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DIGITAL TRANSFORMATION OF THE PLASTIC PRODUCTS FACTORY

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Introduction

The major disruptive technological changes in the plastic industry can be distinguished in terms of digitalisation, materials science, additive manufacturing even while we recognise that their effects are closely inter-related. These changes taken together are transforming the plastics factory. This transformation has implications not only for process and production efficiency, but also the landscape of international competition by allowing smaller manufacturers to achieve the market access and technological capabilities that previously could only be attained by medium-to-larger players.[3]

The South African plastic industry has lagged behind these changes and has performed poorly when compared to its upper middle-income counterparts.[4] Years of poor performance have meant that instead of a virtuous circle of investment, increased efficiency, and economies associated with throughput and scale reducing average costs, the South African plastics industry has experienced a vicious circle. There has generally been low-levels of investment in machinery and skills. Out-of-date machinery implies higher costs in terms of energy usage and raw materials through rejections, scrap and reworking.[5] Between 2002 and 2016, the industry has experienced sharply higher levels of import penetration, a loss of competitiveness in export markets and has shed 27% of total jobs in the industry in 2016.[6]

The turnaround urgently needed in South Africa can only be achieved by effective engagement with the changes brought by industry 4.0. In the absence of an effective industry and technology strategy the South African plastic industry will continue losing competitiveness, placing the remaining 60 000 jobs at risk. Failure to turn the sector around also has wider implications due to linkages across industry in the economy. Plastic products are often components of more complex products and, as such, manufacturing capabilities in plastics are a critical part of much wider manufacturing capabilities. For this reason, the plastics industry has been characterised in countries such as South Korea as a ‘root industry’ for the fourth industrial revolution.

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[3] Siemens. 2017. The Digitalization Productivity Bonus Plastics.
[4] Mondliwa, P. 2018.
[5] We note that the picture is not uniform and some segments, such as packaging, have performed relatively better.
[6] Quantec Data

This brief considers the opportunities presented by the technologies associated with industry 4.0 and how adoption could improve South Africa's competitive position and potential grow the plastics sector.

Global technology disruptions

The major disruptive technological changes can be distinguished in terms of digitalisation, materials science, additive manufacturing even while we recognise that their effects are closely inter-related.

Digitalisation of the plastics factory

Digitalisation of the plastics factory brings about major transformation in terms of process monitoring and data management and process optimisation.[7] The factors that will lead to increased productivity include shorter setup and changeover times; reduced downtime, improved product quality and reduced energy consumption (Figure 1).

Figure 1: Digitalisation and automation drivers of value in the plastics industry

Source: Siemens white paper on Productivity Bonus

Digitalisation has meant a massive improvement in the quantity and precision of data collected and analysed from machinery through the production processes. Using a Manufacturing Execution System (MES) allows automated real-time and accurate data analysis on machines and materials from different suppliers and different time periods. Digitalisation also has the added benefit of connecting plastics manufacturers with geographically diverse sites across various locations. In one example, UK and Thai manufacturing sites have been linked with development and sales centres in China, Japan and the United States using Enterprise Resource Planning (ERP) systems to coordinate the diverse systems to provide a unified, real-time view of productivity, capacity, inefficiencies and areas for improvement.[8] This allows for optimisation of the shop floor and ensures that there is an efficient supply chain.

[7] Interview with Plastic Omnium
[8] Interview with Plastic Omnium

Process optimisation through digitisation is generally associated with a reduction in scrap rates, downtime and better monitoring of machines for predictive maintenance. This digitalisation is supported by a range of technologies including sensors installed to collect real time data combined with cloud computing that allows for complex data analytics. With machine-learning, the processes can self-adjust to the observed conditions or notify operators to adjust the system and/or conduct maintenance.

As in other process manufacturing, unanticipated shut-downs result in losses. For example, in most thermoplastic process polymers are melted and then formed into required shapes using a range of processes. If the machine cuts-off during the process then one has to allow the machine to cool down, remove the materials that were in the machine (in certain industries where re-grinds are not allowed this would be discarded at a loss) and then it takes approximately 3 hours to restart the machine again. Monitoring for predictive maintenance therefore significantly reduces the downtime of the machine as well as the potential scrap from the process.

Potential challenges that arise with digitalization include interoperability of technology platforms, connectivity and data ownership and security. In terms of interoperability, software development companies and machine manufacturers are all creating data standards in isolation, which results in difficulties in integrating systems between suppliers, manufacturers and customers. To address this challenge, the European Machinery Association launched a common digital standard that allows machines from different companies to be able to communicate with each other.[9] This is essential for interoperability in 'production ecosystems. The standard was developed for injection moulding machines and allows standardized communication between the machine and the MES.

