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THE NEED OF TECHNOLOGY TRANSFER OF RP IN PROTOTYPING AND CASTING INDUSTRIES OF DEVELOPING COUNTRIES

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ABSTRACT

This paper presents work on Rapid Prototyping (RP) through comparative evaluation of industrial products, which are produced by workshop-based, casting and RP. Parameters such as production time, cost, accuracy, surface finish and strength of product are used for comparative evaluation. Experimental case studies have been done to test the feasibility of RP technology implementation in Developing Countries (DC).Advance manufacturing system (AMS) has been suggested for these DC manufacturing industries with the concept of RP.

Keywords: Rapid prototyping, Developing countries, Casting, Reverse engineering.

1. INTRODUCTION

In the last fifteen years a number of educational institutions, research centers and companies have been motivated to use the computer assisted technologies in product design and manufacturing in order to reduce the production time and cost [1]. In particular, companies experience immense pressure to provide varieties of complex products in shorter product development cycles, coupled with a desire to further reduce costs and improve quality [2]. One possible way to achieve this goal is through the use of state-of-the-art technology such as RP. But still few research works has been done to validate possible application of RP technology in DC. This work has been motivated to substantiate that there are many areas where RP technology can be applied with shorter production time, less cost and quality product in comparison with the conventional way of making prototype as well as final products. From the working experiences and training in some prototyping and casting companies of Bangladesh (Machine Tools Factory, Tara Pump Company, Design and Technology Centre) as well as the other countries authors select some areas where RP technology can be applied. Three case studies have been taken such as

- A part of a Hand Tube Well (HTW), a domestic used products
- Load carrying devices like hook and chain
- Car spares parts (i.e. steering knuckle)

There are other sectors like architectural, refinery and medical prototyping etc, where RP technology can be applied [9]. Research result shows that using some latest development in RP technology (3Dprinting, Z Cast System) not only prototype but also mold making can be possible with significant result. This paper also propose some mold & pattern design for single & multiple pieces manufacturing system that can be made using RP technology with greater economical benefits as compared with the conventional system of manufacturing. It also suggests the cost effective way of using RP technology. After comparing with all major RP system only two or three were found compatible and cost effective in the DC economic scenario.

2. OVERVIEW OF THE RESEARCH

In this paper, RP method has been suggest in the prototyping and casting industries (P&CI) for DC. At first, some experimental studies have been done with major RP system then analyze each system and compare with the other prototyping methods. For comparative evaluation RP system production cost, time and quality of the product (i.e. surface finish, accuracy, and strength) have been used. After comparing, two RP systems have been selected that can be applied in P&CI, considering the economical scenario and market demand. The production process using selected RP system has been compared with conventional system of making prototyping as well as final product. Finally, advanced manufacturing system (fig 7) with the help of RP that can be applied with significant result has been proposed.

Also some experiment has been done with world fastest and cheapest RP system, VLM that has been developed by KAIST (Korea Advanced Institute of

Science and Technology).This VLM system shows significant result to implement it in Bangladesh. VLM system can be applied in Bangladeshi architectural firm with considerable amount of time and cost saving for prototype making .Total overview of the research is shown as follows(fig-1).

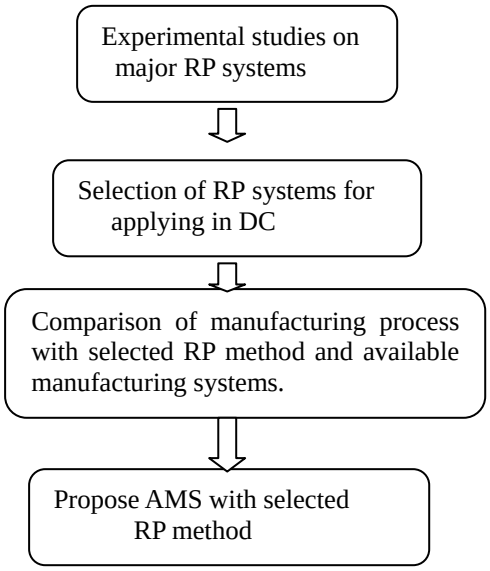


Fig 1. Systematic procedure of research

3. EXPERIMENTAL RESULT FOR SELECTION OF RP PROCESS

Experiment has been done with the following major RP systems to test each system production cost, time and quality of the products such as strength, surface finish and accuracy.

