Establishment of rapid prototyping/additive manufacturing in South Africa

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Synopsis

South Africa had a late start with rapid prototyping (RP), with the first system being available in 1991. Up to 1994 only three systems were available in SA. Through active research participation from the CSIR and a number of universities, supported by technology transfer programmes and industry awareness workshops, adoption of RP technologies started to grow. Internationally, RP grew to the extent that several country-based member organizations were formed, and an initiation meeting of the Global Alliance of RP Associations (GARPA) took place during the SME Rapid Conference in Dearborn, USA in 1998. South Africa (SA) was invited under the auspices of the Time Compression Technologies Centre (TCTC) launched by the CSIR, and received an invitation to become a member of GARPA through the launch of a national, inclusive organization. The latter gave rise to a RAPDASA planning/launch meeting held at the University of Stellenbosch, which culminated in the first RAPDASA international conference held in November 2000 at the CSIR, and the election of a first RAPDASA management committee, also at the 1st AGM held during the conference. RAPDASA has been a pillar of strength since then, with an annual international conference being presented. As South Africa's RP awareness grew through the RAPDASA and independent activities, so did the availability of RP platforms in SA. SA also became a benchmark for other countries/late adopters to follow, as slowly a position of following became a position of leading through innovative applications. The paper highlights SA's development approach and history, together with the discussion of case studies in various fields. Contribution to the light metals industry will also be discussed.

Keywords

Rapid prototyping, additive manufacturing, product design, rapid tooling, rapid manufacturing, medical product development.

Introduction: Progressive development

South Africa's rapid prototyping (RP) (Now termed additive manufacturing (AM)) activities took off approximately one decade after the international community, and as such, started from a position that was lagging behind other industrialized countries. The RP machines introduced into the country were put to work in a wide range and many innovative applications. Some perfect triple-helix models between higher education (HE), industry and government were aimed at an efficient use of the country's limited economic resources.

The first RP system (3D Systems SLA 250), was introduced into RSA in 1991 and was followed by two FDM 1500 machines, later upgraded to 1650s, owned by the Council for Scientific and Industrial Research (CSIR). Central University of Technology, Free State (CUT) purchased a Sanders ModelMaker II and an SLA 250 in 1996. This was followed by the installation of an SLA 500 by the CSIR in the same year and two years later, the CUT purchased a DTM Sinterstation, which brought the number of machines available in SA to seven. Except for the SLA 250, all other machines were owned by academic or research institutions. 'This is indicative of the fact that RP was initially introduced into HE and other research institutions with the aim of assisting their co-operation with industry. In addition, the diverse and complimentary nature of the machines installed allowed active collaboration, efficient planning and conducting of research programmes'[1].

Research and government initiatives

The majority of the research performed, addressed specific applications, rather than basic research. Numerous examples have been published by various SA researchers. In a paper by Campbell and De Beer[1], it is concluded that the particular situation primarily developed from research funding opportunities such as THRIP (Technology and Human Resources for Industry Programme (THRIP)), where through government support, collaboration with industry was a requirement (and opportunity) for grant-funding, and resulted in a high level of industrial participation in research programmes. Some technology platforms were funded for

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particular applications, leading to wider applications and an obligation to transfer research outputs to industry. Research institutions involved effectively became technology demonstration centres. In parallel with process development and improvements, to produce models and components, the research also affected on managerial aspects of the product development process, inclusive of RP usage, e.g. product development innovation[2] and support of concurrent engineering[3].

RP implementation and research has proceeded with the firm support of central government. One reason for this is that the 1998 National Research and Technology Foresight Project's Manufacturing Report produced for the Department of Science and Technology in 1998 showed that manufacturers wishing to compete internationally should focus on integrated product development, process and production system design to speed up production time. The report also listed rapid prototyping and tooling among the key technologies that would assist with this aim. This indicates that RP and related technologies have been firmly established within the RSA government's strategy for industrial development for the past decade (Interestingly enough, many of these ideals have come to fruition only in the past number of years, and again, many of these results can be attributed to RAPDASA and efforts made by individual researchers/ research teams and their technology transfer initiatives.)

