Globalization in the Field of Fluid power

Jožef PEZDIRNIK, Franc MAJDIČ

An interview with Prof. Dr. Monika Ivantysynova, one of the most prominent experts in the field of Fluid Power worldwide, and Head of the Maha Fluid Power research Center on Purdue University, USA.

Ventil: *Dear Prof. Dr. Ivantysynova, it is a great honor for our fluid power engineering journal Ventil to be able to conduct an interview with you, as one of the most prominent professors and experts in the field of fluid power worldwide. What were the main reasons that you started working in the field of fluid power?*

Prof. Ivantysynova: I like physics a lot and when I started studying mechanical engineering I liked fluid mechanics and thermodynamics the most. I decided to do some undergraduate research during my 3rd year of study. During that time I developed a first simulation model to calculate the dynamic pressure field between a piston and a cylinder. I won the first prize in a student competition in Czechoslovakia with this research study. I think this motivated me a lot and so I decided not only to do my master's thesis in the field of fluid power, but also my PhD. After completing my PhD thesis I started my carrier in the fluid power industry. Then, after 10 years in industry I moved back to academia and continued my research in fluid power.

Prof. Dr. Monika Ivantysynova

Ventil: *If we look backwards, you finished your PhD study in the Slovak Technical University of Bratislava in 1983. How did your professional career develop from the time of your PhD study in Bratislava until today, when you are in charge of the Maha Fluid Power Research Center at Purdue University?*

Prof. Ivantysynova: If I look backwards it might look like everything was well planned, but that is not true. After I finished my PhD I started working in industry as a design engineer for hydraulic systems. I was also involved in pump design. When I started working in industry I did not have any plans to become a professor one day. However, after seven years spent in industry I moved back to academia, where I first did research on new primary flight-control systems for large commercial aircraft. In 1996 I became Professor for Fluid Power and Control at Duisburg University in Germany. I started building my own lab and hired my first PhD students. After three years at Duisburg University I received a faculty position at the Institute for Aircraft Systems at Technical University of Hamburg-Harburg. I moved my lab from Duisburg to

Hamburg-Harburg and took all my PhD students with me. In 2003 I was asked if I would be interested in joining Purdue University in the USA. I found that a wonderful opportunity and agreed to move my laboratory from Hamburg, Germany to Purdue, where I became the Maha Professor of Fluid Power Systems and Director of Purdue's newly established Fluid Power Research Center.

Ventil: *Please, can you shortly describe Your Maha Fluid Power Research Center.*

Prof. Ivantysynova: After my arrival at Purdue I established the Maha Fluid Power Research Center in August 2004. Otto Maha, a former Executive of Parker Hannifin, had given $4 million to Purdue for an Endowed Chair position in the field of fluid power to promote research and education. The Maha Fluid Power Research Center has grown continuously since 2004. We are performing fundamental and applied research in fluid power with the main focus of new energy-saving actuation and drive-system solutions, hydraulic hybrid systems and computational design of pumps and motors. In 2010 Prof. Andrea Vacca joined the Maha team. Our external research funding reached $2.6 million last year. Currently, more than 30 researchers work in the Maha lab. For more info please visit our website *https://engineering.purdue.edu/Maha/*

A building of Maha Fluid Power Research Center and all current Maha researchers, i.e. PhD students and MS students doing research at Maha

Ventil: *Your main research focus is hydraulic pumps and motors, especially the axial piston type. When did you start working on the field of hydraulic pumps/motors and what was the reason for that?*

Prof. Ivantysynova: As I already mentioned, I did my first student research study on modeling the piston/cylinder interface of a swash-plate-type axial piston pump. I continued my research through my master's thesis study and my PhD study. Later on I worked as a designer of pumps and motors. After my return to academia I continued this research as a professor. I built my own research group and hired my first PhD students. Approximately half of them worked on research in the field of axial piston machines. Computer power had grown rapidly since I finished my PhD thesis and I saw the opportunity to discover the secret of pumps and motors, which all had been designed by very experienced designers but based on trial and error.

