Rapid Prototyping – Applications in Various Field of Engineering and Technology

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Abstract - *In the product design and development process, the prototyping or model making is one of the important step to finalize a product which helps in conceptualization of a design. Rapid manufacturing is a new mode of operation that can greatly improve the competitive position of companies adopting it. The key enabling technologies of rapid manufacturing are rapid prototyping (RP) and rapid tooling (RT). Rapid Prototyping (RP) is layer-by-layer material deposition started during early 1980s with the enormous growth in Computer Aided Design and Manufacturing (CAD/CAM) technologies. Since 1988 there are more than twenty different rapid prototyping techniques have emerged. Today, they are used for a much wider range of applications and are even used to manufacture production-quality parts in relatively small numbers. The edges and surfaces of a complex solid model and their information are used for defining a product which is further manufactured as a finished product by CNC machining.*

Key Words: **Rapid Prototyping, 3D Printing, Manufacturing, Laser, CAD/CAM design**.

1. INTRODUCTION

Global competition, mass customization, accelerated product obsolescence and continued demands for cost savings are forcing companies to look for new ways to improve their business processes. The first method for rapid prototyping became available in the late 1980s and was used to produce prototypes and model parts. Today, these methods are used in various type of applications and are used to built-up manufacture-quality parts in relatively minor numbers if preferred without the typical critical short-run finances. Rapid prototyping (RP) have emerged as key enablers for rapid manufacturing, a new mode of operation promising improvements to the competitive position of companies adopting it.

RAPID PROTOTYPING (RP) is defined as a group of technologies used to quickly produce a scale model of a component or group of components using 3-dimensional computer aided design (CAD) data. Prototyping or model making is one of the important steps to decide a product design. It helps in conceptualization of a design. Before the start of full production a prototype is usually made-up and tested. It gives to the designer the opportunity of authenticating the shapes /look of the product, certify if it fits into the assembly or if it fulfils with the desired role/functions. It actually shortens the required time to design a product. Basically RP technology has covered industrial applications to get faster the design and manufacturing process. The —three dimensional printers permit the designers to quickly create tangible/physical prototypes of their designs rather than two dimensional pictures. They make excellent visual/graphic aids for interconnecting ideas with clients or customers apart from design testing. For example Automobile Engineer might mount a model of car to express aesthetic look.

Due to the worldwide competition of the product the manufacturing industries has given more important in the product development phase. Therefore the RP and manufacturing techniques plays the vital role in a product development. It has been high prospective to reduce the cycle and cost of product development. It is an important tool in digital manufacturing in rapid product development. There are a variety of methods that can be used in RP to deposit the material for creating a prototype model through RP technique.

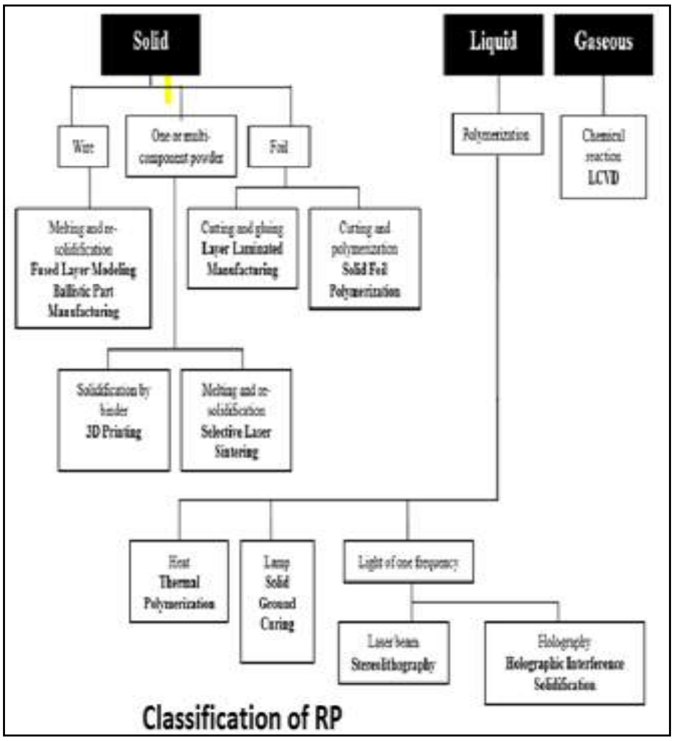

Fig -1: Classification of Rapid Prototyping

RP comprises of two general types-

Subtractive type RP- Material removal process. Examples- Turning, milling, grinding, etc.

