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Parametric Design System Development of Centrifugal Pump Impeller Based on SolidWorks

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Abstract: In order to realize the prototype-free three-dimensional modelling of the impeller and the parametric modelling of the front and rear cover plates, the design efficiency of the centrifugal pump impeller is improved. The system uses VB6.0, Microsoft Excel to achieve the secondary development of SolidWorks, and puts forward the basic principles and implementation methods for the development of the centrifugal pump impeller parametric design system based on SolidWorks, and derives the right-angle coordinate points of the blade flow line based on the wood-mode diagram, which greatly shortens the design and development cycle of the impeller.

Keywords: SolidWorks secondary development; centrifugal pump impeller; parametric design; VB6.0.

1. Introduction

Centrifugal pump is a general-purpose machine widely used in various fields, which mainly relies on the high-speed rotation of the impeller to do work on the liquid to achieve the transport of liquid, so the impeller is the core component of the centrifugal pump. When designing the impeller, due to the complex geometry of the impeller, it is often necessary to re-model the whole impeller by modifying one parameter, and if the traditional manual modelling is used, the designers need to repeat a lot of work[1], which is not only time-consuming but also cumbersome. Using the parametric method in this paper to parametrically model the impeller of centrifugal pumps can not only reduce the workload of designers, but also shorten the design cycle of the impeller, thus greatly improving the design efficiency of the impeller of centrifugal pumps and accelerating the research and development progress can greatly enhance the competitiveness of the centrifugal pump production enterprises.

With the rapid development of 3D modeling software and its associated programming languages, secondary development of 3D modeling software has become increasingly common. To improve the production efficiency of complex parts, many researchers have used secondary development of 3D software for parametric modeling of parts, achieving notable results. Peng Shijing[2] studied the parametric design of ship centrifugal pumps and developed a hydraulic design module for the impeller using VB6.0. Using UG/Open secondary development technology, he completed the parametric modeling of the impeller, achieving automation of the impeller design and modeling. Guo Shuying[3] and others used the API interface provided by SolidWorks in combination with Excel, taking the arrester mounting plate in the KYN28 high-voltage cabinet as an example to realize the parametric design of components. Sang Huaxi[4], based on Visual Studio 2019 software, used VB language interface design for SolidWorks 2020 interface program development, enabling secondary development of SolidWorks cam parametric modifications under VB. Designers can use a modular program for dimension modifications to parametrize existing cam parts. Li Gen[5] focused on automotive spiral springs and developed an automatic modeling system for the front suspension spiral springs of a particular car using VBA technology for secondary development of CAITA. Yan Zhaochao[6] and others, in order to address the complexity and manufacturing difficulties of non-circular gear pairs, developed a high-order elliptical gear pair curve design system using SolidWorks as the development platform in a VB environment, improving the efficiency and accuracy of elliptical gear transmission design. Zhang Jiankun[7] and others, to shorten the design time for standard modular part manufacturing processes, performed secondary development on SolidWorks using VB.Net and established a parametric modeling system for milling cutter disks, shortening the time required for designers to design gears and milling cutter disks. Zhang Xingwang[8] and others used C# language for secondary development of SolidWorks and Excel to achieve parametric design of 3D models and corresponding 2D engineering drawings for standardized series products of transformer structures, allowing for automatic generation of 3D models and corresponding 2D drawings. Additionally, the system allows for the free addition of standardized product types.Zhang Wu[9] and others, addressing the complex issues of steel cables with intricate spatial structures and the cumbersome design and modeling process, performed secondary development on SolidWorks. Based on the Visual Studio programming platform, they used VB.net language and corresponding API functions to achieve rapid parametric modeling of steel cables.

In summary, some scholars have realized the parametric design of the model through the secondary development of modeling software, which provides a technical reference for this study.This design takes VB6.0 as the development environment, uses VB6.0 control to call PCAD to generate blade streamline data according to flow, head, speed and other variables, stores the blade streamline data in the Microsoft Excel data table, reads the data in the table using VB6.0, and transmits the data to SolidWorks, and SolidWorks automatically completes the forming of the centrifugal pump impeller.

