Abstract: This paper presents the application of a feature-based design features within simulation model development procedure. Based on a review of the feature technology and previous research work, paper focuses on the modeling of intricate relations among features of different design aspects. The authors propose a set of CAD-CAE features that are oriented to both the design and analysis processes. This paper describes flow chart of the simulation model modelling. The secondary objective of the research is to prepare correct solid model for numerical simulation in software package MAGMASOFT. The dental faced model which is imported from My VGL software has some unclear geometry and uncorrected facets. This model requires analysis, and subsequently corrections and reconstruction using advanced modelling Pro/E tools. Integrated CAD-CAE model is parametric, object-oriented, and feature-based.

Key words: IC; analyze; solid; numerical simulation, DB

1. INTRODUCTION

Investment casting (IC), or “lost-wax” casting, is a precision casting process where wax patterns are converted into solid metal parts following a multi-step process. IC enables economical production of near net shaped metal parts containing complex free-form geometries and features from a variety of metals, including difficult-to-machine or non-machinable alloys. To produce precise components, the near net shape of castings can reduce machining time and cost to bring components into specifications. Despite its popularity, traditional IC suffers from high tooling investments for producing wax patterns. As such, IC is prohibitively expensive for low-volume production typical in prototyping, pre-series, customized or specialized components productions. IC has benefited numerous industries as an economical mean for mass-producing quality near net shape metal parts with high geometric complexity and acceptable tolerances. The economic benefits of IC are limited to mass production. The high costs and long lead-time associated with the development of hard tooling for wax pattern molding renders IC uneconomical for low-volume production. [1, 2, 3, 4].

Traditional IC using casting machine by „BEGO“ consists of the block mold and the more common ceramic shell process (Fig. 1) consists of the tooling, shell fabrication and casting stages [2, 5].

Fig. 1. Convential investment casting

Upon cooling, the mold is stripped to extract the patterns. Individual patterns are attached onto a wax sprue system to form a cluster in the shell fabrication stage. The cluster is repeatedly dip coated in investment slurry containing graded suspensions of refractory particles and followed by stucco application to build shell thickness and strength. When dried, the wax pattern is melted out via autoclaving to reveal the cavities (impressions) of the ceramic shell. The shell is fired to build strength and remove residual volatiles. In the casting stage, molten metal is poured into the heated shells to form the castings, which are extracted after cooling by cracking the shell during the knockout process. Individual castings are separated, cleansed and subjected to finishing processes. [2, 6, 7, 8].

Besides human factors, the CAD system used can sometimes be limiting factor in the production of accurate digital representations of the required design and the conversion of native CAD data from My VGL to data fully acceptable by RP or MAGMASOFT. [7, 11].
The aim of this study is to create a simulation model with correct solid features and the gate subsystem, for casting of metal substructure of a metal-ceramic crown.

2. SPECIFICATION OF SCANNING MODEL

A complete surface model of a typical 3D object is constructed from the integration of its multiple partial views. Since the method is effective in the registration of range images, it is attractive for applications where surface models of 3D objects must be constructed. My VGL is concerned with the problem of range image registration for building 3D facet model [7]. Facet model exported from My VGL to into Pro/E for further unclear feature reconstruction. VGL is used in a variety of application areas such as industrial CT, medical research, life sciences, and many others. Project files (and folders) i.e., VGL files contain basic information on the project including references to the object files and supplementary files belonging to the project. The data range mapping determines the range of gray values used for scanning object, i.e. it specifies the maximum number of different gray values available for dental cast. The size of the data range is always smaller or equal to the numbers of gray values in the data type. The window shows the result image of the rendering process (Fig. 2.). The coordinate system tripod in the lower left corner of the window indicates the orientation of the currently chosen coordinate system as is presented in Fig. 2. Software provides basic features of the scanned object as well as for saving images or image stacks. Thus, the software allows user to handle the two basic file types: object files, and project files. Object files contain voxel data representing dental real object, basically the output of the CT-scanner „Zeiss Metrotom 1500“ (after scanning and low reconstruction) or contain other data for representing object, such as polygons. Scanner settings and additional information might be included in the data files or in separate files. Few X-sections and shaded representation view of the scanning simulation model generated in My VGL software are presented in Fig. 2.

![Fig. 2. Few sections of the scanned model](image)

Simulation model consists of the model of metal substructure of metal-ceramic crown, together with adequate gate subsystem. [7]. A complete flow chart of simulation model design is shown in Fig. 3. The flow chart of the modelling of simulation model, can be divided into two operation boxes. The first one presents 3D scanning and facet model creation into My VGL software package. Second operation box presents revise facet/solid model and assembly creation into Pro/E software package as total solution (Fig. 3.).

