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Abstract

By examining “Company A”, a leading Chinese carbon fiber manufacturing company as a case study, an examination of the role that classic quality management and variability reduction systems play will be examined. This thesis hopes to give incite to the opportunities and challenges “Company A” faces as it moves into more complex and demanding production applications. The use of advanced production systems based on classic statistical process control and quality management are explored in this thesis through interviews with managers at “Company A” and are contrasted with interviews from global professionals in the industry. A revolution in global manufacturing has taken place in recent decades. This change was first born out of the quality deployment and variability identification systems pioneered by W. Edwards Deming's statistical process control (Statistical Method from the Viewpoint of Quality Control, 1939; Out of the Crisis, 1982) and Joseph Juran’s quality management systems (Quality Control Handbook, 1951), their contributions framing later management innovations. These innovative concepts gave way to the quality revolution that brought about Toyota’s Total Quality Management (Liker, 2004) and Motorola’s Six Sigma (B. Tjahjono, 2010). Although they have largely fallen out of public discourse, these systems remain today an essential part of manufacturing industries globally (Chung, 2014; Miller, 1994). As China emerges from its economic miracle of the last few decades, largely based on low cost manufacturing, it is faced with new challenges as it pushes into advanced manufacturing systems and faces great opportunities if it is able to keep pushing forward with the momentum of the last few decades (Chung, 2014; Seferis, 2013).

The Problem

With substantial support in the form of financial resources, access to machinery, intellectual property, and a qualified labor pool, “Company A”, a leading Chinese carbon fiber manufacturer, has not advanced as quickly as anticipated by investors and management. Specifically, “Company A” has faced repeated challenges in the form of consistency in quality and material properties, having a wide variation in key material characteristics. To approach this problem, “Company A” has taken a number of actions including the hiring of foreign managers with expertise in the carbon composites industry. Additionally, foreign consultants have been brought in to give context to the factories standard operating procedures (SOP) by comparing them with other industry leaders, and to explore potential factors limiting the consistent and measureable improvement being sought by “Company A”. Contributing factors suggested by these experts and managers within “Company A” include machinery limitations, precursor technology limitations, maturity of the industry in China, and management shortfall in the form of systems control processes and strict adherence to SOP. To understand the specific demands of “Company A” it is necessary to explore first the nature of their manufacturing process and the challenges inherent in the production of carbon fiber composites and common cause variables, and secondly to examine the potential special cause variation that could be specific to their manufacturing facility, exploring environmental, human, and input variables that could be influencing factors (Huge, 1990).

The Context of “Company A”: Carbon Fiber manufacturing in China
In the last three decades, China has experienced an economic miracle, but the underlying drivers of it are different from those of the Japanese post WWII economic come back in the second half of last century. China’s miracle has been facilitated by its role as the world’s factory floor, with vast material and human resources China reinvented itself as the world’s manufacturing base. With an emphasis on lower tech manufacturing and price competitiveness, China has supplied products to the world’s shelves. Indeed, the models of mega-stores that have been so successful in the last decade, such as Wal-Mart, are built on the back of China’s capacity to deliver these products. Wal-Mart produces 70% of its products in China (Chan, 2011). The Chinese government now has unprecedented resources to build its economy from the ground up. Strategically investing in infrastructure and expanding their manufacturing capacities in a controlled way allows them to pick not only winners and losers within industries, but winning and losing industries. Those sectors perceived as being strategically relevant for the future of China are outlined in not only five year plans, but receive soft support in the form of media attention and endorsements from government officials and news agencies. Carbon fiber composites are one of those industries that receive both ideological attention and financial backing in China. This can be seen not only by the numerous entrants into the industry, billions of dollars of investment, and substantial government subsidies, but with the growing popularity of composites in the national dialog. With the major strategic push for a Chinese commercial aircraft, carbon fiber and composites have entered the spotlight as a key component of China’s future (Aviation Week, 2014). With the popularity of composite industry conferences in China growing exponentially (major conferences being: SAMPE China, China Composites Expo, and JEC Asia, with a number of smaller regional conferences such as the Fiber Society, PCM, etc), China has taken the global stage in promoting this targeted and strategic industry. China has indeed picked carbon fiber as an industry to succeed. The question must be asked, when will it, why hasn’t it already, and what will it take to make it happen? The exploration of that question is what this thesis will do in hopes of bringing more understanding to the industry both inside and outside of China. The obstacles faced by “Company A” may be able to shed light on challenges being faced by the wider industry.

