-rate-on-particles' distribution apart from the impeller is found to follow qualitatively the time-averaged inner flow shear rate distribution. Referring to impeller speed 5–12.5 Hz, the dimensionless wall shear rate varied between 200 and 1000. In power law fluids, the shear rate on particles decreased up to 50%. The fluid-foil NS-generated shear field was found comparable to the shear field induced by conventional flat-blade turbines and appeared in cases less sensitive to polymer presence. The shear rate produced by the fluid-foil impeller in the highly shear-thinning model solution *(n* ~ 0.4*)* exceeded the flat-blade RT-imposed shear rate. The analysis has been extended to skin friction drag on particles. It is shown that, while exerting an undoubtedly greater angular deformation in water-like fluids, in polymer presence the conventional flat-blade turbine introduces a flow geometry that imposes particle drag that is close or in some cases even less than the one generated by the fluid-foil impeller. The fact implies a weak shape effect of radial turbines on shear-sensitive particles or particle dispersions in power law liquids.

10. Martinov, M., F. Gancel, Ph. Jaques, I. Nikov, S.D. Vlaev, (**2008),** "Surfactant effects on aeration performance of STR", *Chemical Engineering Technology,* 31 (10), 1494-1500, IF = 1.223.

Abstract: The effect of surfactants on aeration performance in stirred tank reactors (STR) at high rates of foaming is studied. The volumetric oxygen transfer coefficient (*k*L*a*) and foaming activity estimated as foaming height (*H*f) were determined. Biotechnology of lipopeptide biosurfactants from aerobic organisms, e.g., Bacillus subtilis were addressed. Using model solutions of known foam-generating properties, high-molecular weight surfactin and low-molecular weight sodium dodecyl sulphate (SDS), as well as impellers of different types, with flat and fluidfoil blades, clues on the concentration dependence of STR oxygen transfer and foaming as well as options for foam reduction in the presence of biosurfactant were sought. In response to a two-fold decrease of surface tension by surfactin, *k*L*a* values decreased up to 30% but remained within the range expected for the mixing system in water; the experiments with SDS showing stronger dependence on surfactant concentration and surface tension. Mixing of surfactant media by a standard six-blade disc turbine (RT) imposed rate limitations on gassing. A lowshear impeller Narcissus (NS) could be used to avoid bulk foam outflow, while preserving *k*L*a* values that remained unchanged. The 'power per unit volume' correlation of *k*L*a* in stirred tanks is tested in the presence of surfactin.

2. Публикации в списания без импакт фактор - 9

11. Martinov, M., D. Nikolov, ***(1993),***"Изясняване влиянието на характерните за метода на флотация с предварителен контакт зони на контактиране и вторична концентрация" (Studding the Influence of the Contact Zones and Zones of Secondary Concentration Typical of the Method of Preliminary Contact Flotation), *Annual of the University of Mining and Geology, Sofia, 39(2), 163-166.*

Abstract: Model investigations by the method of preliminary contact flotation with a two-component raw material have been carried out to study the interaction between the selectivity of separation, production of flotated material and extraction of useful components as a function of the length of the zone of preliminary contact and zone of secondary concentration typical for the method.

It has been established that responsible for the final technological results are the conditions in both zones, i.e. when controlling the entire process special attention to both stages should be paid as their participation is equal. The suggested kinetic equations for describing the recovery at single suspension leaking and recovery in function of the rate frequency of control operation answer satisfactorily to the nature of the process and can bre successfully used for implementing the technological results from model and laboratory into semi-industrial and industrial scale.

12. **Martinov, M**., S.Vlaev, **(1999)"** Comparison of Mixing Power Characteristics for Curved-Blade (NS-60), Flat-Blade and Hollow-Blade Impellers", *Hung. J. Ind. Chem*. 27, 179-181, **Намерени цитати :** 6.

Abstract: The paper presents the mixing power characteristics of a new type of a curved-blade impeller with 60 deg. angle blade, the Narcissus NS-60 based on the impeller version reported by Kraitchev et al. Experiments in a conventional mixing tank geometry with ID 0.4 m are described. Both Newtonian and non-Newtonian cases are considered. Water, a 0.5 % pseudoplastic xanthan gum solution and viscoelastic 2 % carboxymethylcellulose and 1 % polyacrylamide solutions were used. The impeller rotational speed varied between 1 and 15 rps at intervals of 1 rps, and gas now rate varied between 0 and 2 vvm at intervals of 0.16 vvm. In parallel, Rushton flat-blade turbine (FB) and hollow-blade (HB) turbine were tested at similar conditions. The functions Po = f(Re) and Pg/Pu = f(Fl) corresponding to the three types of impellers were determined and compared. The data obtained for the FB and HB impellers are shown to be close to the figures reported in the literature.

