Recent Developments in the Field of Rapid Prototyping: An Overview

Umesh Sable and Prashant T. Borlepwar

Abstract New technologies are developed every day in the field of manufacturing for better product accuracy, better quality, improved tolerances, etc. Subtractive manufacturing is gradually becoming obsolete due to new non-conventional methods being introduced. Rapid prototyping is one such method in which we can obtain physical models rapidly. Various researches have been done in this field ever since it was discovered back in the late 1900s. This paper tries to overview some of those recent advances in the field of rapid prototyping.

Keywords Rapid prototyping · Additive manufacturing

1 Introduction

Rapid prototyping originates from two main techniques viz. topography and photosculpture. It was developed in the nineteenth century. The first methods were developed in the late 1980s. Earlier the process used to be laborious. Hideo Kodama from Japan and Charles Hull from the USA were the first to introduce this technology. Rapid prototyping is the technology that produces physical models directly from a CAD model. The various technologies of rapid prototyping are stereolithography apparatus (SLA), selective laser sintering (SLS), laminated object manufacturing (LMO), inkjet-based systems and 3-D printing.

Subtractive manufacturing methods are not capable of making complex shapes because of the fact that the tool allowance needs to be considered for manufacturing. But for more complex shapes and intricate parts, additive manufacturing methods are

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mainly used nowadays. Though, large-scale manufacturing may not be quite possible in AM. The prototypes of exact size, shape or volume can be produced which also aid in testing without having to waste precious materials. Thus, AM is quite trendy and has become a very important part of rapid prototyping in today's world.

The recent developments in RP prove that researchers have favouritized this topic which could reinvent manufacturing on a whole new level and also compel us to scrap the age-old and conventional manufacturing techniques. Various RP technologies have been integrated with computer-based systems so as to automize manufacturing. Thus, also in some non-engineering fields, like biomedical, tissue production, orthopaedics, dentistry, etc., RP has been a revolution. This study intends to review the various developments in the field of RP.

2 Literature Review

Dharipalli et al. [1] have classified and compared rapid prototyping technologies. Rather, the classification was done into three categories:

(1) Solid-based rapid prototyping
(2) Liquid-based prototyping
(3) Powder-based prototyping.

The comparison was studied by Dharipalli et al. on the basis of process parameters like raster width, path speed, slice height and tip dimension.

Alves et al. [2] have given the reasons for 3-D shape recovery and also stated that the shape can be emulated by virtual modelling which can be done by computer-aided technologies like rapid prototyping. A BIOCAD system has been used employing algorithms for three-dimensional shape recovery of digital images. The ciliary calibration algorithm will emulate the human vision.

Monzon et al. [3] have strived for achievement of an innovative mould design mainly with the help of electroforming technology. A mandrel (rapid prototyped) has been achieved. Slow production rate of rotational moulding is a disadvantage but can be converted into an advantage. Nickel chloride can be used to increase the conductivity. The primary advantage is that the geometry of the mould can be changed in a few minutes for another design (Figs. 1 and 2).

Sanna Peltola et al. [4] speak of 3-D scaffolds manufacturing using RP. stereolithography process can be used to produce these scaffolds. Mainly, RP helps in satisfying individual needs, elevated accuracy and leverage to control the pore size. However, some cons definitely raise eyebrows like weak bonds between powder particles, roughened surface, post-processing and restrictions on material selection (Figs. 3 and 4).

Yarlagadda et al. [5] designed, developed and evaluated the performance of mould inserts using powder sintering process where materials like maraging steel powder, sintering acid and other binder materials were used. The testing was done using

