MAKING INNOVATION HAPPEN: THE INTELLIGENT FLUID POWER SYSTEMS

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Abstract. *The purpose of this paper is to call attention for the role of established technologies as an important source of continuous innovation. In order to get new insights of the subject we have studied some innovation strategies for the fluid power systems. Although radical innovation may gain more attention and investments, in the long term, incremental innovation will be the one to sustain the organization. Therefore, keep equilibrium between incremental and radical innovation is key in all levels of innovation strategies.*

Keywords: *Hydraulics and Pneumatics, Mechatronics Systems, Innovation Strategies*

1. INTRODUCTION

Over the past decades, policy makers have invested considerable resources for the development of emerging technologies such as nanotechnology, biotechnology, and information technology. It is expected that their applications in new products, processes, and services will helps to create a new market and value network.

The type of innovation brought by this set of knowledge is called radical innovation. Although breakthrough technologies are in the core of government innovation strategies, and advocated by people discussing innovation management, as a matter of fact, a radical innovation project is less likely to get to market than one that addresses a more certain incremental growth opportunity. A sustaining or incremental innovation does not create new markets but rather only evolves existing ones with better value, allowing the firms within to compete against each other's sustaining improvements.

These two types of approach are also related with the geography of innovation. According to Soskice (1996), the US and the UK are strong in radical innovation, while Germany, Sweden and Switzerland are strong in incremental product and process innovation, often at a scientific leading edge, in established technologies.

In Brazil, the National Strategy for Science, Technology, and Innovation Plan 2012-2015 provides the guidelines of S&T as the foundation of the nation’s development. Although the importance of innovation in industry is recognized, the focus of discussion is on international comparison metrics such as research and development expenditure and patents awarded. After it has briefly mentioned SIBRATEC and EMBRAPII Programs, the plan moves on to highlight a set of sectors that is expected to enable the future (Information, and Communication Technologies, Health Care Industry, Oil and Gas Industry, Defense Industry, Airspace, Nuclear, Biotechnologies, Nanotechnologies, Green Energy).

The central question raised by this paper is: given the nature of innovation – radical versus incremental - and the implications observed in more industrialized countries, what lessons can be learned by countries such as Brazil? The paper assumption is that it is not possible to achieve radical innovation – and all its benefits-without a strong support of more established industries. Therefore, advanced technologies found in more traditional fields of knowledge can have as a strong impact on the industrial sector value chain as a new one. In fact, even the digital economy cannot depend on emerging technologies alone. Technologies that reinvigorate traditional sectors value chain should also be considered as part of innovation policies.

In order to answer these questions, this paper uses the concept of incremental innovation to analyze the technological development of fluid power (hydraulics and pneumatics)´s technology. The reason fluid power technology was chosen is due to the fact that, according to the Energy Efficient Hydraulics and Pneumatics Conference (2012), it is used in dozens of industries and hundreds of applications to precisely control the movement of machinery and material. Yet many engineers and technicians working in those industries do not fully understand the design concepts critical to developing efficient fluid power systems and the diagnostic and maintenance techniques essential to keep those systems operating at peak efficiency. These concepts and techniques can result in significant energy and cost savings for companies that use hydraulics or pneumatics, as well as for the customers they serve, making fluid power a more competitive technology choice.

2. THE NATURE OF INNOVATION

One of the most important concepts in innovation literature is the differences between radical and incremental innovation. While incremental innovation consists in improving existing products, radical innovation is about inventing completely new product, or more precisely new product categories. They are new to the market, but also to the firm that creates them (Garcia and Calantone, 2002).

Commonly, incremental innovation - sometimes referred to as sustaining innovation - is defined as the refinement, improvement, and uses existing forms or technologies as a starting point. Incremental innovations build on and reinforce the applicability of existing knowledge and subsequently strengthen the capabilities of incumbent firms and their dominant business design. It either makes incremental improvements to something or some process or it reconfigures it so that it may serve some other purpose. The management of incremental innovation is characterized by reliability, predictability, and low risk.