Government support for RP research has come both directly, through funding made available to purchase RP systems, but also through funding a series of initiatives where RP has been able to play a prominent role. For example, the National Product Development Centre (at the CSIR) was initiated to be the hub of a national network giving support to the manufacturing industry. Members of the network at that time included the Automotive Industry Development Centre in Gauteng, the Centre for Rapid Prototyping and Manufacturing in Bloemfontein, the Global Competitiveness Centre and Stellenbosch Automotive Engineering (both in the Western Cape Province), the Centre for Engineering Research in Durban, the Automotive Components Technology Station in Port Elizabeth and the Centre for Design and Manufacturing at Potchefstroom University. Many of these centres also engaged in RP research and have been able to develop this aspect further within the network through government funded technology transfer initiatives. The network promoted active collaboration between centres with different RP systems, and aimed to benefit South African product developers.

THRIP provides matching funding in different formulae for collaboration between industry and academia (matching funding that is provided by the industrial partner in either 1:2; 1:1 or 2:1 funding ratios, depending on the size and composition of such an industry partner). Several research institutions have made very effective use of this for industry-related RP research, including the Central University of Technology Free State, CSIR and Stellenbosch University.

The Technology Stations Programme was established under the auspices of the Tshumisano Trust (Tshumisano means co-operation or partnership, an is now taken in under the Technology Innovation Agency (TIA) banner) to promote the transfer of technology from technical universities to small and medium-sized enterprises[4]. Each technology station has its own area of expertise with several of them covering topics relating to product development technologies. Once again, RP has had an important role to play in technology platforms offered as part of the technology transfer process by many of these technology stations. At least six of these technology stations employ rapid prototyping platforms. In many cases, these Technology Stations also serve as technology demonstration centres, where potential buyers of RP technologies can access and evaluate the impact of specific technologies on their day-to-day business, prior to making financial commitments.

Some other government-led activities that led to further opportunities for RP research and development were the National Research and Development Strategy[5], the Advanced Manufacturing Technology Strategy (AMTS) from the National Advisory Council on Innovation[6] and the South African Tooling Industry Support Initiative[7].

RAPDASA and its annual conference

No discussion of RP/AM establishment in South Africa would be complete without reference to RAPDASA (the Rapid Product Development Association of South Africa). RAPDASA was formed in 1999 to act as the representative organization for those involved in the RP and wider rapid product development (RPD) community within South Africa. It has members from both research organizations and industrial companies and, since its inception, the mission has been that the organizing committee be composed in a manner that reflects this diversity. RAPDASA is involved in a range of activities that are all aimed at encouraging the further development and use of RPD technologies. Most important of these is the annual conference that started in 2000. The conference offers a platform for researchers and practitioners to share their knowledge and experience with others. It has benefitted from international participation from the start, which allowed attendees the luxury of also discovering what is happening in the international RPD world.

The conference furthermore has become a hub for networking opportunities, and many national and international collaborative projects and partnerships have in fact been grown from the various RAPDASA conferences. A further consequence of this international participation is that the conference has become an international information source for RP developments in South Africa.

RAPDASA is a member of GARPA (Global Alliance of RP Associations) and first hosted a GARPA international summit at the conference held in 2001, and then again in 2004. During a process that started in 2009 and which was concluded in 2010, RAPDASA successfully nominated Dr Willie du Preez, founder member of RAPDASA, as one of the first GARPA International Fellows. The role that RAPDASA has undertaken has contributed much to the progress of RP and manufacturing in South Africa. A particular strength is that its remit is not limited to RP and so the relationships with other RPD technologies and the product development process feature widely in its activities.

Results shown as part of the development of the SA AM landscape

Through dedicated attempts to expose RP technology to industry and academia, steady growth started to take place in terms of the overall number of machines, but still with limited numbers in private companies. During 2003, Terry Wohlers forecasted that it would be the year for 3D printers[8]. This proved to be particularly true for South Africa, as local RP availability started to follow a very positive growth trend. In 2003, 35% of local installed systems were 3D printers, with a significant number of new orders placed for 3D printers. This trend towards 3D printers continued to develop and led to a significant increase in the growth of SA's RP machine base, and with industry ownership starting to overtake university/research institution ownership. A total of 12 machines were sold in 2004, 27 in 2005 and 26 in 2006. This suddenly took the number of machines from 17 in 2003, to 90 in 2006 and the positive growth is still continuing. An estimated 22 machines were sold in 2007, 22 in 2008, and 9 in 2009 (the downturn was in line with the worldwide downturn in economical activities). A very positive upturn however, is currently being experienced, also due to the availability of lower cost machines. Current sales trends may take the cumulative number of machines for 2010 beyond 200. Figure 1 shows the South African RP/AM development curve between 1991 and 2010.

As can be seen from the graph shown in Figure 1, it is evident that RP/AM found a solid basis in South Africa. The author is of the opinion that technology transfer and dissemination activities, in which RAPDASA played a significant awareness and educational role, helped to position RP/AM in the country.

