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Automatic Die Cast Part Redesign for Better Manufacturability

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Abstract

In this paper, a method for redesign of feature based part CAD model using CAD software API has been proposed. The primary objectives for the developed system includes, development of part CAD model, extracting model dimensions from the part CAD model, comparing the dimensions of the part model with the standard dimensions and finally incorporating changes in the dimensions of the part CAD model. The designed system on the basis of the framework has been implemented on a sample 3D model.

Keywords: Feature, feature tree, CAD/CAM, part dimensions, manufacturability,

INTRODUCTION

Die-casting is a 'near net shape' manufacturing process extensively used for realizing quality products required in many engineering applications. It uses a mold made of metal that can be re-used. It consist of two halves known as core and cavity that are assembled and poured with molten metal under pressure to produce the required part. The use of solid modeling in the process of die casting part development is very important and that start with the development of the part design using solid modeling.

SOLID MODELING

The solid model of a cast product is the backbone for various CAD/CAM programs that help in improving the accuracy and speed of different tasks in casting development [1]. Various geometric features of castings and different techniques for creating a solid model are of utmost importance. The majority of castings require a combination of all techniques. For example, the overall shape of a cylinder block or exhaust manifold is created by sweeping a few sections, then combining them with other primitives using Boolean operations, followed by subtracting the volume corresponding to the internal ducts [1].

Local features like holes, bosses and ribs are modeled next. Feature modifiers, such as fillets and taper are applied last. In the present implementation, Feature based modeling is used for creation of the 3D model of the die cast part [1]. Various model representation schemes, storage and exchange formats, model verification techniques and the requirements with respect to casting applications are also worth discussion.

The two most common approaches to solid modeling include extrusion of a 2D section and constructive solid geometry [2]. Another approach, called features-based modeling, is also available in most solid modeling systems today. These techniques are useful to define the base feature of a casting as well as its local features.

Extrusion or sweep: This technique involves sketching a cross-section on a plane and sweeping it through a straight or curved path. The cross-section can have inner loops, leading to hollow shapes [2]. Depending on the path, straight extruded shapes and solids of revolution can be generated. For straight extrusion, the distance has to be provided. Revolution can be along the complete circle or a part of it. It is also possible to have negative extrusion, referred to as cut extrude, which produces depression features in an existing solid. For example, a cut extrude circle produces a hole [2].

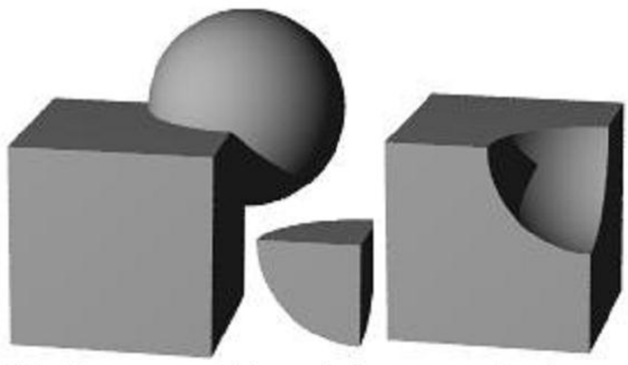


Figure 1: Results of Boolean operations one solids (a) union (b) intersection (c) difference [3]

Constructive Solid Geometry: This technique uses Boolean operations: union, intersection and difference on pairs of simpler models to create the desired shape (figure 1) [3]. A library of solid primitives such as cube, cylinder, sphere, cone and torus are provided to initiate the modeling. Each of these is instantiated by supplying the values of its dimensions, location and orientation. The model created by extrusion or by combining primitive solids is then combined with other primitives or other solids to eventually obtain the designed shape of the component [3].

FEATURES BASED MODELING

Features are defined to be parametric shapes associated with *attributes* such as intrinsic geometric parameters (length, width, depth etc.), position and orientation, geometric tolerances, material properties, and references to other features. Features also provide access to related production processes and resource models [4]. Features are generally expected to form a basis for linking CAD with downstream manufacturing applications, and also for organizing databases for design data reuse.

Standard features include hole, pocket, slot, boss, rib and fillet. These can be modeled by Boolean operations; for example a hole can be produced by subtracting a cylinder from the base solid [4]. Features-based modeling makes this operation more intuitive to engineers by adding a hole feature (instead of subtracting a cylinder), which is essentially a negative cylinder. The user selects a face (on the base feature) or a set of edges/faces (as in the case of a fillet), and specifies the feature parameters. The features tree is preserved, so that the user can easily move, modify or delete a specific feature [4].