1. Stereo lithography (SLA500)
2. Selective Laser Sintering (SLS2000)
3. Fused Deposition Modeling (FDM8000)
4. Laminated Object Manufacturing (LOM1030)
5. 3Dimensional Printing (3DP, Z Corp.)
6. VLM System (VLM-foam)

Table-1 data shows, products using different prototyping method have different strength depending on the process and material used. Prototype made from SLA shows the highest strength of 66 Mpa and the lowest is the prototype made from Z-Corp, 3DP. SLA shows highest strength because it produce prototype directly from the liquid and liquid is turned into solid by curing reaction. Strength test has been done by universal testing machine (UTM) shown in fig 2 and test specimen type is ASTM D638.Experimental results show that on completion of the prototype, after building with minimal post processing, SLA provides greater accuracy than the other RP process. Accuracy and roughness test have been done by CMM (Co-ordinate Measuring Machine). In case of SLA accuracy value is 100-120 micrometer and 3DP, value is around 500 micrometer. Thus SLA provides the highest accuracy than the other RP system. The mechanical properties of parts made by 3D Printers are much inferior compared with SLA or FDM. However, most commercially available 3D Printer produces parts much faster than other RP technologies. Cost and finishing time have been calculated by the sample part (fig 2), that has been made by all five RP processes. The sample has 100mm×100mm×25mm dimension. Experimental result shows that 3D printing (Z Cast) PR process has the minimum cost as well as production time that is why; it is most applicable in the context of Bangladesh. Comparative result shows, 250000mm3 volume of prototype part can be made by 50000 Korean Won (1000 Won=1$) in 2 hours only. In Bangladeshi labor cost 50000 won will be around 500 taka ($ 8). So Z Corp RP System is suitable in Bangladesh, for instance.

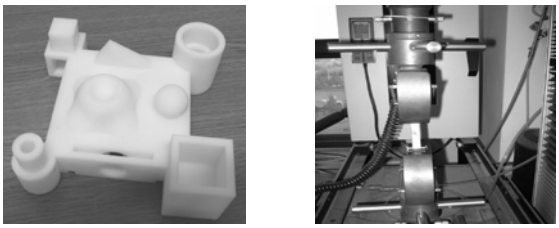


Fig 2. Left: Sample RP part made by FDM, Right: Strength test is being done by UTM.

4. COMPARATIVE EXPERIMENTAL RESULT

To compare production process of RP with conventional method, prototype of load-carrying hook (fig 5) has been made with Computer Numerical Control (CNC) machine and also with SLA500 RP method. Process flow diagram of both systems is shown in fig 3 & fig 4 respectively. Prototype made by CNC machine needs more time than that of RP, but its shows better accuracy and surface finish. As in both cases, final product made by sand casting, accuracy and surface finish does not affect much that do in case of production time.

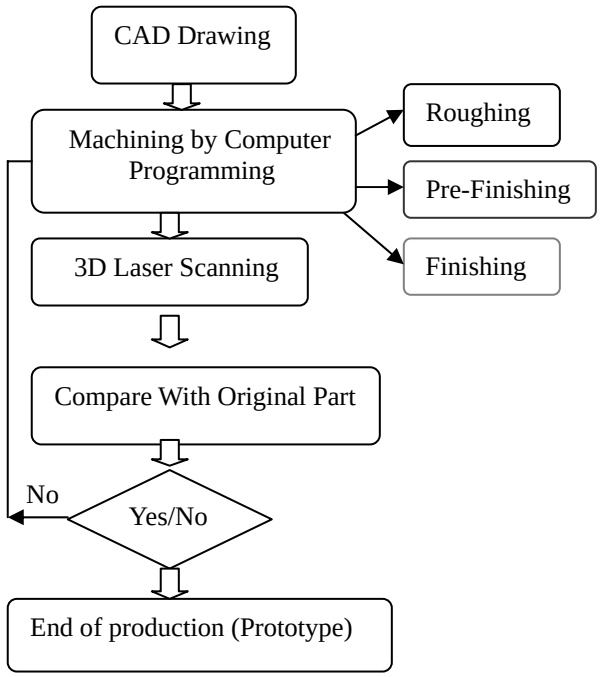


Fig 3. Process flow diagram of making prototype of Hook by CNC Machine

Table 1: Experimental data for selection of RP (*1 man won = $ 10)