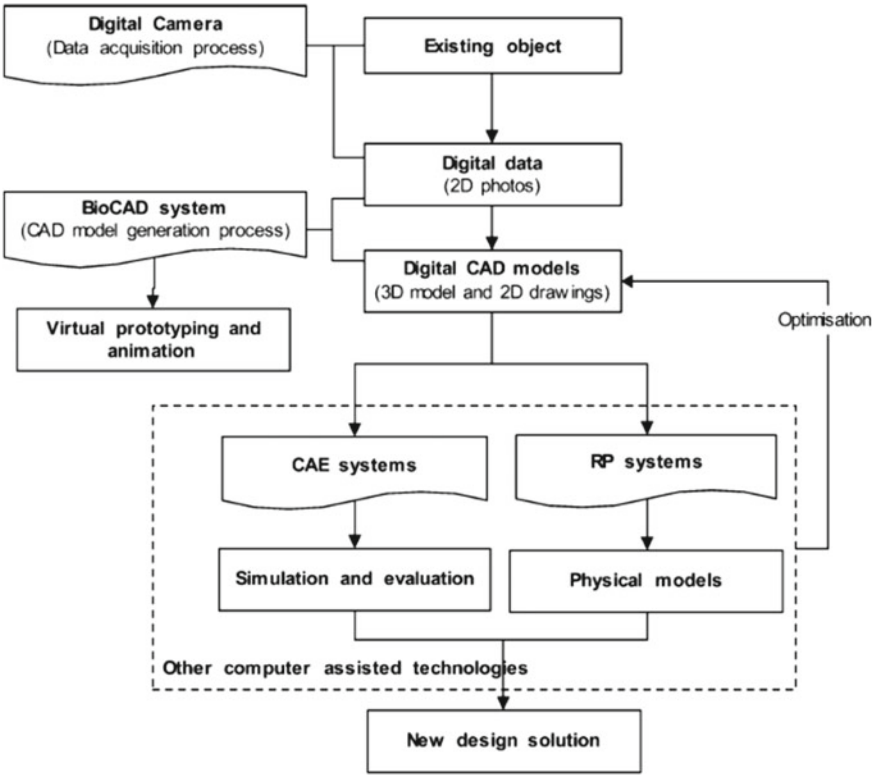

Fig. 1 Representation of a Bio-CAD system [2]

intelligent manufacturing systems for minor changes. IMS specimens were developed. A prototype for the development of IMS stereolithography core model was established. The tolerances of CAD model and functional IMS parts were compared. The other parameters like distortion and shrinkage volumes were also compared and were found to be satisfactory and acceptable. The new IMS specimen showed density more than 95% (Fig. 5).

Laeng et al. [6] speak of laser metal forming process which can produce models directly from a CAD file without the requirement of an intermediate step. The software for rapid metal forming process includes modelling of a 3-D CAD model in standard STL format, generation of layer representation of object and creation of CNC codes for the tool path. Here, a hardware system along with a software system and process parameters were determined (Fig. 6).

Costa et al. [7] studied the degradation of polymer resin through time. The specimens were tested at intervals of 0, 30, 60, 90 and 120 days. Tests like tensile strength test and experimental cantilever beam test were performed. Rapid and virtual prototyping were simultaneously studied. The material used was Veroblue 840. The tensile strain tests were performed on a universal testing machine EMIC DL2000.

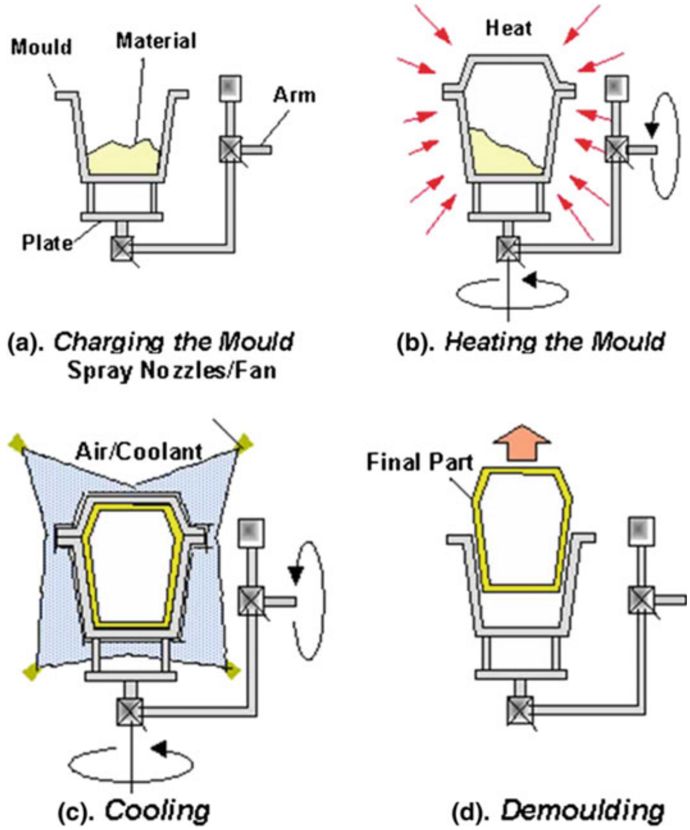

Fig. 2 Rotational moulding [3]