Feature-based modelers allow operations such as creating holes, fillets, chamfers, bosses, and pockets to be associated with specific edges and faces. When the edges or faces move because of regeneration, the feature operation moves along with it, keeping the original relationships [4]. The choices made developing these models are very important.

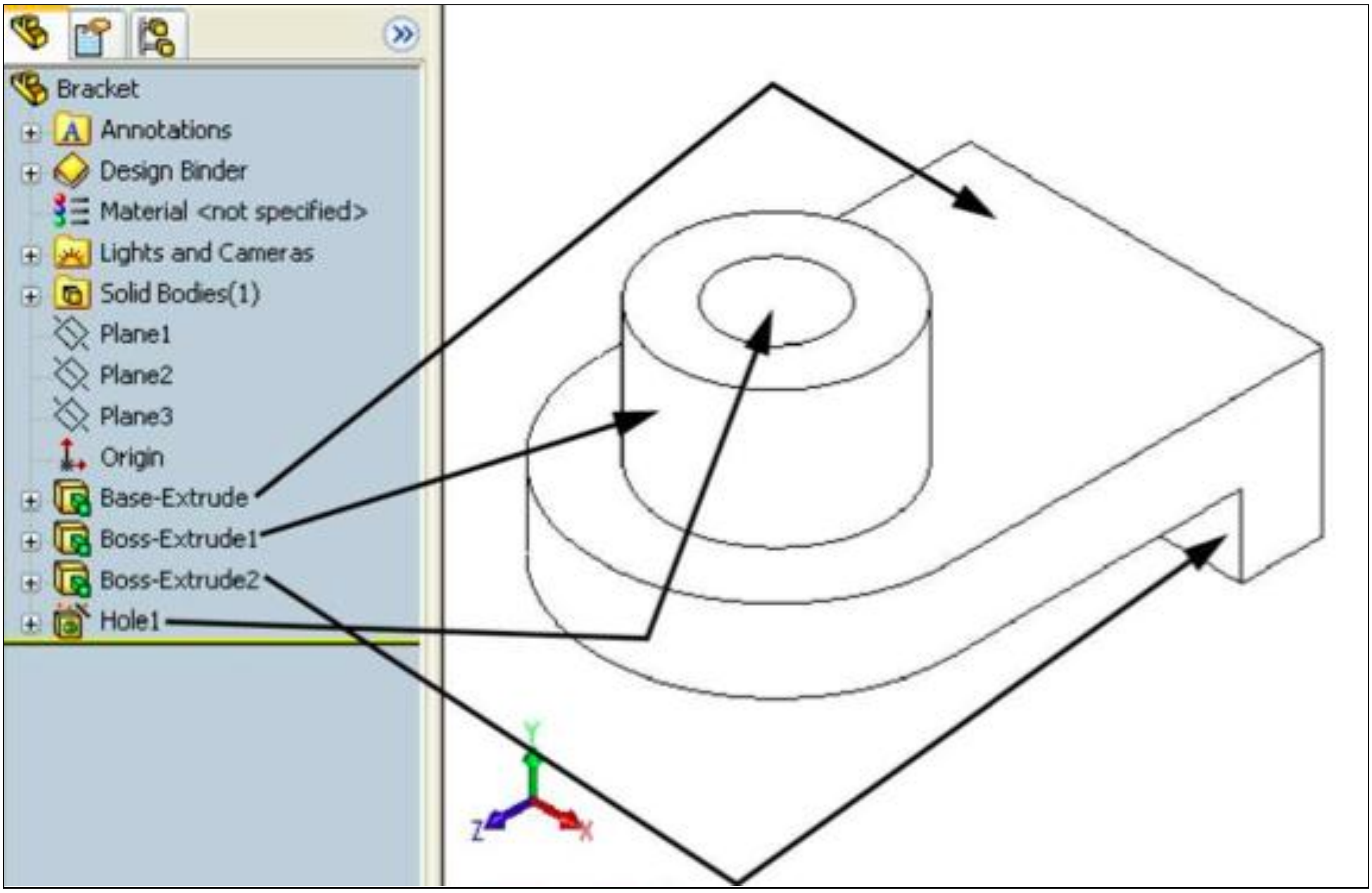


Figure 2: Feature based modeling [4]

The majority of castings require a combination of all techniques. For example, the overall shape of a cylinder block or exhaust manifold is created by sweeping a few sections, then combining them with other primitives using Boolean operations, followed by subtracting the volume corresponding to the internal ducts, which are themselves modeled by complex sweep and CSG techniques [3, 4]. Local features like holes, bosses and ribs are modeled next. Feature modifiers, such as fillets and taper are applied last.

