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An integrated framework for product design and macro process planning based on ISO 10303 standard-a case study: integration of glass bottle and its mold design

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Abstract. Nowadays the world of manufacturing and production has been encountered with a constantly changing behavior's of customers. Moreover in the global market, a company can survive if it has the efficient capabilities for rapid product development.These capabilities are known to be important and they mainly affect on the market penetration and cost reduction. One way to enhance such capabilities is to integrate the essential activities of a manufacturing with the help of information technology. In recent years, the researchers have proposed integration of the computer-aided design (CAD), computer-aided manufacture (CAM) and computer-aided process planning (CAPP) as the main phases of product development lifecycle. These phases play an important role in the manufacturing environment and their integration will result in high-class production with minimum lead time. This paper focuses on the die design and process planning activities to produce the molds seamlessly . It studies the recent works on integration solutions and proposes an integration framework for glass bottle manufacturing companies.The paper considers the integration of the part design, macro process planning and the mold design activities. Moreover, the solution has used the ISO 10303 (STEP standard-International Standard for the Exchange of Product data). The novel aspects of the framework have been discussed through a case study. The case study highlights the integration of glass bottle design, process planning and bottle mold design to show the capabilities of the proposed framework.

Introduction

Industrial molds are greatly utilized in various aspects of the industry [1]. Application of molds for manufacturing of the parts has been started nearly three centuries ago [2]. Traditional mold manufacturing often relied on experience and techniques of engineers . Mold making traditionally is known to be the process of creating a cavity, usually inflexible vessel for surrounding an item to shape it [2,3]. Nowadays,most of the molding operations are manufactured either by CNC machining or by using electrical discharge machining processes. Considering the various types of parts and processes in mold manufacturing, it's necessary to have a framework that assures achieving a correct mold [2,4]. In recent years, many researchers have proposed various frameworks for molding operations. However, the proposed frameworks lack an effective solution for integration of CAD and CAPP. Moreover, they do not satisfy the standard formatting for geometric mold output to insure interoperability with common related computer aided applications. These frameworks do not apply the international standards for integration among CAD & CAPP so losing product information in each stage of the product cycle resulting in increasing cost and time. Using an international standard in the integrated framework is essential for enterprises who collaborate in different product life cycle phases [5,6,7]. The latest research works present frameworks to enable an integrated System of Mold Manufacturing through Process Integration and

Collaboration. In these frameworks the PPR (Product/Process/Resource) based architecture for the master data is considered. This has an important role in an integrated framework. However, no concentration on the computer aided process planning (CAPP) was found. CAPP is a bridge between design and manufacturing in product development cycle which is very important and extremely affect in time and cost [8,9,10]. The other recent framework has proposed a concurrent process planning system for mold manufacturing [11]. This framework supports concurrent mold manufacturing process planning and simplifies the rationalization, automation of mold design and process development. This leads to improvement of the efficiency, quality, and reduces the cost of modeling development. However, there is no attention on the feature recognition system for extracting physical features from computer aided design (CAD) which can help industrial engineers in process planning. The solutions haven't used a standard approach for exchanging data [11,12]. In this article, a new solution for glass mold design and manufacturing is studied. This idea purposes an integration between computer aided design (CAD) and computer aided process planning (CAPP). This solution includes a new algorithm which can be used by industrial and manufacturing engineers to improve the efficiency in process planning for glass molds. This solution is based on an International Standard for the Exchange of Product model data (STEP)-ISO10303) along with an object-oriented design software application which is included in Java language.

Glass bottle manufacturing

Glass products are commercially manufactured in an almost unlimited variety of shapes. Many are produced in very large quantities, such as light bulbs, beverage bottles, and window glasses. Others, such as giant telescope lenses, are made individually [13]. One of the manufacturing process of glass bottle manufacturing is the blow-and-blow method. This method is used to produce bottles. The sequence is two (or more) blowing operations. There are variations to the process, depending on the geometry of the product, with one possible sequence shown in Figure 1. Blow-and-blow methods are used to make jars, beverage bottles, incandescent light bulb enclosures, and similar geometries [14].

