

# Multiphase systems in chemical engineering

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EDITORIAL

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We are pleased to present this special issue of the journal *Hemijska industrija* (Chemical Industry) dedicated to Professor Željko Grbavčić and his extraordinary scientific and professional contributions to the progress of chemical engineering, especially in the field of heterogeneous systems.

Dr. Željko Grbavčić (1948-2015) was a professor emeritus at the Faculty of Technology and Metallurgy at the University of Belgrade (FTM). He was born in Vrbas, where he began his primary education, and continued it in Belgrade, where he next graduated from high school. He obtained his B.Sc. in Chemical Engineering at the Faculty of Technology and Metallurgy in Belgrade in 1971 followed by the M.Sc. degree in 1975 and the PhD degree in 1989 at the same Faculty. From 1972 to 1990, he worked at the Institute of Chemistry, Technology and Metallurgy (ICTM) in Belgrade, where he was at the position Director General from 1978 to 1980 and President of the ICTM Council from 1984 to 1988. In 1989 he was a visiting researcher at the Rensselaer Polytechnic Institute in Troy, USA. From 1990, he was employed as Assistant Professor at the FTM, followed by the appointment of Full Professor in 1995. In two mandates (1995 to 1998 and 2000 to 2004), he was appointed Vice Dean for Scientific research and collaboration with industry, FTM. He was also President of the FTM Council for two terms (2006 to 2012). In 2014, he was elected Professor Emeritus.

Since 2004, Prof. Željko Grbavčić was a member of the editorial board of the journal *Hemijska industrija* (Chemical Industry). From 2004 to 2010 he was President of the Management Board and from 2010 to 2015 President of the Association of Chemical Engineers, Serbia. He was also a corresponding member from 2004 and a full member since 2012 of the Academy of Engineering Sciences of Serbia (AINS). He was a member of the Serbian Chemical Society (SHD) and received the SHD Medal in 2008 for his outstanding contribution to the application of science in industry and for scientific and engineering achievements.

His journey into the world of chemical engineering began during his student years, when he met Professor Dragoljub Vuković, who recognized his undeniable talent for the chosen profession. He then entered the world of multiphase systems and left a permanent impression in this field.

The most important results of fundamental research in the field of multiphase systems, to which Professor Grbavčić devoted most of his attention, include (i) development of various techniques for experimental determination of transfer coefficients of momentum, heat and mass in fluidized beds, spout-fluidized beds and in pneumatic and hydraulic transport, (ii) development of mathematical models for determination of fluid-particle friction coefficients in particulate fluidized beds as well as basic fluid dynamic properties in spouted and spout-fluidized beds, and (iii) establishment of an analogy of momentum, heat and mass transfers in multiphase fluid-particle systems. In order to solve specific engineering problems, he has been intensively engaged in theoretical and experimental studies of drying processes of solutions, suspensions and pastes in moving particle beds, especially in fluidized beds, with the aim of developing drying processes with significantly lower energy consumption, as well as research into combined processes and multifunctional reactors for waste gas purification.

His overall scientific research has led to the publication of: 6 chapters in international and national monographs; 72 articles in prestigious international journals and 26 articles in leading national journals. He has presented 92 papers at international conferences and 76 papers at national conferences.

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Professor Grbavčić led or participated in realization of: 22 national basic research as well as technological development projects funded by the Ministry of Science, 2 Yugoslav-American projects, 4 innovation projects, and over 40 technical and technological projects and investment studies that resulted in 7 innovative solutions. The immense engineering contribution of Professor Grbavčić is reflected in the construction of several industrial plants based on original process solutions.

After his transfer to the FTM, Professor Grbavčić began teaching, too, no less successfully. He taught subjects in several study programs, some of which are: Transfer Phenomena in Dispersed Systems, Mechanical Operations, Equipment Design in Chemical Industry, Process Scale-up, Multiphase Systems and others, for which he wrote 3 textbooks. Many colleagues and students recognized that there was much to learn from Professor Grbavčić. He was the supervisor at 9 doctoral theses, 11 master's theses, 49 bachelor's theses, 6 final BSc theses and 3 final MS theses, as well as he participated in numerous thesis defense committees at all study levels at the FTM, the Faculty of Technology in Novi Sad, Serbia, and the Technical Faculty in Bor, Serbia.