2. Development Principles and Tools

2.1. Development Principles

SolidWorks provides a wide range of API functions, which are also OLE/COM interfaces[10]. These interfaces offer good compatibility and can easily connect with various development software, allowing programmers to directly access SolidWorks. SolidWorks can record macros to capture the macro operation code during the modeling process. The required parts of the code can then be copied and added to the development platform. By driving design variables through the program, modifications to parameters and updates to the model can be achieved. Excel also has a macro recording function, which, when combined with the API interfaces provided by SolidWorks, can embed macro code into VB6.0 buttons to enable access and operation of SolidWorks, thus enabling secondary development of SolidWorks.

2.2. Secondary development interface SolidWorks API

To facilitate secondary development for users, SolidWorks provides numerous API functions, totaling several hundred types. These functions are based on COM or OLE development technologies and represent callable methods and properties of SolidWorks objects. Designers can use programming languages such as VB, VC, VBA, Delphi, C#, VS, and C++ to develop custom programs for SolidWorks, meeting the personalized needs of different users. Objects, as representatives of server programs, have simple and abstract characteristics, and they are interconnected through an object model or object hierarchy. Whether for internal development within SolidWorks or external development, its object system must be invoked to achieve functionality. Figure 1 illustrates the hierarchical structure of the SolidWorks object model. Any programmer who wishes to perform secondary development on SolidWorks and write code must utilize the object system to implement it. The SolidWorks API encapsulates the modeling functions of SolidWorks and provides them for designers to use.

