Technological and Market Challenges Faced by the Precision Engineering Industry in Singapore

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Abstract – The Singapore precision engineering industry, which has grown in tandem with the electronics and semiconductor industries, continues to underpin these as well as the emerging medtech, oil and gas, and environmental and green technology sectors. The PE companies face not only challenges in technology upgrading but also the increasingly stringent operational and regulatory demands. The recognition of the vital role of the PE industry in the national economy is manifested by the availability of the numerous assistance and support schemes and structures.

The Precision Engineering (PE) industry is sometimes referred to as the mother industry as it serves the important role of underpinning many other industries. PE companies are usually small and medium-sized enterprises (SMEs) catering to the multifarious needs of the original equipment manufacturers (OEMs). In the current dynamic trend of shrinking product life cycles and increasing product mix and complexity, PE companies have to be agile, adaptive and innovative. The Singapore PE industry has grown largely in tandem with the semiconductor and electronics industries; the modus operandi being the mass production of precision parts and assemblies, with emphasis on rapid throughput and quality standard in the order of parts per million. Progressively, the PE companies have leveled up to the production of higher value added components; entailing investments in higher capital equipment, upgrading of skill level of the workforce and the development of the necessary technical competencies. A major challenge facing the PE companies is the rapid changing industrial landscape with the emergence of new industry sectors such as medical technology (medtech), aerospace, oil and gas, and environmental/green technologies.

Over the years, the PE companies have responded well to the numerous national financial and assistance incentive schemes to encourage them to innovate and enhance their technologies and capabilities. Taking the example of plastic and transfer mould production, the PE companies have been quick to adopt electro-discharge machines (EDMs) instead of continuing to rely on skilled craftsmen and tedious machining. Although the early EDMs were relative unstable and the need to produce electrodes out of graphite and copper was something new to the operators, the perseverance paid off as better quality and more complex moulds could be produced in a faster turnaround time. This was critical at a time when plastic injection moulding of casings and other key components and transfer moulding to encapsulate integrated circuits were important parts of the electronics and semiconductor supply chains. Similar swift progress was found in the adoption of wire cut EDMs for production of precision sheet metal parts. Another milestone for the machining PE companies was the acceptance of high speed machining. By using higher cutting speeds it is possible to reduce the cutting forces imposed by the cutting tool on the work surface and obtain far better surface finish. This advantage facilitates the machining of moulds made of hard materials and also the achievement of very thin sections for soft metals such as copper and aluminum. The first generation of high speed machines were mere adaptations whereby a three-axis machining centre was retrofitted with a high speed spindle and a rotary table incorporated at the worktable to provide two additional axes. Apart from the high cost of such machines, users encountered severe tool wear as existing carbide tools in the market were not adequately hard to provide an acceptable tool life. With the introduction of more dedicated high speed machines that can reach up to 42,000 rpm and the availability of fine grain coated carbide tools the adoption of high speed machining accelerated. Today, high speed machining has largely replaced die sinking EDM in the production of plastic injection moulds. Another area where the machining community has made significant stride is their capability in computer aided design (CAD). Through a national initiative in partnership with a major CAD vendor, many of the PE companies took the opportunity to upgrade their CAD competencies from 2D to 3D. This served as an important foundation when some of the companies migrated to 5-axis machining to meet the demand for increasingly complex machined components.

The plastic injection moulding companies constitute a sizeable number of PE companies. Faced with fierce competition from the newly industrialising countries, many of these companies have relocated their lower cost operations outside of Singapore to refocus their operations on higher value added products. One opportunity came from the surge in demand for plastic lenses and other optical components. There is a steep learning curve as the plastic moulding industry has little know-how in optical design, components manufacturing and characterization. The moulds and components have to be machined with a diamond tool on an ultra-precision machine to attain the complex profile and the optical surface finish. Due to the extremely short life of the single crystal diamond tool when machining directly on steel, the mould surface is usually coated with electroless nickel. There are many problems associated with the machining of such moulds. Firstly, unless the quality of the electroless nickel coating is good pores and other defects will appear on the machined surface, leading to expensive scraps. Secondly, the imported diamond tools are expensive and have to be shipped to the suppliers for re-grinding. Assistance to overcome these problems came from SIMTech, which has spearheaded the development of capabilities in ultra-precision machining. Until companies were confidently enough to purchase their own equipment, SIMTech offered the service to produce the moulds. There was also the facility to regrind the diamond tools, thus saving considerable time and cost. It was also significant that SIMTech researchers came up with an innovation to machine steel directly with minimum tool wear. This breakthrough development resulted in the spinning off of a company, Delta Optics, which now takes on jobs from all over the world. SIMTech is continuing with their R & D in ultra-precision machining to handle freeform machining.

Due to their limited resources PE companies do not have much in-house capability for technology generation. Their low level in the supply chain renders them relatively short term and risk averse in their outlook. One initiative that has been successful in helping the PE companies is the Local Industry Upgrading Programme (LIUP). Under this programme a multinational or large local company works in partnership with a group of the PE companies on specific projects to effect the technology transfer. The manager in the mentoring company is fully paid by the programme. Due to the synergistic relationship between the mentoring companies and their PE counterparts, the projects lead to clear goal and benefits. Under LIUP, there have been cases where the PE companies end up acquiring operations that were previously in the mentoring companies. They then enter into a subcontracting arrangement.

Singapore has historically looked to the multinational companies to bring in investments and technologies. The situation is gradually changing with the emergence of some large local companies. While the R & D activities in these companies have grown, the pace needs to be hastened. To address this, the research institutes (RIs) were set up in the 1990s, to fill the gap. Unlike the universities, the RIs were tasked to work on technologies that can eventually be commercialized. A number of precision engineering technologies have achieved this target.

One of these technologies is powder injection moulding (PIM). Although the concept and benefits of PIM have been known for some time, the commercialization has been limited by the heavy capital investment and process scalability. A significant advantage of PIM is the versatility of the process in terms of the range of materials (metals, polymers and ceramics) and the complexity of shapes. One outstanding example is the cost effective bulk production of a ceramic wirebonding capillary with an internal diameter of 30 µm and a bore that is smooth to avoid the breakage of the gold wires. Singapore can now claim to be a leading country in the production of PIM parts.

Another novel technology that has come out of the laboratory is liquid forging, which is a casting-cum-forging hybrid process. The advantage of liquid forging is that while requiring less force than forging, it eliminates the porosity problem associated with conventional casting. Liquid forging is ideal for forming components with complicated shapes and high aspect ratios. Such components are usually produced by machining. So far, liquid forging has been used to produce a range of heat sinks, especially those used for LED lightings. The material for liquid forging is now restricted to aluminum. Research is underway to extend the use to copper and magnesium.

The development of such technologies is well beyond the resources and capabilities of the PE companies. However, the accessibility to such technologies would enhance their range of offerings and increase their value proposition to their clients.

The greatest challenge for PE SME companies is to be dynamic in order to be able to address the fast changing industrial needs. Not only do they have to be aware of technology trends and possibilities but only the tightening operational and regulatory conditions. Even in the electronics industry, stringent quality specifications are compelling PE companies to produce in a clean or even cleanroom environment. For example, fasteners for the high end disc drive are now vacuum packed, with a quality standard down to particle counts in the order of parts per million. Similar, if not more exacting demands, are encountered in the growing medtech, oil and gas and aerospace industries.