Ventil: *Can you compare the research success in the field of fluid power in the United States with EU and Asia? Which country/region do you think*

Picture is taken inside the lab of MAHA showing members and PhD students with Matteo Pelosi in a Piston costume after his PhD defense day

now has the dominant role in the field of fluid power?

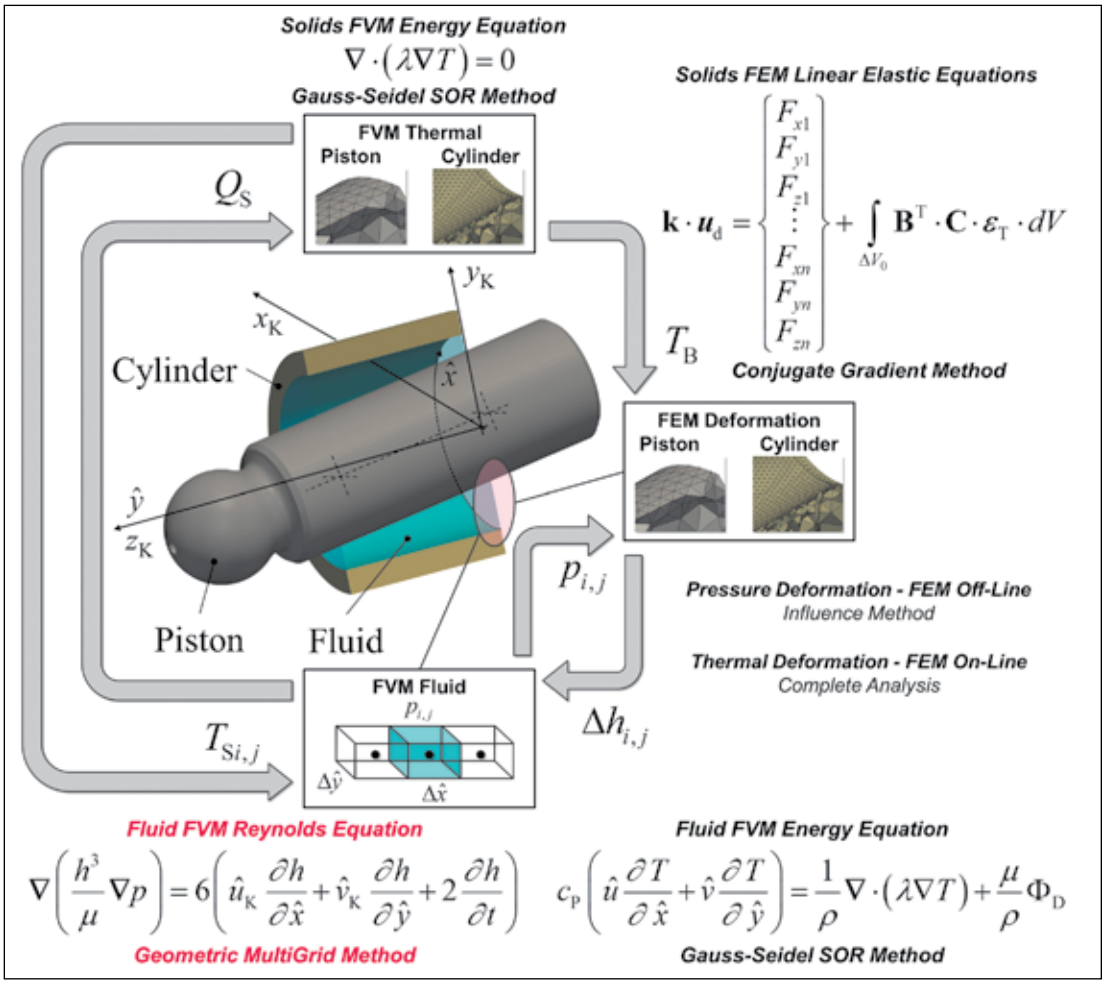
Prof. Ivantysynova: This is not an easy question to answer. During the 1970s, 80s and 90s, only very little research was being conducted in the field of fluid power in the USA and many more activities were on-going in Europe and Asia. After my move to the US and especially since the establishment of the National Science Foundation funded Engineering Research Center for Compact and Efficient Fluid Power (CCEFP) things have changed drastically. Today, more than 50 faculties are involved in fluid power research in the USA. Therefore, I would answer your second question by saying that we have a relatively balanced situation in research output between Europe, Asia and the USA at the moment, however efforts in China are growing continuously.