The Numbers

Over the last two decades there has been substantial investment in the carbon fiber composites in China both public and private. Billions of dollars in subsidies alone have propelled the Chinese composites industry into the spotlight of Chinese industrialists. While numbers are hard to confirm, many efforts have been made to quantify both the investment and capacity of the Chinese carbon fiber composites industry (Research and Markets, 2014; Lucintel, 2014). While the exact statistics are uncertain, and change depending on who you ask, is it certain that China now represents a sizable percentage of global production capacity, at least 9% of potential production with existing installed equipment. The global industry looks to triple from $1.8 billion dollars in 2013 to $3.3 billion by 2019, much of this growth expected from China (Lucintel, 2014). Despite these numbers and the attention carbon fiber has gotten in China through the aforementioned government support and private investment, having begun in earnest in the mid 1990’s and exploding in the the previous decade, consistency and quality challenges that prevent this fiber from reaching international markets or high-end domestic applications such as aerospace parts abound. Indeed, while China manufactures a great deal of fiber, nearly all the carbon fiber being effectively utilized in China is imported, representing a massive opportunity loss and waste of resources for both China nationally and its manufacturers individually (Robins, 2013). Additionally, the utilization of imported fibers in domestically produced prepreg and subsequent parts manufacturing is also immature as an industry. With so much investment and energy behind that industry, what is limiting the Chinese from taking hold of their goal?

After various interviews with experts in the industry working both in China and around the world, a number of factors hindering the advancement of carbon fiber production, utilization, and sale have been identified. While many of these obstacles are external, such as export controls on input materials
and advanced machinery, it has been pointed out that these obstacles are not primary, and should not be a substantial hindrance to the industries development.

Background

The Japanese post-war economic miracle, beginning in the 1950’s, was fueled largely by a revolution in manufacturing principles. With the combined influence of Joseph M. Juran (Quality Control Handbook, 1951) and W. Edwards Deming, with his lectures on statistical process control (SPC) in Japan in 1951, the Japanese were able to formulate a set of principles that would lay the groundwork for decades of global manufacturing dominance (Aguayo, 2010). The methodologies laid out by Japanese giants such as Sony, Mitsubishi, and Toyota, operated by a strict system of variable identification and statistical variability reduction, bringing efficiencies in production never before achieved. Juran and Deming are considered the fathers of the quality management revolution that, beginning with the Japanese, later swept the world, giving rise to Toyota’s total quality management (TQM) and Motorola’s Six Sigma management philosophies. The miracle of Japan and their economic coup, bringing global manufacturing to its knees through simultaneous superiority in quality and lower cost, changed the way managers equated the relationships between quality, productivity, and profitability (Deming, 2012). After an identity crisis in the early 1980’s (Dobyns, 1980), the American’s finally began addressing their inability to compete with the Japanese in the proper context, and identified those management principles pioneered by two Americans, but adopted wholeheartedly by the Japanese decades earlier, as the reasons behind their crisis. The world would follow, and systems of continual and measurable improvement for quality would become an essential component of manufacturing.

In today’s global business acumen, the basic concepts of TQM and variability reduction are accepted as a baseline for efficiencies of production, but are limited largely to business schools and seem to have almost completely fallen out of popularity among the upcoming generation of entrepreneurs and business owners. This is largely due to a shift in the business sectors that are on the front lines of innovation, today being largely focused on services and tech, not manufacturing. Silicon Valley app startups appear have little interest in manufacturing efficiencies outlined a half-century ago. Exciting ideas for entrepreneurs with dreams of being the next Facebook acquisition read things like The Lean Startup and Seth Godin’s prolific collection on topics like smart marketing strategies. The weaknesses of a business model focused entirely on efficiencies is even pointed out by Michael Porter from Harvard Business School as being a dead end race to the bottom of profitability, noting that today Japanese manufacturing giants have failed in strategic differentiation, and suffer, save a few winners, from chronic mediocrity (Porter, 2011).