In the work that all researchers and professors are engaged in, an important and very demanding step is the application of the results and knowledge gained in practice, i.e. the connection between science and industry as well as the transfer of the experience gained to young colleagues. In all of this, Professor Grbavčić managed to embody the roles of scientist, engineer and professor. Despite his wide-ranging interests, he always found time to make contacts with colleagues and students and selflessly share his experience. Therefore, the merits of Professor Grbavčić are far greater than the numerous scientific papers, technical solutions and projects mentioned above. His approachable demeanor meant that his closest colleagues had in him first a great friend and then a teacher. All of us who worked and socialized with him will never forget his modesty, humor, energy, diligence, perseverance and vision.

The articles in this special issue dedicated to Professor Grbavčić come from different faculties and institutes and deal with different topics, but they have one common denominator: the authors of these articles pay tribute to their friend Professor Željko Grbavčić and his great contributions to the development of chemical engineering.

# Višefazni sistemi u hemijskom inženjerstvu

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REČ UREDNIKA

Sa zadovoljstvom predstavljamo ovo specijalno izdanje časopisa Hemijska industrija posvećeno profesoru Željku Grbavčiću i njegovom izuzetnom naučnom i stručnom doprinosu u unapređenju hemijskog inženjerstva, a posebno u oblasti heterogenih sistema.

Dr Željko Grbavčić (1948-2015) bio je profesor emeritus na Tehnološko-metalurškom fakultetu Univerziteta u Beogradu. Rođen je u Vrbasu gde je počeo osnovno školovanje, a nastavio u Beogradu gde je završio i gimnaziju. Diplomirao je na Tehnološko-metalurškom fakultetu u Beogradu na Odseku za hemijsko inženjerstvo 1971. godine. Na istom fakultetu je magistrirao 1975. godine i doktorirao 1989. godine. Od 1972. do 1990. godine bio je zaposlen na Institutu za hemiju, tehnologiju i metalurgiju (IHTM) u Beogradu gde je stekao zvanje višeg naučnog saradnika. Od 1978-1980. godine obavljao je dužnost generalnog direktora IHTM, a od 1984-1988. godine bio je i predsednik Saveta IHTM. Tokom 1989. godine bio je na studijskom boravku na Politehničkom institutu Rensler (Rensselaer Polytechnic Institut), Troy, SAD. Od 1990. godine bio je zaposlen na Tehnološko-metalurškom fakultetu u zvanju docenta, gde je od 1995. radio u zvanju redovnog profesora. U periodu od 1995-1998. i 2000-2004. godine bio je prodekan za naučno istraživački rad i saradnju sa privredom. Od 2006-2012. godine u dva mandata je bio predesednik Saveta TMF. U zvanje profesora emeritusa izabran je 2014. godine.

Bio je član uredništva časopisa Hemijska industrija od 2004. godine. Od 2004.-2010. godine bio je predsednik Upravnog odbora, a od 2010.-2015. godine predsednik Skupštine Saveza hemijskih inženjera. Od 2004.-2012. godine bio je dopisni član, a od 2012. godine i redovni član Akademije inženjerskih nauka Srbije (AINS). Bio je član Srpskog hemijskog društva (SHD), a 2008. godine dobio je medalju SHD za izuzetan doprinos primeni nauke u industriji za naučne i inženjerske rezultate.

Njegov put u svet Hemijskog inženjerstva započeo je tokom studentskih dana u susretu sa profesorom Dragoljubom Vukovićem koji je u njemu prepoznao neosporan talenat za odabranu struku. Tada je zakoračio u svet višefaznih sistema i u toj oblasti ostavio neizbrisiv trag.