![Fig. 3. Flow chart of the modeling of simulation model](image)

3. REVISE OF THE MODEL USING PRO/E

3.1 Super-feature design

Free-form surfacing features are called super-features, because they can contains limitless number of curves and surfaces. Freeform surfacing features are flexible; they have own internal parent/child relationships, and can also have relationships with other advanced UDF. Free-form surfacing (ISDX) is a design environment within Pro/E that allows user to create free-form curves and surfaces quickly and easily, and to combine multiple elements into super-features. Our researchers’ team used free-form surfacing advanced tools such as: [7, 10, 12, 13]

- Create curves and surfaces at the facet part level.
- Create simple features or multiple-element super-features.
- Create a curve on surface (COS), a special curve type that lies on a surface.
- Create surfaces from boundaries that do not have to be trimmed to corners.
- Reconstruction individual geometric entities or a combination of entities in the feature.
• Create internal parent/child relationships for Free-form surfacing features.
• Create an integration of CAD-CAE UDF.

We used inner and outer quilts for creating and manipulating non-solid surfaces. Quilts represent a "patchwork" of connected nonsolid surfaces. A quilt consists of a single surface or a collection of surfaces. A quilt contains information describing the geometry of all surfaces that compose a quilt and information on how quilt surfaces are "stitched" (joined or intersected). Quilts are generated as set of blend boundary surfaces. All quilts were joined to one surface (OQ). After that our research team generated inner join quilt using same operation (IQ) and used (OQ) for thin solid design (TS). After creation joined surface using merge join option we analyzed Pro/E functions in free-form surfacing such as curvature, radius, tangent options, draft check, dihedral angle and shaded curvature. If analyses pass, then surface have G1 characteristics.

3.2 Cleaning the facet geometry and shrink wrap model extraction

A facet model of a metal-ceramic crown substructure, without the gate subsystem and after the use of clean command (with the free-form option) is indicated in Fig 4.

![Fig. 4. Facet dental model without gate subsystem](image)

Facet model with gate subsystem after the use clean command with the mechanical option is indicated in Fig. 5.

![Fig. 5. Facet model of metal substructure with gate subsystem](image)

After cleaning of irregularities in facet geometry, the model of metal substructure was extracted to shrink-wrap model. The recommended method for creating a shrink-wrap model is to specify a low quality setting, preview the results, and gradually increase the quality level as necessary. All geometry imported and created inside the style feature becomes part of the Style feature. Objects internal to the Style feature, such as individual surfaces, curves, and so on do not have parent-child dependencies outside the Style feature or between each other. This enables that to free manipulate surfaces without being concerned with references and parent-child relationships between Style feature objects and the rest of the model. Quality is inversely proportional to the size of the triangles used for creation of the facet model. At a lower setting, the system creates fewer, larger triangles more quickly, producing a roughly accurate representation of the object's shape. At a higher setting, the system creates smaller triangles, producing a more detailed and accurate representation of the model.

3.3 Checking the geometry and verifying the feature

All imported and exported geometry need to verify into Import Data Doctor (IDD). IDD was used for control import options from VGL file, providing user with immediate access to most commonly used import settings including use template, enable ATB, and accurate import facet model. IDD extends the troubleshooter dialog box with a series of new error and informational geometry checks unique to the environment. Match tool is a repair mode tool that replaces poor quality imported facets with good quality facets, surfaces or patches.

3.4 Data Base of the gate subsystem

Data base (DB) consists of few CAD models of the gate subsystem. Model contains different GPS features such as Average diameter of the runners (Ø4mm, Ø5mm, Ø6mm); Central angle between sprue and vertical runner datum plane (12°, 15°, 18°, 20°, 22°); Investment materials (remanium 2000+ (CoCrMoW) acc. to DIN EN ISO 9693 / DIN EN ISO 22674, Trivest, Castorit super C, BEGO`s Wirobond C (CoCrMoW), Heranium Partial Denture Alloys (CoCr) acc. to EN ISO 22674 etc.) and IC parameters for ICM „BEGO“ [7,9].

4. CONCLUSION

The results indicate that the use of decribed tools can enhance performance, which can further improve the quality of a dental restorations. The objective of this research was to develop a correct simulation model of metal substructure of dental crown (facet and solid) with good performance using Pro/E. The described working process modelling are feature-based, parametric, based of solid and facet models, and object-oriented. The resulting models can be directly imported into CAD or CAE systems without loss of the semantics and topological information inherent in feature-based representations. In addition, the feature-
based approach facilitates methods capable of producing highly accurate models, even when the original data has substantial errors. The IDD improves quality redesign, reduces errors, and provides geometric and precision information necessary for numerical simulation. Future research will be directed towards two main goals. The first will be to generate IC parameters using SA method and selection of optimal IC parameters, dental materials with appropriate gate subsystem from DB, using contemporary KBE techniques such as PDT, RBR, IR, MHS, LP, and NP. The second goal will be to design collaborative KBS.

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5. REFERENCES


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