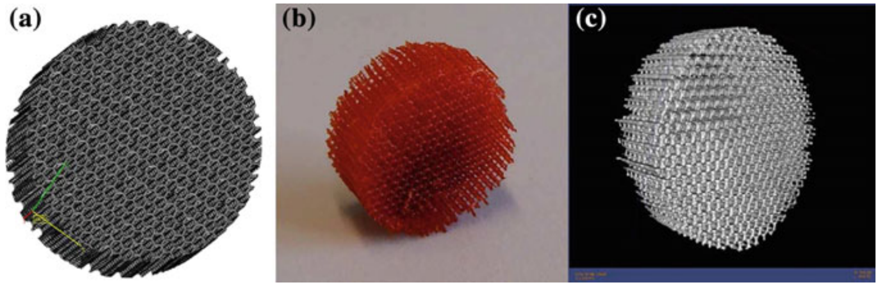

Fig. 3 Example of a scaffold fabricated using stereolithography (SLA). **a** Computer-aided design (CAD) image of the structure. **b** Completed SLA-fabricated scaffold with very regular pore size distribution. **c** Micro-computerized tomography (microCT) image of the scaffold [4]

The value of strength for RP material was observed very near to that proposed by the manufacturer.

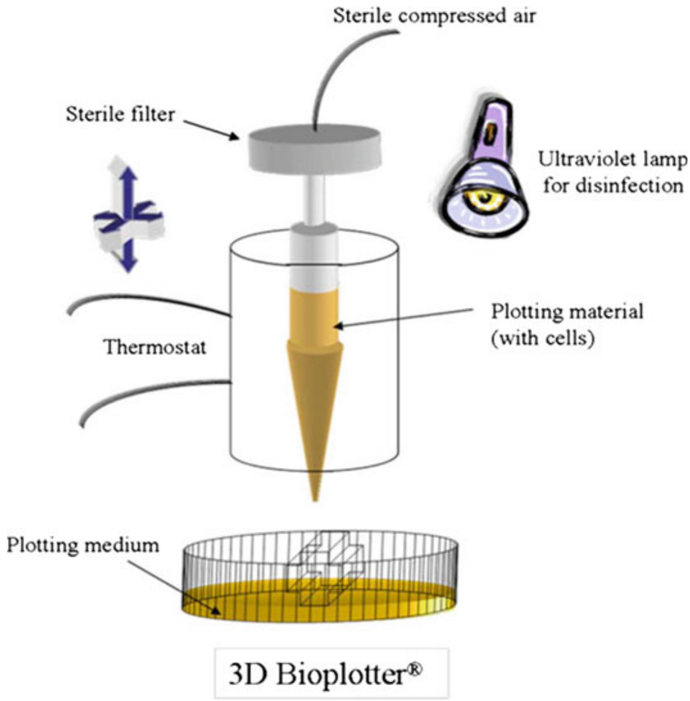

Fig. 4 3-D bioplotter [4]

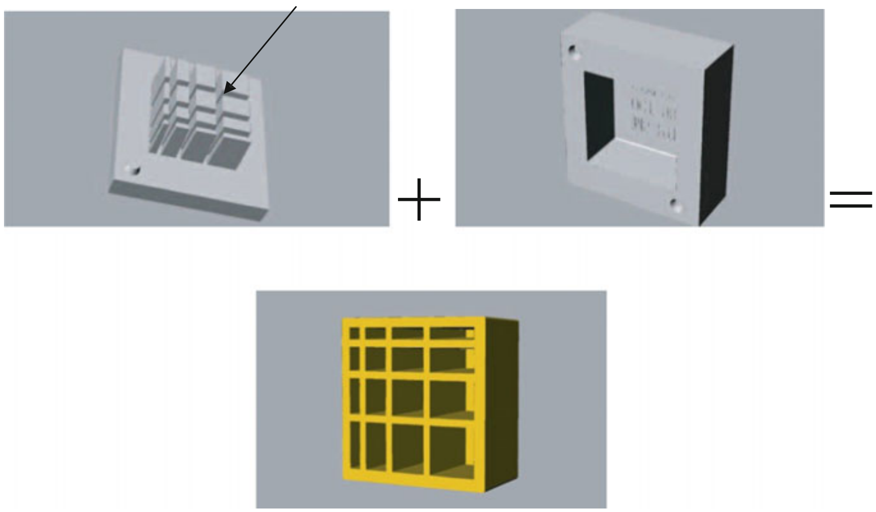

Fig. 5 Steps involved in IMS part making [5]