The Continued Relevance of Deming and Juran

While it is true that Western economies have largely shifted away from a manufacturing based economy, and those industries that remain are largely automated, it is certainly not true that manufacturing has disappeared from the world, it has simply moved. According to the United Nations Conference on Trade and Development, China today is the second largest manufacturer of goods in the world ($2.05 Trillion in 2009), having recently overtaken Japan ($1.16 Trillion in 2009), and quickly gaining on the United States ($2.33 Trillion in 2009). While China’s manufacturing capacity has been largely lower tech, it is quickly developing advanced production capacities in areas such as consumer electronics, green technologies, and pharmaceuticals. China has thus far been very successful in establishing itself as an economic super power, its infrastructure investments and easing on business operational restrictions have opened up a new frontier for global business. Some industries, however, remain in stasis, not having pushed forward with the kind of momentum that many would have expected with the investment and favorable climate that exists in China. Advanced material production is one of these industries. Many of these higher tech and discipline oriented manufacturing processes
have yet to take hold in the Chinese production mindset so as to allow for the organic development of advanced production systems.

The replication of foreign technology and the purchasing of foreign manufacturing equipment can only bring China so far, there is a necessity of all countries and companies to examine their own internal process of innovation and development so as to facilitate an internal growth and understanding of the industry they operate within. China has overcome its first major hurdle on its way to true manufacturing supremacy, built on the back of foreign demand and investment. China today has used that boost of the last few decades to jump-start its own domestic consumption engine. Many experts think it is now time for China to push up the next hill, developing its own internal culture of innovation, research and development, and process control for consistent, gradual improvement of advanced production systems (Chung, 2014).

**Significance of the Study**

While the Western world has largely forgotten about Deming and Juran, the lessons they gave the world have never been more applicable. By looking to the challenges that are being faced in the advanced materials processing industry in “Company A”, it is hoped that a larger picture of the challenges, and opportunities, that exist for China as they push into advanced manufacturing will be exemplified. Carbon fiber composite materials require strict systems of control, variability identification and quality deployment. These challenges have thus far isolated the industry from having many entrants. Today that is changing, and China has made it part of their national strategy to promote carbon fiber and carbon fiber composite structures. By using “Company A” as a case study, and interviewing key players within it, it is hoped that there will be some illumination of production challenges that will face China more broadly as it pushes into more advanced production systems in the coming years.

With the use of carbon fiber booming globally and the world on the threshold of a materials revolution, it is essential that “Company A” compete effectively in this growing and strategic industry. While the necessary investments have been made, “Company A” still lags behind global competitors in the quality of material production, and the capacity to utilize carbon composite material in advanced structures. Carbon composite industry leaders have many years of experience in complex systems and advanced materials manufacturing, and if “Company A” wishes to get up to speed it must adopt all of the best practices painstakingly developed by these leaders over the past forty years. This includes not only technical expertise but also managerial optimizations in integration, and the cultural adaptation necessary to implement foreign expertise into “Company A”’s management team and system. Not only is it in “Company A”’s interest, but also in China’s best interest to establish a strong domestic advanced composites materials manufacturing base, and invaluable to the global supply chain. While many foreigners might be hesitant to see the Chinese advance in a strategic industry like carbon fiber composites, it is in fact an inevitable and beneficial addition to what will become the new base line in materials utilization around the world for most every application where weight and strength matter. The increased accessibility to quality carbon fiber and carbon fiber composite parts allows for a global broadening of the industry, further reducing costs through economies of scale and making way for global innovations. With their reduced weight and higher strength to weight ratios, carbon fiber composites look to revolutionize a number of industries. Transportation, energy generation and architecture are just a few of the industries that stand to be revolutionized by ubiquitous carbon fiber composites technology. Already the push for carbon fiber frames in automobiles promises increased efficiencies that would greatly reduce the impact on the environment and global warming. With further development and utilization of carbon fiber, that is just the beginning.
INTERVIEWS ROUND (1) and (2)

Interviews with composites experts gaining general understanding of the requirements for the effective production of carbon fiber composite materials relevant to “Company A”. A form of grounded theory methodology was used in the collection of these interviews to allow the extrapolation of hypotheses.

Interviews of managers and technicians from “Company A” that were specifically designed to answer the questions and hypotheses developed from the GTM deployed in the first section of interviews.