Ventil: *Do you think that the axial piston type of hydraulic pumps/motors is the most promising type for the future? If yes, why do you think so?*

Prof. Ivantysynova: The future belongs to piston machines and among them axial piston pumps and motors (both swash-plate type and bent axis) will have their place. There are several reasons for this. Swash-plate-type machines can work at high pressures, are easily designed as variable displacement units and achieve relatively high efficiency, excellent dynamic performance and are very compact and have a through-shaft ability. On the other hand, bent-axis machines can achieve the highest efficiencies and have higher maximum speeds than swash-plate type units. However, the bent-axis design is a more complex design, resulting in higher production costs. We will also see radial piston pumps and motors. The shorter length of radial piston machines allows the easy packaging of multiple units in one machine. This can be an advantage for several future applications of pump-controlled actuation.

Ventil: *People often compare fluid power drives with electrical power drives. Which branch, in your opinion, has a better future?*

Prof. Ivantysynova: First of all we need to differentiate between hydraulic drives and electric drives. Electric drives can get the energy from the electric grid or batteries and are therefore more suitable for stationary applications. Hydraulic drives should be used in combination with combustion engines, i.e., for applications in the transportation sector, mobile machinery, etc. The power-to-weight ratio of electric machines to hydraulic is approximately 1:10, i.e., a hydraulic motor is 10 times lighter and smaller compared to an electric motor of the same power. This difference in power density is given by the fundamental physics of the operation of both machines, i.e., the basic principle of the transfer of energy in both types of machines. Unfortunately, many engineers do not know this fundamental difference.



Fully coupled fluid strucrure interaction model for piston cylinder inteface

Society will need more actuation and drive systems in the future and we will see both technologies competing; however, for off- and on-road vehicles, airplanes and all kinds of mobile machinery, an electric drive is not the right choice. Hydraulic drives and actuation systems will have a bright future in all movable equipment and machinery, because of the high power den-

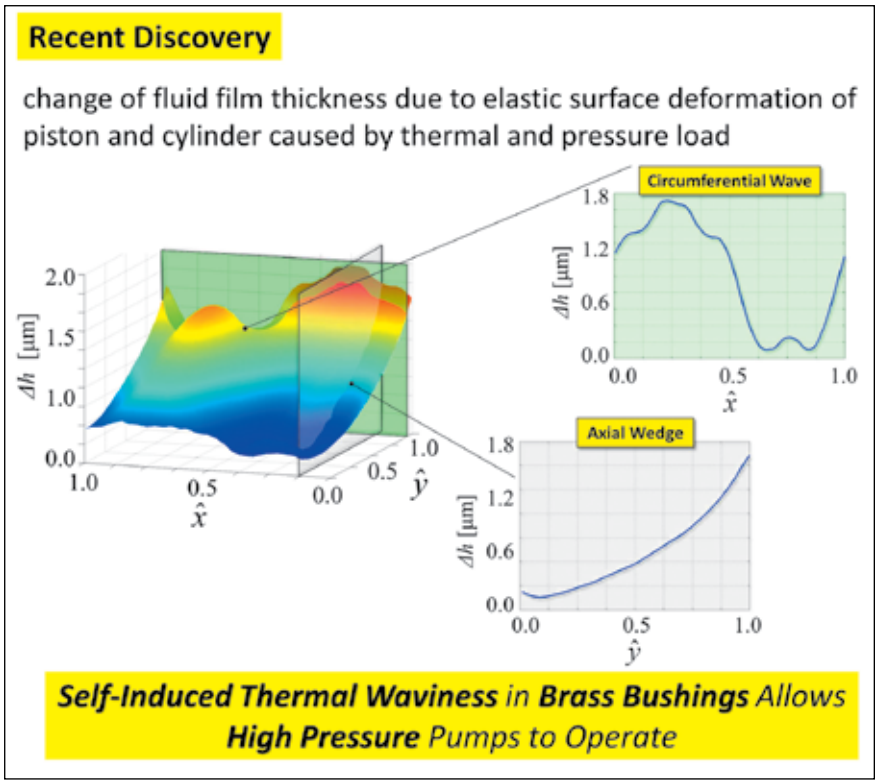
sity resulting in a lower weight, smaller size, higher dynamics and also lower costs.