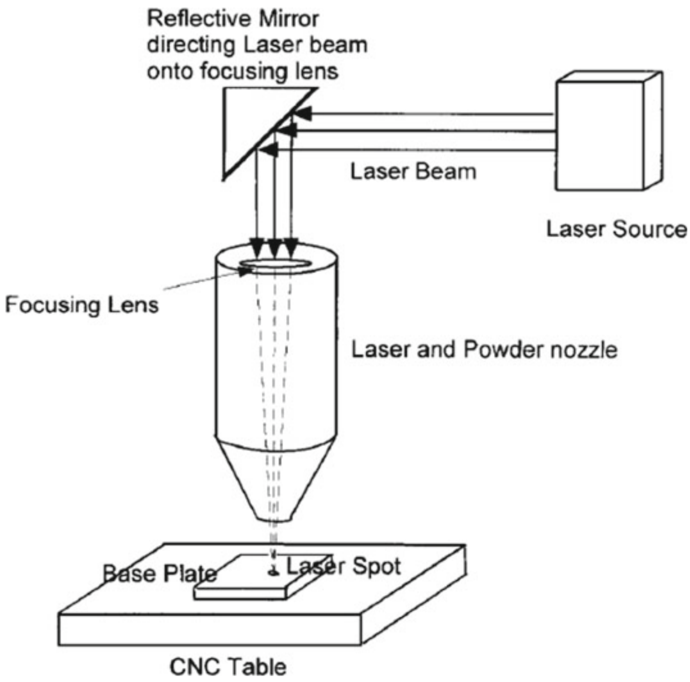

Fig. 6 Laser metal forming process [6]

Chaudhary et al. [8] support the RP of high-performance sportswear which plays a rather vital role in deciding various factors like the durability and strength of sportswear. As sports mainly depends on timing, the proper and optimized design of sports accessories play an important role in helping an athlete to win. The process involves 2-D scanning of an athlete's body. Aerodynamic, thermodynamic and hydrodynamic properties are specially taken care of in designing of sportswear. The anthropometric dimensions are used for RP. For the making of a ski jumper, a scanner called NX-16 was used. GRAPHIS software was used for designing the building blocks like zippers and buttons. Wehr et al. [9] have tried to build an experimental set-up by integrating a rolling mill and piezoelectric actuator. A real-time system DS1006 is used as central component. The dynamics of a spindle drive and piezoelectric actuator has to be studied. Thus, a set-up of roll milling and rapid tooling was clubbed and was found to work desirably (Fig. 7).

Kriesi et al. [10] have discussed about a desktop injection moulding machine on which prototypes can be made and tested. The testing was done with the help of a three-point bending test. Some plastic components were prototyped, and four Fs were addressed. Due to some administrative errors, a desktop moulding machine had to be developed. 3-D printers and bench CNC mill were used at TrollLABS. The strength was monitored by a three-point bending test. Firstly, small-sized moulds were produced for surety of strength and then large- and complex-sized moulds

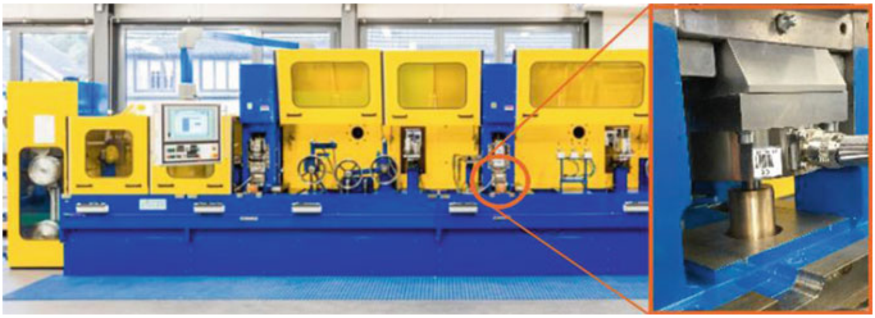

Fig. 7 Integration of rolling mill and piezoelectric actuator [9]