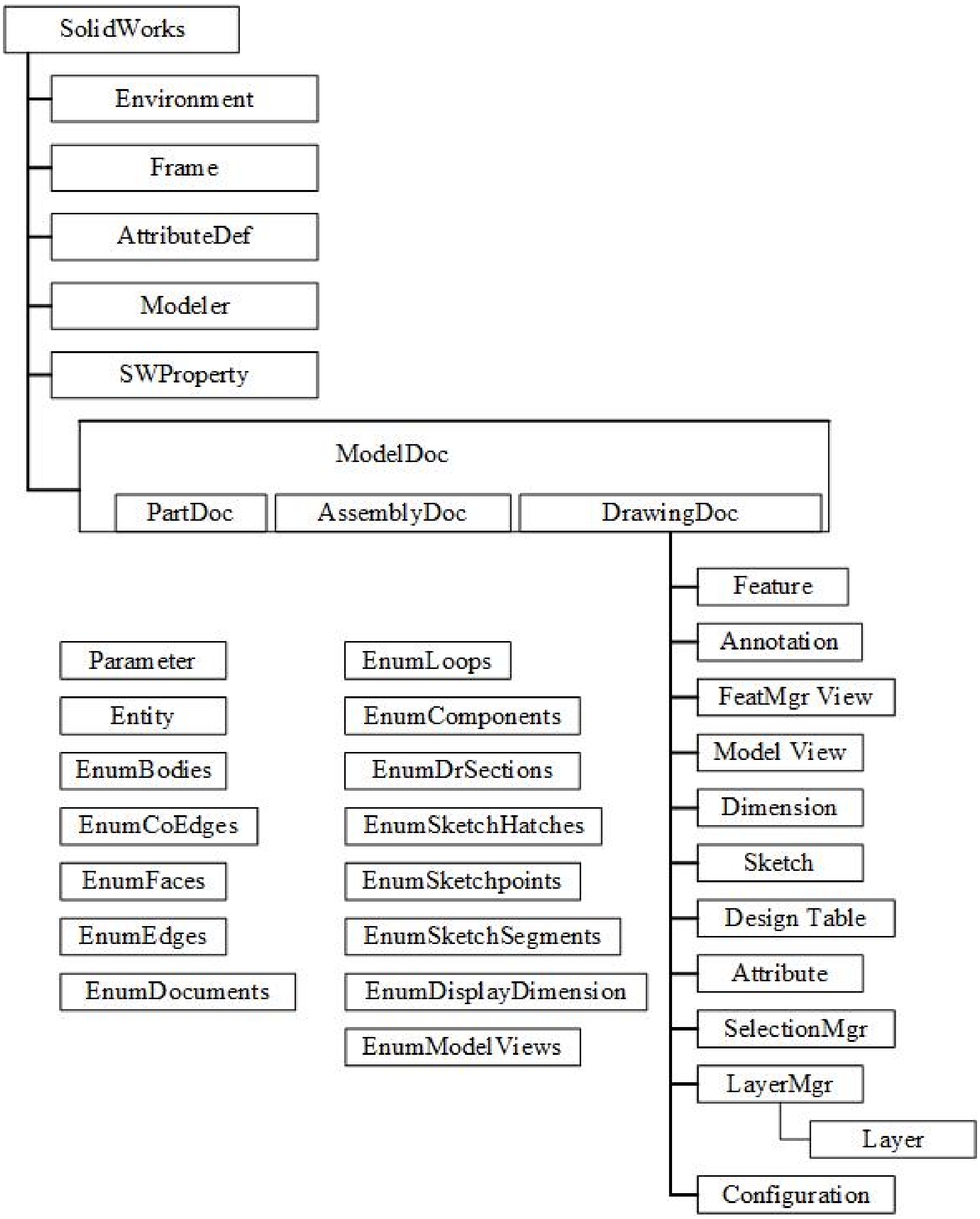

Figure 1. SolidWorks object hierarchy tree diagram

2.3. 3D modelling software SolidWorks2021

SolidWorks software is the United States Dassault developed a Windows-based three-dimensional CAD mapping software, SolidWorks can provide precise and suitable design solutions based on design requirements and product characteristics, improving product design efficiency and reducing development cycles.has a powerful, easy to learn and use and technological innovation of the three characteristics, can be engineering drawings of parts or components of the digital features of the parameters for collation, in order to build three-dimensional model, the characteristics of the parameters as well as the processing requirements, digital composition, through the processing flow and the analysis of the process to develop a digital model programming. Through the analysis of the machining process and technology to develop a digital model programming.

2.4. Microsoft Excel 2019 and Visual Basic 6.0

Microsoft Excel 2019 is one of the components of Microsoft Office 2019. The Excel worksheet allows for the editing of calculation formulas and the combination and association of calculations [11]. This software provides an easy-to-read data table, facilitates data insertion, deletion, modification, and querying, and supports VBA, offering an independent programming environment.

Visual Basic 6.0, a visual software, provides OLE controls that allow users to embed and link Microsoft Excel data tables into the program, making data transmission more convenient. It also offers a graphical user interface (GUI) with a rich set of components (e.g., picture box, label, text box, button, list box, etc.). It does not require extensive code to describe the appearance and position of interface elements. Instead, users can simply drag and drop pre-established objects to the corresponding positions on the screen, making the operation very straightforward.

3. General Design Ideas

The entire system design is divided into three parts. The first part involves calculating the wooden model diagram of the centrifugal pump impeller based on parameters such as head and flow rate. The data obtained from the wooden model diagram will be stored in a Microsoft Excel spreadsheet, and the rectangular coordinates for each data point will be calculated. The second part involves using VB6.0 controls to link Microsoft Excel, read the data from the table, and transfer the data into SolidWorks. This data will drive SolidWorks to automatically complete the impeller blade modeling. After the blade modeling is finished, the system will move to the cover plate parametric design page. Here, reasonable geometric dimensions will be input to parametrize and model the front and rear cover plates of the impeller and complete the impeller's forming process. If the formed impeller model does not meet the requirements, the user can return to the cover plate parametric modeling page and perform the impeller forming operation again. If the impeller meets the requirements, the model will be saved, and the system will be exited. The overall design process is shown in Figure 2.

