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BEST FEATURE IN IT JOURNALISM

Rajat Ubhaykar

Rajat Ubhaykar won the PoleStar Award for his article, 'The Emerging World Of 3D Printing', which appeared in Outlook Business

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Before joining Outlook Business, he worked as a business analytics associate with ZS Associates, a multinational management consultancy firm. He has a B.Tech in Electrical Engineering from IIT Kanpur and a Post Graduate Diploma in Journalism from Asian College of Journalism, Chennai. He is also an omnivorous reader and finishes one book per week religiously. His interests span a wide variety of subjects including writing, literature, history, business, travel, films, music, art, geopolitics, science, and chess.

The Emerging World Of 3D Printing

3D printing ecosystem is quietly taking shape in India with corporates leveraging the technology

Rajat Ubhaykar

Talking shop: An array of 3D printers at Imaginarium, a Mumbai-based service bureau catering to a variety of industries

The city of Mumbai hides in its crevices little secrets that wouldn't be apparent to the naked eye of a passerby. Who would have thought that the dreary new passport office in the industrial hub of Marol, in Andheri, houses a tastefully designed modernistic office? We are standing in Imaginarium, the 'self-proclaimed evangelists of 3D printing in India', as their technical and operations head, Guruprasad Rao, puts it. The office decor is heavily influenced by cubism: sharp angular designs in tune with their futuristic line of work and imparting the illusion that all office furniture and accessories have been 3D printed en masse.

Imaginarium is owned by H Dipak, a company which claims to be the world's largest manufacturer and distributor of princess cut diamonds. Imaginarium counts among its press-friendly products the Filmfare trophy — of which it delivered 42 copies costing ₹12,000 each, after making desired design modifications in the form of a lotus pedestal — as well as the Mumbai Press Club Red Ink Award for journalists.

When we step into their swanky workshop, we are told they own 17 3D printers spanning all categories that can print in 24 materials along with a 3D scanner, indeed making it a 'one-stop shop'. As we walk down the corridor, to our left is a temperature- and light-controlled chamber housing the relatively noiseless 3D printers, refrigerator-like machines with a transparent front-panel through which we see layer being deposited upon layer, creating the desired object.

All the machines are remotely controlled by the technical staff seated on our right. The 200-strong staff and the machines are largely segregated from each other. An army of 10-15 workers armed with sandpaper is furiously scrubbing 3D printed mobile phone covers, making them neatly uniform and ready to be sold off as finished products. It turns out that the company is quite wary of intellectual property violations and is reluctant to allow us to photograph the premises as we wish.

In another chamber, artisans with micro-motor powered polishers are polishing jewellery made by pouring molten metal into 3D printed wax-like resin moulds. One of the workers is from Madhubani, Bihar, and has been working as an artisan since the last eight years.

A new grammar in design is coming up, and the new grammar is no grammar — Guruprasad Rao, Head, Technology and Operations, Imaginarium

Contrary to stereotypical perceptions of jewellers being an antiquated lot, the industry has been one of the earliest adopters of 3D printing technology. According to Rao, most young sons of family jewellers are made to learn computer-aided design (CAD) and Tanishq, the Tata-owned jewellery major, started investing in the technology in the mid-2000s.

More than half of Imaginarium's revenue is earned from the jewellery industry, the rest is derived from 'engineering', an umbrella term for around 40 different verticals that the company has a reasonable presence in. On the application front, 30% revenues are from rapid prototyping and 70% from end-use parts such as jewellery and automobile parts such as headlights and tail lights.

Rao, previously a professor of design, calls the company 'design-enablers', meaning they help execute the design that jewellers bring to them, using their team of CAD designers. According to him, a new grammar in design is coming up and the 'new grammar is no grammar'. Ankit Mehta, owner of Imaginarium, while refusing to divulge numbers, says, "Revenue has tripled in the last five years and the company is profitable." The plant runs at a capacity of 60-70%, according to Rao.

Imaginarium isn't the only one to adopt this technology and provide it as a service. Kolkata-based Marco Polo was one of the first service bureaus to set up shop. "We started in 1999. Our first customers were appliance makers such as LG and Whirlpool, who used our machines for the development of refrigerators and washing machines.