Additive type RP-Layer by layer material addition process. Examples: Stereolithography, Fused Deposition Modelling (FDM), 3D printing, etc.

2. LITERATURE REVIEW

Rapid Prototyping (RP) is a new forming process which fabricates physical parts layer by layer under computer control directly from 3D CAD models in a very short time. In contrast to traditional machining methods, the majority of rapid prototyping systems tend to fabricate parts based on additive manufacturing process, rather than subtraction or removal of material. Therefore, this type of fabrication is unconstrained by the limitations attributed to conventional machining approaches. RP technology has been introduced successfully in the industries of automotive, aerospace, electronics, toy and so on. The RP methods commercially available include Stereo Lithography (SL), Selective Laser Sintering (SLS), Fused Deposition Manufacturing (FDM), Laminated Object Manufacturing (LOM), Ballistic Particle Manufacturing (BMP), and Three-Dimensional Printing (3D printing).

R. Kumaravelan, V. C. Sathish Gandhi, S. Ramesh, M. Venkatesan (Rapid Prototyping Applications in Various Field of Engineering and Technology):

RP is one of the fastest growing new technologies of manufacturing the various products by adding the material in layer by layer and directly from the 3D CAD model connected with the automated machine. This paper deals with the various RP model related to the field of applications. This paper provides a platform for researchers, new learners and product manufacturers to create an awareness of rapid prototyping and manufacturing technology for creating the complicated and different contour products in various field of applications. The various points are discussed in this paper for the researchers to insight the challenges associate in rapid prototyping. However, some of the factors are given for developing the RP techniques in Indian scenario.[5]

D T Pham and S S Dimov (Rapid prototyping and rapid tooling-The key enablers for rapid manufacturing):

The remarkable increase in the number of commercially available RP and RT solutions of the 1990s can be explained by advances in three-dimensional CAD modelling, computer aided manufacturing, computer numerical control and the development of new materials. These technologies were used initially in the fast growing, highly competitive, high technology, automotive and aerospace industries, which generated added momentum. In the first part of the last decade, the annual growth in sales of RM systems approached 40–50 per cent. In the last few years, the same rapid growth has not continued. However, developments in this area still attract significant interest and in the last two years alone 208 new patents were filed. In 1999, sales growth was 22 per cent and it was estimated that 3.4 million parts were built worldwide using RP technologies. Another important aspect is that the application of RP and RT has extended to other sectors of the economy. This strong and consistent growth in sales and the widespread use of the technology present very optimistic prospects for the future of rapid manufacturing. [2]

Aman Kaushik, Suman Kant, Parveen Kalra(Rapid Prototyping Technologies and Applications in Modern Engineering -A Review):

RP is one of the fastest growing new technologies of manufacturing the various products by adding the material in layer by layer and right from the 3D CAD model connected with the automated mechanism. This paper briefly discusses with the numerous RP model related to the field of applications. It also incorporates a platform for new learners and researchers and product manufacturers to create an consciousness of rapid prototyping and manufacturing technology for generating the complicated and different contour products/models in various field of applications. [3]

