MANUFACTURING PLANT FRONT LINE LEADERSHIP ADAPTATIONS FOR INCREASED THERMOPLASTIC COMPOSITES PRODUCTION SUCCESS VS TRADITIONAL METAL AUTOMOTIVE APPLICATIONS

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Abstract

As opportunities to increase the use of reinforced thermoplastic composites in automotive applications increase front line leadership will see many changes. I will outline the many technical material differences and ways to adapt leadership to new operations. The demographics of the manufacturing workforce in the United States is changing along with opportunities to develop technical and leadership skills. Those who have worked with traditional metal materials will need to learn processes along with those who they supervise in the manufacturing plant. Many significant processing differences between metals and composite materials of all kinds require proper operation of new equipment, basic understanding of material chemistry and changes in production cycles.

New equipment and techniques for finishing, assembling and bonding of materials will challenge the manufacturers who cannot adapt to changes. Training for supervisors and management will be important to control product waste and production delays. Opportunities to train new leaders will be key in the conversion to the lightweight thermoplastic composites for large scale automotive production moving forward. Front line plant leadership is key to the training and retention of new workers that can allow domestic producers to compete in a worldwide market.

Background and Requirements

Increased thermoplastic composites use in automotive is occurring and can drive innovation moving forward in automotive composites manufacturing. Despite the many recognized challenges of gaining and maintaining a future workforce changes in workforce management requirements are needed for manufacturing efficiency. New skills for the management teams, integrating their leadership and process knowledge for thermoplastic composites manufacturing is critical. Most of the emphasis on workforce is on the hourly, technician, entry level and production worker but a focus in management of the plant floor is critical. Key influencers of production execution are the managers at the plant level. The automotive manufacturing industry has many aspects of management that will need to adapt as thermoplastic composites use grows. This includes not only the facilities that make the composites but those that handle, assemble and finish them.

Survey Data and responses

Business and technology trends in thermoplastic technology must consider the personnel. management, particularly management at the production plant level for composites manufacturing. They will require increased knowledge of composites processes. Thermoplastics offer great opportunities for increased growth in automotive applications. To be competitive with other materials proper production implementation is needed. Based on U.S. demographic data