Shine on: An artisan polishes jewellery made using 3D printed resin moulds

A NEW DIMENSION

The future is on its way, one disruptive step at a time. The fevered imagination of science fiction novelists is already being translated into hard reality in so many ways. One such futuristic innovation is additive manufacturing (AM): the rendering of 3D software models into real-world replicas in a host of different materials ranging from ceramics and plastics to glass and metal. 3D printing finds widespread application in various industries such as aerospace, automobiles, jewellery, medical devices and space technology. According to the Wohlers Report 2014, the most authoritative annual report on the 3D printing industry, revenues from 3D printing are expected to quadruple from $3.07 billion in 2013 to $12.8 billion in 2018 and is expected to exceed $21 billion by 2020. However, a major constraint of the technology is the size of objects and the speed at which they are created.

At that point of time, even new product development was at a nascent stage in India. When the product development business picked up, automobile companies started using it and our auto business grew quite a bit in 2010-2012. Right now, it's mostly auto and auto ancillaries who're our clients," says Ankit Kumar, owner and founder of Marco Polo.

Marco Polo has four 3D printers spanning all dominant technologies, SLA, SLS and FDM, and employs around 60-65 people. In addition, Marco Polo has subtractive technologies such as computer numerical control (CNC) machines and vacuum casting. Pricing is usually done on an ad-hoc basis. "We take into account the material costs, manpower costs, the load factor of the machine, the overhead costs such as rent and power, and arrive at a number. Material costs account for 25-30% of the total cost," says Mehta.

Imaginarium has a pricing team of five people that designs algorithms to determine the cost of 3D printing a part, which varies from product to product. Mehta admits that in the absence of market forces, quotes can vary wildly, but customers eventually gravitate towards reliable service providers.

To the fore

The recent buzz around 3D printing doesn't mean the technology is recent. In fact, in technology terms, it's quite a dinosaur, having been around since 1986 when Chuck Hull, founder of 3D Systems, patented his stereolithography (SLA) technology. Yes, that is how long it takes for a wishful idea to turn into an everyday reality. In fact, it wasn't even called 3D printing then.

Nomenclature has evolved over the years from rapid prototyping to 3D printing to the now-popular term of additive manufacturing (AM). Over the years, the technology, too, has evolved and various other multinationals came up with patented proprietary technology for 3D printing: Stratasys patented its fused deposition modelling (FDM) technology and EOS patented its selective laser sintering (SLS) technology. All these technologies have their own optimal application.

Meanwhile, Hewlett Packard (HP) has recently announced plans to introduce its own commercial 3D printer in 2016, something which will most likely shake up the industry and propel the industry into commercial viability, given HP's size and clout. Presently, given the prohibitive pricing of several of these patented 3D printers, only corporations have been able to avail this technology, primarily in the aerospace, automotive, medical devices and jewellery industries.

The stock prices of 3D printing firms such as 3D Systems and Stratasys have fallen in the last few months, with Stratasys posting a loss for the first time in the last 10 years in 2013. However, technology analysts remain upbeat about the industry's prospects. Gartner, in a report by analyst Janessa Rivera, places 3D printing in the top 10 strategic technology trends for 2015, noting, "3D printing will reach a tipping point over the next three years as the market for relatively low-cost 3D printing devices continues to grow rapidly and industrial use expands significantly. New industrial, biomedical and consumer applications will continue to demonstrate that 3D printing is a viable and cost-effective means to reduce costs through improved designs, streamlined prototyping and short-run manufacturing."

According to Gartner's latest forecast, "Worldwide shipments of 3D printers will reach 217,350 units in 2015, up from 108,151 in 2014. 3D printer shipments will more than double every year between 2015 and 2018, by which time worldwide shipments are forecast to reach more than 2.3 million." Pete Basiliere, Research Vice President at Gartner, says in a press release, "As radical as the forecast numbers may seem, bear in mind that even the 2.3 million shipments that we forecast will be sold in 2018 are a small fraction of the total potential market of consumers, businesses and government organisations worldwide."

Corporate embrace

Industry, where time means money, has been nimble in adopting this potentially disruptive technology and has been reaping benefits. Companies in the aerospace and automobile sectors are using it to streamline prototyping process while jewellery and medical device companies are using it for direct manufacturing of final products (see: Making its mark).

3D printing enables us to optimise cost, quality and performance before the launch — Ajay Purohit, Technical Chief, Rapid Prototyping, Tata Motors

For most engineers, the first part they make using a 3D printer remains an experience of a lifetime. For Ajay Purohit, his first experience with a 3D printer at Tata Motors, while memorable, certainly wasn't auspicious. "I will never forget that first job. It was a piece of a car's bumper, measuring around 50cm x 50 cm. We made the part and excitedly called all our top bosses to see it.

