Session 3263

Impact of New Technologies on Integrated Product Development

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ABSTRACT

The purpose of this research was to investigate the impact of a new methodology of integrated product development through solid modeling, analysis, optimization, prototyping and testing. The aspects of simultaneous engineering methods, reduction of development time, reduction of costs and increasing product quality could be achieved by using these technologies. Examples are presented here that show the connection of the various technologies and their integration into a product development process. The result of testing of the prototype samples provides new orientation for making stronger prototypes.

1. INTRODUCTION

Engineering design and manufacturing have long been recognized as the most critical core activities of the industrial product development process [1]. A number of evolutionary changes have taken place over the past couple of decades in the areas of both design and manufacturing. Current methods in product development involve an integrated approach in which design, analysis and optimization, prototyping and testing are all integrated [2].

The new methodology of integrated product development delivers a single, comprehensive benefit. It enables us to create the best possible robust mechanical design. This methodology is achieved when parametric solid modeling, analysis and optimization, rapid prototyping and testing become integral, accessible elements of a design and manufacturing system [3-4]. Figure 1 shows the concept of the integrated product development.

The research objective was to develop the new methodology of product development through the new and emerging technologies of solid modeling, analysis, rapid prototyping and testing. The methodology used required an extensive use of computer-based programs. These programs were used to complete feasibility studies early in the program, to set design parameters, and to provide insight into defining initial component structures for final product development.

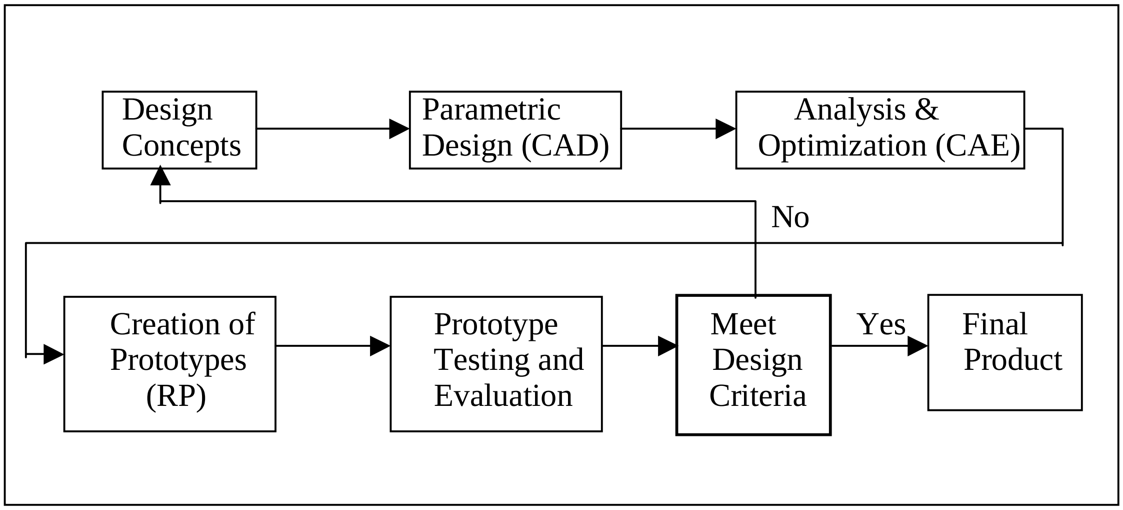

Figure 1: Concepts of Integrated Product Development

The research is expected to strengthen the new methodology of integrated product and process development through solid modeling, analysis, rapid prototyping and testing. It is also expected that the new methodology will reduce the cycle time for product development and increase the quality and reliability of products.

2. METHODOLOGY

The concepts of integrated product development are demonstrated using the following four phases of Solid Modeling, Analysis, Rapid Prototyping and Testing.

(1) Solid Modeling using Pro/Engineer
In this phase, a solid model of a helicopter blade was created using Pro/Engineer software package from Parametric Technology Corporation (PTC). The advantage of using the solid model was that it provided the parametric design and materials data that were used later for analysis and manufacturing. The design was parametric so that when we changed the dimension of a part or a feature, the entire design database was upgraded automatically [5]. The advantages of solid modeling are the following:

- accurate description of model
- easier ways to find mistakes and solving problems because of improved analyzing tools.
- calculation and simulation.
-direct transmission of data to NC machines.
- quick changing of CAD models because of parametric design.