Digitalizing the production process makes it possible to capture and retain a detailed audit trail of production. This is enormously important for ensuring traceable safety standards, such as those that apply to toy manufacturing, right through to minute and provable compliance with stringent regulatory standards, such as those that apply to medical device manufacturing.

Design, material science and additive manufacturing for rapid prototyping and tool making

Rapid prototyping and tool manufacturing enable a more seamless integration of the design and prototyping process. This significantly reduces the time from idea to prototype. Additive manufacturing together with advances in materials science and virtual simulations means that prototypes can be printed in a few days compared to the previous process that took several months.

Despite various interventions the level of tooling production and maintenance skills in South Africa has not improved significantly.[10] Very few plastics companies have been able to employ people that came out of the tooling initiative.[11] Firms have noted that manufacturing of tooling in South African is very poor, the local tools are more expensive than imports, and the lead times are also very slow.[12] For example, a mould that can be manufactured in South Africa for

[9] http://www.plasticsnewseurope.com/article/20180508/PNE/305089999/euromap-unveils-first-digital-4-0-standard
[10] Beare, M., Mondliwa, P., Robb, G. and Roberts, S. (2014). Report for the Plastics Conversion Industry Strategy. Research report prepared for the Department of Trade and Industry.
[11] Beare et al, 2014.
[12] Beare et al, 2014.

US$150 000 with an estimated delivery time of one year can be sourced from Taiwan in two months for the same price.

Rapid prototyping through additive manufacturing can enable South Africa to leapfrog over the tooling challenges experienced.

Additive manufacturing for customization and production

Increasingly additive manufacturing is being used for production of complex components as well as to create individualized, customized component parts in what is virtually a mass production process, along with shortened development, setup and start-up times. A good example of this is the smart addition of three-dimensional individualized designs on a piece-by-piece basis to deliver personalized products at mass-production speeds and costs.

Injection moulding firms, in particular, are also using virtual simulation technology to examine flow simulation in extrusion dies, mainly to optimize process quality and reduce defects, which both have a considerable effect on commercial efficiency and customer satisfaction. As consumers become accustomed with the option to customize products this will become more standard in the industry.

Additive manufacturing also introduces an interesting dynamic where products can be remotely printed close to the customer. This may potentially change the patterns of trade. Western countries such as the United Kingdom are leveraging this to support a strategy if reshoring manufacturing. Although this is not widely practiced at the moment, it is possible and will likely gain popularity in the near future.

Evolution of plastic processing machinery

There have been major evolutions in plastic processing machinery in recent years. First, the development in injection moulding machines to make them smart machines has changed the production process. For example, Engel launched Injection 4.0 to meet the demands of the ever-changing production environment. Injection 4.0 is premised on three things namely smart machines, smart services and smart factory. Under smart machines Engel seeks to improve the benefits to operators/manufactures by optimising production the machine by allowing the machine to self-learn, self-correct and ultimately improve precision. The smart machines are able to detect and monitor the injected material volume, control and automatically correct the holding pressure. This represents a solution to manufactures since it reduces wastages as a result of the interruptions of the machine and length of time it takes the machines to return to a rhythm. Importantly this improves the machine stability and guarantees that each product is exactly the same. All this is enabled by the use of sophisticated mathematical algorithms called the iQ weight control deciphers. Other elements of the smart machines that Engel has brought involves the use of machines that can achieve a consistent and efficient temperature control processes and use of intelligent clamp force optimisation. With Smart service the machines are linked to a server which will enable the extraction of information on the behaviour of the machine. This information will be used to detect machine breakdown, identify wear and hence reduce down times.

Second, twin sheet blow moulding machines allow for the production of blow moulded products in one stage. For example, plastic fuel systems are increasingly produced using extrusion blow moulding. This has various benefits for the automotive industry including weight reduction for better fuel economy and lower carbon emissions. An average plastic tank weighs one-third less than an average steel tank.[13] The plastics tanks are also more cost effective due to a combination of factors including design, and manufacturing flexibility for complex shapes, mechanical and chemical resistance, the quantity of materials used and plastic processing is undertaken at lower temperatures than steel.

