Research Focus

Project 1 A.2: "Optimal Power Management for Mobile Fluid Power Machines Using Displacement-Controlled Actuators"

An excavator in action

Project Summary: Large machines like excavators run on diesel fuel. Today's machines burn much more fuel than they need to, which costs a lot of money and hurts the environment. The project will create new hydraulic systems and computerized controls for construction machinery that work better and use less fuel.

What is the overall goal of this project?

We are all painfully aware of rising fuel prices. With diesel near $5.00 a gallon, we need new solutions for improving the efficiency of mobile hydraulic machinery. Our project focuses on machines with multiple actuators that work simultaneously—excavators, telehandlers, timber harvesters, and so on. The main source of power loss on these machines is the flow control valves. Even load-sensing systems have high throttling losses when multiple cylinders and motors operate at different pressure levels. Our mini-excavator simulations are showing that more than 40% of the total engine energy is wasted in valve losses during a typical trench-digging cycle. The solution we propose is **displacement-controlled actuation**, using variable displacement pumps to control the cylinders directly. This eliminates the power losses inherent to valves and allows energy recovery as the pumps can run in motoring mode.

How did this particular project come about?

This is a topic that Prof. Monika Ivantysynova has been studying for nearly 10 years, first in Germany and now in Indiana at Purdue University. Our original research was with wheel loaders. Now with support of the CCEFP, we're developing a 5-ton excavator with all functions under displacement control.

What direct application will this project have in the fluid power industry?

This is definitely an applied project. We hope that the fluid power industry will take the circuits and controls that we develop and put them into production. Of course there are obstacles: the current cost and availability of necessary components, packaging constraints, competition from other alternative technologies, and the tremendous inertia of the status quo. When I present at conferences, the response from industry is often "That's a great idea, but pumps are just too expensive. It won't be commercially viable." Our answer is that bringing displacement-controlled actuation to market would generate enough volume to drive the price down considerably. Add the value of advanced controls to much higher fuel efficiency, and this could be a competitive solution.

What work has been done so far and what have been the results?

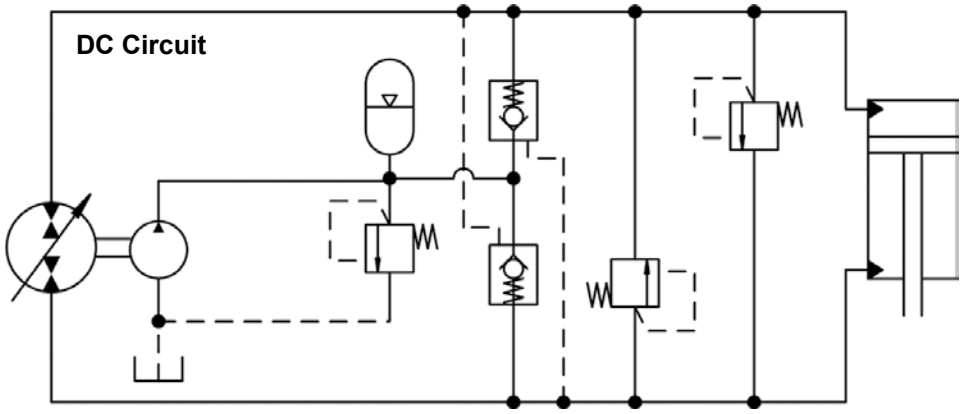
In simulation, we're seeing 30-45% savings in total energy. Our next step is building a prototype and verifying these results experimentally. We're working on this right now.

Looking ahead, what is planned for this project in the future and what is the time frame?

Pump-controlled hydraulics is really just the tip of the iceberg. Lower power loss is an important contribution, but perhaps just as important is the transition toward electrohydraulic control and hybrid systems. With displacement control, we can actively control engine speed and pump displacement to keep the system operating at optimal efficiency for additional fuel savings. Add position sensors, and we can make the machine easier to operate and more productive with cylinder coordination, automated functions, manipulator motion optimization...The sky's the limit.

What is your role in the project? How and why did you get involved?

I'm responsible for developing the excavator controls. My PhD topic is power optimization with displacement-controlled actuators, including optimizing the operation of the engine, hydraulic components and manipulator trajectory. I joined the project because it looked like a great opportunity for interesting work and a marketable education. And if I can do a



little bit to help the economy and the environment, that's a bonus.

What has the experience of working on this project been like for you? What have you learned by being a part of it?

What I like most about this project is its practical relevance. Much of the academic research that goes on is very theoretical. Some poor graduate students spend several years of their lives probing the depths of an obscure topic and writing a thick dissertation that ends up on a dusty shelf in the back of the university library. I appreciate the fact that what I am learning about designing, modeling and controlling fluid power systems is not only interesting to me, but it is also in demand.

Why do you feel the CCEFP is important?

I remember a conversation I had with another mechanical engineering grad student. When I told her about my research, her response was "Isn't hydraulics a mature field?" as though there was nothing left to study. Maybe this is a common perception. There hasn't been much academic research in fluid power in the United States in the past 30 years, even though this research has continued in Europe and Japan. All of this is changing with the CCEFP. The number of professors, graduate students and research projects in hydraulic and pneumatic technology is on the rise. If these projects are successful, there will be tremendous improvements in components, systems and fluids. And even if not, a new generation of engineers and scientists with fluid power training will revitalize academic and industrial research in this country for years to come.

To answer her question, yes, fluid power technology is mature. Just like turbomachinery and internal combustion engines. And like these other fields, recent advances in materials, electronic controls and computational analysis methods combined with new demands for energy and environmental conservation are spurring ongoing fluid power research. There is still plenty of work to do, and with the CCEFP, there are now more resources to do it.

Additional Information:

Maha Lab website: http://pasture.ecn.purdue.edu/~mahalab

Chris Williamson earned his undergraduate bachelor of science degree in mechanical engineering from Brigham Young University. He has completed his masters degree and is currently pursuing his PhD from Purdue University in Agricultural and Biological Engineering at Purdue. Chris has industrial research and development in his bright future! His work takes mobile hydraulic machines and adds electrohydraulic pump control systems. This saves fuel and allows computerized machine control for better performance and productivity. His control systems will be implemented on the excavator test bed, and hopefully some of his contributions will find their way into commercial application. The result would be a new generation of construction and agricultural equipment that are easier and more comfortable to operate and are significantly more efficient. Also, Chris has recently been elected to serve as the SLC's new Vice President. He can be reached at williaca@purdue.edu.


Chris Williamson


Summer 2008 Group Photo