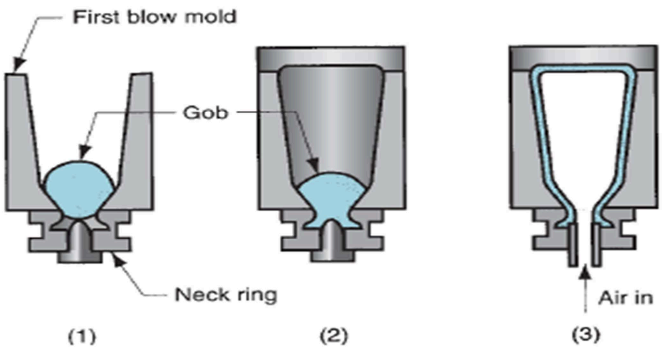

Fig. 1. Blow-and-blow forming sequence: (1) gob is fed into inverted mold cavity; (2) mold is covered; (3) first blowing [14]

Proposed idea for integration of CAD&CAPP in Glass mold design and manufacturing
International Standard for exchanging data-ISO10303.

The STEP standard – ISO 10303 – is the result of attempts for product data integration [15]. Product information models in STEP are defined in EXPRESS, ISO 10303-11, and a modelling language which combines ideas from the entity–attribute-relationship family of modelling languages with object modelling concepts. ISO 10303–21 defines a character based file format for the exchange of data corresponding to an EXPRESS information model that is sufficient for traditional data exchange [16]. ISO 10303 consists of application protocols (APs) as parts of the standard that define data models for a certain application domain. Each AP defines classes of objects and their relations. Using APs, STEP addresses many industrial data exchange requirements. For example AP203 for configuration controlled 3D designs of mechanical parts and

Assemblies [17]. Today the most important and the most comprehensive standard that can be applied in industry is International standard STEP [18]. With the help of this standard and using its protocols, information on design and process planning can be stored in a special kind which is easy to use at other stages of production. Configuration Controlled 3D Design of Mechanical Parts and Assembles(ISO 10303-203:1994) is one of the STEP's protocols which is about designing a part and saving its geometric information by using Boundary Representation (B-Rep) technique as a design tool [19]. Figure 2 illustrates a STEP file which is human readable. In header section there is some information about the designer and the part that is drawn and in data section there is various information about the mechanical part. In this section There are Those information which is important for extracting physical features which will extract form entities and attributes and their relations [20]. Figure 2 indicates a sample file of STEP AP203 and the information in each section can be read by human or be as an input file for a program language.

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('CATIA V5 STEP Exchange'),'2;1');

FILE_NAME('C:\\Users\\Arya\\Desktop\\MOULD.stp','2015-
07-02T15:17:56+00:00',('none'),('none'),'CATIA Version 5
Release 16 (IN-10)','CATIA V5 STEP AP203','none');

FILE_SCHEMA(('CONFIG_CONTROL_DESIGN'));