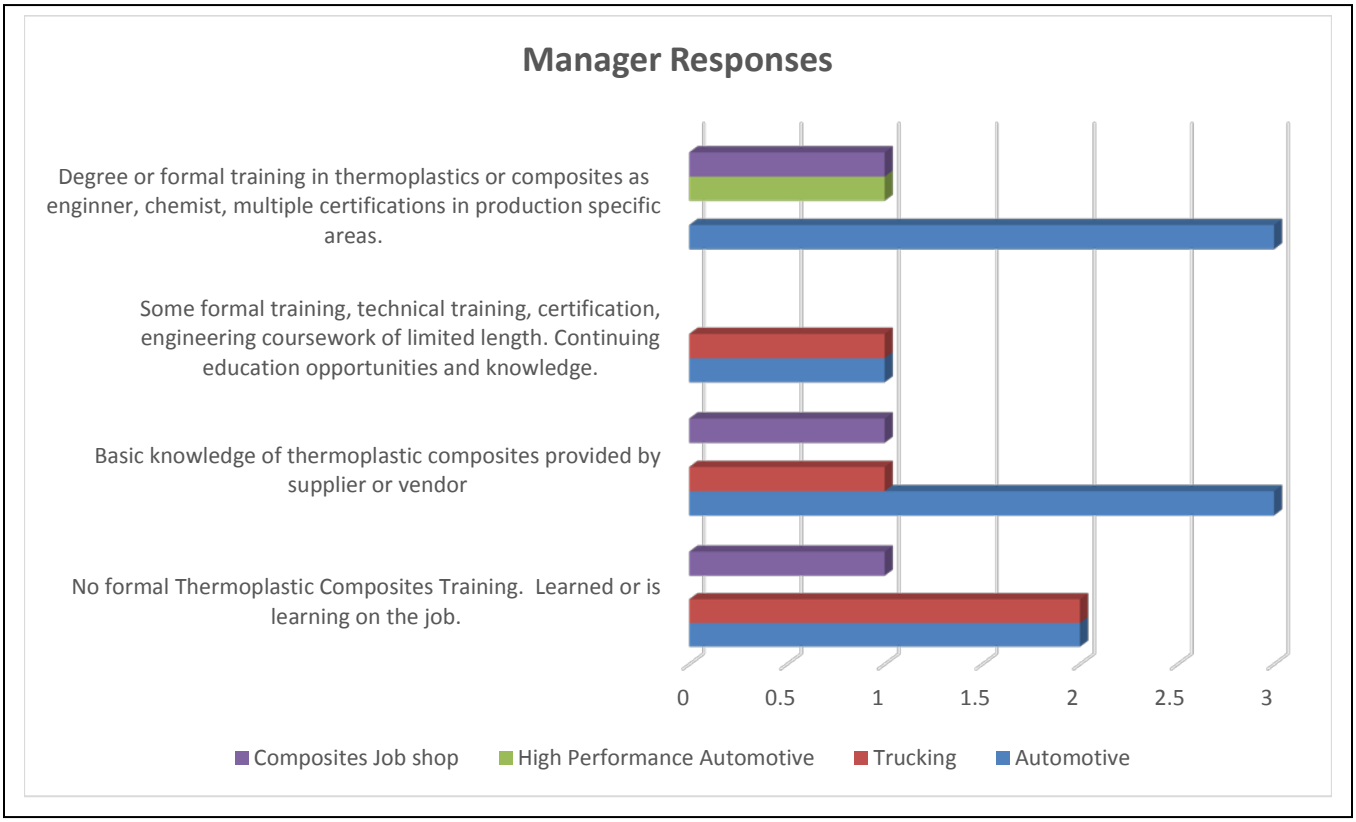
for workforce compiled by the Deloitte – Manufacturing Institute study “The Skills Gap in US Manufacturing and Beyond 2015 – 2018” over 2 million jobs in the United States will go unfilled due to the skills gap. As manufacturing retirements continue to increase many of these jobs will be at the manufacturing plant management levels. The studies workforce projections from 2015 to 2018 have proven to be accurate thus far and with unemployment rates at modern era record lows a shortage of overall U.S. workforce in manufacturing is already being felt.

Using informal survey methods, the author asked two questions to 17 composites manufacturing managers of plants, buildings, production areas over the last 3 mo. All answers were collected with assurance of anonymity through in person questions, phone or email requests. When referring to the data keep in mind that requests were made to a total of 25 managers selected based on their involvement in the thermoplastic composites industry or general composites management. A total of 17 individuals were willing to share this information at a response rate of 68%. The author selected the surveyed individuals based on relationships previously established, contacts and knowledge of their interest and knowledge of the production processes. The two basic questions asked were?

1. Do you have formal training in thermoplastic composites manufacturing, engineering, chemistry or properties?
2. How much experience in these materials and their production do you have?

These questions were asked and answered by 17 composites manufacturing managers. Nine represented production facilities currently producing automotive composite parts. Four of the questioned managers were primarily involved in the production of trucking parts, one a high performance automotive specialty shop doing low volume composite part production and 3 in job shops that currently do multiple composite production area parts with 40% or more being used in various transportation sectors. Ten of the seventeen individuals that were willing to respond had limited or no formal training and qualifications related to thermoplastic composites.

Figure I: Manufacturing Managers thermoplastic composites qualifications survey



The question responses were followed in the cases of 8 different respondents with a conversation. They explained caveats regarding the individual managers level of experience in thermoset automotive production, automotive assembly or metal component manufacturing in all cases where no formal composites training was indicated. About half of the respondents had confidence in the materials specialists or process engineers who were providing the technical leadership for the thermoplastic production process areas. Many of those transitioning to thermoplastic composites came from thermoset production or the thermoplastic injection molding manufacturing areas.

This data is not and was not presented to represent all the production management personnel involved in the U.S. thermoplastic composites industry. It does show a limited snapshot which is likely representative of many of the other individual industry managers. Some industry members have more extensive experience in thermoplastics, more expertise and have been manufacturing in that sector for a longer period. It is clear that "Manufacturers are optimistic about growth for these four decades-old industries, especially in aerospace, automotive, light rail, medical and oil/gas sectors"[1] As growth continues to increase opportunities for managers with specialty knowledge of thermoplastics will likely increase.