On the other hand, radical innovations are generally defined as innovations with features offering dramatic improvements in performance or cost, which result in transformation of existing markets or creation of new ones. Typically they are described via “New to the world performance features”, “Significant (5-10x) improvement in known features” and/or “Significant (30-50%) reduction in cost”. Radical innovations build on fundamental technological discoveries and thus are new to the firm and/or industry and offer substantially new benefits and higher performance to customers. In many cases, radical innovations entail the creation of a new business model (Hollen et al, 2013). In table 2.1 we can see a summary of the main characteristics of incremental and radical innovation.

Table 2.1 Summary of incremental versus radical innovation

Incremental *versus* Radical Innovation		
	Incremental	**Radical**
Emphasis	Cost or feature improvements in existing products, services, or processes	Development of new businesses, products and/or processes that transform the economies of a business
Technology	Exploitation of existing technology	Exploration of new technology
Prototyping	Ironing out wrinkles near the end of the design phase	Teaching the market about the new technology and learning from the markets how valuable that technology is in that application arena
Trajectory	Linear and continuous	Sporadic and discontinuous
Business Case	Detailed plan can be developed at the beginning of the process	Business model and plan evolves through discovery-based learning
Idea Generation & Opportunity Recognition	Occur at the front end; critical events are largely anticipated	Occur sporadically throughout the life cycle, often in response to discontinuities in the project trajectory
Key Players	Formal cross-functional teams	Cross-functional individuals, informal networks
Process	Formal, phase-gate model	Informal, flexible model at early stages due to high uncertainties → formal at later stages after uncertainties have been reduced
Organizational Structures	Cross-functional project team operates within a business unit	Project starts in R&D → migrates into an incubating organization → transitions into a goal-driven project organization
Resources and competencies	Standard resource allocation; the team has all competencies required to complete the process	Creative acquisition of competencies and resources from a variety of internal and external sources
Operating Unit Involvement	Formal involvement from the very beginning	Informal at early stages → formal at later stages

Source: Kotelnikov, 2013

3. METHODOLOGY

In fluid power, the demand for new types of more efficient systems concepts has called for new design parameters, which has, consequently, affected the dynamic behavior of the whole system. Understanding the design rules is essential so that the problem can be controlled. Moreover, it is important to highlight that the design process should be performed at the system level rather than at the components level. In short, innovation in fluid power has been much more part of incremental, but constantly improvements in design, aiming systems performance optimization rather than technological advancements, or breakthrough innovation.

The work is based on an exploratory case study, which is a qualitative research method, in the fluid power technology. Fluid power is a designed system to transmit and control energy by means of a pressurized fluid, either liquid or gas. According to the US Fluid Power Association, fluid power technology has multiple applications in a wide variety of markets such as mobile, industrial, and aerospace. Table 3.1 gives an overview of the fluid power technology, divided by market, type of application, products, and end users.

Table 3.1 Fluid power applications

Market	Fluid Power used for	Product	End Users
Mobile	• Transporting • Excavating • Lifting • Controlling • Powering	• Backhoes • Graders • Tractors • Truck brakes • Suspensions • Spreaders • Highway maintenance vehicles	• Construction • Agriculture • Marine • Defense
Industrial	• Power transmission • Motion control	• Metalworking equipment • Controllers • Automated manipulators • Material handling • Assembly equipment	• Machine tools • Industrial automation
Aerospace	• Operating • Propelling • Propulsion	• Landing gear • Brakes • Flight controls • Motor controls • Cargo loading equipment	• Commercial aircraft • Military aircraft • Spacecraft • Related support equipment

Source: Pereira, 2013

The design of fluid power systems has generally focused on power and productivity giving little thought to the efficiency of the system. In recent years, however, new and stricter emissions regulations and increasing energy costs have caused the industry to look for more efficient system designs (CCEFP)

Therefore, the greatest challenge facing designers and product developer’s teams working on fluid power systems are:

1) Minimizing energy consumption
2) Decreasing power requirements
3) Achieving international emission requirements
4) Improving standard machine design
5) Identifying the technological barriers to achieving these goals

From a socio-economic point of view, all the sectors where fluid power can be applied play a key role in the process of economic development, employment creation, and income generation and redistribution in BRIC. At the same time, the emergence of new demand for innovative solutions creates opportunities for companies located in those countries.