Process	SLA500	SLS2000	FDM8000	LOM1030	3DPZCorp.
Material	SL5410	Duraform P/A	ABS	Paper	ZP100
Tensile strength (Mpa)	66	34	12	26	4
Elongation (%)	4-5	8-9	5-6	10	0.7
Accuracy (μm)	100-120	125-150	150	200	400-500
Roughness (μm)	8	12	28	30	16
Built time (Hr)	4	4	10	3	2
Part cost (Man Won*)	30	30	25	20	5

Therefore, RP is preferable over CNC prototyping where prototype does not need much precise and accurate rather short production time. Other recognizable feature of making prototype by RP is the cost of production. Comparative experimental result (table 2) shows that in case of RP, production cost is 5 times less than that of CNC machining. Manufacturing system with cheaper production cost is always preferable to implement. So RP system can be implement cost effectively in DC.

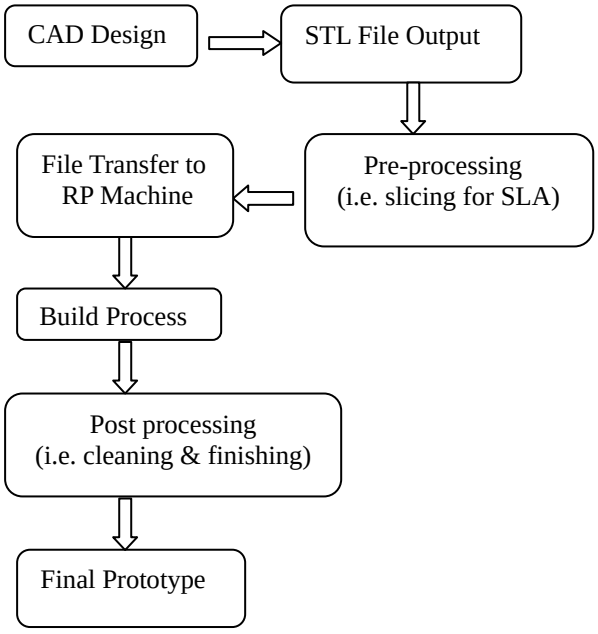


Fig 4. Process flow diagram of making Prototype of Hook by RP

Table 2: Comparative experimental result

Prototype (Hook)	By CNC Machine	BY RP (SLA 500)
Production Cost ($)	400	150
Production Time (with CAD drawing)	3 days	5 hours
Accuracy (μm)	12.5	100
Roughness (μm)	2	8

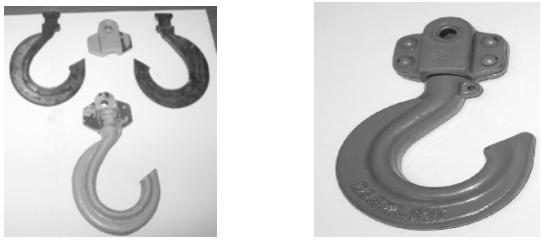


Fig 5. Experimental Manufactured part of Hook, Right: Prototype made by CNC, then final product by casting, left: Prototype made by **SLA 500** (up) final product (down) by sand casting using the same prototype as master pattern

Hook prototype has been made by locally (Korea) available RP system (SLA500), which costs $150 and 5 hours with CAD drawing but with cheapest RP system (3DP Z Corp.) it can be made at the cost of one-third with half production time than SLA500.

5. PROPOSED ADVANCED MANUFACTURING SYSTEMS (AMS)

Case Studies Implementation with AMS

5.1 Case Study -1 (Hand Tube Well)

About seventy percent people of DC use HTW (fig 10), which is their only source of water supplier. Tube well the term generally used to describe water well, the subcontinent including Bangladesh, Nepal, Pakistan, and India which are termed as borehole or water well in other parts of the world [10]. In our research it has been proved that HTW can be made by RP. Prototype of HTW inside valve (IV) has been made with SLA500 and final product by sand casting (fig 6). Experimental result shows that HTW-IV prototype can be made with almost all RP process with design flexibility, less time, better surface finish and accuracy. Comparative result with conventional method shows that production process by RP system is much better than that of available system.

