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CONCEPT OF USING A BENCHMARK PART TO EVALUATE RAPID PROTOTYPING PROCESSES

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INTRODUCTION

In this fast changing modern global economy, companies that generate prototypes quickly can finalise designs and penetrate markets earlier than the competition. These advantages motivated the development of many computer based rapid prototyping processes(4). Such processes are based on a computer generated solid model of the part that is being prototyped. Proprietary software then sections this drawing into layers. Then the rapid prototyping machine builds the prototype from the bottom layer upwards. For example, in stereolithography a laser beam is focussed on a vat of photosensitive resin. Then the beam traverses across the cross section of the layer that is being processed. This causes the resin to polymerise and a layer of solidified material is created. In this manner the prototype is built from the bottom upwards with layers being bonded to each other.

Different rapid prototyping processes that are currently available use different raw materials and different energy sources. For example,the materials range from photosensitive liquid resins to powdered metals. Some processes are fully automated while others require manual interaction to complete the part. Such diversity makes it difficult to compare to the capabilities of the various rapid prototyping processes.

The objective of this research is to develop a tool that can verify the purported capabilities of any rapid prototyping process. This tool is a benchmark part which is designed to have unique product details and features . The extent to which a rapid prototyping process can reproduce these features becomes a measure of the capability of the process. Since rapid prototyping is a dynamic technology, this benchmark part should be used to continuously monitor process capability of existing and developing technologies. Development of this benchmark part will therefore be based on an understanding of the properties required from prototypes and characteristics of various rapid prototyping processes and measuring equipment that is used for evaluation.

PROTOTYPE PROPERTIES

Current rapid prototyping processes produce three distinct types of prototype products: show and tell products, form and fit products and functional products. The properties and expectations from each type are different. For example, show and tell products are used to establish the overall design of a product and obtain feedback from product managers and customers. In addition, the product design can be evaluated for potential manufacturing and inspection problems and can be used for materials and allied planning activities. Form and fit products are more precise products that additionally allow assembly and tooling strategies to be established. Functional products are most desired as they can be field tested and thus provide useful and timely information to the designer and potential user. The goal of any rapid prototyping process is to generate such functional products in the quickest possible manner. However at present, most rapid prototyping processes can produce prototypes that are either show and tell products or form and fit products. Characteristics of the more widely used rapid prototyping processes are described herewith.

RAPID PROTOTYPING PROCESS CHARACTERISTICS

At present, the laser based rapid prototyping processes are the most widely used. These include stereolithography (3), selective laser sintering (1),and laminated object manufacturing (4). Processes based on the ink jet droplet deposition principle such as three dimensional printing (3) are gradually becoming more widely accepted. Processes that involve deposition of molten beads of material such as fused deposition modelling process (4) is also discussed. A brief description of these processes is given herewith:

a) Stereolithography. The basic process has been described earlier. After part build is over in the stereolithographic machine,the part is manually cleaned and further cured in an ultra violet light chamber.

b) Selective laser sintering. The process also utilises a vertical axis computer controlled laser beam . But this beam raster scans the surface of a bed of plastic or metal powder, across the section of the part that is being built. The laser fuses the powder upon contact and the part is built from the bottom upwards. Upon completion of the build the part is removed from the powder bed, excess powder is dusted off and the part is considered complete.

c) Laminated object manufacturing. Adhesive backed film is initially pressed to a flat reference plate. A vertical computer controlled laser then cuts this film along the periphery of the section of the part that is being processed. A fresh layer of film is then bonded over this recently cut contour and the contour corresponding to this new layer is then cut. The process then continues until the part is completed.

d) Inkjet processes. There are two different processes based on the ink jet principle. The first process deposits a binder on a bed of ceramic powder across the section being processed. Successive layers are thus created until a "green" part is fully built.This "green" part is then sintered to produce the completed part.