3. BASIC PRINCIPLE OF RAPID PROTOTYPING PROCESS

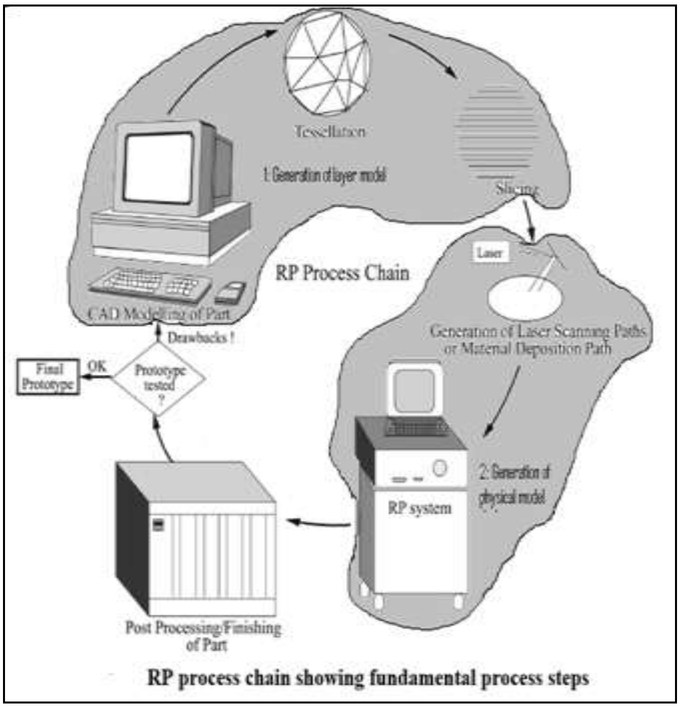

Fig -2: RP Chain showing fundamental process steps

3.1. CAD Model Creation

First, the object to be built is modelled using a Computer-Aided Design (CAD) software package. Solid modellers, such as Pro/ENGINEER, tend to represent 3-D objects more accurately than wire-frame modellers such as AutoCAD, and will therefore yield better results. This process is identical for all of the RP build techniques. [3]

3.2. Conversion to STL format

To establish consistency, the STL format (an abbreviation of "Stereolithography") has been adopted as the standard of the rapid prototyping industry. The second step, therefore, is to convert the CAD file into STL format. STL format represents a three-dimensional surface as an assembly of planar triangles as "Standard Triangle Language" & "Standard Tessellation Language".STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation. [3]

3.3. Slice the STL file

In the third step, a pre-processing program prepares the STL file to be built. The pre-processing software slices the STL model into a number of layers from 0.01 mm to 0.7 mm thick, depending on the build technique. The program may also generate an auxiliary structure to support the model during the build. Supports are useful for delicate features such as overhangs, internal cavities, and thin-walled sections. [3]

3.4. Layer by Layer Construction

The fourth step is the actual construction of the part. RP machines build one layer at a time from polymers, paper, or powdered metal. Most machines are fairly autonomous, needing little human intervention. [3]

3.5. Clean and Finish

The final step is post-processing. This involves removing the prototype from the machine and detaching any supports. Some photosensitive materials need to be fully cured before use. Prototypes may also require minor cleaning and surface treatment. Sanding, sealing, and/or painting the model will improve its appearance and durability. [3]

4. RAPID PROTOTYPING PROCESS

4.1. Fused Deposition Modelling

In Fused Deposition Modelling (FDM) process a movable (x-y movement) nozzle on to a substrate deposits thread of molten polymeric material. The build material is heated (approximately above 0.5 C) its melting temperature so that it solidifies within a very short time (approximately 0.1s) after extrusion and cold-welds to the previous layer. Various important factors need to be considered such as steady nozzle and material extrusion rates, addition of support structures for overhanging features and speed of the nozzle head, which affects the slice thickness. More recent FDM systems include two nozzles, one for part material and other for support material. The support material is relatively of poor quality and can be broken easily once the complete part is deposited and is removed from substrate. In more recent FDM technology, water-soluble 7 support structure material is used. Support structure can be deposited with lesser density as compared to part density by providing air gaps between two consecutive roads. [5]