13. Vlaev, S.D., **Martinov, M**., **(1999)**,"Shape Effects on Impeller Power Characteristic for Mixing and Gassing Power Law Fluids, *I. Chem.Eng. Symp. Ser.* 146, 253-262, **Намерени цитати:** 1

Abstract: An analysis of the effect of blade shape on the impeller characteristics in stirred das-liquid dispersion with non-Newtonian properties is presented. Using the flat blade and the hollow blade impeller as the basic for comparison, the study considers differences in power draw generated by an alternative concave blade shape. The new shape described as a partial epicycloid has shown power differences up to 20 % compared to the hollow-blade and up to 60 % compared to flat-blade impeller. Apart from showing a reduced power number, this specific shape has been found to introduce flat power ratio characteristics for some gas flow regimes encountered in bioreactors. The notion of tighter control on the power consumption in non-Newtonian process media by fitting blade shape is checked by example power law dispersions prepared with polyacrylamide and carboxymethylcellulose. An improved power ratio is found for power law fluids when mixing with a higher blade angle.

14. Martinov, M., S.D. Vlaev, **(1999)** "Average Shear Rate and Power Consumption of a Curved Blade Impeller for Agitation of Shear-Thinning Fluids", *Bulg. Chem. Commun.* 31, (3/4), 471-476.

Abstract: The power consumption of a stirred vessel equipped with a six-blade impeller with partially concave blades is determined in parallel for Newtonian and a non-Newtonian fluids in laminar flow. Based on the Metzner method, the specific average shear rate constant, k_m, for this impeller is determined. The value of k_m obtained for the new impeller, is comparable with the values, reported for curved blade paddle impellers in pseudoplastic fluids, namely 8.1 for the new impeller against 7.1 for paddle impellers. Referring to the average shear rate concept, the deviation of the power consumption caused by assuming the flat –blade average shear rate approximation on power is found to account for less than 20% change of the power number.

15. Sisak, Cs., T. Venyige, **M. Martinov**, S.D. Vlaev, **(2001),** "Studies on Small-Scale Liquid Mixing in Liquid Fluidized Bed and Gas-sparged bioreactor systems by Heat Pulse Anemometry ", *Bulg. Chem. Commun.* 33 (3/4) 331-336.

Abstract: The heat pulse anemometry (HPA) measurement technique is applied for diagnostics in single-phase and multi-phase flows in reaction vessels: e.g. a fluidized bed and an air-lift reactor. Small-scale liquid mixing has been analyzed. The influence of the solid particles in the first case and of the non-Newtonian flow in the second case has been investigated. The time function of the standard deviation of fluid phase residence time is determined and the equation β-power index has been checked for interpretation. In both cases, the small-scale liquid mixing has been qualified in an attempt to ensure experimental evidence for further prediction of mass transfer rates in complex practical bioreactors.

16. Martinov, M., S.D. Vlaev, **(2001),** "Gas Dispersion and Mixing Power Characteristics of a Novel Impeller: The Effect of Blade Angle ", *Comp. Rend. Acad. Bulg. Sci*. 54, (5) 47-52

Abstract: In this paper, the effect of modified blades and blade angle are considered. This paper aims to discuss the mixing power and gas dispersion characteristics of a new tape of hydrofoil impeller (narcissus, NS) in two version with different blade angle, namely 30° and 60°. The conventional Rushton turbane (RT) stands for the sake of comparison. The significance of a single change of geometrical parameter namely, the impeller angle is tested. The conclusion about the effect of blade angle is that increasing blade angle the power requirement increases, while the character of gas hold-up distribution specific for the NS impeller is preserved at in increased power.

17. Nikov, I., S.D. Vlaev, **M. Martinov**, **(2004)**, "Average Shear Rate Measurement in Stirred Tanks", *Compt. Rend. Acad. Bulg. Sci*., 57,(6), 77-82

Abstract: An extension of the electrochemical shear rate measurement technique is tested to ensure evaluation of the shear field in a stirred reactor bulk fluid. The extension comprises introduction in the stirred reactor of a mobile probe containing a micro-electrode that can be rotated at various angles in order to ensure estimates of angle-average values of the velocity gradients corresponding to the orthogonal (Cartesian) flow direction. Using this technique, the local average shear rates in semi-tech scale vessels agitated by flat-blade and fluid foil impeller are determined and compared.

18. Nikov, I., S.D. Vlaev, **M. Martinov, (2005),** "Effectiveness of power law fluid mixing in stirred reactor utilizing new-foil blades ", *Bulg. Chem. Commun.* 37, (2), 126-130.

Abstract: Mixing effectiveness based on local skin-friction drag over immersed particles in stirred tank reactor, equipped with fluid foil impeller NS is targeted. An attempt is made to uncover external flow friction conditions effecting dispersion mechanisms in power law fluid media, corresponding to different impeller types. The local skin-friction force and drag are determined based on shear stress and shear rate data, generated by electrochemical measurement of the ion transport in the diffusion boundary layer by means of a spherical probe. A summary of flow uniformity is worked out as well as the field of friction drag force and drag coefficient relevant to mixing intensity specific for various impeller designs and rheological properties. It is shown that compared to flat-blade impeller, the fluid foil blades ensure a higher effectiveness, identified by comparable friction drag at lower power input that is presumably due to lower pressure drag.