Creation of the Helicopter Blade

The helicopter blade was created with the idea of incorporating the maximum flexibility into the design intent. Using Pro/Engineer's powerful Variable Section Sweep capability, the helicopter blade was created as a swept section which was guided not only by the leading and trailing edge parametric control curves, but also by parametric graphs which controlled both the variable height along the length of the blade and a variable angle (dihedral) of the blade. After the blade was created, the graphs could be easily changed, thereby causing the angle and height of the blade to follow any complex change in the graphs. Any other dimensions plus the leading and trailing edge control curves can instantly change the shape of the blade parametrically. The rotor blade part is shown in Figure 2.

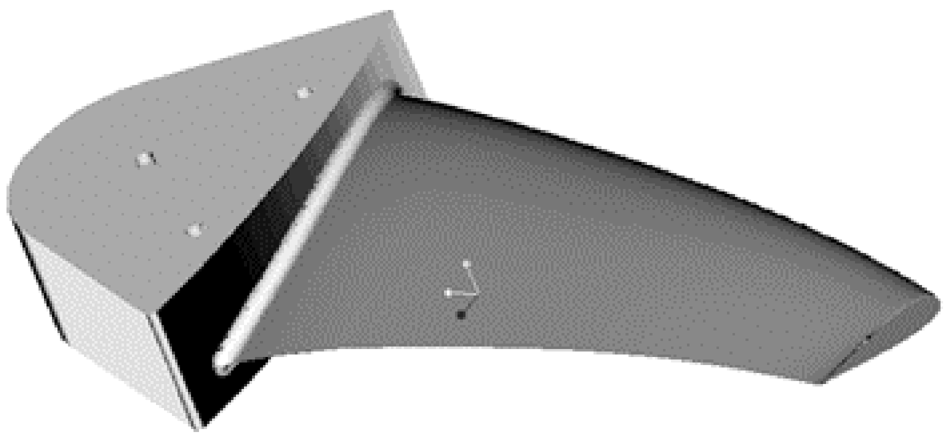

Figure 2: Rotor Blade

(2) Analysis and Optimization

In this phase, the model created in the first phase, was analyzed to determine if it met the design criteria. Most industries use Finite Element Analysis (FEA) to perform the analysis of product design. We used Geometric Element Analysis (GEA) to complete the analysis because the Pro/Mechanica software package from PTC, which is based on the concept of GEA, assures accuracy while greatly simplifying the modeling process [6-7]. Geometric elements are large, simple regions with curved edges or faces. Analysis results are insensitive to typical element distortions, skew or warp. The advantages of analysis and optimization are the following:

- verification of model meeting the design needs.
- ensures whether the model will stand up to the test of real environment.
- optimization of a model will reduce cost and increase reliability.
- provides freedom to experiment with more than one variable.
- provides best design configuration (shape, size and topology).

The finite element analysis of the rotor blade showed stress concentration at the joint of the base and the wing. Based on this finding, the joint was rounded to reduce the stress concentration and the risk of failure.

The finite element analysis was also conducted using Cosmos/M software from Structural Research and Analysis Corporation. The result of the analysis was similar to that of Pro/Mechanica software analysis. FEA was used as a tool here to find the area of maximum stress concentration.

(3) Rapid Prototyping

Rapid Prototyping (RP) is a new technology that is a part of the new methodology of integrated product development [8]. RP takes information from the 3D CAD database and manufactures solid model (prototypes) of the design. One can turn a design concept into a prototype, test it for fit and forms, and even simulate product performance without excessive cost and time of traditional prototyping. The advantages of RP are the following:

- provides form, fit and functionality requirement.
- clear visualization of the model.
- early verification of any design error.
- prototypes can be used for casting or as a final models for many applications.
- reduce waste for the product development process.

The Fused Deposition Model (FDM)-1650 RP machine from Stratasys Co. was used to prototype the rotor blade. FDM extrudes a thin stream of melted polymer through an extruder head whose position is controlled by a computer. Parts are built up by moving the extruder head through the volume of the head.