The designer requires training and experience in deciding the strategy for modeling, in particular, combinations of primitive solids that will lead to the final shape in the least number of steps. Sometimes it becomes necessary to retrace the steps during modeling and take a different approach to complete the shape [2, 3, 4].

LITERATURE REVIEW

Dixon and Poli [3] have determined the characteristics of parts that determine part manufacturability and cost. They have reduced the manufacturing engineer's knowledge of injection-molding and die-casting to a set of part features and feature characteristics. A comprehensive survey of various manufacturability evaluation approaches can be found in the work of Gupta et al. [4]. Shah et al. [5] explained that feature based manufacturing uses features to design the model and bridge the gap between design and manufacturing applications. Using a feature-based approach, the evaluation of part manufacturability at the configuration and parametric design stages has been dealt with in the monograph by Poli [6]. Dastidar [7] discuss how the presence and location of holes, projections, and other features affect the tooling and processing cost for injection-molding, die-casting, and stamping. Datar et al. [8] developed a feature based approach to manufacturability assessment of die cast components. The feature information is generated a module to change design for better manufacturable parts leading to lesser trials. O'Driscoll [9] discussed that implementation of manufacturability guidelines for various processes, results in reduction of design changes. This was also concluded that with the implementation of DFM guidelines for various processes, the simulation problems are reduced to a great extent, resulting in a better simulation environment. Chen et al. [10] focused on manufacturability assessment of discrete parts made by injection molding. The geometric characteristics such as depth, height, thickness etc. were formed by feature interactions based on the generalization of feature shapes.

METHODOLOGY

The working methodology of the proposed system is as follows:

1. Designing the part

Firstly a part CAD model having various features is created using feature based modeling in CAD software. The model will then be loaded into the CAD software using API programming by running a project designed in VB.net. The proposed system extracts part dimensions from the part CAD model. In the proposed system, the user will be prompted to input the part CAD model developed using CAD software.

2. Designing the feature library

Feature based library of the standards incorporating part dimension aspects and process capability of die casting is created. The feature library will check about the standardization of the design. The knowledge base for the proposed system is designed based on standard die casting features, standard guidelines, process knowledge, and material and machine data. The proposed feature based library lists important design dimensions from the standards available in the die casting industry and research groups.

3. Generating the manufacturability advice

The proposed system generates suitable manufacturability advice for the part. The design dimensions of the model will be compared with the designed database discussed in the previous section. If the parameters are within standard range, keep the parameters. If parameters are out of range, system suggests the range or value of the parameters, also seek user suggestion for updating the parameters.

4. Regenerating updated design

On the basis of the suggestion of the designed system, the part dimensions are updated and the design is modified. The database of the designed part is also updated. The updated parameters can be used to automatically update the model. The functionality of the model is not allowed to affect under any circumstances with this updation.

5. Validation of the design

The proposed model has been validated for with a case study. The user is able to update the database at all times for improvement as well as data base has also been enriched automatically time by time.

RESULTS AND DISCUSSION

The present system has been implemented in visual studio 2010 & Solidworks® Educational Edition. The system works on the principles of application programme interface (API). Figure 3 shows the form tool developed (GUI) in visual studio 2010. The execution of the form, developed in visual studio, activates Solidworks®.