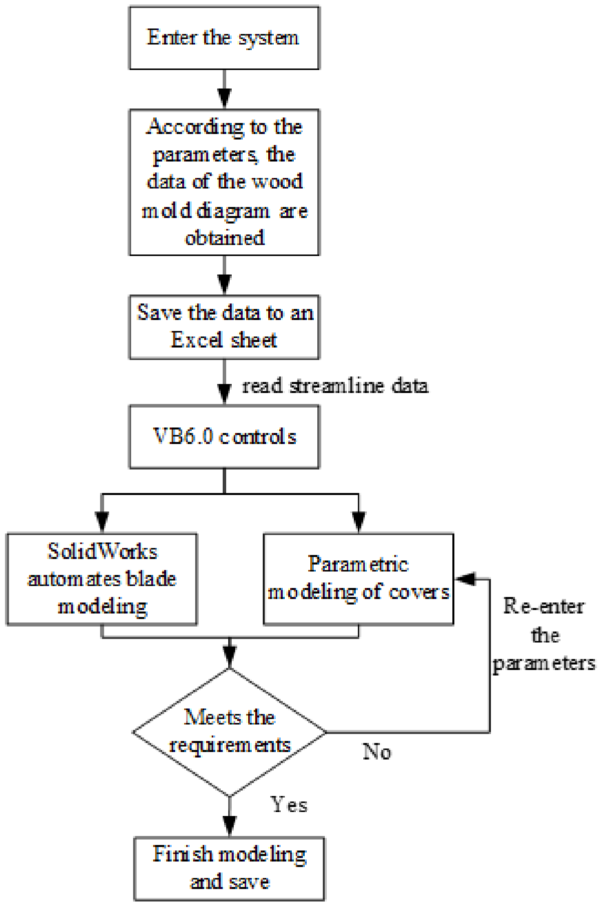

Figure 2. Overall design idea diagram

3.1. Data table design

The data table stores each group of data for blade modelling and the endpoint data of the wood model diagram, including data related to the modelling of the working surface and the back surface, such as the front and back streamlines, the inlet edge, the outlet edge, and so on, and each group of data includes the X, Y, and Z coordinates of the data points corresponding to 0°to 140°. The points in right-angle coordinates are calculated based on the column coordinate radius R and the rotation angle θ in the axial model diagram using the formula calculation function of the Excel sheet. Each data is stored in a different cell and every three cells are a group (X, Y, Z) of data.

3.2. Uplink

The data is stored in Microsoft Excel data table, VB6.0 accesses the installation path through the button to achieve the connection with Excel, and then reads the content of each cell and displays the content in the corresponding Text text box of the visualisation interface. Similarly, VB6.0 connects with SolidWorks and inputs each set of data into SolidWorks and connects each data point with a line segment to complete the modelling of the blade model frame.

3.3. 3D modelling

Embed the modelling code into the modelling button, click the button to drive SolidWorks to automatically complete the modelling of the centrifugal pump impeller, including twisting the blade, rounding the corners, cutting the blade and blade array and other operations. After the impeller is drawn, you can enter the page of drawing cover plate and impeller moulding to draw the cover plate as well as the moulding of the cover plate and impeller. You can input the modelling data of the cover plate on the page, and call SolidWorks by the control of VB6.0 to finish the moulding operation of the impeller automatically.

Table 1. Description of variables

geometric parameter	variable name
impeller outlet diameter	d2
impeller inlet diameter	d1
wheel diameter	d0
inner arc radius	R1
outer arc radius	R2

4. Parametric Modelling System for Impellers

4.1. Modelling data acquisition

From the system's main interface, the user first enters the basic parameter design interface for the blades. According to the requirements, the pump type is selected, and parameters such as head, flow rate, and rotational speed are input. The specific speed, efficiency, and other parameters of the pump are then calculated and displayed in the input box on the right, as shown in Figure 3. This system selects a single-stage, double-suction centrifugal pump. The input parameter values are: flow rate of 80 m^3/h, head of 78 m, and rotational speed of 2950 r/min. Based on these parameters, the calculated specific speed is 61, the efficiency is 70.8%, and the shaft power is 24.017 kW.