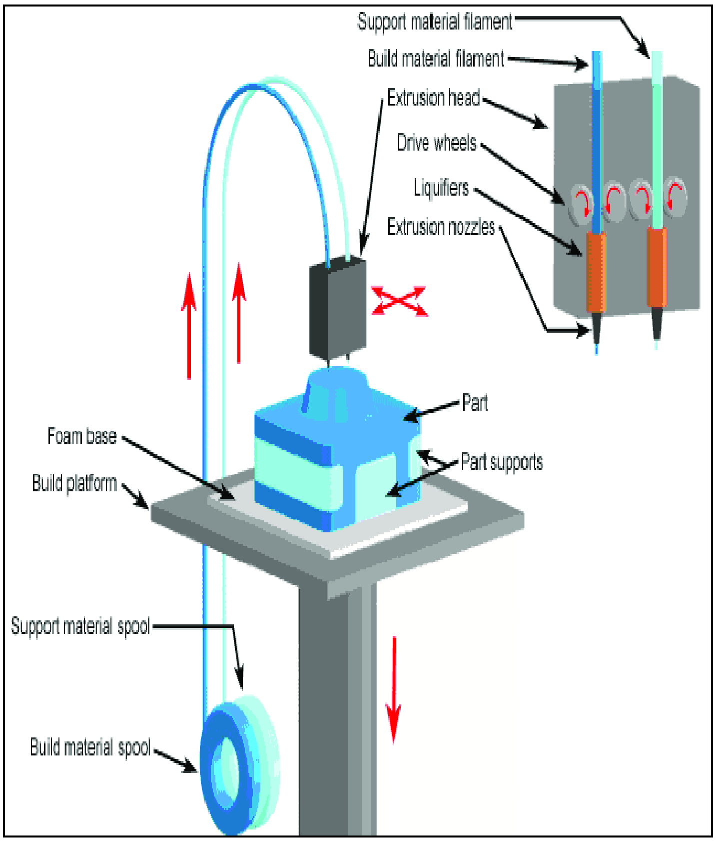

Fig -3: Fused Deposition Modelling

4.2. Ballistic Part Manufacturing Process (BPM)

BPM employs a technology called digital Micro synthesis. In the first step of the process, molten plastic is fed to a piezoelectric jetting mechanism, almost like those of inkjet printers. Next a multi-axis controlled NC (Numerical Control) system shoots tiny droplets of material onto the target, using the jetting mechanism. Last, small droplets freeze upon contact with the surface, forming the surface particle by particle. This process has the ability to perform in microgravity and vacuum. It has Low cost of materials, minimum power consumption & Low toxicity. The process allows use of virtually any thermoplastic. BPM has no size constraints because of this, there are no health hazards involved. [3]

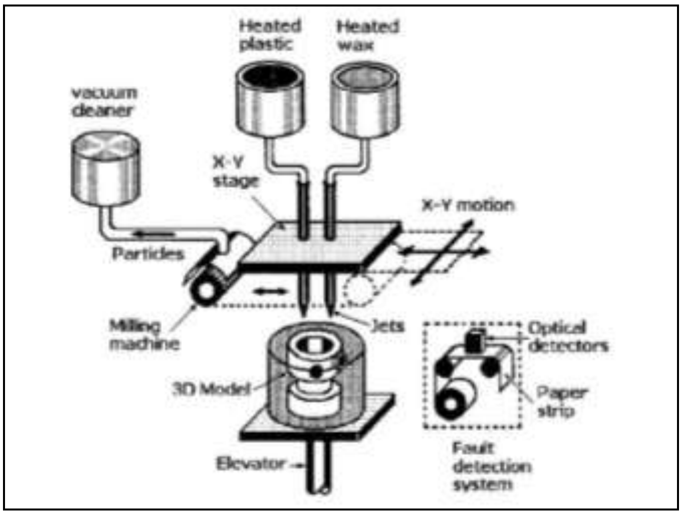

Fig -4: Ballistic Part Manufacturing Process

4.3. Binder Jetting

3D printing technique- Binder Jetting uses a powder like building material to be joined by liquid binder for 3D printing. In a typical apparatus for binder jetting, there are two chambers where one chamber is filled with powdered building material to feed into the other chamber and the second chamber is used for realizing the 3D model. The 3D model is built by gluing together the powdered building material using the liquid binder. The powder is filled into first chamber and feed to the second chamber by rolling sufficient amount for each layer by a levelling roller. The advantage of using this process is that there is no need of using support structures while creating the 3D model. The model created has better mechanical characteristics and robust build. The commonly used building materials for binder jetting process are stainless steel, glass and some polymers like Acrylonitrile Butadiene Styrene (ABS), Polyamide (PA) &Polycarbonate (PC). [1]