In order to gather information on trends and changes in organization of design of the fluid power systems we have proposed a field research in sites such as universities and industries located in countries like Brazil, India, China, and Sweden. This paper is part of a larger project that has started in May 2011 aimed at promoting collaboration in research between Brazilian and Swedish universities and companies in fluid power engineering and system design.

3.1 Data collection

A set of data collection techniques, such as key informant interviews, correspondence with experts, organization of workshops, and field observation has been used for conducting the research. However, as a starting point some literature review and research on Fluid Power Associations provided us with critical background information.

The next step was arranging meetings with academic experts in the field of our inquiry. In this sense, they are crucial tool to obtaining information from the state of the art of and the historic development of the field. These people are in a position to know the community as a whole and also in particular portion we are interested in.

It is important to remember that usually academic experts in fluid power have a close relationship with industry, which has fostered an environment of cooperation and mutual assistance. To sum up, the contact with academics help us selecting informants with different backgrounds and affiliation. Giving the geographic distribution of the project, another method to collect information and keep track of what was going on was correspondence with experts

The first workshop on Innovative Engineering for Fluid Power and Vehicular Systems brought together Brazilian, Swedish and international industry and academia to promote collaboration in development of technologies, education, innovation management, and methods and tools for system development and design. Organizing and attending the workshop was an opportunity for taking notes at lectures given by experts and to meet and talk with speakers and fellow attendees as well as to learn and practice the language of the field. Following the workshop, technical visits to three multinational companies located in Brazil allowed us to observe the field. Table 3.2 provides the main characteristics of companies visited.

Table 3.2 Information on studied companies

Company	Headquarters	Products
A	United States	Tractors
B	United States	Components
C	Germany	Components
D	Brazil	Components

Source: Adapted from Pereira, 2013

The visits have provided us with a wide variety of learning experiences. This time was possible to talk with product engineers on site, at the same time we saw how companies behave, and how they provide their products and services. Since this visit was made in group, later on a conversation allowed us to share our impressions differentiating between fact and opinion.

In March 2013, the same group was invited to be part of the Academic Forum at Motion, Drive & Automation (MDA) Fair, which showcases electrical and mechanical power transmission and control technologies from all over the world, as well as the latest innovations in hydraulics and pneumatics.

3.2 Data analysis

In order to strengthen the case study findings and conclusions we propose the triangulation of the collected data as the analysis technique. Triangulation is broadly defined as synthesis and integration of data from multiple sources through collection, examination, comparison and interpretation. By first gathering and then comparing multiple datasets to each other, triangulation helps to counteract threats to validity in each approach.

4. INCREMENTAL INNOVATION IN INTELLIGENT FLUID POWER SYSTEMS

To increase the efficiency of industry operations and automate repetitive tasks, a great rebirth of innovation-based fluid power technology, and the simultaneous improvement of the efficiency offered by such technology, should be implemented, while further enhancing control accuracy and the repeatability of the solutions. The study indicates that technological progress in a number of industries was achieved through the introduction of the latest materials, motion and control systems and state-of-the-art electronics.

The possibility of a broad spectrum of dynamics and control operations within machines and plants is solely attributed to hydraulic and pneumatic power transmission and control technology. For instance, lifting and lowering movements, linear and rotary movements, positioning and holding, transferring power, and many other operations, are effectively done with the help of hydraulic and pneumatic systems.

In direct comparison with other varieties of power transmission engineering, hydraulic control systems demonstrate a notably high power-to-size ratio and a low power-to- weight ratio, which makes it suitable for mobile applications in communal machines, construction machinery and agricultural equipment.

However, pneumatic control systems serve as a typical example for speed and compactness. In particular, the ease of handling and assembly and the cost efficiency of pneumatic systems make it suitable for different applications. The analysis indicates that it is possible that pneumatic control systems have become an inseparable part of automation. With dynamics, productivity and speed in the smallest area, these control systems are used in clean rooms in medical fields, chips and printed circuits production, food processing, assembly and handling tasks, positioning tasks, joining, sorting, and testing procedures.