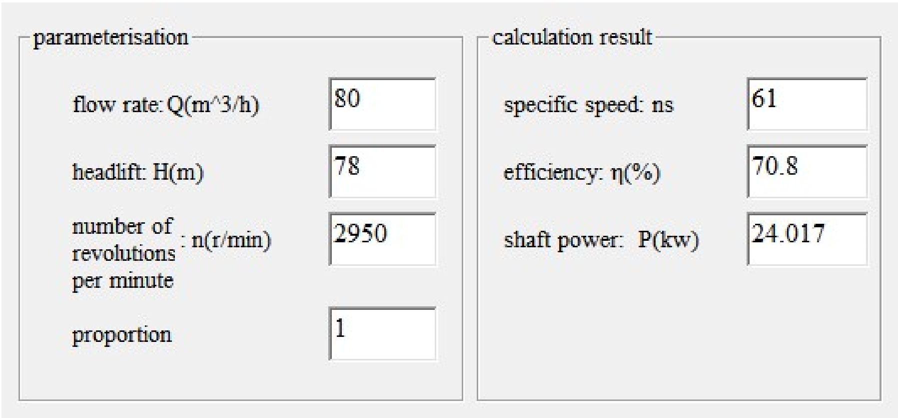

Figure 3. Blade basic parameters calculation page

After the parameter calculation is completed, the system enters the main geometric parameter input page. On this page, the designer can input the hub diameter d0 (mm), specific speed ns, number of blades z (with values ranging from 3 to 8), exit angle β(with exit angle values ranging from 15 to 35), inlet diameter d1(mm), impeller outer diameter d2(mm), and exit width b2(mm). The input parameters are shown in Figure 4.

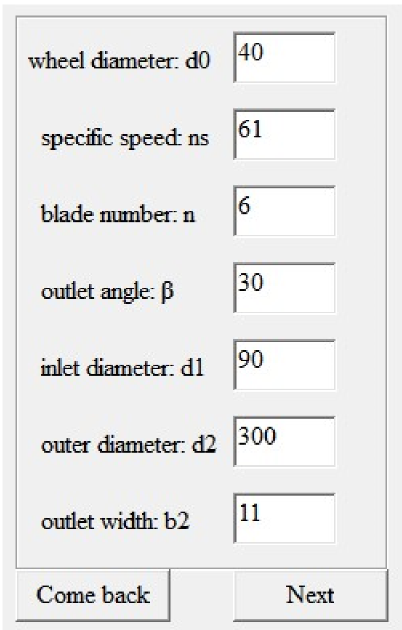

Figure 4. Calculation page of main geometrical parameters

Finally, based on the generated parameters, the wooden model diagram of the impeller is obtained, as shown in Figure 5. From this wooden model diagram, the shaft shadow diagram and its various parameters, including the inlet and outlet attack angles of the blade flow lines, and the blade wrap angle, are derived. The obtained data is then stored in

Microsoft Excel, where the function calculation features of Excel are used to calculate the values of X, Y, and Z, as shown in Figure 6.

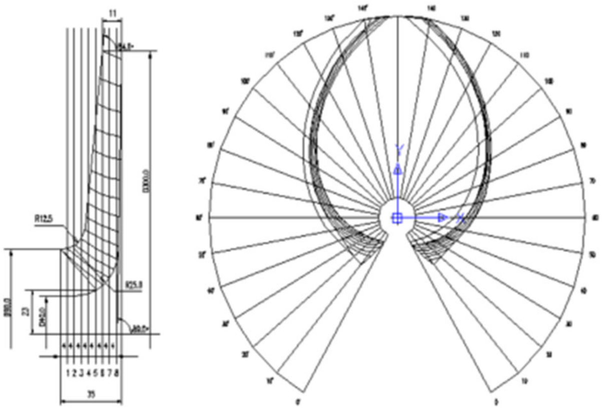

Figure 5. Wooden moulding diagram

forward sloping line	R	X	Y	Z
0	0	0	0	0
10	45	44.32	7.81	-33.29
20	45.21	42.48	15.46	-31.01
30	46.77	40.5	23.39	-26.88
40	50.09	38.37	32.2	-23.22
50	55.28	35.53	42.35	-20.99
60	61.68	30.84	53.42	-20.28
70	68.98	23.59	64.82	-19.52
80	77.37	13.44	76.19	-18.63
90	86.77	0	86.77	-17.65
100	97.21	-16.88	95.73	-16.55
110	108.93	-37.26	102.36	-15.32
120	121.69	-60.85	105.39	-13.98
130	135.42	-87.05	103.74	-12.53
140	150	-114.91	96.42	-11

Figure 6. Front and back streamline data

4.2. Prototype-free parametric modelling

4.2.1. Parametric modelling of blades

By VB6.0 to read the data in the table to the TextBox text box. As shown in Figure 7. Then transfer the data to SolidWorks and automatically complete the blade line insertion, blade twisting, rounding, cutting and other operational steps, as shown in Figure 8, 9,10

forward sloping line

0	0	0
44.32	7.81	-33.29
42.48	15.46	-31.01
40.5	23.39	-26.88
38.37	32.2	-23.22
35.53	42.35	-20.99
30.84	53.42	-20.28
23.59	64.82	-19.52
13.44	76.79	-18.63
0	86.77	-17.65
-16.88	95.73	-16.55
-37.26	102.36	-15.32
-60.85	105.39	-13.98
-87.05	103.74	-12.53
-114.91	96.42	-11