The Trends and Challenges

[1] *Queen, Karen Haywood. "Good Times in Thermoplastic Composites," Smart Manufacturing Magazine, SME Media, Southfield, MI Mar 2018.*

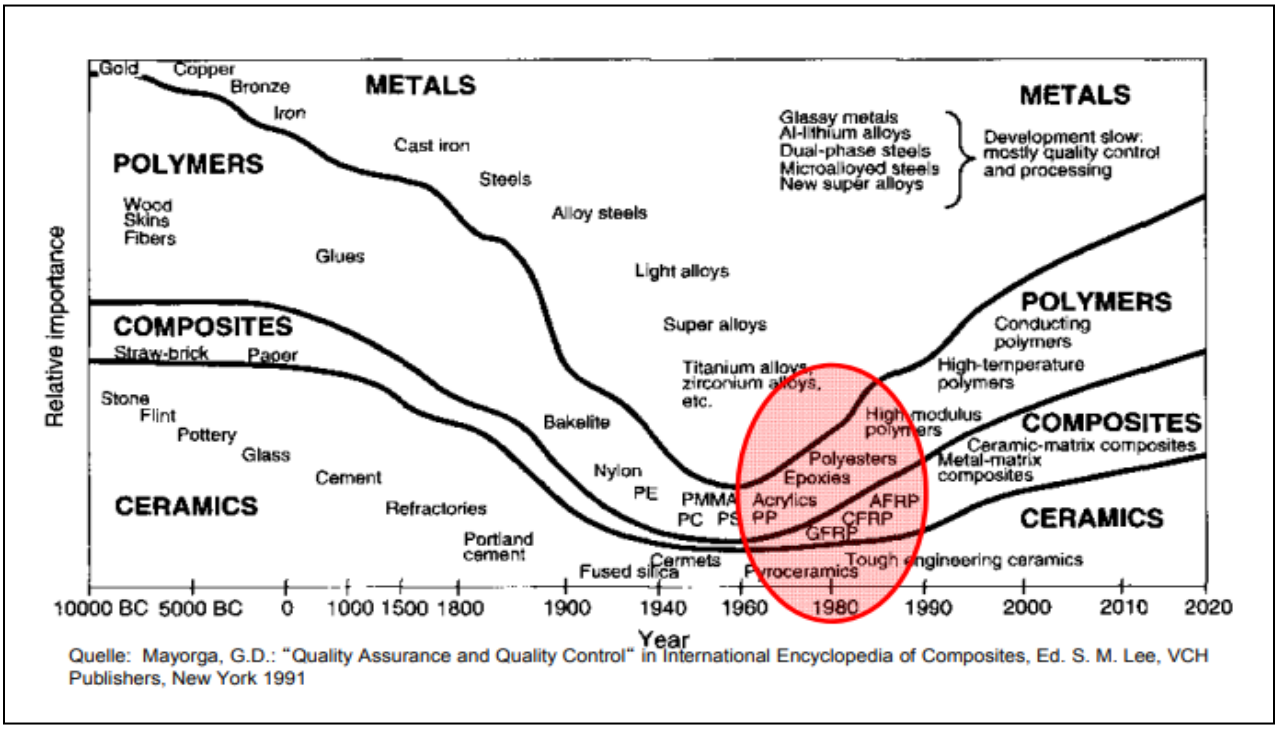
Development of thermoplastic composites have been moving forward for some time. The challenge is as cycle time reduction, research and chemistry have advanced not nearly enough production management personnel have been involved as would be ideal. As technology increases the demands of production in 2018 are keeping the best front-line manufacturing leadership busy with just trying to keep up the manufacturing pace. Research universities have increased their concentration in this area. Engineering schools are coming on board and materials science programs are growing. Increased collaboration between chemistry researchers and mechanical engineering programs has helped make rapid advancements. One important area that could be improved is cooperation and better collaboration between production managers and academics. As more partnerships continue to be formed between universities and industry this area can see continued growth. Much of the research into new materials takes a long time before it can be converted into a manufactured product. It is critical that research personnel understand and realize the requirements for manufacturing as they develop new thermoplastic composites.