ENDSEC;
/* file written by CATIA V5R16 */
DATA;
#5=PRODUCT('Part1','','',(#2)) ;
#1=APPLICATION_CONTEXT('configuration controlled 3D
design of mechanical parts and assemblies');
#14=PRODUCT_DEFINITION(' ',' ',#6,#3);
#16=SECURITY_CLASSIFICATION(' ',' ',#15);
#15=SECURITY_CLASSIFICATION_LEVEL('unclassified')
;
#47=CARTESIAN_POINT(' ',(0.,0.,0.)) ;
#52=CARTESIAN_POINT('Axis2P3D Locati
--
--
ENDSEC;
END-ISO-10303-21;
```

Fig. 2. STEP AP203 sample file

Solution framework and structure

The solution which has been proposed is divided into four stages; designing by CAD software application, feature recognition algorithms, extracting geometrical features and making process plans by using manufacturing capabilities database. First, it's important that industrial parts manufacturers, especially glass mold makers, use those design software, which can store geometrical information in the standard STEP AP203 because this standard can store all information in such a way that can be used in other stages of production. In the second stage, the algorithms for recognizing features should be developed, in other words, all geometrical features have their own algorithms for recognition. Industrial engineers can develop these algorithms through a programming language which is built by Java language for using them in the manufacturing of different parts,especially in the glass mold industry. These programs are employed in the next stage for extracting geometric features.In this section feature recognizer program should be run to get parameters for making process plan. In other words, it proposes a solution that involves feature recognition program which analyses the B-RP geometrical information of the mold. After extracting entities and attributes from the CAD file, the feature recognition program extracts the type of geometric feature and its parameters based on ISO 10303 standard. After reading