Figure 7. Data reading page

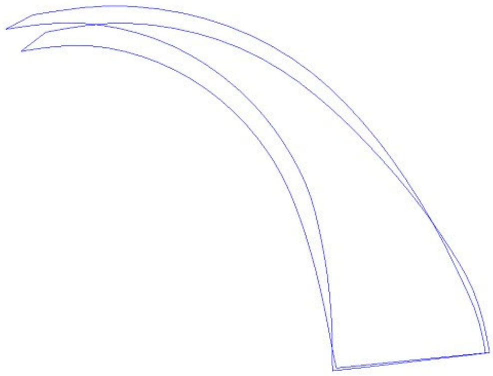

Figure 8. Block diagram of a single twisted blade

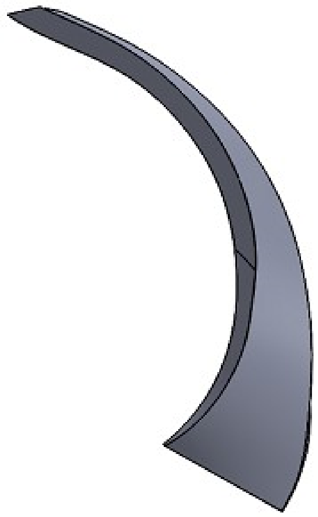

Figure 9. 3D solid model of a single twisted blade

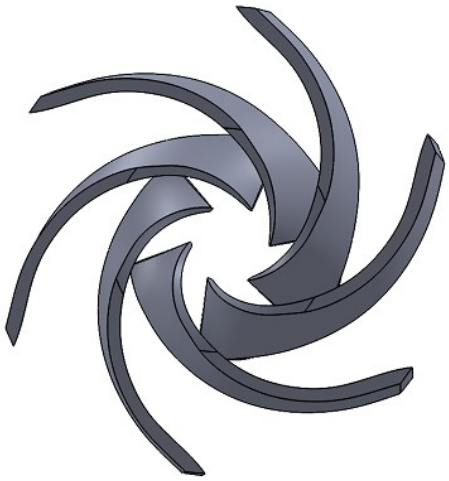

Figure 10. 3D solid model of twisted blade

4.2.2. Parametric modelling of cover plates

The endpoint data of the wood mould diagram in Microsoft Excel is read from the page of parametric modelling of the cover plate, and then the operator inputs the parameters of the wood mould diagram of the cover plate, and the modelling page of the cover plate is shown in Fig. 11. SolidWorks is driven by the Button control to carry out the parametric modelling of the cover plate and the moulding operation of the impeller according to the data in the page, and the moulded impeller is shown in Figure 12.

