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Modeling and optimization of Rapid prototyping for an agricultural tractor component

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ABSTRACT

The paper proposes a Virtual reality system for modeling and optimization of rapid prototyping process for an agricultural tractor component. The system aims to reduce the manufacturing risks of prototypes early in a product development cycle, and hence, reduces the number of costly design- build test cycles. It involves modeling and simulation of RP in a virtual system. Modeling of RP is based on quantifying the measure of part quality, which includes accuracy, build time and efficiency with layer thickness. A mathematical model has been developed to estimate the build-time of the selective laser sintering (SLS) process of SLA 5000. It has been integrated with the virtual simulation system to provide a test-bed to optimize the process parameters for virtual fabrication of a modified R.S.Arm.

Keywords: Rapid prototyping, parameter optimization, virtual prototyping, R.S.Arm

1. INTRODUCTION

Rapid prototyping or Layer Manufacturing refers to fabrication of parts layer-by-layer. It involves adding raw materials successively, in layers, to create a solid of a predefined shape. These parts are used in various stages of a product development cycle. A.K.Matta [1] conducted a survey on integration of CAD/CAM and RP in product development. A.K.Matta [2] coupled CAD with VR by developing the interactive virtual environment for correction of stereo lithography tessellated list file system to an agricultural tractor R.S.Arm. The fundamental aims of R.P [3] are

- To build arbitrarily complex 3D shapes of automobile components.
- To use a generic fabrication machine SLA 5000 which does not require part-specific fixtering or tooling.
- To generate a prototype model automatically, based on a CAD model.
- To minimize human effort.

A.K.Matta [4] presented optimal parameters in building complex 3D shapes of Automobile discs. S.H.choi [5] quantified the requirements for optimization of RP and to simulate the fabrication of prototypes for visualization in virtual reality. The objectives of this paper are to quantify the requirements for optimization of RP and to simulate the fabrication of prototypes for visualization in virtual reality.

2. MATHEMATICAL MODEL

Average cusp height represents the mean of the linear deviations of all facets.

Average cusp height (ACH) = $\frac{\sum_{i=1}^{Ni} hci}{Nf}$

Where N_f is Total no. of facets

H_{ci} is the cusp height in mm

The build time estimator evaluates the time as a function of the laser velocity as shown below

Velocity v = $\frac{pl\,(1-R)}{\rho dblm[cp(Tm-Tb)+kllh]}$

Where P_l is laser power in W

R is reflectivity of the mirror

The ρ is material density in gmm^{-3}

d_b is laser beam diamerer in mm

l_m is machine layer thickness

C_p is specific heat ($Jg^{-1}k^{-1}$)

T_m is melting temperature in K

T_b is bed temperature

K is sinter factor

L_h is latent heat (Jg^{-1})

Build- time of a part = $\frac{h}{lm}$Ts+ $\frac{\sum_{i=1}^{Ni} dsi\,(\frac{l}{lm})}{Lv}$

Where

l_m is machine layer thickness

h is total height of the part in mm

T_s is setup time of a layer in s

d_s is scan distance of a layer in mm

l is layer thickness in mm

l_m is machine layer thickness in mm

C_p is specific heat ($Jg^{-1}k^{-1}$)
L_v is laser scan velocity (mms^{-1})

Orientation efficiency $\dot{\eta} = \frac{\sum_{i=1}^{Np} Vpi}{hm\ Aw}$

Where

V_p is enclosing box volume of a part in mm^3
h_m is maximum height of the part in mm
A_w is surface area of work part in mm^2

3. SIMULATION OF MODIFIED R.S.ARM

From a CAD design to a final prototype, the part is represented in several file formats [2]. Pro/ Engineer model, the STL file after triangulation, binary format or ASCII format and the slice generated by the slicing software. The STL file errors are compensated with 1 surface, 592 triangles, X direction 354.1375 mm, Y direction 93.0000mm, Z direction 72.8747mm.

To demonstrate the application of the system, fabrication of a modified R.S.Arm on a 5000SLS machine with nylon was simulated and the results are shown in Fig.1. The laser diameter is 0.20mm and the layer thickness 0.1mm. Depending on the distribution of facets, the surface accuracy, build-time and efficiency could be different for three different directions.

Table.1, Table.2 and Table.3 indicate the surface accuracy, build time, orientation efficiency and no. of layers when the part was sliced about the x, y and z axes respectively as shown in Fig.2, Fig.3, Fig.4.The surface accuracy was mainly dependent on the layer thickness, no. of faces and the build direction. The part for direction 72.87mm and 186 layers gave minimum surface accuracy of 0.039 and build time of 0.81hrs.