the entities and attributes, the program makes decisions through a rule based system or extracting geometrical features and their parameters. Features information saved in a STEP file. This file is used in process planning stage. In fact, a database is formed for process plans, according to the company's capabilities. The following figure shows the proposed framework and integration of information between CAD and CAPP for making a process plan of glass bottle mold.

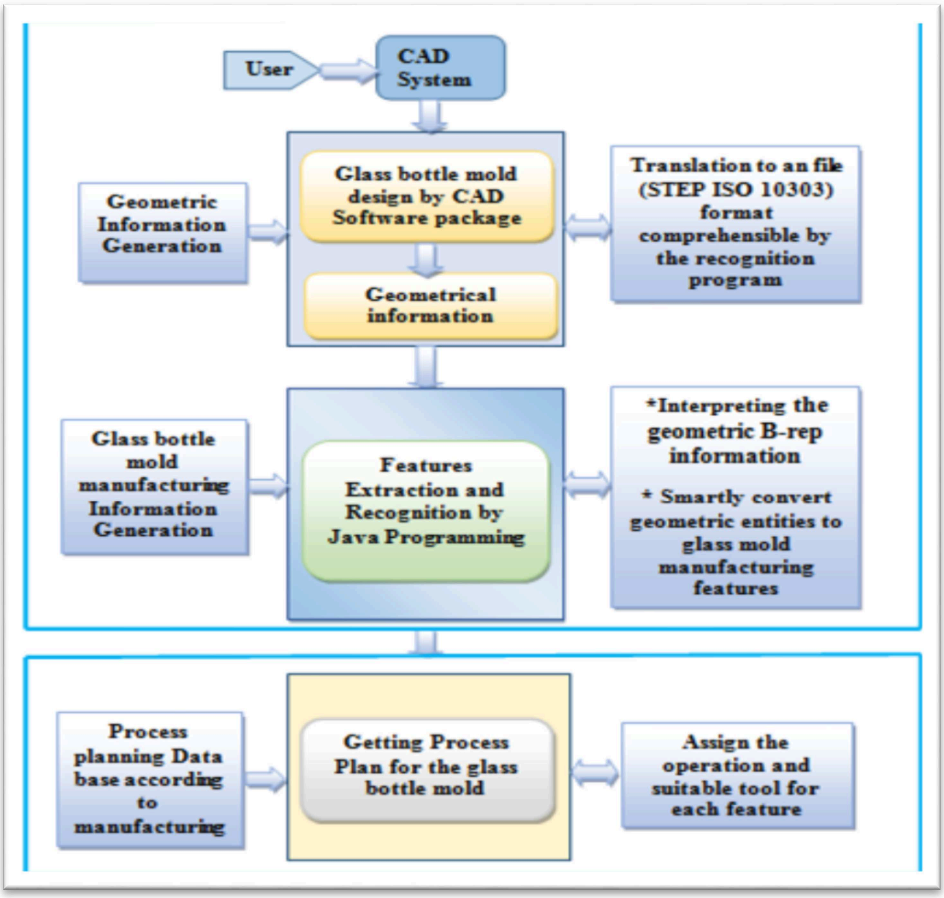

Fig. 3. An Integrated framework for making process plan

Case study

This case study is about glass mold design and manufacturing and shows the use of the proposed framework for integration of CAD & CAPP.

Designing through a CAD software package

At this stage a bottle is designed, using a design software that supports the STEP standard. A glass bottle design is shown in figure 4.

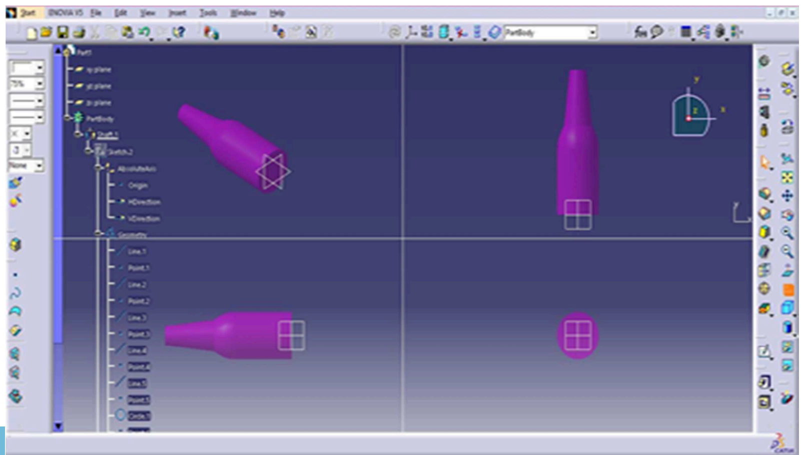

Fig. 4. Design of glass bottle part

Figure 5 shows the result of glass mold bottle design through mentioned procedure.

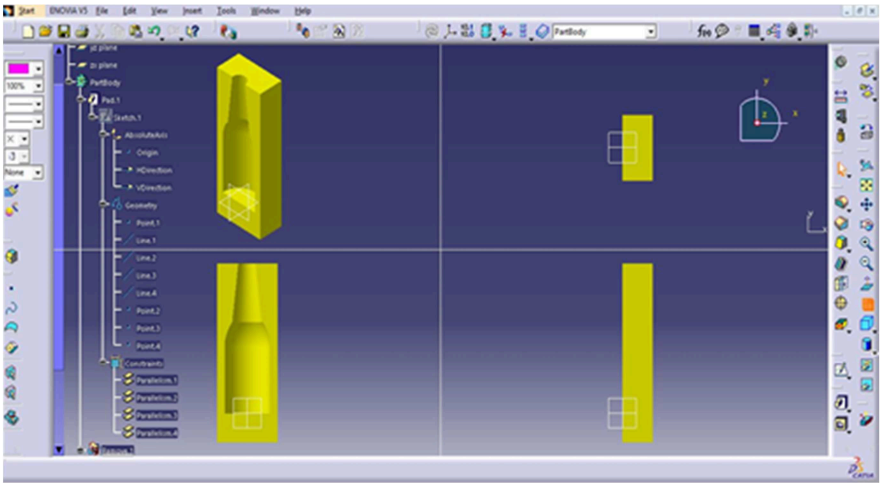

Fig. 5. Glass bottle mold design

STEP AP203 output for bottle mold design from CAD software is shown in the following figure.

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('CATIA V5 STEP Exchange'),'2;1');
FILE_NAME('C:\\Users\\Arya\\Desktop\\MOULD.stp','2015-
07-02T15:17:56+00:00',('none'),('none'),'CATIA Version 5
Release 16 (IN-10)','CATIA V5 STEP AP203','none')
FILE_SCHEMA(('CONFIG_CONTROL_DESIGN'));
ENDSEC;
/* file written by CATIA V5R16 */
DATA;
#5=PRODUCT('Part1','','',(#2)) ;
#1=APPLICATION_CONTEXT('configuration controlled 3D
design of mechanical parts and assemblies') ;
#14=PRODUCT_DEFINITION(' ',' ',#6,#3) ;
#279=CIRCLE('generated circle',#278,30.) ;
#294=CIRCLE('generated circle',#293,30.) ;
#316=CIRCLE('generated circle',#315,20.) ;
....
ENDSEC;
END-ISO-10303-21;
```