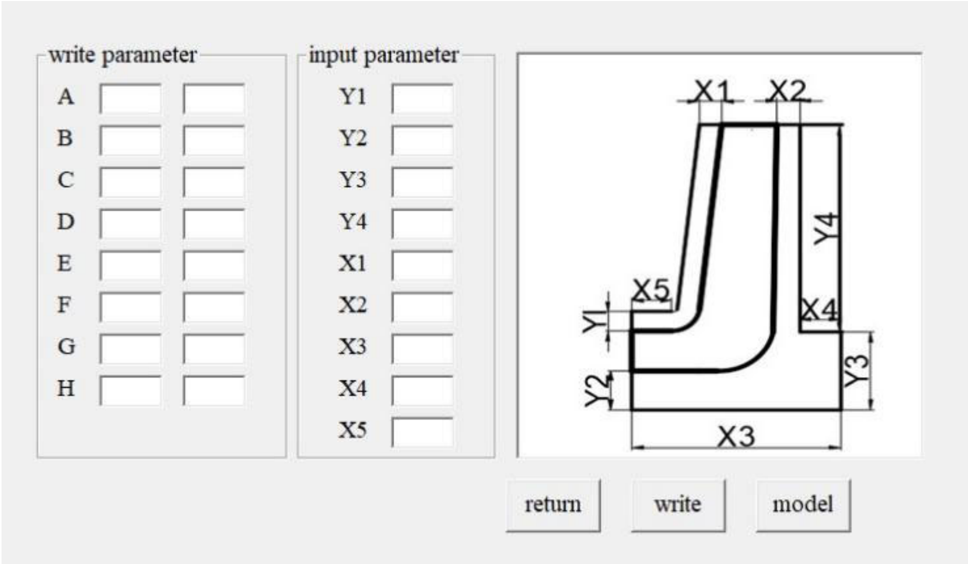

Figure 11. Parametric modelling page for cover

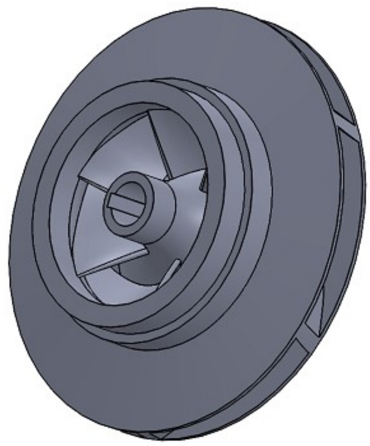

Figure 12. 3D solid model of impeller

4.2.3. Modelling section implementation code

In the VB6.0 platform environment, the impeller of the centrifugal pump is modeled using the VB language, and the code linking the Microsoft Excel and SolidWorks API interfaces and other codes are as follows:

(1)Use VB6.0 to connect to Microsoft Excel and get the data.

```
Dim xlsApp As Object
Set xlsApp = CreateObject (" excel.application ")   ' Establish a connection with Excel
Set xlsWb = xlsApp. Workbooks(" numbers.xlsx ")   ' access the Excel numbers file
Set xlsWorksheet = xlsWb. Worksheets(1)   ' access Worksheets(1) in the file.
Text4.Text = xlsWorksheet. Cells(4, 3)
Text5.Text = xlsWorksheet. Cells (4, 4)   ' Use the Text5 text box to read the data in the fourth column of the fourth row.
Text6.Text = xlsWorksheet. Cells (4, 5)   ' 4, 5, 6 The data in the text box are the X, Y, Z coordinates of a point
xlsApp.Quit
```

(2)Use VB6.0 to connect to SolidWorks and drive SolidWorks to complete the modelling automatically.

```
Dim swApp As Object
Set swApp = CreateObject ( " sldworks.application " ) ' Establish a connection with Solidworks
swApp. Visible = True
Set Part = swApp. ActiveDoc   ' Drive SolidWorks to generate drawings
Part. InsertCurveFileBegin   ' Start plotting the 3D spline curve
boolstatus = Part. InsertCurveFilePoint ( Val(Text4.Text ) / 1000,
Val( Text5.Text ) / 1000, Val( Text6.Text ) / 1000)   ' Insert the X, Y, Z coordinate values of the first point
boolstatus = Part. InsertCurveFileEnd ( )
```

(3)Modify the dimensions of the model and re-model it.

```
Part.Parameter( " D1@Sketch1 " ). SystemValue = R1 / 1000   ' Make changes to R1's dimensional size
```

5. Summary

The system is developed using VB6.0 as the development tool and employs a programming-driven software modeling approach to realize the parametric design of a centrifugal pump impeller's 3D model based on SolidWorks secondary development. VB6.0 is used to connect with SolidWorks software, inputting the main geometric parameters into the system. The system generates the wooden model diagram of the centrifugal pump blades based on the input parameters.

From this wooden model diagram, it produces the front and rear streamline data of the blades, as well as other modeling data needed for parameterization. VB6.0 then reads the saved data and inputs it into SolidWorks to drive SolidWorks to automatically complete the 3D modeling of the centrifugal pump blades. Through the cover plate modeling page, the system drives SolidWorks to perform the parametric modeling of the front and rear covers of the impeller and the forming operation of the impeller. Additionally, the system allows for modifications of the size parameters of the generated centrifugal pump impeller. This system uses a simple human-machine interface to realize rapid, prototype-free parametric modeling of the centrifugal pump impeller and modification of the model's size parameters. It offers fast modeling speed, high accuracy, avoids a lot of repetitive manual work, reduces the design time of the centrifugal pump impeller, and improves the design efficiency.

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