By mistake, the piece, which was made of a brittle resin, slipped from the person's hand and shattered into fine pieces in front of everybody. It came very much as a shock to us after looking at the part resting in the machine for three-four days," he says. That was around 10 years ago — the situation today is very different.

Tata Motors, one of India's largest automobile companies which manufactures both cars and heavy vehicles, bought its first machine in 2003. Purohit, Technical Chief, Rapid Prototype and Craftsmanship Tools, says, "3D printing has radically changed the way we build a prototype. The prototyping process time has reduced from two months to two days. We are able to launch a car much faster in the market and we are able to come up with faster prototypes of better quality."

Making its mark

Automotive, aerospace and medical industries drive the bulk of innovation in 3D printing

Source: Deloitte report on additive manufacturing, October 2014

Earlier, Purohit says that they would sometimes launch products in the market knowing there were improvements that could have been made in the design. Now there's no scope for such regret. 3D printing enables them to make design improvements in the software model so the management, too, can see a prototype model before giving it to the vendor for mass manufacturing. "Every designer wants to optimise his design in terms of cost, quality and performance before launching it in the market. 3D printing or additive manufacturing enables us to do just that," says Purohit.

Purohit makes the observation that time is extremely valuable in the field of new product development, so integrating 3D printing into their prototyping process can lend companies a crucial competitive edge. "In the real world, if you launch a car late by six months, you are making a notional loss of crores. We have to launch new products as early as possible otherwise the opportunity is lost. Your design becomes obsolete," he says.

Tata Motors is currently using 3D printing to manufacture cosmetic trim parts such as dashboards, as well as some major underhood (engine) parts, especially those which require a lot of optimisation and multiple iterations before they get it right.

"For instance, the geometry of the intake manifold which supplies fuel and air mixture to the cylinders is critical in optimising the performance of the engine. We require multiple iterations to optimise this geometry," says Purohit.

At present, Tata Motors possesses four direct 3D printing machines, two SLA machines, one SLS machine and one low cost 3D printer. In 2009, the company acquired a machine that enabled 3D printing of large parts. This machine can make big parts such as a car dashboard in one piece. "What happens is that if you build a part in multiple pieces, a lot of time is wasted in joining them. Also, joining parts defeats the purpose of automation since manual error creeps in," says Purohit.

Currently, Tata Motors has no plans to use 3D printing for direct manufacturing since it is not cost-efficient to use the technology for mass production. "Also, across the world, all parts in vehicles needs homologation from regulatory agencies such as the Automotive Research Association of India (ARAI). At present, 3D printing materials and processes are not standardised and have to go through rigorous testing to be used on production cars. Also, performance over a long duration and reliability is still not established for most of the 3D printed material.

With this are issues of high cost of materials, longer manufacturing times for mass production and standardisation and reliability conformance. ARAI needs to validate the materials used and additive manufacturing of final vehicle parts is not possible right now," says Purohit. However, Tata Motors is planning to invest in direct metal rapid prototyping and multi-material printers in the future to make good quality parts.

On the assembly line

Another company to bite into the 3D-printing pie is the General Electric that has invested extensively in this technology. According to a Deloitte report on 3D printing, "GE plans to mass-produce 25,000 LEAP engine nozzles [the first jet engine designed using 19 3D-printed fuel nozzles that are five times more durable and 25% lighter than previous models] with additive manufacturing with already $22 billion in commitments."

3D printing makes it possible to build a part with rigid and soft materials on either end — Sanjay Anikhindi, Head, 3D Printing Lab, GE India

GE's multidisciplinary R&D centre based in Bengaluru, acquired its first 3D printers around two years ago. At present, it has around six 3D printers divided between two technologies: FDM which enables them to build parts of a certain quality, shape and speed, and polyjet, which allows them to build soft and transparent parts.

Verticals such as power and water, aviation and oil and gas have large programmes dedicated to making certain parts using the 3D printing process. "We have a variety of plastic printers which cater to the needs of designers. We also have a metal printer which is undergoing installation. Within the next two months, it will be running," says Sanjay Anikhindi, Head of the 3D Printing Lab.