An analysis of the data supporting the numbers shown in Figure 1 (see Figure 2) makes a significant contribution in terms of understanding the SA AM landscape. Although the 3D printing numbers seem to totally outscore the high end machines (91% of available machines fall in the 3D printing category, whereas only 9% of available machines fall within the high end category), it should be understood that the value of the investment made in the latter currently represents 48% of the cumulative investment made in RP/AM technologies. Another important statistic is that currently 91% of the available 3D printing machines are in industry, with 81% of the high end machines in research institutions.

In an article by Campbell, De Beer and Pei (in press)[9], a similar analysis was done up to 2008. It shows that although all the major universities in SA have a strong presence in manufacturing-related research, approximately 48% of all SA universities now have AM facilities in house. Furthermore, it shows that AM research, however, is still only pursued by some 39%, whereas the other 9% have AM facilities that support other manufacturing-related research.

Research contribution through the RAPDASA community

As reported by the author and co-worker in a previous report[1], even though RP came relatively late to RSA, much knowledge was already available (through international case studies, vendor's literature, etc.) on what it could be used for. The SA research base quickly responded by identifying

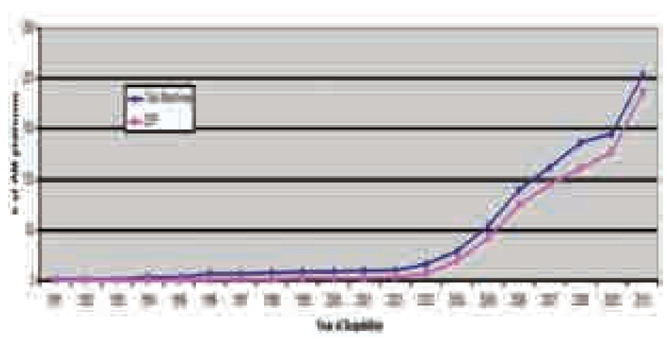

Figure 1—SA AM Evolution: 1991–2010

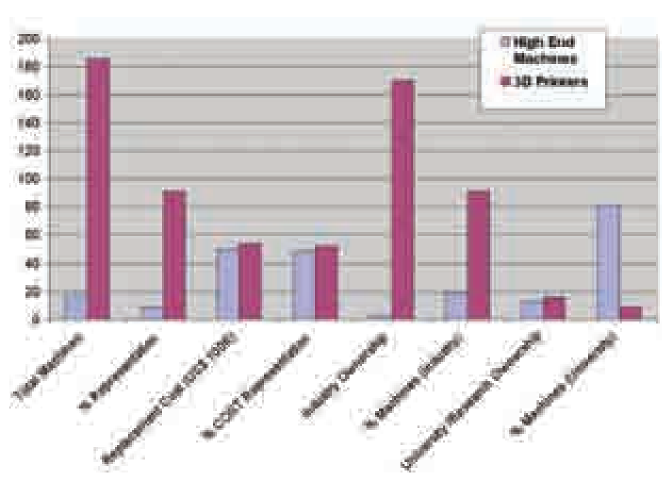

Figure 2—Analysis of the SA AM landscape

relevant RP application areas. To some extent, a bit of a drawback was the fact that the RP base in SA had to serve a very wide and diverse range of application areas, such as automotive components, anthropological studies, jewellery masters, medical visualization, industrial design models, architectural models, low-volume tooling and rapid manufacturing of functional parts. The above-mentioned also had an impact on funding/funding models. Interestingly, the majority of initial acquisitions were made through industrial investments and THRIP or other government agency funding supplementation. As applications were proven, more platforms were purchased with university and NRF funding respectively, and later by relevant industries. In the case of CUT, all of the EOS machines were acquired through industrial intervention, although industry did not contribute financially to all of the acquisitions. In some cases, (as also with the Vaal University of Technology (VUT) recently), a clear case could be made to develop specific applications needed by industry, where the latter would be prepared to 'buy' the end product (such as direct-manufactured parts through a direct digital manufacturing (DDM) application mode).

As such, an opportunity that emerged from this initial weakness, was that the very same (wide) application areas helped to raise awareness of RP within the local industry through publishing case studies, exhibiting at trade shows, offering subsidised trials to companies, organizing workshops, etc. Due to the above-mentioned, experience in using RP was gained quickly and the potential economic developmental role of RP within South Africa was clearly defined.