Fig. 6. STEP AP203 file of mold

Entity, attribute and feature recognition module

This program is written by the Java language.

In the first step the program recognizes the following entities: Circles, Cartesian points, Directions. The bottle consists of cylindrical and frustum features. The feature recognition algorithm for a cylindrical and frustum feature are discussed below:

For all circles
  If [there were two circles
    Which they have equal radius & they have the same directions]
Then
  There is a cylindrical feature in the part. Save the feature parameters; radius, height, CenterPoint and direction in the output file.

Another feature is frustum;

For all circles
If [there were two circles
Which they haven't equal radius & they have same directions]
Then
There is a feature frustum in the part. Save the feature parameters; radiuses, height, CenterPoint and direction in the output file.
The Java code for these algorithms are given in the figure 7.

```
int E=Entitycounter;
        for ( int r=0;r<Entitycounter;r++)
          {
            for( int rr=r+1;rr<Entitycounter;rr++)
            {

if((X[r]==X[rr])&(Y[r]==Y[rr])&(R[r]==R[rr]))
              {
    result[E]="      There is a clynderical shape with radius=
"+R[r]+"mm. "+"and the height is "+(Z[rr]-Z[r])+"mm. ";

                break;
              }

if((X[r]==X[rr])&(Y[r]==Y[rr])&(R[r]!=R[rr]))
              {
                E++;

    result[E]="      There is a  frustum shape with radius R1=
"+R[r]+"mm. and radius R2= "+R[rr]+"mm. and the heigth
equals to H= "+(Z[rr]-Z[r])+"mm.";

              break;
              }
            }
          }
```

Fig. 7. Java code of feature recognition

Extracting the feature's parameters
Output of programs which is feature's parameters should be extracted and saved in a file to be used in other manufacturing stages. The following figure illustrates the features, parameters output of a glass bottle mold. The output is used for the design of process plan according to the shop floors capabilities.

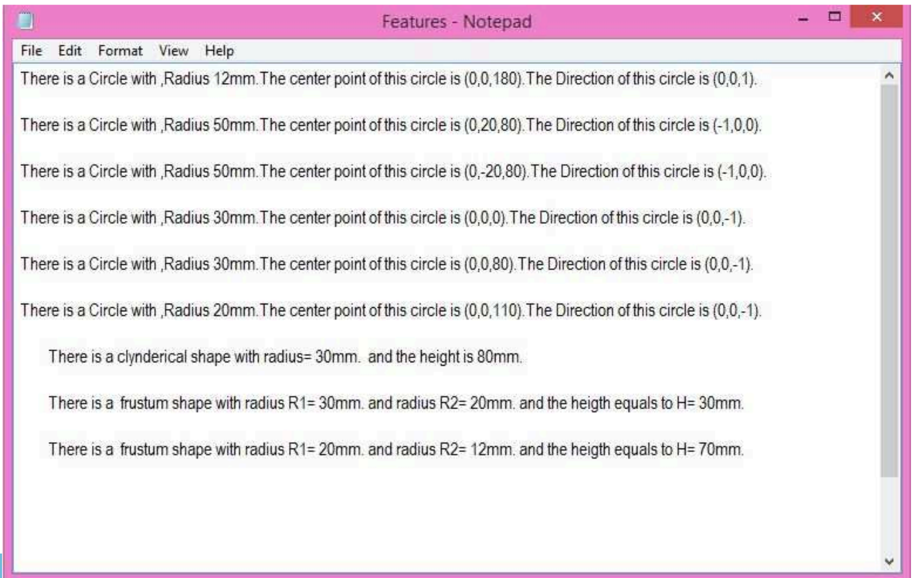

Fig. 8. Feature's parameters of a glass bottle mold.

Conclusion

Nowadays enterprises to be competitive in global market involved in product design and product process planning. They require a platform to enable them to integrate their product data seamlessly. The integration of product development cycle, especially the integration of CAD/CAPP/CAM will increase the efficiency of the mold manufacturing. In recent years, many researchers have proposed different solutions and frameworks to integrate CAD and CAPP domains. Of the most remarkable solutions are the automatic feature recognition tools. The feature recognition tools play an important role in connecting the bridge between CAD and CAPP systems and highly improves the level of integration. Despite the proposed researches for feature recognition, there is a need for efficient solutions of the CAD/CAPP/CAM. The files containing detailed geometric information of the parts, which are suitable for using in the downstream applications such as process planning. To overcome this shortcoming, this paper proposes an intelligent feature recognition solution to enable an efficient feature recognition system for macro process planning of mold design This system has the ability to communicate with various CAD/CAPP systems. The proposed solution is developed for 3D prismatic parts using B-Rep technique-a famous geometric modeling technique-as a drawing tool. The system takes a neutral file in ISO 10303 standard. The B-Rep geometrical information on the glass mold design is then analyzed by a novel proposed feature recognition algorithm which extracts the manufacturing features from the geometrical information. The feature recognition module uses a novel idea based on a geometric reasoning approach and it is implemented using object oriented design software application which is included in Java language. The further research to improve the proposed solution for the feature recognition algorithms to be able to recognize a wide variety of manufacturing features such as steps, slots, holes, etc, also the compatibility with Initial Graphics Exchange Specification (IGES) standard is highly recommended. Moreover, the integration of the proposed solution with CNC machining domain is also recommended.

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