Like at Tata Motors, 3D printing is changing the way manufacturing and prototyping is done at GE. "3D printing is helping us at a very early stage of design. Earlier, we had to make various drawings, explain it to the manufacturer to make it on conventional machines. Now, the CAD model is directly used to 3D print a part. It enables us to make parts of good quality with faster turnaround times, and validate our designs quickly," says Anikhindi.

For instance, design engineers can now 3D print complex parts used in turbines which are difficult to visualise on a 2D computer screen. Turnaround times in fabrication of parts have also reduced drastically. "What used to take a month now takes around a week. It allows us to do more design iterations, faster," says Anikhindi.

We have been able to shorten the design cycle time by around 60% using 3D printing — Vaman Kulkarni, Director, Aero Mechanica, Honeywell

Another area where 3D printing is helping GE is in making parts that are not possible to make using traditional manufacturing techniques. Typically, parts that have totally enclosed flow paths within the structure need an elaborate multi-step manufacturing process. There are limitations on internal "features" in the air-flow paths. These parts can be easily made by 3D printing with very few limitations on the geometry. "We are looking at a lot of components across various verticals for 3D printing, but they are still in the evaluation stage. It will take us some time before we put these parts for demanding applications because we will need to do their testing and qualification," says Anikhindi.

A big advantage with the advent of 3D printing is the new set of materials and properties that are opened up for manufacturing. "For instance, an object that has rigid material on one side and soft material on the other. This is very difficult in a conventional process. It would be possible to significantly vary material properties within the part," says Anikhindi. An air flow duct, for example, can be made of rigid material and the end seal is made of soft, flexible material which allows sealing with the mating part.

Anikhindi thinks there is immense potential in 3D printing to revolutionise manufacturing since it drastically reduces the number of steps required to make a part. "But it won't be a direct replacement for CNC. That's not where the disruption is going to come," he says. Anikhindi thinks 3D printing could dramatically change the assembly line, the bedrock of efficient manufacturing. "In a traditional manufacturing setup, you need a whole set of machines to make a part conventionally: milling machine, finishing machine etc. To a large extent, 3D printing reduces it by several steps," he says.

"A factory floor in the future is definitely going to look very different. The manufacturing and assembly line will be shrunk since 3D printing will allow you to do distributed manufacturing with smaller manufacturing units spread over different locations," says Anikhindi. Another change is that one machine will allow you to make parts with differing geometries, since custom designs are possible with 3D printing.

However, Anikhindi is careful to specify the technology's limitations. "At present, CNC is used for precision machining of larger components that require significant material removal. It is unlikely that 3D printing will replace those parts that are large and material-intense, such as large castings or fabricated parts. Also, it is not competitive in terms of time or cost for producing high-volume parts, which are made using special-purpose machines. It will be more beneficial for intricate parts with demanding material properties," he says.

Anikhindi says an excellent part that showcases the potential of 3D printing is the LEAP jet engine fuel nozzle. "This has intricate and very complex parts made by 3D printing technology. This part is representative of what 3D printing enables us to do. It has multiple components made into one single part with demanding material properties," he says.

Upon standardisation, 3D printing will trickle down from prototyping to manufacturing — Sridhar Balaram, Managing Director, Intech DMLS

Design parameters are extremely important for aerospace companies such as GE, affirms Sridhar Balaram, Managing Director of Intech DMLS, a 3D metal-printing solution provider. His company, headquartered in Bengaluru, focuses not only on printing metal parts but also provides weight-reduction solutions without compromising on the structural strength. In the aerospace sector, reduction in weight of components means saving thousands of dollars in fuel costs.

For metal printing, Intech DMLS had acquired know-how from Germany-based EOS GmbH, a leader in the 3D metal-printing space. Intech started less than two years ago and owns three EOS machines and other support systems and software. Intech says it provides a solution-based approach, whether it is aerospace or tooling. In its first year, Intech has an order book worth $1.5 million and is targeting $12 to $14 million in three years.