A challenge is – how many of these new professionals will become manufacturing management personnel of the future. Do they have the people management skills, ability to work in a fast paced and demanding environment effectively? Past generations have mentored engineers, drawn experienced personnel management professionals from the military and developed specific skillsets through internal programs. These traditional technics are becoming harder to utilize due to lower employee tenure with companies, rapidly advancing technology and a mix of many materials for automotive system optimization complicating the production processes.

The below referenced 1991 publication was predictive of increased thermoplastic use in industry. The author was aware as the mix of materials changed in importance issues and challenges with quality control in production would be reflected.[2]

[2] *Mayorga, G.D. "Quality assurance ad Quality Control," International Encyclopedia of Composites, Ed.S. M. Lee, VCH Publishers, New York 1991.*

Figure II: Relative Importance of Materials, polymer and composites growth by material.



Quelle: Mayorga, G.D.: "Quality Assurance and Quality Control" in International Encyclopedia of Composites, Ed. S. M. Lee, VCH Publishers, New York 1991

While indications were that advances in thermoplastic composites volume would increase and those trends have held true, a few factors prevented manufacturing readiness from a management standpoint. The first was the recession of 2007 – 2009 and slow growth thereafter. Many manufacturing facilities shut down, others in the United States cut back on production. Costs associated with training management and hourly employees resulted in reduced training. The composites industry in automotive was especially influenced by U.S. car manufacturing cut backs, bail outs and poor sales. Corporate research programs and their associated funding also slowed during difficult financial times.

These events had many results but the effect on ingenuity as defined by Steven Blue's book was profound.[3] The research into the materials was in process or completed but the conversion into manufacturing processes was set back. Managers were dealing multiple challenges which restricted ingenuity in materials process advancement and made necessary survival. This had an influence on culture and gave managers in manufacturing facilities limited leadership credibility in an environment where cost cuttings and layoffs were in a large part an industry survival instinct.

With these events as a backdrop, many of the long time manufacturing skilled laborers and leadership teams are now moving into retirement eligibility. The demographics of the workforce are changing in America. At the same time the thermoplastic composites automotive processes finding their way to the production floor are technology driven. Fiber placement, resin infusion, curing and demolding processes run by advanced digital systems and processes have been introduced. While the new technology is a great advance in repeatability for composites manufacturing it comes with many challenges. Management personnel must understand the new

[3] *Blue, Steven L., American Manufacturing 2.0: What Went Wrong and How to Make it Right, 2016, Praeger, Santa Barbara, CA.*

technology and how faster processing of thermoplastics can be monitored, controlled, and troubleshooting can take place. Managers typically have less personnel with more highly skilled positions. Traditional repeated assembly and manufacturing processes once held by low skilled employees are replaced by automated equipment. Manager knowledge of processing conditions, materials and chemistry is even more important in having an effective production operation.

Thermoplastic Composite process advances in Automotive – research to production reality.

New processes must be led by those who understand the digital technology, materials science and chemistry of thermoplastics. Those people are not always the individuals in the production management positions. Many new generation automotive engineers, managers and thought leaders are much more comfortable with digital formats, technology and development than they can manage automotive production floors. Production management can require long hours, personnel management, high stress levels and time and cost constrained decision making.

An example of this is carbon fiber reinforced thermoplastic part forming. Understanding of how material sizing chemistry reacts with various thermoplastics at varying temperatures and pressures can have a significant effect on the ability to manage production of quality parts at required manufacturing speed and flow to the product.[4] This is a case where the new development of materials must be understood by those monitoring the manufacturing processes. Thermoplastic composites temperature, material handling, and fast processing under strict controls is much different than production processes used in the past. Even the quality control process for incoming materials much be managed with more precision to ensure production success. The chemist or materials scientist who understands the material is not always the same as the production manager running the part manufacturing line.

Competitive advanced manufacturing must be efficient and control product scrap that can result from the many processing variations that can be introduced by management if not well versed in the production method. A manager from a metal stamping or vehicle assembly background can be very capable but they need to have the time and make the effort to learn the nuances of thermoplastic composites. New management and engineering personnel who are on the cutting edge of material development can find opportunities in thermoplastic composites. New managers must have desire to work on the automotive production floor and work to build the necessary skills and experience in today's economic climate is difficult. Some previously accepted process restrictions, development times, labor practices will likely have to adjust to the realities of a changing workforce.