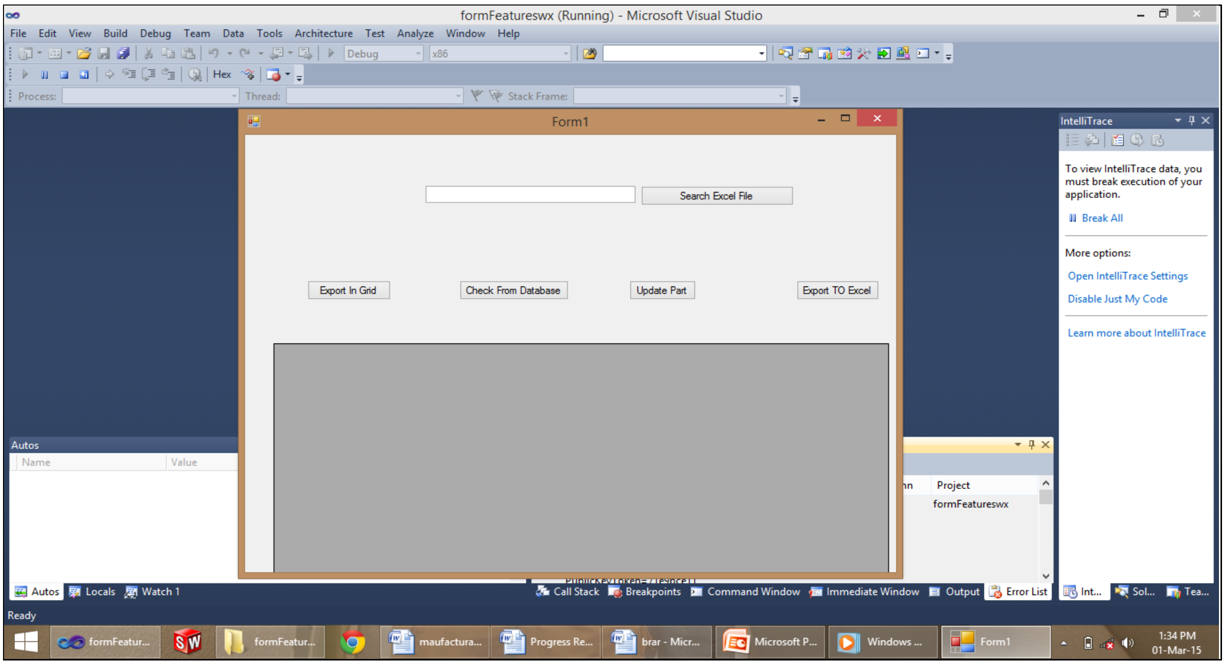


Figure 3: Form tool GUI

The proposed system has been tested on a CAD part shown in figure 4. The part CAD model is designed using feature based modeling. Part dimensions are extracted from the part CAD model. The die casting dimensions are extracted from the part CAD model from the feature tree data.