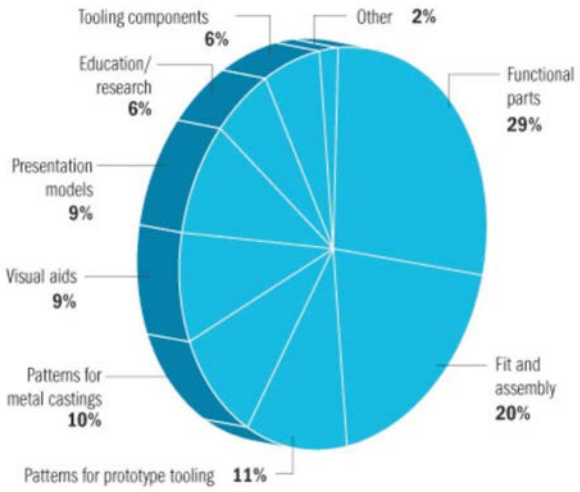
Balaram plans to focus on the overseas market and says that very soon, "some flying hardware for global OEMs will be made in India." Balaram is happy to break even in four years, but

predicts that in another 10 years, we will see a machine on every street. When asked about his optimism, he says, "The new technology has a lot of promise for every industry vertical and will slowly trickle down to manufacturing once standards are established. Also machines will become faster and the raw material will get cheaper once the volumes grow. Soon, we might just see a 3D industrial metal printer on almost every machine shop floor."

In fact, the shift towards direct digital manufacturing is already happening, with revenues from production of final parts now accounting for 35% of the global 3D printing market in 2013 (the corresponding figure for 2012 is 29%) compared to 3% in 2003, according to the Wohlers Report 2014 (see: Made to order).

Made to order

Functional parts account for a third of additive manufacturing applications



Source: Deloitte report on additive manufacturing, October 2014

Honeywell is another company that has successfully leveraged the technology. It has seven metal printers in the range of $800,000 to a million and 15 plastic printers in the range of $150,000-200,000. It started using 3D printers around 10 years ago, beginning with thermoplastics.

Vaman Kulkarni, Director, Aero Mechanica, at Honeywell says, "We use this technology to make prototypes and do functional test validations. We have shortened the design cycle time by around 60% using this technology, from around six months to two-three months, since design iterations can be made quickly. The applications are in aerospace, and in making turbochargers for passenger and commercial vehicles."

Kulkarni says that they are in the process of undertaking some benchmark studies to find the cost of direct manufacturing using 3D printers. "Right now, we're only using it in prototyping, around a year from now we'll be using it in the production of intricate parts, saving 30-50%. However, we need to establish consistency and repeatability of 3D printing in order to convince authorities," he says.

According to Kulkarni, applications for direct manufacturing are higher in the aerospace industry because of smaller volumes while it is not feasible in the transportation systems space since volumes are bigger. Typically, 3D printing is preferred for complex and intricate parts, "For a simple turning and milling operation, we can simply use conventional machinery," he says.

Imprints in space

Meanwhile, usage of 3D printing is not limited to private-sector companies. Government organisations such as Defence Research Development Organisation (DRDO) and Indian Space Research Organisation (ISRO) are also using 3D printing technology to streamline manufacturing processes. "We are presently using 3D printing in making intricate satellite components, especially wave guide components.

3D printing allows us to build intricate satellite parts with less material wastage — SS Gill, Scientist, ISRO

Earlier, we used subtractive methods like CNC which waste a lot of material and energy. 3D printing helps us build the part from bottom to top without much wastage," says SS Gill, Scientist with ISRO. However, ISRO doesn't own any 3D printers as of now. "Right now, we don't own 3D printers but are using the services of Wipro in Bangalore. We don't have any plans to buy 3D printers in the near future. First, we want to establish the technique to see whether it can generate spaceworthy hardware," he says.

Enthusiasm regarding 3D printing is shared by the government as well. R Chidambaram, Chief Scientific Advisor to the Government of India, says, "If India is to become a knowledge economy, we have to develop experience in technology development and back it up with high-quality manufacturing. Additive manufacturing has to be a part of this picture," he says.

However, when questioned about incentives for early adopters of the technology in terms of low import duties and cheap credit, Chidambaram is dismissive. "Let's talk about science here please," he says. "Also, many of my colleagues share the view that whatever Europeans can make, we can make at half the cost. That is our advantage.We can achieve world-class quality and reduce the cost, so we don't need incentives. We can beat them on their terms," he explains. Chidambaram cites the example of corrector magnets used in the Large Hadron Collider (LHC) supplied by India for $40 million, half the price in Europe.

"The third Industrial Revolution has been led by the Internet and a broad term called 'digital manufacturing'. AM is a part of digital manufacturing. But it will be more useful when you have low volumes since economies of scale don't matter. Presently, AM is also used to make complicated components or those that are no longer commercially available. One can simply 3D scan the object and recreate it faithfully," he says.