19. Martinov, M., D. Hadjiev, S.D. Vlaev. (**2010**), "Gas-Hold-Up and Bubble Size Distribution in a Fibrous Fixed Bed Biofilm Reactor", Journal of International Science Publication: Materials, Methods and Technologies, Volume 4, ISSN 1313-2539, Part 1, 454-466

Abstract: Bacteria adhere to surfaces of polymer materials in multi-cellular assemblies as bio-film. Bacteria-associated EPS interact with the material surface during fermentation in arbitrary

relationships. Observations reveal bio-film structures that vary from small clusters to extensive bio-films. The surface properties of the solid support, the nutrient availability and the productivity of the colonized bacteria strongly influence the biofilm structure. The study presents some relationships of formation of these EPS-related structures by examining visually the extent to which bio-film formation is an intrinsic component of the support microbe interaction in the case of Pseudomonas putida grown in sucrose. In a preliminary stage, the adhesion of various solid polymer plates is correlated with surface free energy in order to select the appropriate polymer support sample to be tested. Further, the colonization over the selected surfaces is studied by SEM (electronic micrographs) and IR-spectra and counting showing variations between active depositions both qualitatively and in NAC. The deposition is studied both in flasks and in vessels with horizontal stratified flow. The data lead to the conclusion of the importance of the growth conditions – of flow and nutrient – for the deposition quality and control.

3. Доклади публикувани в пълен текст в сборници с редактор - 3

20. Nishkov I., D. Lazarov, **M. Martinov**, E. Beas, C. Hanriquez, **(1994)**, "Surfactant-Hydrocarbon Oil Emulsions for Molibdenite Flotation", *Proc. of 4 Meeting of the Southern Hemisphere on Mineral Techn. and 3 Latin-American Congress of Froth Flotation, Concepsion, Chile, volume II - Flotation,* Editors:S. Castro and J. Alvarez, *319-329.*

Abstract: The effect of surface active agents on the wetting and spreading of hydrocarbon oil on too a molybdenite surface and on the floatability of molybdenite is investigate experimentally. Many reagents commonly used in other industries as oil emulsifiers are tested in the flotation of molibdenite-bearing porphyry copper ores. The emulsification studies show that small amount of surfactants modify Diesel oil interfacial properties, lowering the oil/water interfacial tension, which is turn lowers the energy required to spread the collector oil across the molybdenite surface. An increase of the zeta potential of oil droplets, which reduces their coalescence by collision, is also observed. It is found that the surfactant/oil emulsions enhance significantly the oil spreading at the molybdenite/water interface and lead to stabilization of an oil film on the molybdenite surface, improving the flotation response.

21. Martinov, M., S.D. Vlaev, **(2001),** "Effect of Rheology on the Structure of Gas-Liquid Dispersion in Stirred Reactors with a New Impeller", *Proc. of Balkan Seminar on Reology,* Sofia*,* Editor Y. Ivanov, 147-153.

Abstract: A significant part of chemical, biochemical, food and pharmaceutical processes require mechanical agitation of complex-rheology systems. Such mixing operation are highly energy consuming and developments responding to such conditions are considered. A new type of impeller that reduces power consumption has been proposed. The paper presents an experimental analysis of the gas hold-up structure generated by the new impeller in non-Newtonian condition. The effect of pseudoplastic and viscoelastic properties upon the structure of dispersion of the stirred systems is determined and compared with the Newtonian one.

22. Montastruc,L., J. P. Brienne, **M. Martinov**, I. Nikov, **(2006),** "Gas Maldistribution in a Fermenter Stirred with Multiple turbines", *Proceedings 12th European Conference* on Mixing, Bologna, 27-30 June, Editors: F. Magelli, G. Baldi, A. Brucato, 177-184, **Намерени цитати:** 1.

Abstract. The study is focused on modelling of gas maldistribution of aerated liquid systems in a multiple impeller bioreactor. The phenomenon may or may not depend on column design. The latter case is dependent merely on bed fluid dynamics and could be treated by using the methodology of the residence time distribution (RTD) theory. Accordingly, a specific methodology is proposed, as

follows: the fermenter has been modelled as a reactor network involving a combination of zones representing basic ideal flow patterns. The methodology is based on the wide-spread experimental gas tracer technique extended by a new systemic identification approach. The approach is based on a Mellin-modification of the Laplace transform over the relevant equations. The method allows zerotime solutions for identification analysis. Unlike the diffusion model approximation, the technique considered allows exact approximation of the RTD curves with circulation. The proposed transfer function represents adequately the bioreactor gas maldistribution thus allowing fast overview of the studied reaction and prompt feed back control on the physical situation.