Ventil: *Efficiency in general is nowadays one of the most important themes. In fluid power we have a lot to do to improve the efficiency of fluid power components and systems. One of your mottos is to use as few hydraulic components as possible to get better efficiency. If we look forward into the future, what do you think about the possible expected efficiency of hydraulic pumps/motors?*

Prof. Ivantysynova: Our current hydraulic pumps and motors have a relatively poor efficiency for two major reasons. The first reason is that in current valve-controlled systems a large portion of the energy is wasted. In many machines more than 50% of the energy is transferred into heat. In such an environment the lower efficiency of the pumps and motors does simply not matter. Once we eliminate throttling as a control principle in hydraulic actuation systems we will see that suddenly the efficiency of pumps and motors determines the overall system efficiency, like is the case already in the field of hydrostatic transmissions. The second reason is that the improvement of pump and motor efficiency is not a cheap engineering task, especially if the current state of the art of pump and motor design is used. The future, however, in pump design is computational design and this approach will allow us to apply multi-parameter optimization schemes within the design process. This will open a complete new potential for an increase of efficiency over the entire range of operating conditions.

Ventil: *Do you believe in general that it is possible to calculate/predict the efficiency of hydraulic pumps and motors numerically?*

Prof. Ivantysynova: The majority of losses are generated in the rotating group of pumps and motors. We have made major breakthroughs in understanding and modeling the complex physical phenomena taking place in the rotating group. With that we will be able to predict the major losses of pumps and motors; however, there are additional losses contributing to the overall efficiency, like churning losses and losses in the shaft bearings, which are difficult to predict numerically. That is why I think it is, and will remain also in the future, difficult to accurately predict a pump's efficiency numerically. But I think it is more important to state that we have the models that allow us to design pumps and motors with the highest possible efficiencies or lowest losses created in the pump or motor. Figure 1 shows the structure of our newest model for the piston cylinder interface. Figure 2 shows some of our newest discoveries about self-induced surface waviness due to thermal deformation of piston and cylinder surface in the case of the use of brass bushings pressed into a cylinder block made from steel.



Fluid Film between piston and cylinder in axial piston pumps for unwrapped gap

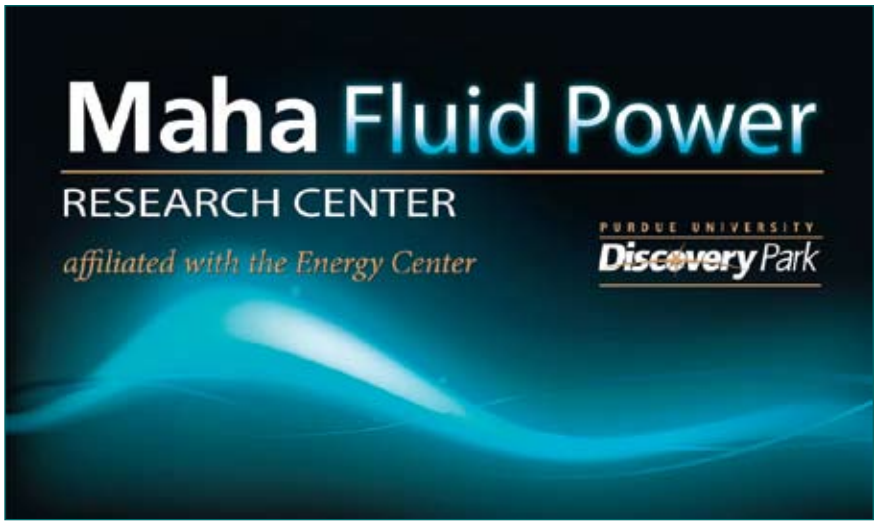
Ventil: *Your book Hydrostatics Pumps and Motors, New Delhi, 2000, was one of the first books in this field in the English language, and which was also translated into German. Do you plan to prepare new edition of it?*

Prof. Ivantysynova: The book was first published in German and English in 2000. I have plans for a new version with a special focus on piston pumps and motors, but it might take some more time.