The twin-sheet blow moulding system integrates components into a fuel tank during blow moulding, reducing costs and emissions at the same time.[14] This technology could produce plastic fuel systems with more complex designs that will meet the strictest of performance and emissions standards. In the new process already in use, sheets are extruded between a central core and a mould. Core actions attach the components during initial sheet forming. Then empty core is withdrawn, and the mould is closed to join the formed sheets in a second blowing step. Components that can be attached to the core include baffles, gauges, valves, jet pumps, lines, fuel modules and canisters. The Twin-Sheet Blow Moulding process allows improved wall thickness control. There is an additional 10% savings through component simplification and reduction in finishing costs.

Third, the changes in process technologies are being connected in smart factories a whereby a central connector monitors the whole production process with a manufacturing plant. For example, TIG has developed a system which completely integrates all the machines at a manufacturing site. This helps in facilitating traceability of any faults, monitoring performance of each machine. The interface helps the manufacturer to quickly identify a problem and allows remedial action to be taken promptly.

South African technology responses

Responses to industry 4.0 by South African industry vary substantially. The adoption of industry 4.0 technology advancements is happening in the high value segments of the plastics industry, including automotive components, medical devices and engineering plastics. The packaging sector is also adopting these changes. However, much of the industry lags substantially.

Within the higher value segments, firms that are part of multinational corporations (MNCs) and/or part of global value chains appear to be fast followers in terms of adoption and/or development of strategies for adoption. This is driven by the access to the MNC research and development and testing facilities which are often not located in South Africa and pressure on the supply chain to adopt from tier 1 firms in GVCs. An additional advantage for plants within MNCs is the constant benchmarking of various businesses within the group to monitor and improve efficiencies.

The public institutions have been both fast followers and leaders in terms of additive manufacturing and material science. The take up of these services by industry have, however, been slow and needs to be urgently reviewed. Although South Africa is considered to be a late adopter of additive manufacturing technology, the public institutions have been able to build a viable additive manufacturing market in the country with collaboration and constant innovation.[15] Between 2014 and 2018, the country's public institutions invested approximately R358 million in 3D printing technology research and development.[16] The Vaal University of Technology in Gauteng, the Central University of Technology in the Free State and the Rapid

[13] https://www.plasticomnium.com/en/automotive-equipment/auto-inergy-division/innovative-systems/plastic-fuel-systems.html
[14] http://atozplastics.com/upload/literature/Innovative-fuel-tank-twin-sheet-blow-molding-process.asp
[15] https://3dprint.com/147991/south-africa-3d-printing/
[16] https://3dprint.com/147991/south-africa-3d-printing/

Product Development laboratory in Stellenbosch all have additive manufacturing facilities that are open to firms for rapid prototyping and production services.

With regards to material science, CSIR has capabilities across the spectrum, ranging from polymer formulation and additives, to testing facilities, bio-plastics development and encapsulation. There is also research and development on fibres and composites, additive manufacturing materials and techniques, governance on waste and recycling development and enterprise development, including in recycling. It is commendable that through the support from the Department of Science and Technology these various programmes are available. The focus going forward should be on marketing these services to industry and consideration should be given for discounting to small and medium firms that are not able to afford the full cost of the services offered. Improved industry involvement with the university-based centres requires governance structures that support the flexible arrangements required for these partnerships rather than the somewhat bureaucratic governance that typifies universities.

There are also limited facilities to test new technologies in South Africa. Firms typically wait for technologies to be tested in Europe first and then adopt.[17]

Impact and implications for South Africa

South Africa needs to recognise the manufacture of plastic products as a root industry for the fourth industrial revolution. A comprehensive set of interventions needs to promote a stepwise change in investment and adoption of new technologies.

Internationally, the adoption of automation and digitalizing plastic production systems has been estimated to create productivity gains equivalent to between 6.3% and 9.8% of annual revenues.[18] In South Africa, this would translate to between R4,79 billion and R7,45 billion based on 2017 total convertor revenues.[19] However, due to slow adoption of the technological advances South Africa is yet to realise these gains.

Most South African plastic convertors continue to use old machines averaging at approximately 18 years in age and this makes it difficult for them to be integrated with the latest technological advancement such as automation.[20] The poor investment in up-to-date machines is due to a combination of factors. First the machines are relatively expensive, and the industry is mostly made up of small and medium enterprises. Second, the local industry is typically characterised by low margins making it difficult for firms to accumulate sufficient capital to reinvest in the business.[21] Third, generally the production volumes are relatively low which prevents firms from benefiting from economies of scale enjoyed by firms in Thailand or China, for example. Firms also noted the fluctuation of the exchange rate and political uncertainty as undermining investment decisions. In terms of upgrading to a complete smart factory system, the take-up of key systems is very poor.

The estimated productivity and efficiency gains from adopting industry 4.0 technologies means that if South African firms do not invest in upgrading their technologies the industry will further lose competitiveness.