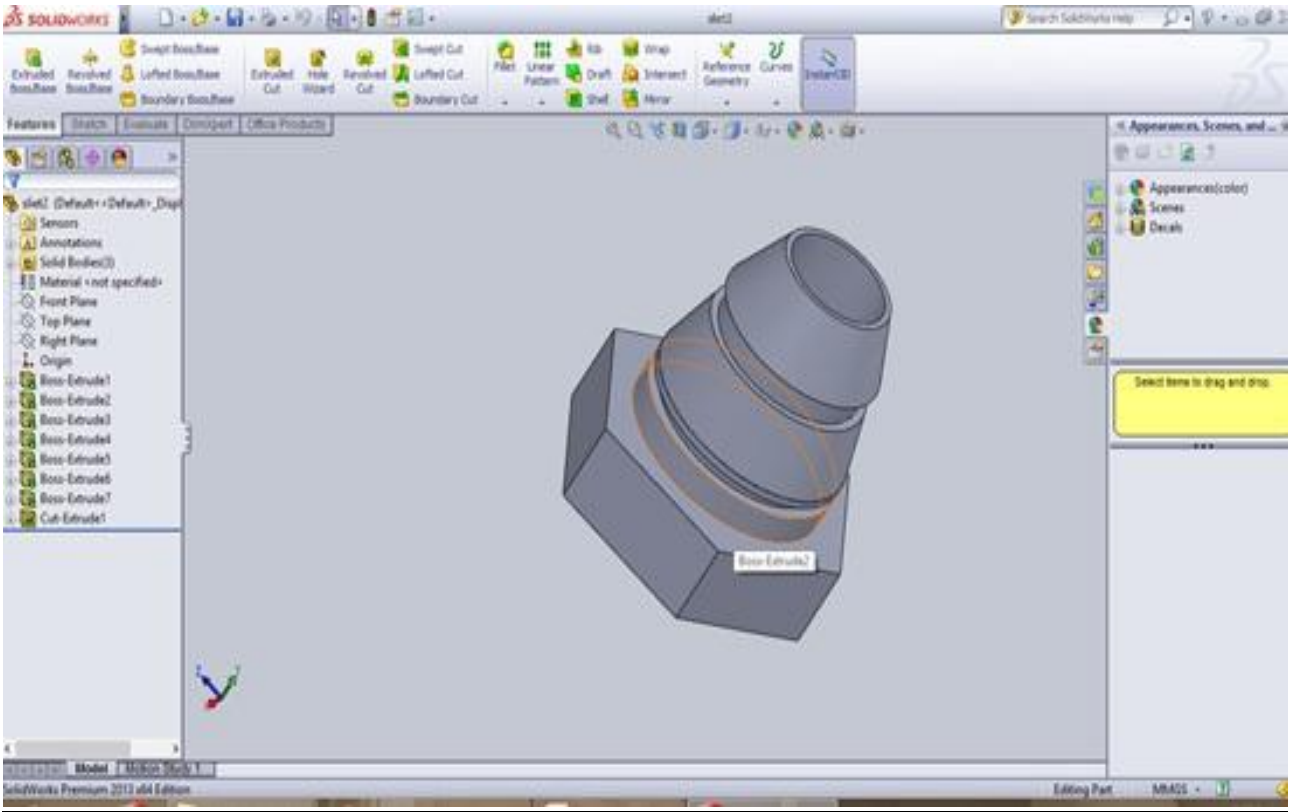
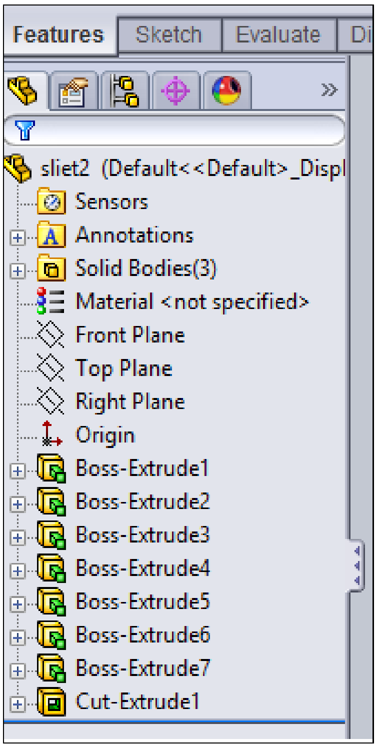


Figure 4: Die cast part CAD model

Figure 5 (a) & 5(b) shows the feature tree and part dimension data extracted from the part CAD model and stored in the database.



(a)

DIM_NAME	DIM_VALUE
D1@Sketch1@2.part	60
D1@Boss-Extrude1@2.part	30
D2@Sketch2@2.part	40
D2@Boss-Extrude2@2.part	5
D3@Sketch3@2.part	35
D3@Boss-Extrude3@2.part	5
D4@Sketch4@2.part	40
D4@Boss-Extrude4@2.part	25
D4@Boss-Draft1@2.part	10
D5@Sketch5@2.part	30
D5@Boss-Extrude5@2.part	3
D6@Sketch6@2.part	35
D6@Boss-Extrude6@2.part	25
D4@Boss-Draft2@2.part	30
D7@Sketch7@2.part	20
D7@Boss-Extrude-cut1@2.part	113

(b)

Figure 5: (a) feature tree and (b) exported dimension data of the part CAD model

The knowledge base is designed using various standards and guidelines for die casting. The NADCA standards and standards followed and developed during different researches are used for designing the knowledge base. The part dimensions are extracted from the part CAD model and compared with standard data in knowledge base. The dimensions that are not as per standards are identified (red color) as shown in figure 5(b). User is prompted to input either correct value or value in specified range as per the standard. Figure 6 shows the updated design data after implementation of the suggestion of the developed system.