Najznačajniji rezultati fundamentalnih istraživanja u oblasti višefaznih sistema kojima se profesor Grbavčić najviše bavio su: razvoj različitih tehnika eksperimentalnog određivanja koeficijenata prenosa količine kretanja, toplote i mase u fluidizovanim slojevima, fontansko-fluidizovanim slojevima i pri pneumatskom i hidrauličkom transportu; razvoj matematičkih modela za određivanje koeficijenta trenja fluid-čestice u partikulativno fluidizovanim slojevima i za određivanje osnovnih fluido-dinamičkih karakteristika fontanskog i fontansko-fluidizovanog sloja; uspostavljanje analogije prenosa količine kretanja, toplote i mase u višefaznim sistemima fluid-čestice.

Celokupni naučno istraživački rad je rezultovao objavljivanjem: 6 poglavlja u međunarodnim i nacionalnim monografijama; 72 rada u prestižnim međunarodnim naučnim časopisima i 26 radova u vodećim nacionalnim časopisima. Saopštio je 92 rada na skupovima međunarodnog značaja i 76 na skupovima nacionalnog značaja.

U cilju rešavanja specifičnih inženjerskih problema intenzivno se bavio teorijskim i eksperimentalnim ispitivanjima procesa sušenja rastvora, suspenzija i pasta u pokretnim slojevima čestica, posebno u fluidizovanom sloju u cilju razvoja procesa sušenja uz znatno niži utrošak energije kao i istraživanjima kombinovanih postupaka i multifunkcionalnih reaktora za prečišćavanje otpadnih gasova.

Profesor Grbavčić je rukovodio odnosno učestvovao u realizaciji: 22 nacionalna projekta osnovnih istraživanja i tehnološkog razvoja resornog Ministarstva za nauku; 2 jugoslovensko-američka projekta; 4 inovaciona projekta; preko 40 tehničko tehnoloških projekata i investicionih elaborata odakle je proisteklo 7 tehničkih rešenja. Ogroman inženjerski



doprinos prof. Grbavčića ogleda se u izgradnji više industrijskih postrojenja koja su bazirana na originalnim procesnim rešenjima.

Prelaskom na fakultet profesor Grbavčić je počeo da se bavi, ništa manje uspešno, i nastavnim radom. Držao je predmete na više nastavnih programa, a neki od njih su: Fenomeni prenosa u disperznim sistemima, Mehaničke operacije, Projektovanje uređaja u hemijskoj industriji, Uvećanje razmera procesa, Višefazni sistemi i dr., za koje je napisao i 3 udžbenika. Da se od profesora Grbavčića može mnogo naučiti prepoznale su mnoge kolege i studenti tako da je bio mentor 9 doktorskih disertacija, 11 magistarskih radova, 49 diplomskih radova, 6 završnih radova i 3 master rada uz brojna učestvovanja u komisijama za odbrane radova na svim nivoima studija na Tehnološko-metalurškom fakultetu u Beogradu, Tehnološkom fakultetu u Novom Sadu i Tehničkom fakultetu u Boru.

U poslu kojim se bave svi istraživači i profesori važan i vrlo težak korak je da se dobijeni rezultati i znanja primene u praksi, odnosno da se spoji nauka i industrija i da se na kraju stečeno iskustvo podeli sa mladim kolegama. Upravo je u svemu tome uspeo profesor Grbavčić da u sebi objedini naučnika, inženjera i profesora. I pored svojih širokih interesovanja uvek je nalazio vremena za druženje i nesebično deljenje svojih iskustava i zbog toga su zasluge profesora Grbavčića mnogo veće od navedenih brojnih naučnih radova, tehničkih rešenja i projekata. Upravo neposredan pristup koji je imao značio je da su njegovi najbliži saradnici prvo u profesoru imali velikog prijatelja, a onda i učitelja. Svima nama koji su sa njim radili i družili se ostaje u sećanju zauvek njegova skromnost, duhovitost, energija, vrednoća, istrajnost i vizija.

Radovi u ovoj svesci posvećenoj profesoru Grbavčiću su stigli sa različitih fakulteta i instituta i razmatraju različite teme ali jedno im je zajedničko: autori ovih radova su odali poštovanje svom prijatelju profesoru Željku Grbavčiću i njegovim velikim zaslugama za razvoj hemijskog inženjerstva.