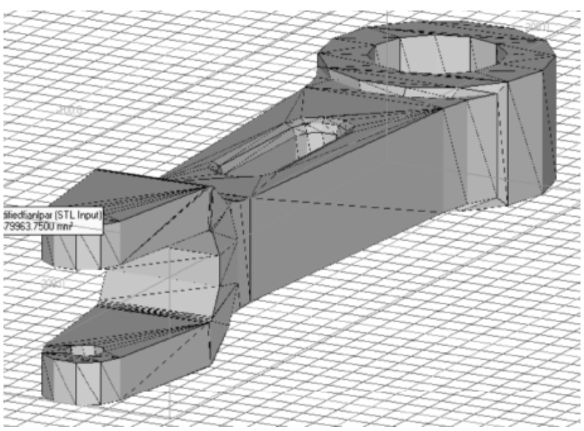

Figure 1 Modified R.S.Arm

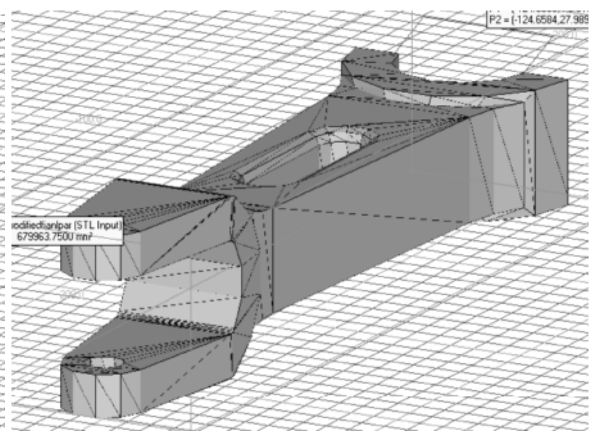

Figure 2 Modified R.S.Arm about x-axes

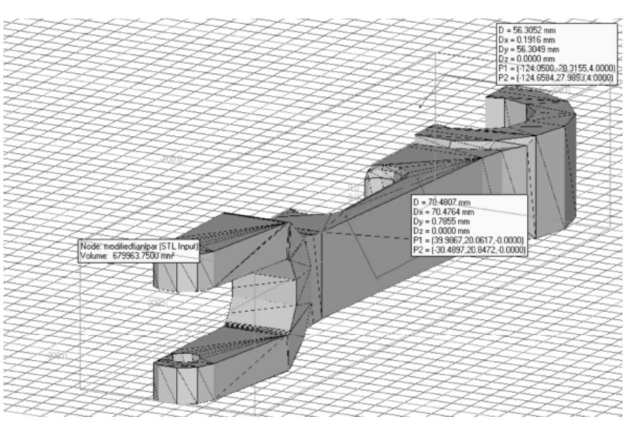

Figure 3 Modified R.S.Arm about y-axes

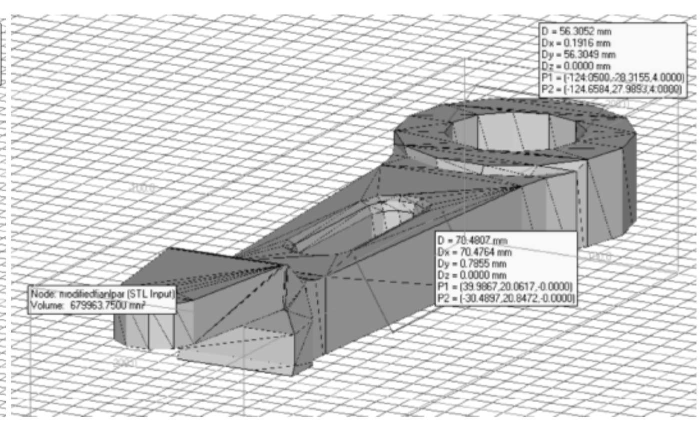

Figure 4 Modified R.S.Arm about z-axes

TABLE 1 SIMULATION RESULTS OF THE MODIFIED R.S.ARM ABOUT THE X- AXIS (H = 72.8747MM)

No. of layers (l) = 0.1mm	127	186	240	287	325	354	371	377	372	365
Surface accuracy ACH mm	0.057	0.039	0.030	0.025	0.022	0.021	0.019	0.019	0.019	0.02
Build time h	0.5	0.81	1.04	1.25	1.41	1.54	1.6	1.7	1.6	1.6
Efficiency ἠ %	0.5	1	1.5	2	2	2	2	2	2	2

TABLE 2 SIMULATION RESULTS OF THE MODIFIED R.S.ARM ABOUT THE X- AXIS (H = 93.0000MM)

No. of layers (l) = 0.1mm	127	186	240	287	325	354	371	377	372	365
Surface accuracy ACH mm	0.073	0.05	0.038	0.032	0.029	0.021	0.026	0.025	0.025	0.025
Build time h	0.5	0.81	1.04	1.25	1.41	1.54	1.6	1.7	1.6	1.6
Efficiency ἠ %	0.5	0.5	0.5	1	1	1	1	1.5	1	1

TABLE 3 SIMULATION RESULTS OF THE MODIFIED R.S.ARM ABOUT THE X- AXIS (H = 354.1375MM)

No. of layers (l) = 0.1mm	127	186	240	287	325	354	371	377	372	365
Surface accuracy ACH mm	0.28	0.19	0.15	0.12	0.11	0.1	0.09	0.09	0.09	0.09
Build time h	0.5	0.81	1.04	1.25	1.41	1.54	1.6	1.7	1.6	1.6
Efficiency ἠ %	0.5	0.5	0.5	0.5	1	1	1	1	1	1

It was observed that for 93.0000mm direction and 287layers gave surface accuracy of 0.032 and build time of 1.25hrs and for 354.1375mm direction 354 layers gave surface accuracy of 0.1 and build time of 1.54hrs.Since the number of layers were 186 instead of 354 and build time 0.81 hrs. It is expected to virtually fabricate in the direction of 72.87mm. Consequently, fabrication of high precision prototypes of agricultural tractor component would become possible.

4. CONCLUSION

This paper proposes a virtual system to aid a designer to select process parameters for RP. The system adept's surface accuracy, build time and orientation efficiency as the key manufacturing requirements. Part direction, layer thickness, are identified as the key control parameters that influence the requirements significantly. A mathematical model was developed to relate the requirements with key control parameters. It also provided utilities for the designer to visualize and analyse the surface accuracy to perform a number of trials with control parameters for a given part.

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Conflicts of Interest

The authors declare no conflict of interest

Data and materials availability

All data associated with this study are present in the paper.

Peer-review

External peer-review was done through double-blind method.

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