HWT made by traditional method is lengthy process and quality of the product is not good as compared with that of RP. It has been proved that manufacturing process of HTW-IV by RP is better than that of traditional method.

(a) (b)

Fig 6. HTW-IV made by RP (a) CAD model by Pro-E, (b) left: Prototype by SLA 500, right. Final product by sand casing using same prototype as a master pattern

5.2 Case Study - 2 (Load Carrying Hook)

Making prototype of load carrying device Hook, is very difficult with conventional system (i.e. by CNC machine).It need lots of time as well as money. So RP method can be introduced this sector, which concludes better manufacturing system. Fig 8 shows the hook manufacturing process by RP. In this process not only prototype but also mold can be made and final product can be made by Direct Pouring (DP) method of Z Cast System [9]. Mass production can also be possible by DP method. In this method multiple pieces in a single mold can be made.

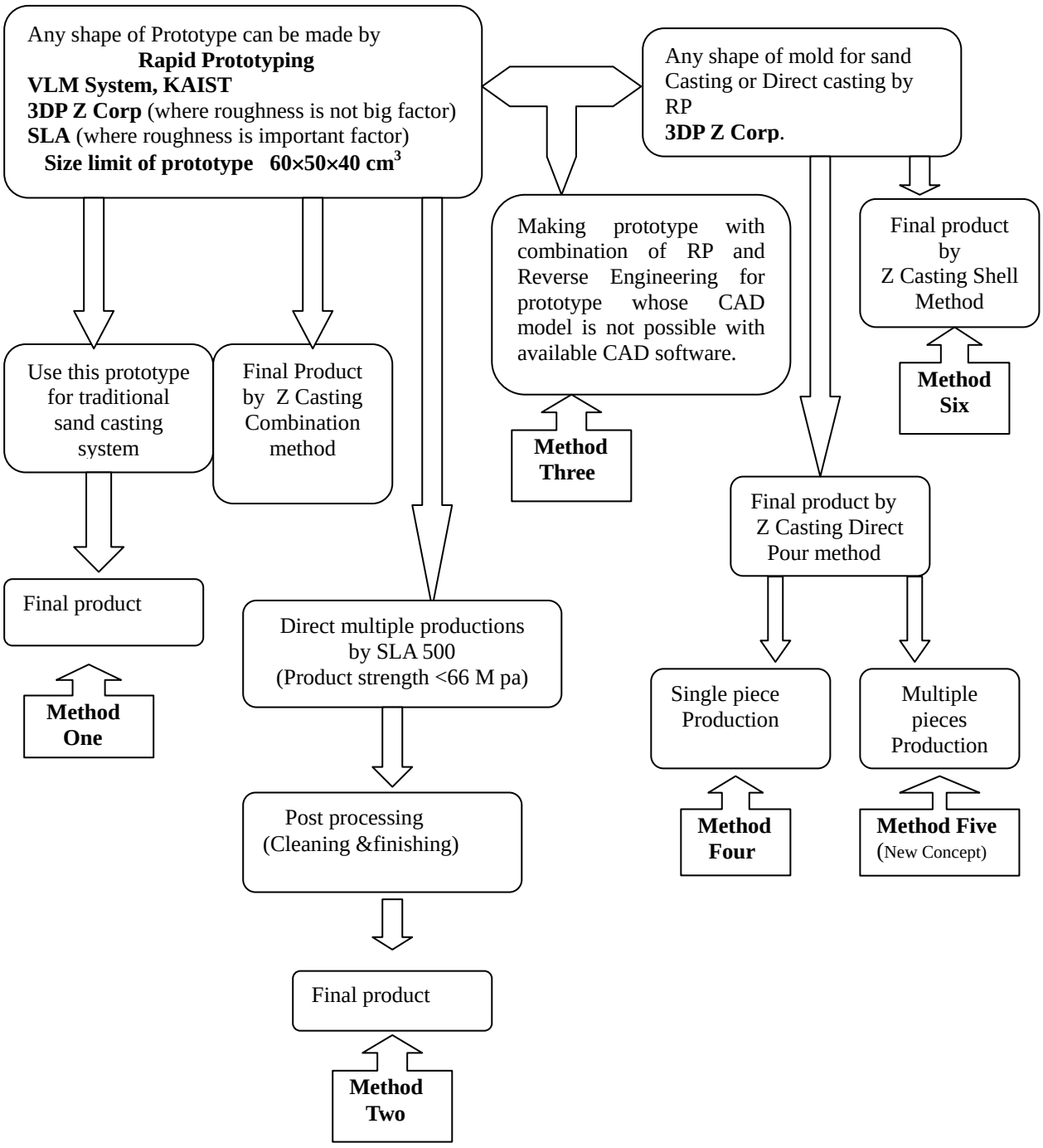
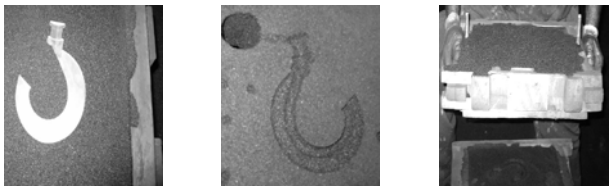