The rotor blade part was saved as a binary file. The QuickSlice software of the prototype machine then sliced the rotor blade.stl file. The software put support materials for support and overhang. A piece of foam substrate was placed on the build table. The machine was allowed to proceed with the model making process. It took the machine about eighteen hours to prototype the part. The prototype is similar to Figure 2.

(4) Testing

The final phase of the project involved testing and evaluations of the prototyping materials as well as the RP process. Testing of Rapid Prototype materials is important for determining prototype properties. Prototypes are used during the product development phase of production. If the prototypes have similar properties as the actual production parts, then the entire design and development phase is sped up. Consequently, the use of P400 ABS rather than wax is a step in the right direction of prototype technology, but the properties of the P400 ABS prototypes must be determined.

A second reason for testing of Rapid Prototype materials is that almost all materials, like the P400 ABS, experience shrinkage as they change from the semi-liquid to the solid state.

Accordingly, each prototype created is slightly smaller than its design dimensions, which makes it difficult to test the design for form, fit, and function, (11). The question which is to be answered with further research is: Would there be a certain orientation of deposited layers more suitable than others to solidify with less shrinkage, maintain critical dimensions of the part and maximize surface finish?

An FDM (Fused Deposition Modeling) 1650 machine manufactured by Stratasys Inc. was used in this study. Five models were created in CAD (Computer Aided Design) and imported into a program (Quick Slice) specifically designed to interface with the FDM machine. The first model that was rapidly prototyped was deposited layer by layer along the length of the samples, called 0° orientation. A second model was deposited at ±45° orientation, which is the method Stratasys adopts, and this is considered the baseline and called 45/-45° orientation. Other orientations were at a +45° orientation, 90° orientation and at 0° and 45° layers called 0/45°orientation. Samples for tensile testing were rapidly prototyped of 4.0" gauge length, 1.0" width and 0.125" thickness.

The exact dimensions of each sample were recorded and the tensile testing was performed using an Instron 4505 universal testing machine with crosshead speeds of 0.05 in/min and 0.11 in/min respectively.

3. TENSILE TESTING RESULTS

The tensile data of the ABS samples with different orientations: 45/-45°, 0°, 45°, 90° and 45/0° yielded the following results. The ultimate and yield strengths were the highest for the 0° orientation, 2.98 and 2.36 Ksi respectively. The 45/0° was second (2.03 and 1.97 Ksi), followed by the base line or the standard orientation, 45/-45°, that Stratasys Inc. adopts (1.99 and 1.50 Ksi). The weakest orientations were the 90° (1.35 and 1.14 Ksi) and the 45° (1.02 and 0.96 Ksi).

This result clearly shows that the layering orientations of the rapid prototype samples significantly affect their mechanical properties, i.e.: the rapid prototype samples are <u>mechanically anisotropic</u>.

The ratio of the highest (0° orientation) to the lowest (45° orientation) ultimate and yield strengths are 2.9 (2.98/1.02) and 2.5 (2.36/0.96) times respectively.

The ratio of the 0° orientation to the 45/-45° (Stratasys baseline method) orientation in the ultimate and yield strengths are 1.5 (2.98/1.99) and 1.6(2.36/1.5) times respectively.

The fracture path of all the samples also was dependent on the layering orientation, always occurring along the layer interface. In the 45/-45° two fracture paths at ± 45° initiated and intersected, in the 0° orientation, the samples broke <u>layer by layer</u> parallel to the length and to the stress direction with some of the layers not breaking at all. In the 45° and 45/0° orientations, the samples broke at a 45° angle and in the 90° orientation the samples broke at 90° to the length of the sample (or to the tensile axes). Figure 3 shows a schematic presentation of the rupture geometry.

The ductility or percent elongation was <2% and was difficult to measure because the samples broke in different patterns, Table 1. Accordingly to measure the ductility directly an Izod impact test was performed and to confirm the strength data, a three point bend test was carried out.