DIM_NAME	DIM_VALUE
D1@Sketch1@2.part	60
D1@Boss-Extrude1@2.part	30
D2@Sketch2@2.part	40
D2@Boss-Extrude2@2.part	5
D3@Sketch3@2.part	35
D3@Boss-Extrude3@2.part	12
D4@Sketch4@2.part	40
D4@Boss-Extrude4@2.part	25
D4@Boss-Draft1@2.part	3
D5@Sketch5@2.part	30
D5@Boss-Extrude5@2.part	3
D6@Sketch6@2.part	35
D6@Boss-Extrude6@2.part	25
D4@Boss-Draft2@2.part	6
D7@Sketch7@2.part	20
D7@Boss-Extrude-cut1@2.part	113

Figure 6: Updated data of the part CAD model

Figure 7 shows the updated part CAD model. The model is redesigned (updated) as per modified dimensions and the database is also updated (enriched) using export tab in form tool. The redesigned model is with standard dimensions as suggested by various research groups and die casting standards.

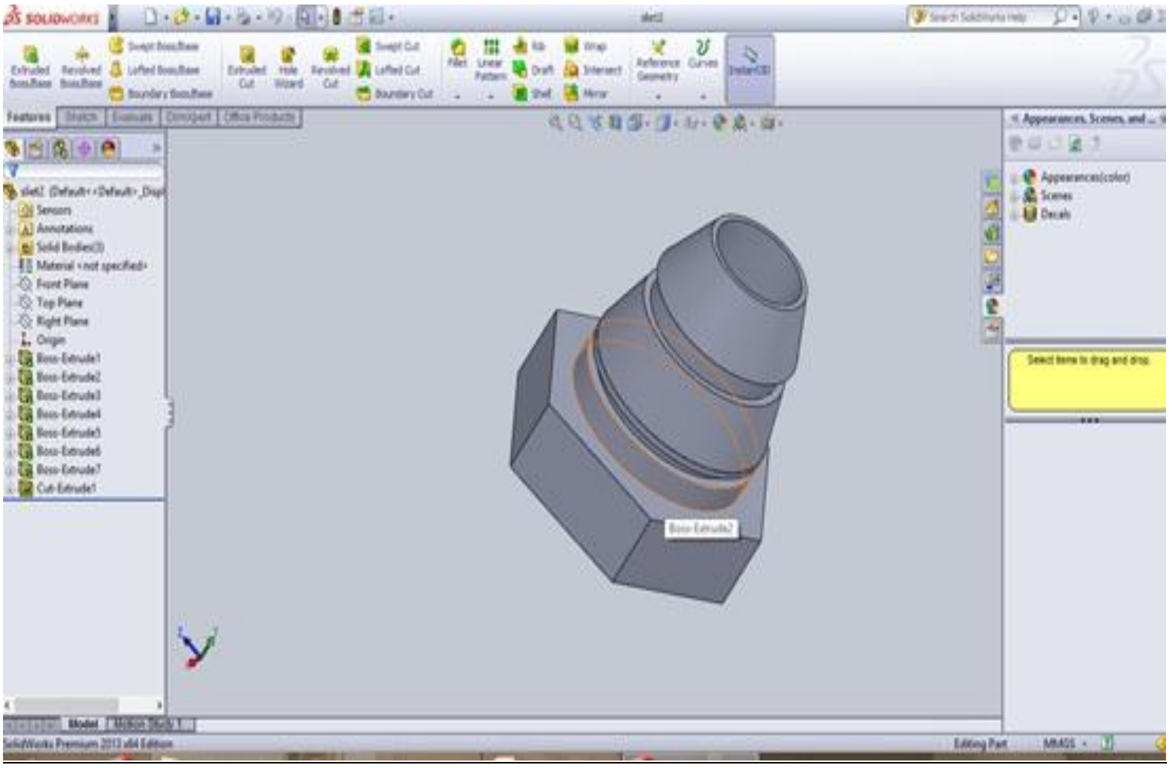


Figure 7: Updated die cast part CAD model

The weights of the existing and redesigned part model were found to be 3.244kg and 2.11kg respectively. So the weight of the part has been reduced by 35%.

CONCLUSION

In this paper, a method for redesign of feature based part CAD model using CAD software API has been attempted. The developed system explained a methodology to extract important dimensions from the part model and updating the dimensions and the model by comparing the part dimensions with the standard values as suggested by NADCA or research groups. A concept of using API programming of CAD software using VB.net is proposed. The designed system on the basis of the framework has been implemented on a sample 3D model. As the weight of the part has been reduced so it leads to saving in material, cost, time to market and so on. Also the model is now as per the set standards, so it would be better manufacturable as compared to the original model.

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