For South African research and development, the wide range of applications also meant staking a claim in the international research environment. A host of papers in international and local popular/technical/industry journals covering various topics are creating a base for further research and development, but also makes RP/AM results available for the SA industrial and academic communities.

As an example, the CUT research group's results have been reported extensively by De Beer, Campbell, Booysen, Truscott, and Barnard together with postgraduate students. Papers describing successful applications are: AM development in SA[1,9]; design orientated support[10–12]; AM process support[13]; direct digital manufacture[14]; innovative medical product development[15–18]; innovative application areas[19,20]; and rapid tooling[21].

From the University of Stellenbosch, Dimitrov and co-workers have published extensively on overviews and analysis of 3D printing, its applications, accuracy issues and process chains[22–26]; tooling for injection moulding[27,28]; sand casting applications[29]; reverse engineering (RE) development[30], and innovative applications to build large prototypes[31].

Du Preez and co-workers at the CSIR started with a series of short courses under the CSIR-managed National Product Development Centre (NPDC) in 2000. In hindsight, these were to an extent way ahead of their time. The majority of topics covered in short courses such as: the development of processes for the processing of materials to manufacture components, through using simulation and modelling to design and optimize forming processes and tools; the application and adaptation of concurrent engineering for different development situations, etc. not only helped to create an educational and 'retraining' basis for both academia and industry, but are actually being applied in industry, some 10 years later. Furthermore, Du Preez's group supplemented the short courses with relevant research in, amongst others, modelling techniques, as well as complete product development and commercialization case studies[32,33]. Under the NPDC and CSIR banner, various RP/AM awareness articles have been published[34,35], and[36]. A very important part of Du Preez's contribution through the CSIR goes beyond publishing and creating awareness. Initiatives such as the research conducted by a community like RAPDASA, needs funding opportunities. A major contribution to some of the research referenced was made possible through amongst others the Light Metals Development Network (LMDN), as well as recently the Titanium Centre of Competence (TiCoC)[37]. These funds are over and above, or supplementary to, the conventional NRF and THRIP funds, mentioned earlier.

RAPDASA has never been an exclusive group or organization, and as participation grew, so did research involvement and outputs. Good examples from more recent ('Recent' implies members/research communities joined after the initial RAPDASA launch, and which has been a continuing process since 2001) participants are research work done under Prof Oscar Philander's research group (including role players such as Erfort and Riddles) at Cape Peninsula University of Technology (CPUT), which focuses on modelling techniques and nano-materials; the Institute for Advanced Tooling (IAT) at Tshwane University of Technology (TUT) under Bob Bond that focuses on product development and tooling; and the Vaal University of Technology (VUT) Innovative Product Development Research Centre, The Iscor Innovation Centre and Technology Station under Jan Jooste and La Grange, which focuses on Product Development Innovation, Technology Transfer and Commercialization. The most recent contributions came from Nyembwe's group at the University of Johannesburg (UJ) that focuses on product development for metal casting and associated modeling techniques.

Conclusion

From the SA AM roadmap and analysis discussed, it is clear that RP/AM has developed into an established technology platform in South Africa. The research case studies and publications referenced, all deal with SA RP/AM activities, and serve to show that a complete value chain was developed—using various forms of government support to enter into successful triple helix models. The value chain as mentioned, incorporates a well-balanced mix of basic and applied research, and as such also tackles a long-standing SA debate on the nature of research to be conducted at certain institutions. The successful model applied here was also a function of multi-, inter- and trans-disciplinary research (MIT) and lead to well established centres of excellence spread over the country, which are all in excellent contact with industry to support technology transfer and diffusion, but also act as technology demonstration centres. What is very important, is the fact that, finally, the platforms created did not stay exclusively within the universities and science councils, but through involvement with industry, also moved into industry. Through RAPDASA's intervention and support, industry members also became part of the research community, and contributed to the SA RP/AM community's research outputs, both in terms of conference/journal papers, as well as in terms of formal conducted research projects. Furthermore, the RAPDASA activities brought continuous international participation into the specific community of practice. As highlighted in the paper, this achievement would probably never have been possible without a non-profit interest group such as RAPDASA, and over and above giving credit to government and its agencies and funding institutions such as the CSIR, NRF, THRIP, TIA, etc., the group of individuals that kept the organization going for just more than a decade have probably been instrumental in one of the most recent industrial evolutions on the African content. Due to the nature of the technology platforms used, the impact went further than only manufacturing, and especially in terms of CAD, CAM, analysis and modelling tools and paradigms, such as concurrent engineering, quality function deployment, etc., major support was given to the SA industry and academia.

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