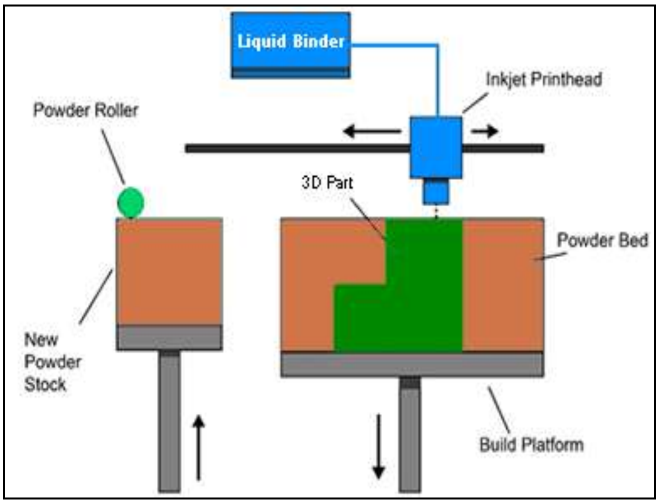

Fig -5: Binder Jetting

4.4. Selective Laser Sintering

Laser sintering (SLS) is an additive manufacturing (AM) technique that uses a laser as the power source to sinter powdered material (typically nylon/polyamide), aiming the laser automatically at points in space defined by a 3D model, binding the material together to create a solid structure. SLS involves the use of a high power laser (for example, a carbon dioxide laser) to fuse small particles of plastic, metal, ceramic, or glass powders into a mass that has a desired three-dimensional shape. The laser selectively fuses powdered material by scanning cross-sections generated from a 3-D digital description of the part (for example from a CAD file or scan data) on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed. Material such as polyamides (PA), polystyrenes (PS) and thermoplastic elastomers (TPE). [2]

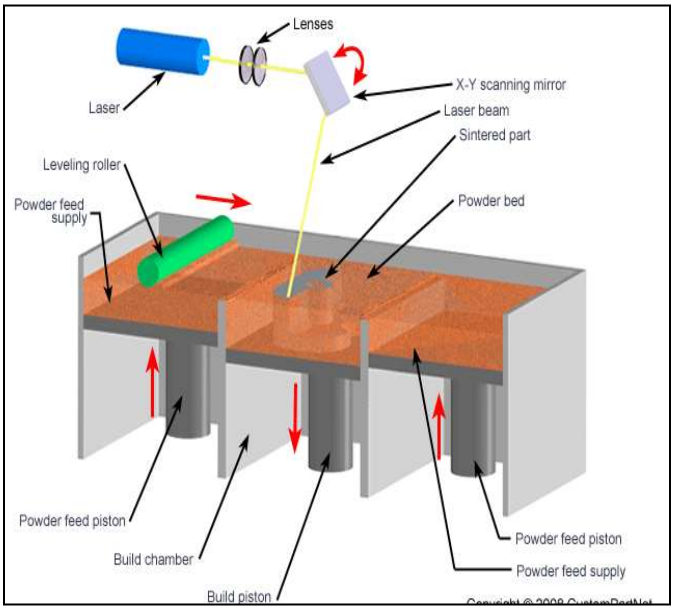

Fig -6: Selective Laser Sintering

4.5. Laminated Object Manufacturing

Laminated object manufacturing (LOM) is a rapid prototyping system in which layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter. Objects printed with this technique may be additionally modified by machining or drilling after printing. Solid physical model made by layers of sheet stock. An outline of the cross-sectional shape of a CAD model that is sliced into layers. The sheet is usually supplied with adhesive backing as rolls. After cutting, excess material in the layer remains in place to support the part during building. [5]