3D printing is more useful with low volumes since economies of scale don't matter — R Chidambaram, Chief Scientific Advisor, Government of India

To enable research collaboration, Chidambaram says we have the National Knowledge Network (NKN), which is a high-speed low-latency network run by the National Informatics Centre and set up by the government at a cost of $1 billion. "NKN connectivity can be used to create an overlaying grid which can be devoted to AM research. For instance, if institutions across geographies are developing something in collaboration, this can be used and since it is a low-latency network the information is shared immediately. We have already connected supercomputers and databases. Institutions can now jointly run a program on a supercomputer which is located in a third location.There already exist grids for topics such as brain research and climate science. We will create a grid for AM, but it'll be a smaller grid," The big advantage is that this comes at no additional cost. "The government has already invested a lot in this technology. It is the job of the government to provide connectivity. Content is the job of the scientists. I provide you the freeway, you drive the car," he says.

Meanwhile, early adopters of the technology complain about government apathy towards the technology in terms of tax incentives and reduced import duties. India levies Most Favoured Nation (MFN) duty rates of 7.5% compared to a global average of 2.8%, along with other additional taxes and duties. The Spanish, British and Korean governments even provide funds to companies for developing 3D printing technology in their respective countries, according to reports.

"There is no subsidy given by the government or advantage offered for upgradation of technology. It is not a priority sector for our government unlike in other developed countries. We borrow at the same commercial rates, pay the same customs duty, pay the same taxes as anyone else would pay because of which the cost is quite prohibitive," says Dinesh Jain, a Mumbai-based dentist who uses 3D printing and scanning to provide high-end dental prosthetics services. He owns 20 3D scanners spread around the country from where patients send in their digital dental imprints.

These imprints are then 3D printed in Mumbai and shipped back. He owns one 3D metal printer. Jain has invested around ₹20-25 crore in the equipment, starting in 2010, and expects to recover his investment in ten years. Jain says the dental space has seen a pick-up in adoption in the last five to six years, but prices of such services are 20-25% higher than that of traditional dentists. In fact, a majority of entrepreneurs using 3D printing technology are yet to recover their investments, except long-established companies which are often reluctant to disclose margins.

Expensive hobby

Apart from their industrial use, 3D printers have also attracted those who couldn't resist the temptation of this new super-toy, without any commercial interests. Parampreet Chadha, a fresh-faced twenty-something in faded jeans, just can't get over what his newly acquired tech-toy can execute; his excitement palpable in the slightly reverential manner with which he handles the self-assembled looping mass of tangled wires and circuit boards in his haphazardly arranged bedroom.

With this rickety machine, Chadha has the power to create objects that previously resided only in his imagination. He has already built a miniature aeroplane model, a pen stand, usable paper clips, and a beverage coaster that has since found a place on his glass dining table. All of this from a pinkish thermoplastic filament called acrylonitrile butadiene styrene (ABS), which is used as the input material in creating objects, and is incidentally the same material which is used to make Lego bricks. The technology functions by 'squirting molten plastic' layer upon layer, thereby creating complex three-dimensional models.

"It was a viral video which showcased a wrench being 3D printed that got me excited about the technology. I eventually bought a cheap home 3D printer for around ₹50,000," says Chadha. He now designs 3D-printable models himself and also downloads designs from Thingiverse, a flourishing online open-source design community that is an indispensable resource for any home 3D printer owner. "Thingiverse has some really cool designs. If you want to 3D print a tree, you can specify how many branches you want and how many leaves on every branch. It is quite an incredible resource," says an animated Chadha.

This is the world of consumer 3D printing: a nascent revolution which holds the potential to democratise manufacturing, relocating it from cavernous factory floors to one's own home in much the same way as the internet relocated information from stuffy libraries to portable mobile devices. But a word of caution is essential. Home-factories on every street are still a faraway reality. As usual, cost-efficiency is a bummer and there are issues regarding the reliability and repeatability of products created using cheap desktop 3D printers.

The world of 3D printing may have come a long way, but the industry's conundrum is much like Balaram's situation: patents and prohibitive costs make a capital-intensive business unremunerative while the future calls out like a siren on the rocks, promising it a place in the sun. Presently in India, the industry's fortunes are tied to new product development in the country. Hence, for the 3D printing industry to thrive, just Make in India won't suffice, there will have to be Create in India. Until then, enthusiasts like Chadha will have to satisfy themselves with ersatz creations.

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