Some efforts have been made and many more are in development to combine materials to make optimized composite products. These combinations bring challenges to production management, especially in cases where thermoplastics are used in combination with thermoset composites. Thermoset composites are widely applied as semi-finished automotive parts.[5] This makes their production in many materials and resin systems consistent and economical especially

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[4] Kohler, Thomas & Roding, Tim "An Overview of Impregnation Methods for Carbon Fibre Reinforced Thermoplastics", Key Engineering Materials, July 2017, Vol 742 (Cambridge Scientific Abstracts), https://doi.org/10.4028/www.scientific.net/KEM.742.473

[5] P. Schneider, C. Hopmann, A. Boettcher, "Manufacture of Hybrid Profiles: Continuous Fiber Reinforced Thermoset Profiles with a Thermoplastic Top Layer." SAMPE Journal, Sept/Oct 2016, Diamond Bar, CA.

if a process such as pultrusion is used. Combining that thermoset with a thermoplastic extruded part to gain an impact resistance as shown in the refenced work by Aachen University researchers was a practical approach grounded in both proven thermoset (pultrusion) and thermoplastic (extrusion) processes. [4] This approach allows two proven and repeatable production processes that finding personnel to manage and run successfully can likely be executed. Smart production planning will become an ever more critical part of successful thermoplastic composites deployment in automotive. Even in this research an acknowledgement of careful temperature and pressure control was needed and resulted in three challenges for the thermoplastic extrusion process.

1. "Risk of thermal degradation of the PU matrix: The higher processing temperature of a thermoplastic melt can lead to thermal degradation of the PU matrix during coating."
2. "Risk of mechanical deformation of the PU matrix: The high pressure of the thermoplastic melt might lead to deformations of the thermoset composite profile, when the two meets at a point where the thermoset matrix is still liquid or gel."
3. "Risk of unsteady flow phenomena during the continuous joining: The different flow types of the single processes (drag flow in pultrusion, pressure driven flow in extrusion) might lead to unsteady flow conditions in the joining areas, leading to poor joining quality and waviness of the surface." [4]

These three challenges are all issues that will require production personnel knowledge to control quality and variations in temperature and pressure. These are common factors in composites. The managers used to traditional metal and automotive stamping must change many common ideas to adapt to multiple materials. Finding production management well versed enough in pultrusion and extrusion processes may be easier than a new process. Variations that take place in combining the processes to manufacturing an optimized product still take a management and production team with significant skills. The alternative of stamping a profile out of metal and attaching a outside sources thermoplastic exterior may be heavier and less optimized. These old materials are appealing because of the production knowledge and ability of the manufacturing team to efficiently deliver product.

Generational Differences in Work Culture

Data brings out the facts regarding millennial employee's outlook on job longevity and that of previous generations. According to Gallup data gathered in 2016, 21% of millennial employees changed job in the past year.[6] This trend seems to continue especially now that economic conditions in the United States have improved and opportunities have increased. The next generation of manufacturing management teams will likely have a large variation in job experiences. While diversity can produce strength the past manufacturing management generations were not always required to learn new materials and processes so rapidly. The combination of technology advances and job changes brings a new dynamic to developing management. This can have advantages and may cause some positive disruption to the automotive supply and manufacturing chain. It also may have negative effects. Training, maintaining and retaining skills and personnel for thermoplastic composites processes is likely to be difficult. If trends of thermoplastic composites use continue upward demand for

[6] *Adkins, Amy, "Millennials: The Job-Hopping Generation." Business Journal, Gallup News, May 12, 2016, (Washington D.C.)*

knowledgeable management will challenge available talent. Competition for management expertise and the fact that many researchers and development engineers have limited interest in working in production management positions will continue to be a challenge.

Ideas and personnel training programs are being promoted nationwide to address the shortage of manufacturing employees in specialized job areas. Thermoplastic composites manufacturing is an area that can benefit. These programs do often begin with STEM training, specialized job skills, technical certifications and school programs. From high school level and technical college programs many opportunities to build a pipeline of industry knowledgeable individuals for future production management leaders is being put forth. More immediate efforts are taking military veterans who have work and leadership and transitioning them to manufacturing management opportunities. Military transition assistance programs are partnering with organizations such as the Manufacturing Institute to create way for talented, seasoned, capable managers to translate their skills into manufacturing environments. "Hiring veterans is good business." [7] Both servicewomen and men transitioning and the manufacturing employers benefit from such partnerships.