In the context of proliferating technologies that help preserve the environment, hydraulic and pneumatic control systems are being widely deployed in wind power stations to enable the movement of rotor blades into the increased wind position, in recycling and waste disposal plants and machinery, sew- age treatment plants, conventional power stations that help in flue gas desulphurization and water treatment plants. Energy storage for energy recuperation, and also for power management for downsizing the diesel engine. The energy storage can be in hydraulic accumulators (Caterpillar) but also fully electric with supercapacitors and electric motors/generators (Komatsu).

In an effort to accommodate the requirements of future systems, hydraulic and pneumatic systems are incorporating ergonomic operating systems, efficient sensors, modern bus systems, diagnostic systems and other advanced systems that combine fluid power with electronics. The extent of the incorporation is such that the gap between motion, drive and automation is rapidly shrinking, while simultaneously integrating communication components that further help improve system productivity. Besides this, fluid power is also witnessing the dominance of microsystems technology and mechatronics in the automation arena. For the development of mobile hydraulic systems the drivers have first been the basic functionality, then the handling characteristics, and more recently with a very strong increase in emphasize on energy efficiency.

Other findings in the study include the price of electric machines declining and the expectation that electric systems, particularly pneumatic systems, are to become more competitive in terms of price. Electronics is also expected to play an increasingly important role. Technological innovation with regard to design, performance and efficiency improvements can be expected to lead to sustained customer interest. The most pronounced trend in designing hydraulic systems is centered on system design rather than individual component design.

There has been a rising demand for new machinery in agriculture, food processing and construction, particularly in Asia, increasing the sales of directional, pressure and flow control valves for hydraulics. Technological developments are relatively frequent in the mobile hydraulics sector and improved steering and braking systems have resulted from a greater investment in R&D in this sector. For example, open flow control with computerized control systems allows for a system with more benign handling characteristics - less oscillant - than load sensing, feeding the flow demands from the valve input signals to adjust the pump flow. In addition, this system can also easily be combined with electrically driven and controlled pumps.

Another case is the digital hydraulic systems. Using fast computer controlled switching (on/off) valves, new, more efficient ways to control systems can be achieved. This can be applied both to pump control to have very efficient variable pumps and also to multi chamber cylinders to achieve force control by pressurizing a variable number of chambers rather than throttling the flow. Each one of this individual solution may be categorized as component innovation that when put together results in a totally new system.

Feedback control systems (involving sensors for e.g. position) starts to appear also in mobile system for automation of some functionality, e.g. cutting to length of timber in Forrest machines, lorry cranes, and in development of new autonomous construction machines.

There are a number of technological advancements in the fluid power industry, such as green innovations. Green technologies in the recent past have been noted to create a more direct response to market needs and the integration of fluid power with computer control and electronics, and its subsequent hybridization with other technologies has been instrumental in constantly reshaping the technology to adhere to market needs. However, despite these advancements, the fluid power industry could be lagging behind other technologies in making use of computer modeling and simulation and embracing newer materials and processes.

In an attempt to keep up with sustainable production and operations, the fluid power industry is aiming at employing recyclable product build-up materials and its subsequent packaging. Research efforts are also being directed towards developing efficient systems that employ degradable and safe fluids for use. Many companies are also working towards making advancements in safety-related technologies and solutions. Also, regulations have imposed the use of a lot of sensors on cranes for safety. This includes pressure and position sensors. Once in place, these sensors can also be used for other functionality, such as for operator assistance.

5. CONCLUSION

When someone thinks of innovation they have in mind the concept of breakthrough. In other words, a technology that completely disrupted an entire industry in a relatively short period of time. When breakthroughs take place the fact of the matter is that people take notice and it can have a significant impact on the world at large. This is why its easily recognized.

On the other hand, it is more difficult to recognize incremental innovation. After all if you create a new technology that only improves upon existing technology what is there to take notice of? What makes incremental innovation so important? The most important aspect of incremental innovation is equilibrium. Breakthrough innovations, especially competence destroying breakthroughs can involve significant risk and affect the sustainability of an organization. The key to success is by finding equilibrium within an organization between achieving breakthroughs and using incremental innovation to sustain what you have and maintain market share. By focusing only on breakthrough innovation and neglecting incremental innovation, government policies are not balancing its portfolio of risk. This is especially true for fluid power system technologies.

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