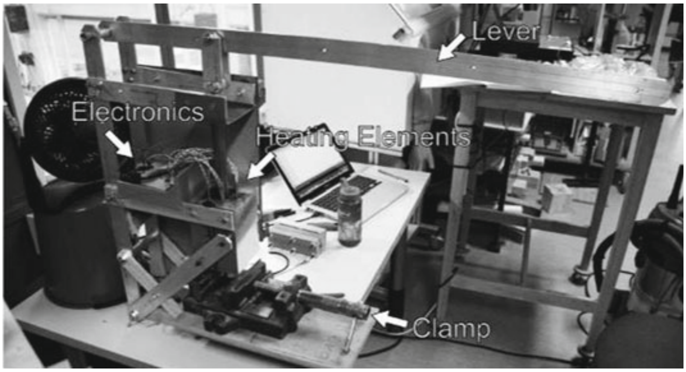

Fig. 8 Desktop injection moulding machine [10]

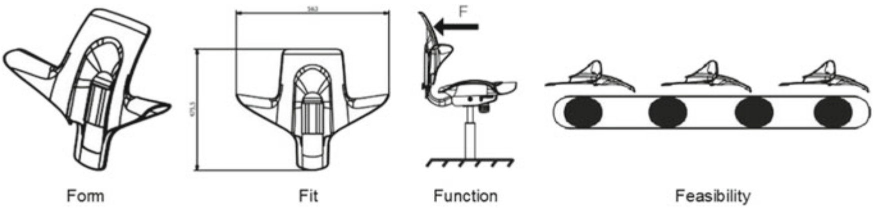

Fig. 9 The four Fs addressed [10]

were produced. It was observed that the general surface finish of the manufactured part was excellent and a completely intact mould was obtained (Figs. 8 and 9).

Roussi et al. [11] have given the comparative advantages and disadvantages of RP technologies (Table 1).

Sarange et al. [12] have put forth a new idea of biomaterial fabrication which has made it possible to produce scaffolds with mechanical and structural properties similar to bone and teeth. But the problem of balling of nanoparticles was encountered (Fig. 10).

Table 1 Roussi et al. [11] comparison of the basic RP systems

Technology	Advantages	Disadvantages
SLA	Excellent quality surface, complex geometry, good accuracy	Support structures, parts deform easily, vapours are harmful
SLS	No need for further sintering, no need of supports, high range of materials	The surfaces are rough and porous, Long-time and considerable energy, patterns for precision castings requires, additional processing (infiltration), significant distortions
LOM	Details can be further processed (polished, drilled), ability to manufacture large parts quickly and cheaply	Thin walls have low strength, readily absorb moisture, separation of the parts is difficult
FDM	A wide range of polymeric materials available, machines are easily adjusted and used in an office environment	Support structures, low strength in the vertical direction, process is slow, rough 'textured' outer surface, problematic for tool manufacture
MJM	Suitable for an office environment, build time is short	The supports are removed and leave traces, which limits their use for casting models, strength is low
3D-P	Short deadlines and cheap raw materials, no supporting structures, complex geometry	Delicate details not possible to produce, infiltration is necessary, rough surface