A second process uses two ink jets. One jet deposits a plastic layer that follows the part section and the second deposits a low temperature wax that is used as a support. After the build is over the wax is dissolved to leave behind the completed plastic part.

e) Fused deposition modelling. A wax or nylon wire is fed through a liquefier that melts this material. This molten material is the forced through a jet that traverses across the section of the product.The product is built up of layers of molten material that fuse to the already deposited layers.

In summary, there are some important commonalities between these rapid prototyping processes. All processes are initiated with a computer solid model of the desired part and the actual rapid prototyping process is computer controlled. The parts are always built up in layers which are created by raster scanning a laser or ink jet deposition system across the section of the part.

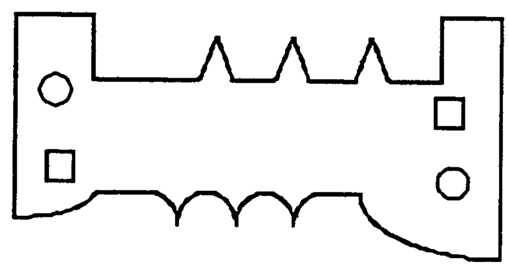
A wide range of materials are used in these processes and the processing techniques vary widely. The control of the various process parameters to obtain consistent parts is still under development. Some processes require manual interaction for cleaning and post processing operations, such as curing or sintering.

These process characteristics are different from conventional manufacturing processes. In addition, prototypes are made in miniscule quantities and of such differing geometries that conventional statistical techniques for control and prediction cannot be used efficiently. Thus there is a need to develop new techniques to evaluate the process capability of these different processes. The benchmark part is a tool that will satisfy this need.

CONCEPT OF BENCHMARK PART

The benchmark part is a reference tool that will be used to continuously upgrade the precision of parts made by rapid prototyping technologies. It will be designed with two major objectives: the first is that it will be utilised by a rapid prototyping process developer to continuously evaluate the dimensional improvements that are made to the process and the second is enable a user to evaluate the dimensional process capability of various rapid prototyping processes.

A planar benchmark part design is proposed for those rapid prototyping processes that do not utilise post processing operations and those that do not need supports. Thus two conditions are such that the product is completely dependent on the characteristics of the process alone and are not dependent on any manual intervention. Since parts are fully supported by inherent process features, any layer that is generated should be a representative of all the layers. Fig.1 depicts the details of the first concept of this benchmark part.



This benchmark part shown on the right has a uniform thickness and contains features with linear and curvilinear dimensions, small grooves and holes. The linear dimensions allow one to assess the capabilities of a process in the x or y axes. The curvilinear dimensions allow one to assess the ability of the process to produce nonlinear details. Positional errors are evaluated by measuring the location of holes The ability to generate details is assessed by the precision with which the triangular and curved projections are created.

The rapid prototyping processes that require supports or post processing will be evaluated with a benchmark part that has vertical walls in the xz and yz planes,in addition to the existing details that are available on the planar reference part. These walls will magnify any deleterious effects caused by the post processing or manual operations.

JUSTIFICATION OF DETAILS ON BENCHMARK PARTS

A rapid prototyping process is highly dependent on process parameters. For example, the length of time that a laser spends on a spot will determine the strength and stability of that a spot.This period of time is dependent on the ability of the machine to maintain a correct scan speed throughout the process.Thus linear dimensions enable one to assess the single axis control of the machine, curvilinear dimensions allow a two axis control to be assessed and the triangles and curvilinear details allow the precision of the process to be established.

All these dimensional details are dependent on the ability of the measuring instruments to assess the error . Ideally, these parts should be measured on a non contact system such as a laser system. However, from a practical viewpoint a coordinate measuring machine can be used. Further, a benchmark part should be made for each set of materials that is processed and also if the density or strength of the part is changed.

SUMMARY AND CONCLUSION

A conceptual benchmark part for guiding manufacturers and users of rapid prototyping technologies is proposed . This is based on a need to have some tool to evaluate the development of this technology and also assist the user in judiciously selecting a process. The proposed part is designed to provide both short and long range feedback and so should be readily accepted by the rapid prototyping community.

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