INTERVIEW ROUND (1): Due to the time period and diverse locations of the first section of interviews, these interviews were conducted in many different locations, including offices, cafes, and at large conferences. A few of these interviews were also conducted over the phone. The interviewee was first informed of the nature of the interview and the materials that would be derived from it.

INTERVIEW ROUND (2): These interviews were all conducted in China, but broken up between the “Company A” facility and one on one in cafes. The interviewee was informed that they were being interviewed for the purpose of gaining a better understanding of the process at “Company A” and were being consulted on their opinions on the list of questions being provided.

Responses to Round One (1)

The collective response to much of the first round of questioning from experts in both the composites industry and in related industries where systems theory and process control were essential maintained much of the same theme. This can be found in the Appendix to this thesis for further clarification. The overreaching message from their interviews was the consensus that (1) it was not a lack of money, equipment, or will that was keeping the Chinese from advancing quickly in the industry. (2), it was not intellectual property directly in the form of patented materials or export controls. And (3) that there was a disconnect in system controls and process development for continuous and measurable improvement of quality. What was unclear is whether or not these quality deployment systems were simply unknown to Chinese manufacturers and “Company A”, or if they were not being implemented effectively. This is not to suggest that this is a simple solution to the challenges facing new entrants into such a challenging industry, but it gives insight into the challenges that players face as carbon fiber manufacturing is one that is sensitive enough to require laboratory like controls for effective consistent production.

4.2 Responses to Round Two (2)

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Hypothesis

After visits to dozens of manufacturing sites, and countless conversations with technical experts, managers, and sales representatives both inside and outside China, the challenges facing the Chinese seemed to appear more internal than external, prompting an examination of what was going on inside Chinese carbon fiber manufacturing that was different than in other successful leaders of the industry. The challenges faced by the management of highly technical process control systems demanded by
carbon fiber and advanced material production are many, and it would appear that something was being lost in the transfer of technology from other countries into China. It appears that these management techniques are not being utilized so as to optimize the potential of the available equipment the Chinese have been able to acquire. Interestingly, it is not the case that these management principles, such as Standard Operating Procedure (SOP), Six Sigma, and Total Quality Management (TQM) were unknown to the managers of these Chinese manufacturers, but potentially not being implemented effectively by managers or carried out by employees. This observation in the composites industry is also a window into the challenges China faces in advanced production systems in general, outlining a threat the Chinese will be facing in the next decade as they transition from a low-tech production economy to a higher-tech one.

Testing the Hypothesis

H1 - Strict quality control mechanisms are essential to the production of carbon fiber composite materials but these systems are not known to managers in “Company A”.

Hypothesis H1 was found to be only partially true, as systems theory and the process control mechanisms that it deploys were not known by name, and were not implemented formally, but an understanding did exist that the elements of these programs should be in place and some attempts had been made to put them in place. Specifically that testing instrumentation was in place for this process to take place.

H2 – Strict quality control mechanisms for the production of carbon fiber composites were known to managers but not being deployed in “Company A”.

This remains unknown officially as no quantitative data was gathered for this thesis, and therefore up to conjecture from managers of “Company A”. One manager did insist that this was indeed the case, or that the system had been suggested but perceived as being too expensive in both time and testing equipment and did not significantly increase the value of the product.

H3 – Culture and the differences of integrating western and foreign management systems in a Chinese company cause difficulties.

This hypothesis was generated from a number of comments made in the first round (1) of interviews with industry professionals who had consulted in the industry and felt that there was a disconnect happening on a cultural level. Question 1 was geared towards this question so as to give insight into a cultural condition that contrasts with that of Western countries. There was a strong showing that personal relationships, i.e. those of either a boss or coworker were perceived as being more important than the following of any system. This supports the “people” based theory of Chinese social organization in contrast to Western “system” based organization, where rules are followed above all else. This aspect of the study warrants further exploration.

Summary

It can be surmised that quality deployment systems are understood to be necessary in the production process in “Company A” but that the actual deployment of these systems is unclear. There also seems to be a strong chance of interviewee bias within this study, where managers and technicians were boasting that they were indeed deploying these systems, contrasting sharply with the word of other managers. This disagreement can be seen in the chart of interview results above and suggests that while there are intentions to fulfill management specifications there is inconsistency in follow through.