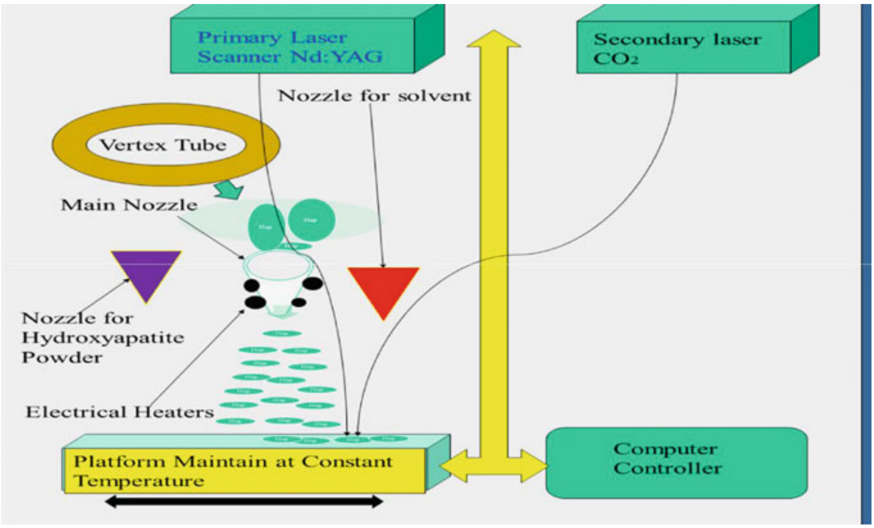

Fig. 10 Experimental set-up given by Sarange et al. [12]

3 Conclusion

Bio-CAD system developed is better for more accuracy in producing the object. The computer-aided process planning (CAPP) will definitely reduce human efforts in RP. The scaffold produced by bioplotter using SLA is definitely a huge leverage in satisfying individual needs. The development of KBRPS ensures faster generation of prototypes at a lower cost. IMS parts prove to be winners with respect to parameters like distortion, shrinkage volume and density. Laser metal forming process can surely eliminate the intermediate step. Also, high-performance sportswear can surely be manufactured using rapid prototyping. We can now emphasize on more research in RP technologies which may stand out. DLRP process can also be thought about because of its flexibility.

References

1. Dharipalli Hyndhavi, S. Bhanu Murthy, Rapid Prototyping Technology- Classification and Comparison, IRJET, Vol. 4, June 2017, 3107–3111
2. Nuno M. F. Alves & Paulo J. S. Bartolo, Automatic 3d shape recovery for Rapid Prototyping, Vol. 3, No 2, June 2008, 123–137
3. Mario Monzon, Maria D. Marrero, Antonio Benitez, Pedro Hernandez & M Kearns, Rapid Prototyping applied to a new development in mould for rotational moulding, Virtual and Physical Prototyping, Vol 2, No 4, Dec 2007, 209–216
4. SannaPeltola, Ferry P. W. Melchels, Dirk W. Grijpma & Minna Kellomaki, A review of rapid prototyping techniques for tissue engineering purposes, Annals of Medicine. 2008; 40: 268–280
5. Prasad K. D. V. Yarlagadda & Lee Kien Wee, Design, Development & evaluation of 3D mold inserts using a rapid prototyping technique & powder sintering process, International Journal of Production Research, Vol 44, No 5, March 2006, 919–935
6. J Laeng, J. G. Stewart & F. W. Liou, Laser Metal forming processes for rapid prototyping—A review, INT. J. PROD. RES, 2000, Vol 38, No 16, 3973–3996
7. Carlos Costa, Paulo Roberto Linzmaier, Felipe M. Pasquali, Rapid Prototyping Material Degradation: A study of Mechanical Properties, IFAC, Management & Control of Production & Logistics, 350–355
8. Harun Chaudhary, FirozAlam, David Mainwaring, Jordi Beneyeto- Ferre, Margaret Tate, Rapid Prototyping of high performance sportswear, Procedia Engineering 34 (2012) 38–43
9. Matthias Wehr, Sven Stockert, Dirk Abel, Gerhard Hert, Rapid control prototyping in cold rolling using piezoelectric actuators, IFAC-Papers Online 49-31 (2016) 55–60
10. Carlo Kriesi, Oystein Bjelland, Martin Steinert, Fast and iterative prototyping for injection moulding- A case study of rapidly prototyping, Procedia Manufacturing 21 (2018) 205–212
11. Roussi Minev, Ekaterin Minev, Technologies for rapid prototyping- basic Concepts, quality issues and modern trends, Scripta Scientifica Medicinae Dentalis, vol. 2, No 1, 2016, pp. 12–22
12. Sarange Shreepad, Warkhedkar Ravi, New Revolutionary Ideas of Material Processing-A Path to Biomaterial Fabrication By Rapid Prototyping, Procedia-Social and Behavioural Sciences 195 (2015) 2761–2768
13. https://en.m.wikipedia.org/wiki/Rapid_prototyping