Ventil: *You are also Editor-in-Chief, from the beginning, of the very well-known International Journal of Fluid Power. Do you plan to obtain an SCI index for the Journal?*

Prof. Ivantysynova: Yes, I am working hard on that. We applied already twice and failed, for one simple reason. We fulfilled all the criteria except for the number of citations. Many of our authors are not very used to this practice and therefore our citation numbers are still low.

Ventil: *In the past five years we have together participated in five scientific-professional conferences all over the world (Tampere 2007 and 2011, Toyama 2008, Aachen 2010 and Dresden 2012) and you have probably observed that our laboratory for Power-Control Hydraulics (PCH) is researching and developing on the field of tap-water*



PCH too. Taking into account the increased demands relating to protection of the natural environment, what do you think about the possibilities of tap water in PCH, especially for machines working in the natural environment.

Prof. Ivantysynova: I believe that this is the long-term future of fluid power; however, we will need to accomplish a lot of fundamental research in order to allow component design and especially pump and motor design with a comparable power density. I am personally convinced that this goal can be reached.

Ventil: *Prof. Ivantysynova, in the name of our journal Ventil and ourselves, we thank you very much for your answers and the time you took for us. We also wish you a successful continuation of your work in the future.*

Jožef Pezdirnik and Franc Majdič,
University of Ljubljana, Faculty of Mechanical Engeenering

Razširjeni povzetek:

Globalizacija na področju Fluidne tehnike

Na vprašanje, kje so bili razlogi, da je začela delati na področju fluidne tehnike (FT), prof. Ivantysynova odgovarja, da ji je všeč fizika in ko je začela študirati strojništvo, je najbolj vzljubila mehaniko fluidov in termodinamiko. Za razvojno-raziskovalno delo na področju FT je kot študentka doma v Češkoslovaški dobila prvo nagrado, ki jo je tako motivirala, da je na tem področju magistrirala in doktorirala na Tehnični univerzi v Bratislavi leta 1983. Po doktoratu se je zaposlila v industriji kot inženirka projektantka hidravličnih sistemov in sodelavka pri snovanju črpalk. Tedaj ni načrtovala profesorske kariere, a se je po 10 letih dela v industriji vrnila na akademijo in nadaljevala z raziskavami na področju FT, in sicer na razvoju krmilnih sistemov za veliko komercialno letalo.

Leta 1996 je postala profesorica za fluidno tehniko in krmilja na univerzi v Duisburgu, ustanovila laboratorij in pridobila prve študente doktorskega študija. Tri leta kasneje je dobila mesto na Inštitutu za letalske sisteme na Tehnični univerzi Hamburg-Harburg ter tja vzela tudi vse svoje doktorande. Že leta 2003 pa je dobila povabilo za delo na Purdue University v ZDA. To je imela za čudovito priložnost. Tja je preselila tudi svoj laboratorij, in sicer v na novo ustanovljeni Raziskovalni center za fluidno tehniko, katerega direktorica je od samega začetka, od avgusta 2004. Temu centru je Otto Maha, bivši izvršni direktor Parker Hannifina, dodelil 4 milijone US dolarjev za promocijo in izobraževanje na področju FT. Maha Fluid Power research Center izvaja temeljne in aplikativne raziskave s področja varčevanja z energijo, hidravličnih hibridnih sistemov ter računalniškega snovanja črpalk in hidravličnih motorjev. Center ima stalno rast od leta 2004, zunanje financiranje je lani doseglo 2,6 milijona dolarjev, trenutno dela v laboratorijih več kot 30 raziskovalcev.

Glede primerjave razvojnih uspehov na področju fluidne tehnike med ZDA, EU in Azijo prof. Ivantysynova odgovarja, da je bil v 70-tih, 80-tih in 90-tih letih razvoj v ZDA zelo skromen v primerjavi z EU in Azijo. Po njenem prihodu v ZDA je bila za področje FT ustanovljena fundacija CCEFP, kar je razmere drastično spremenilo. Danes je več kot 50 fakultet v ZDA vključenih v raziskovalno delo na področju FT. Razmere so se približno izenačile, vendar Kitajska vlaga vse več naporov na področju FT.