Fig 7. Advanced Manufacturing System(AMS) Model



(a) (b) (c)

Fig 8. Experimental hook manufacturing system with traditional casting, using the RP pattern. (a) Half slice of RP hook placed in cope, (b) cope mold, (c) cope is being placed over drag.(same process has been used for making HTW inside valve)

Following figure (fig 9) shows, conceptual CAD design for multiple pieces mold, with proper pouring and ventilation system .This design has been verified by ZCop. USA. Using same technique multiple pieces manufacturing of HTWIV can also be made for mass production.

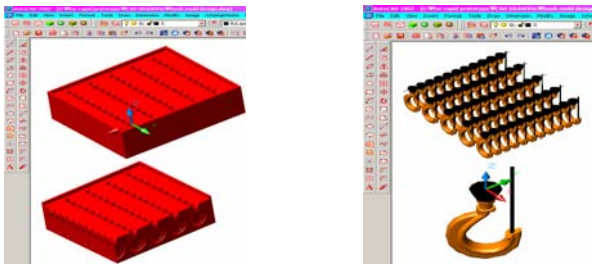


Fig 9. Left: Multiple pieces hook mold design, Right: Final Product of Hook by DP Method (conceptual)

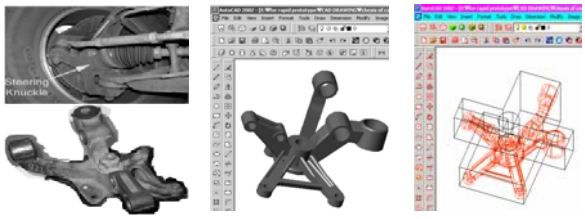
Fig 10. Left: CAD model of HTW, Right: ware frame model of HTW-IV.

5.3 Case Study-3 (Steering Knuckle)

One of the complex processes of making passenger car body part is steering knuckle, which is very lengthy process to design and manufacturing but with the help of RP it can be manufacture quite easily[6&7]. By the help of Z Cast direct pour method or shell method it can be manufactured with greater accuracy, surface finish, less manufacturing time and cost. Conceptual CAD mold design shown in fig 11, has been modeled with AutoCAD software.

5.4 RP with Reverse Engineering

With the help of Reverse Engineering (RE) prototype of very complex shape can be made. RE in light of RP refers to the process of regenerating a physical object



(a) (b) (c)

Fig 11. Steering Knuckle (a) up shown in car, bottom after dismantles (b) 3D solid CAD drawing, (c) Ware frame CAD Mold Design.

back into a digital CAD format, then producing direct or modified copies of the original object using RP. The application of RE spans a variety of industries, and can be accomplished with about as many techniques [3&4]. To verify this method applicability in DC, bone part (fig 12) has been made. This bone part is almost same with the original product, which shows the significant result. Making process of prototype with RE&RP is, first, the physical object to be reproduced must be scanned electronically to provide a point cloud of co-ordinate along the various surfaces of the object. A point cloud is a set of coordinate data points in 3D space representing a solid object.