[17] Interview with Diemaster, 17 September 2018.
[18] Siemens. 2017. SFS-Whitepaper The Digitalization Productivity Bonus Plastics. [Online]
[19] Calculations based on Plastics SA estimates of convertor turnover at R76 billion. See Plastics SA 2016/17 Annual Review.
[20] Interview with Greentech machines. Also see Beare *et al* (2014) for state of machinery in the plastic industry.
[21] Beare et al, 2014.

The biggest technological disruption in the industry so far has been the digitalization of the factory including integration of systems through the supply chain and condition monitoring and predictive maintenance. A strategy to support adoption in this industry has to start with capital upgrading of machinery and equipment. Though there are concerns about the environmental impact of plastics, demand for plastic products is estimated to grow and in the automotive industry plastic is replacing other materials and supporting light weighting and compliance with carbon emissions. Increasingly, Tier 1 manufacturers are expecting Industry 4.0 technology to be filtered down throughout the tiers of their supply chains to support ever leaner manufacturing processes. Failing to match their pace may result in top-tier manufacturers looking elsewhere for future contracts.[22]

These changes will lead to a recompositing of the skills mix that is required by not just plastic firms but also manufacturing more generally. Firms and institutions have reported the need for more and better quality engineers. Digitalization of the production process has had varying impacts on skills requirements. In some instances, digitalisation, integration and machine learning requires that the skills level required from a machine operator is in fact lowered, as all measuring and analytics is taken over by the system. In other instances, the upgrading of systems requires higher skills to be able to engage with and set the machinery.

Potential policy, regulatory and programmatic responses

The major changes required are:

- ***Financing of technological change for SMEs*** in the plastics sector which make up the bulk of the sector. In terms of 3D printing, the Industrial Development Corporation (IDC) has recently launched a new industries strategic business unit, which will involve further development of 3D printing technology. The support provided by the IDC should not only focus on 3D printing, the adoption of smart machines and smart factories is very important for the sector.
- ***Cost and quality of connectivity for successful digitalization.*** *Spectrum policy and regulation* to support availability, reliability, cost and speed of bandwidth for plastics firms to be able to collect and analyse real time data for condition monitoring and predictive maintenance as well as for integration of systems within the supply chain.
- ***Regulating for interoperability of platforms including standardization of data***. As things stand machine manufacturers, software developers are creating multiple standards of data which can undermine interoperability of platforms and integration of supply chains for efficiency gains. The standards agencies such as SABs may consider collaborating with industry to develop standards.
- ***Creating a culture of collaboration through clustering and benchmarking.*** Adoption of the technologies alone are not going to automatically result in the productivity and efficiency increases described above. The company culture is also important in ensuring that the new technologies are fully utilised to realise the maximum gain and that firms are using and responding to data, moving from a reactive to a proactive stance. This can be spurred through clusters and benchmarking of firms. The benchmarking can be required as a condition for firms that have secured finance

[22] https://www.k3syspro.com/how-to-survive-industry-4-0-as-a-plastics-manufacturer/

for adoption of technology from government including agencies to ensure that it is not restricted to plants that are part of MNCs.

- ***Review of training, skills development and re-skilling of employees.*** The skills set required for industry 4.0 is changing. Interviewed firms and institutions emphasized the need for process and mechatronic engineers and the overhaul of supply chain management curricula. Firms complained that the process engineers graduating from South African institution are not comparable to their international counterparts and there is a shortage of mechatronic engineers. Industry 4.0 has also significantly changed the supply chain management within industry and the curricula needs to be updated to reflect these changes. Training and reskilling of employees will need to focus on improving interpretation, modelling and decision making using big and small datasets.

- ***Making public-private partnerships work in additive manufacturing and robotics.*** There is also a need to support the public and private partnerships in order to maximise the benefits from the public investment in technologies such as 3D printing. The public facilities such as VUT, CUT, TUT and others can be used for initial testing, prototyping and even mould manufacturing. This is especially crucial for small and medium firms. Where firms are applying for finance for 3D printers, the development funding institutions should encourage firms to use the public facilities for initial prototyping and testing and this could be funded as part of the project costs. This ensures that the machines and moulds that are procured are appropriate for firm needs. The VUT Science Park already offers virtual simulation to test tool design before manufacturing. An example of a successful public-private partnership is the DST's current flagship Project Aeroswift, which is a collaborative effort between Aerosud ITC and the CSIR's National Laser Centre. [23]

[23] https://3dprint.com/147991/south-africa-3d-printing/