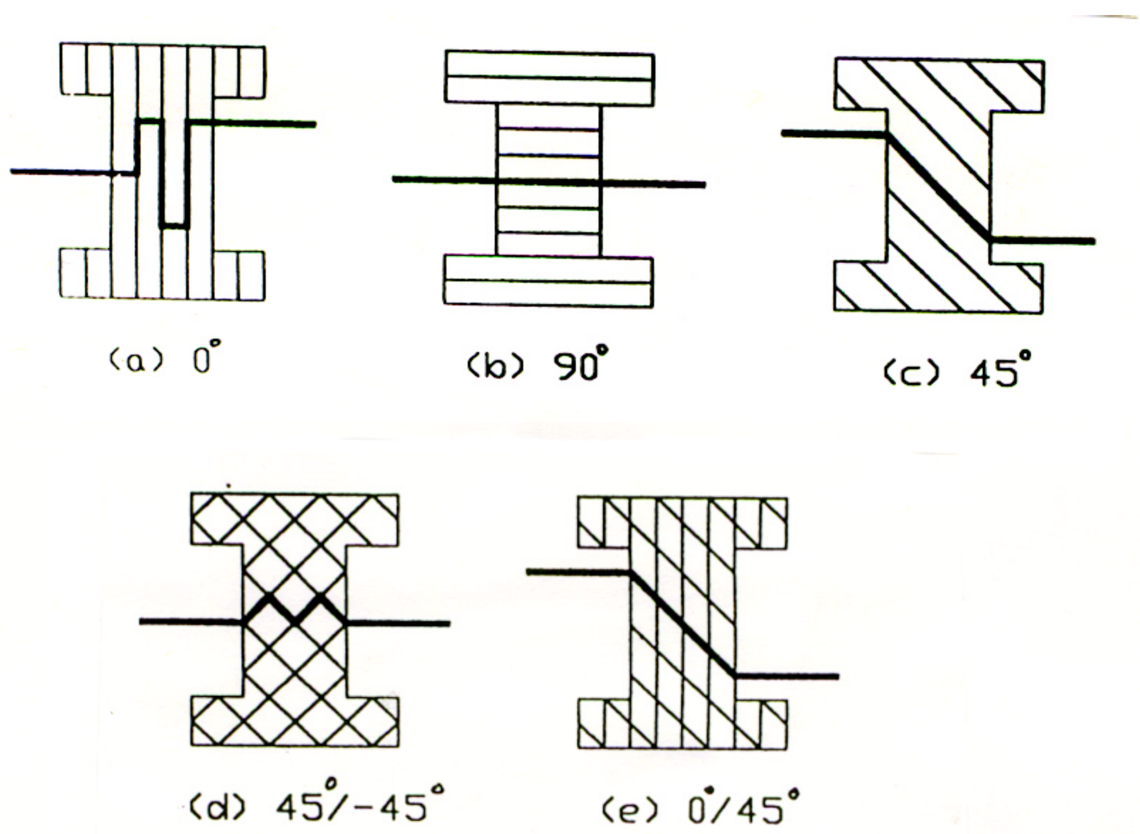

Figure 3: Schematic Representation of Rupture Geometry's on ABS Tensile Samples Varying only by Layer Orientation.

4. CONCLUSIONS AND RECOMMENDATIONS

The integrated product development represents a fundamental change in engineering design and manufacturing that can significantly enhance rapid creation of innovative and affordable products. This methodology combines leading edge technologies effectively to build or assemble a product as well as for designing, testing and prototyping any industrial systems.

Realizing the full potentials of this integrated technology will entail educating and training science end engineering teams not only in the corporate technologies but also in the new approach for collaborative product development. In addition to the known advantages computer supported engineering design, a further reduction of development time, a reduction of cost and an increasing quality can be achieved through the approach of integrated product development.

Our recommendation is that, from now on, all product design should involve the integrated methodology of solid modeling, analysis, rapid prototyping and testing. A very significant result was obtained during the testing of the rapid prototyping models created for this research. The tensile data of the ABS samples with different orientations indicated that the ultimate and yield strengths were the highest in the 0° orientation, followed by 45°/0°, 45°/-45° (baseline), and the 45° in the descending order. We believe that this information will be very valuable to the prototyping companies for increasing the strengths of their prototypes. NASA scientists and engineers can also follow similar orientation during building their ABS-based prototypes.

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