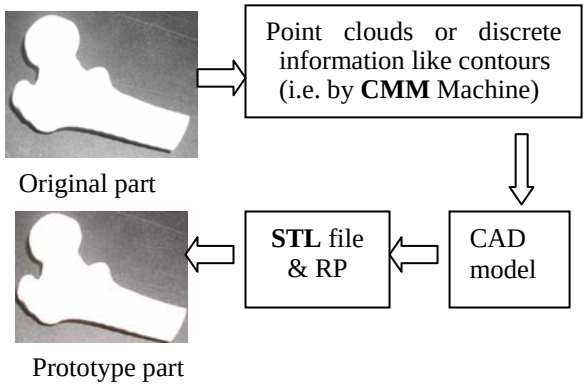
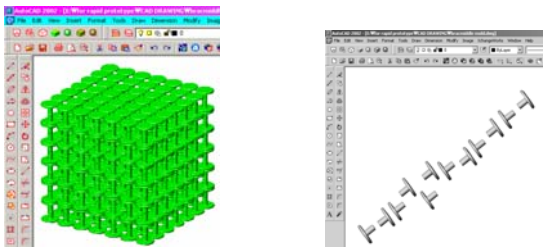


Fig 12. Flow diagram of Experimental process of making prototype with combination of RP and RE

This can be achieved by manual probes, which are placed against the object bay hand then the coordinate data at each point is entered into the computer by clicking a pedal or button. CMM are based on the same concept, except that the part is fixtured and the sensor tip is driven electronically to touch the surface and enter data points. Once a point cloud is generated it must be converted from simple dots in space into actual surface representations. There are various “connect-the-dot” software applications available today that are designed for specific purpose, which usually connect the points and export either the standard STL file for RP or a standard generic CAD file interface known as IGES (International Graphics Export Standard). Finally, the CAD or STL file is created, the parts can be rapid prototyped to provide the models or hardware as needed.

5.5 Direct Manufacturing

Not only prototype but also final product can be made economically by direct manufacturing with SLA 500 RP system. Experimental result shows that inner part of HTWIV has tensile strength around 70 Mpa. This inner part practically does not take much pressure from water as it works as one-way valve. So, prototype part of this inner part can be used as final product, no need to make it by casting. Conceptual CAD design is shown in following figure (fig 13).



(a) (b)

Fig 13. HTW-IV inner part (a) the array of multiple pieces (b) part can be separated (conceptual)

Conceptual result shows that at a time more than 500 pieces can be prototyped together. This part can be directly made by RP rather than making first prototype and then final product by casting.

5.6 VLA System Application

VLA RP System [11] that has been developed by CANESM laboratory KAIST can be applied Bangladesh architectural firm with significant amount of time and cost saving for architectural prototype making. VLM process introduces the unique thick-layered RP technologies with layers and sloped edges into prototyping of a physical part. VLM Slicer generates cutting path from CAD data of 3D solid model to make optimal cutting of hotwire in VLM system. The parts are successively fabricated by automatic feeding, shaping using synchronized automatic 4-axix hotwire cutter and a semi-automatic stacking and bonding. Following figure (fig 14) shows the VLM-foam system flow diagram and sample prototype made by it.

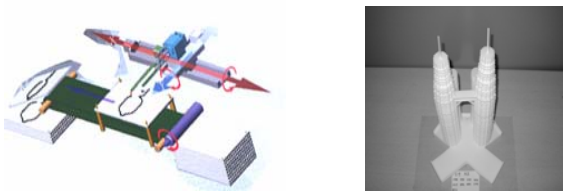


Fig 14. Left: 3D view of VLM System developed by Menix Co. & KAIST (South Korea) Right: Sample architectural prototype of Twin tower made by them.

6. CONCLUSIONS

This work suggests the applicability of RP technology in various domains of product manufacturing. Essentially, it emphasizes that the RP technology can be transferred to the developing countries such as Bangladesh, Nepal, Pakistan, Indonesia and even India. By taking several case studies such as Hand Tube Well parts, Hooks and Chains and a part of a car, RP technologies has been implemented. Various RP principles and methods have been described. Especially a comparison study of various manufacturing processes of products has been made taking into account of many parameters such as production time, cost, accuracy, surface finish and strength of product. These are the important parameters as far as transfer of technology to the developing countries is concerned. This work also includes some experiment on Reverse Engineering, as this has been an integrated method as far as RP is concerned. The combined technology (RE and RP) can be employed in the areas of interest.

7. ACKNOWLEDGEMENT

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