One positive is as parts in automotive continue to become more lightweight, precision manufacturing environments are adopted. In composites processes temperature, pressure, humidity and fod are variations which cleaner and more comfortable work environments control. The same environments make production management positions more desirable for young technologically savvy workers who have grown familiar to climate control and digital platforms. It is a given that automotive parts designed for multiple environments and under the hood applications for thermoplastic composites continued to be advanced. The advancement of new materials with continued chemistry improvements for fatigue and weathering characteristics will undoubtably drive precision processes that require management teams able to solve problems.[8]

Challenges undoubtably exist which include maintaining those new managers and keeping them engaged in the thermoplastic composites industry. Industry in the United States has not experienced the growth we are currently seeing in some time and has many challenges to overcome. For the manufacturing companies a past legacy of layoffs and failure to adapt to changing markets and competition from abroad does limit their appeal to young workers. For young managers several things distinguish them from older manufacturing managers. These include a larger percentage of female managers in the under 30-year-old group by just about 2% according to Harvard Business Review survey data.[9] That data was survey compiled and includes managers in an assortment company. Anecdotal observation would suggest that the actual percentage of female manufacturing plant managers, while growing is much farther behind than in other industries.

Younger managers face perceptions from peers and employees that are challenges that should be kept in mind. These include: [9]

1 Not fully trusted.

2 Lacking experience and deep knowledge.

3 Not perceived as a role model.

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[7] Manufacturing Institute, "The Manufacturing Institute Launches Heroes MAKE America Veterans Training Program." MI News, Washington D.C., Jan 2018.

[8] A. Schaaf, M.D. Monte, E. Moosbrugger, M. Vormald, "Life estimation methodology for short fiber reinforced polymers under thermo-mechanical loading in automotive applications," Material wissenchaften werkstofftech, vol 46, no 2, 2015.

[9] Zenger, J., Folkman, J., "What Younger Managers Should Know About How They're Perceived," Harvard Business Review, Watertown, MA, Sep 2015.

4 Insensitive to others needs.

5 Not capable of representing the organization.

6 Lacking strategic perspective.

The same young manager group does bring strengths to the table and it should be noted that employee perceptions, while important to not always hold true to every young manager. Technical skills and background prior to moving into management positions are also very important when improving manufacturing management in thermoplastic composites.

Transitioning from a technical background, having some materials and chemistry knowledge and perhaps most importantly the willingness to learn is needed. The willingness to gain new expertise is critical for young managers. The programming at the American Composites Manufacturing Association experiences many management personnel working to earn credentials through the Certified Composites Technician CCT program. Their employers utilize this industry standard as a way gain knowledge regarding thermoplastic and thermoset composites processes. An objectively measured credential with accompanied learning and study that is industry specific should always be part of young manager development programs. Senior managers transitioning into retirement in an orderly fashion with some patience and ability to mentor can be a critical asset to new manager development.

Summary and Next Steps

A key area of follow up to this work is building future opportunities to expose manufacturing managers to automotive thermoplastic composites. Training, certifications, coursework and mentoring can be combined to meet the needs of new plant floor leadership. Unlike traditional automotive metal stamping and assembly processes thermoplastic composites have an endless amount of options for material optimization. New additive manufacturing processes further push the industry to consider additional materials and designs. The drive towards manufacturing efficiency and competitive production of thermoplastic composites requires advanced technologies. If done properly they can be converted to successful advanced production technics. Best practice industry standard training programs can and should be adopted to better meet the overall industry needs.

Further opportunities to improve communication and coordination between researchers, development engineers and the manufacturing management of the future holds great promise. New developments in materials allow a rapid increase in efficiency and cost reduction if they can be delivered into excellent products by the automotive manufacturing teams. As high strength, light weight, cost competitive thermoplastic composites continue to penetrate the automotive market demand for a new generation of effective manufacturing managers will remain strong.

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with others I thank for development of my knowledge as I have learned and continue to learn the composites industry. As materials advance it is a lifelong learning experience to further grow the industry and realize more opportunities.

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