Glede prihodnosti črpalk in hidravličnih motorjev (hidrostatičnih enot – HSE) z vidika konstrukcijske izvedbe prof. Ivantysynova napoveduje vodilno vlogo batnim enotam. HSE z nagibno ploščo (NP) imajo relativno dobre izkoristke, so primerne za različna krmiljenja in imajo odlične dinamične karakteristike. HSE z nagibnim bobnom (NB) imajo v primerjavi s HSE z NP boljše izkoristke in višje maksimalne hitrosti delovanja, vendar so zahtevnejše

za snovanje, kar se odraža tudi v višjih stroških izdelave. Prednost radialnih HSE je predvsem krajša dolžina, kar je včasih pomembno zaradi omejenega vgradnega prostora v stroju.

Glede vprašanja prihodnosti »rivalstva« med hidrostatičnimi in električnimi pogoni (HP in EP) prof. Ivantysynova napoveduje svetlo prihodnost hidrostatičnim pogonom predvsem zaradi njihove izrazito večje gostote moči. Ob isti moči kot EP imajo HP približno 10-krat manjšo maso. To je še posebej pomembno za transportni sektor, mobilne stroje itd.

Izboljšanje izkoristkov sestavin in sistemov FT je danes ena najpomembnejših tem. Eden od motov prof. Ivantysynove je, da snovalec sistema FT uporabi čim manj sestavin, da s tem doseže boljši izkoristek sistema. Mnenje prof. Ivantysynove je, da imajo zdaj uporabljane HSE razmeroma slabe izkoristke, isto velja za sisteme FT. V številnih strojih se več kot 50 % energije pretvori v toploto; ob teh razmerah relativno nizek izkoristek HSE sploh nima posebnega pomena. Ko bomo odpravili dušenje kot princip krmiljenja izvršilnih sestavin (aktuatorjev), bo pomembno vlogo igral izkoristek HSE, kar je danes že aktualno na področju hidrostatičnih pogonov. Izboljšanja izkoristka HSE pa ne dosežemo s »cenenim inženirstvom«; prihodnost je v računalniškem snovanju, optimizaciji številnih parametrov in krmilnih shem.

Prof. Ivantysynova pravi, da povzročajo glavne izgube v HSE rotirajoči sklopi. V centru, ki ga vodi, delajo veliko na razumevanju fizikalnih pojavov v teh sklopih in modeliranju, vendar misli, da bo tudi v bodoče težko točno numerično napovedati izkoristek HSE. Delček teh raziskav je prikazan na slikah 1 in 2.

Njena knjiga *Hydrostatic Pumps and Motors* je bila objavljena v nemščini in angleščini leta 2000. V prihodnosti načrtuje novo verzijo te knjige s poudarkom na batnih HSE.

Prof. Ivantysynova je od samega začetka glavna urednica zelo dobro znane revije *International Journal of Fluid Power*. Na vprašanje, če namerava pridobiti SCI-indeks zanjo, je odgovorila, da intenzivno delajo na tem in da je edina pomanjkljivost prenizko število citatov, ker mnogo avtorjev nima izkušenj na tem področju.

Prof. Ivantysynovo smo spomnili, da smo bili skupaj soudeleženci na petih svetovno znanih konferencah s področja FT; naš laboratorij večinoma s prispevki o raziskavah s področja uporabe pitne vode v pogonsko-krmilni hidravliki (PKH). Zanimalo nas je njeno mnenje glede prihodnosti tega področja, predvsem za stroje, delujoče v naravnem okolju. Odgovorila je, da dolgoročno verjame v prihodnost uporabe pitne vode v PKH, vendar bo potrebnih še veliko temeljnih raziskav sestavin in še posebno HSE, da bomo dobili primerljivo gostoto moči. Osebno pa verjame, da je ta cilj možno doseči.

Prof. Ivantysynovi se v imenu revije Ventil in najinem osebnem imenu zahvaljujeva za odgovore in ji želiva uspešno nadaljevanje njenega že doslej nadvse uspešnega dela.

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