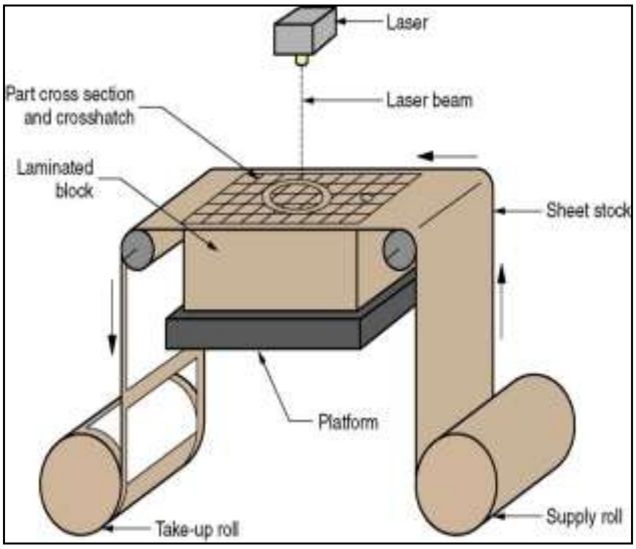

Fig -7: Laminated Object Manufacturing

4.6. Stereolithography (SLA)

In this process photosensitive liquid resin which forms a solid polymer when exposed to ultraviolet light is used as a fundamental concept. Due to the absorption and scattering of beam, the reaction only takes place near the surface and voxels of solid polymeric resin are formed. A SL machine consists of a build platform (substrate), which is mounted in a vat of resin and a UV Helium-Cadmium or Argon ion laser. The laser scans the first layer and platform is then lowered equal to one slice thickness and left for short time (dip-delay) so that liquid polymer settles to a flat and even surface and inhibit bubble formation.[1]

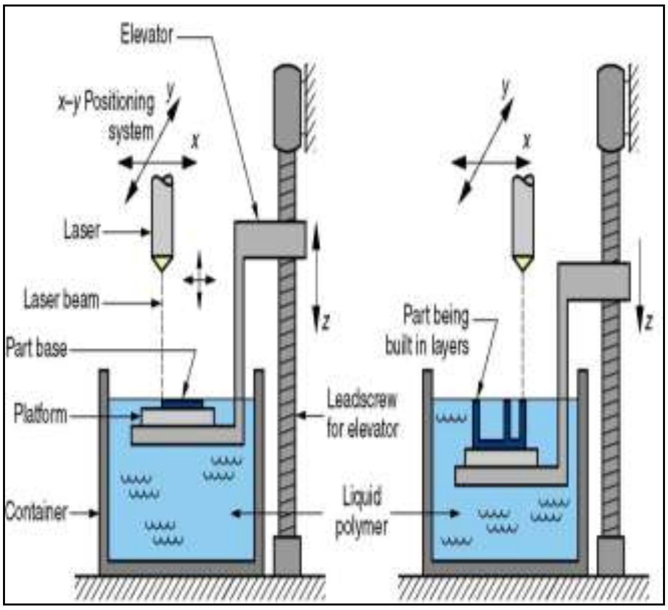

Fig -8: Stereolithography

5. ADVANTAGES

- 3D Printing does not require any mold as a precursor to manufacturing.
- Geometric complexity is not a limitation in 3D Printing
- Less Wastage of Materials. Cut away material can reduce material needs and costs by up to 90%
- Reduced waste by lowering human error in production
- Part Consolidation and Complexity
- Reducing the number of parts in an assembly immediately cuts the overhead associated with documentation and production planning and control
- Less time and labour is required for assembling the product, contributing to a reduction in overall manufacturing costs
- Part complexity is limited only by your imagination
- CAD model can be easily changed according to needs in short time at short notice.
- CAD model/STL files can be transferred to any machine to any corner of the world.
- Time required to manufacture product and market is reduced by 40-80% as compared to traditional methods.
- Aircraft prototype at CMTI took 100 hours to be manufactured as compared to 140 days using traditional processes.
- Mould for electrical cabinet took 16 hours as compared to 30 days by subtractive manufacturing.

6. DISADVANTAGES

- Higher energy consumption.
- This process is too expensive.
- Adopting 3D Printing may decrease manufacturing jobs.
- Harmful Emissions.
- Limited Material.
- Too much reliance on Plastic.

7. APPLICATIONS

- Direct Tooling
- Patterns for Casting
- Form, Fit and Function
- Moulds and Casting
- Bioprinting
- Prototypes for Medical applications

8. CONCLUSION

Despite the fact that 3D Prototyping Technology is still faced with a number of challenges, its benefits far exceed its downsides. Effort is being made to reduce the rather expensive cost of acquiring 3D printers. 3D printing will immensely lower the cost of some products by eradicating the need to ship them across the world. Revolutionary not only to the manufacturing industry, but also retail. In the near future, people will be downloading objects from the internet and fabricating them in the comfort of their homes. You will be able to create and customize anything from shoes to car parts (along with a whole lot of other products) to your own specifications and create them in a matter of hours. Businesses in these sectors would need to think of radical ways to adapt to the change, possibly eliminating mass-manufacturing for good, and offering highly customised products that are not already available for download.

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