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Article

Virtual design and manufacturing technology used for rapid parametric design of mechanical model

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Abstract: In the traditional design methods, there are challenges in quickly adjusting a three-dimensional model according to the variations in mechanical parts. In view of the above problems, a rapid design method for gear reducer based on parametric design is proposed. Instead of directly constructing geometric models based on three-dimensional software, this paper comprehensively considers the parameters and constraints needed for three-dimensional models. By analyzing the parameters and constraints of parts, the design interface of mechanical parts is constructed. Then, the design interface is connected with the parameters and constraints of three-dimensional model through the programming language. Finally, a parametric design system for mechanical parts is developed for rapid design and modification of three-dimensional model. Experimental results demonstrate that the rapid parametric design reduces the modeling time by 28% (for single-parameter parts) and 57% (for three-parameter parts) compared to traditional methods, validating the efficiency of the proposed methodology.

Keywords: rapid parametric design; gear reducer; virtual design; parametric models

1. Introduction

Facilitated by the rapid development of Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR), the metaverse is expected to change our daily lives in different aspects, such as shopping, social interaction, healthcare, education and gaming [1–4]. The design of mechanical parts involves the study of universal mechanical parts in machine operating principles, load-bearing capacity, structures, and maintenance. The traditional mechanical parts design requires a certain amount of engineering and practical experience, resulting in conservative design, long design cycle, and poor reusability [5]. With the development of computer technology, the efficiency and accuracy of mechanical parts are improved through the wide application of CAD. CAD is short for "computer aided design", which refers to taking advantage of computers and graphics device to help designers complete the structural design [6]. As widely known, the traditional CAD methods conduct the design of mechanical parts with long design cycle, which results in low design efficiency and is difficult to be applied in high-efficiency enterprises [7]. The size parameters and restrictions can determine the final three-dimensional mechanical model. When one size or one constraint is changed, the final geometric shapes should be adjusted by a series of adjustments of datum point, datum line, datum level and assembly. Therefore, traditional CAD methods are not suitable for the rapid design requirement of mechanical parts and achieving the models of complex mechanical devices. For rapid parametric design, the geometry shapes of the parts and components are defined by the size parameters and restrictions [8,9]. The creation of model and assembly of parts can be achieved rapidly by changing the relevant parameters directly without serially laborious adjustments, so that the efficiency of design can be increased evidently [10]. At present, lots of scholars engage in the research of parametric design and gain plenty of achievement. Babu and Tsegaw built a parametric template spur gear by designing and developing a spur gear with 3 modules, 30 teeth, 20° pressure angle based on CATIA V5R14 package, which gives insights into the development of gears in different modules and number of teeth [11]. It performs low usability for non-expert users without the user interface for a modelling system. Tzotzis et al. established a parametric design platform which can be used to generate a standardized CAD model by using SolidWorks API and programming language of Visual Basic for Applications (VBA), and then the CAD models can be imported into DEFORM-3D [12,13]. However, the production of platform is restricted to standardized tools, lacking the diversity of design. Mermoz et al. presented a parametric design methodology based on a typical helicopter gearbox design [14]. In the conceptual design phase, the parametric CAD modeling obtained by parametric design methodology facilitates the adaption to the frequent requirement changes of early-stage development phase and speeds up the gearbox design process. That the detailed steps of the parametric modeling process were not presented in researches. According to above researches, it is concluded that the efficiency of parametric design was affected by the incompleted user interface and the unclear parametric design process.

Mechanical design is the basis for the development of excellent engineers [15] and aims to cultivate the ability of analyzing and solving mechanical design problems by comprehensively applying the theory and practical knowledge learning from mechanical design [16]. Traditional mechanical design methodologies fail to meet current industrial demands, which highlight the need for teaching parametric design methods into curricula to bridge the gap between theory and practice. Furthermore, some students and engineers are inadequate about the skill of connecting the three-dimensional structures of machine parts with the theory of curriculum education, and then lack the ability of mechanical parts design under the actual requirements of engineering application, ultimately hindering their development in competent mechanical engineers with comprehensive qualities and innovative abilities [17]. The concept of a metaverse classroom has been introduced, aiming to enhance engagement by exploring the Metaverse's origins, features, and educational benefits, and delving into integrating metaverse technology into online education [18]. The Metaverse differs from augmented reality (AR) and virtual reality (VR): first, while VR-related studies focus on a physical approach and rendering, Metaverse has a strong aspect as a service with more sustainable content and social meaning; second, the Metaverse does not necessarily use AR and VR technologies, even if the platform does not support VR and AR, it can be a Metaverse application; lastly, the Metaverse has a scalable environment that can accommodate many people is essential to reinforce social meaning [19]. The industrial and technological revolution and the use of innovative software have made it possible to create a virtual world from which the parametric machine can be designed to enable students and engineers visually correlating theoretical concepts with mechanical parts [20].

This paper is about the rapid parametric design of mechanical parts in the teaching of "virtual design and manufacturing technology" and engineering application. The practical course of “virtual design and manufacturing technology” is to guide students building rapid design interfaces for parametric design, and input the parameters of different parts through the interfaces, and then realize the rapid design and assembly of the whole mechanical devices.

2. Materials and methods

2.1. Selection of gear reducer

For mechanism, the reducer, as a kind of mechanical transmission device, plays a vital role in the whole process of mechanical transmission of motion and power. More specifically, the design of reducer plays an essential role in the effective engineering training, which is a part of mechanical design courses that cannot be ignored. Compared to other mechanical devices, the gear reducer has many parts and complex composition. The traditional design procedure of gear reducer is initially established by the designers according to their experience and comparisons with the existing gear reducers. Then the procedure can be determined by a series of adjustments until it can pass the tests such as the strength test, rigidity test and so on [21]. This paper takes the gearbox as an example to study the rapid parametric design, mainly to solve the problems that inexperienced designers may encounter in the design and the design and assembly problems caused by the frequent adjustment of parts parameters.

2.2. Selection of software

SolidWorks and VB6.0 were used for modeling and programming, respectively. SolidWorks establishes the initial model. VB6.0 designs the parametric design interface, and provides the connection between the parameters in the interface and SolidWorks through programming statements. When the parameters of model are adjusted through the interface, SolidWorks will immediately adjust the parameters of model and generate a new model. SolidWorks provides the full Windows interface where models are built and parameters are adjusted to implement the rapid parametric design of gear reducer [22]. VB6.0, apart from being referred to programming language, is used for generating a windows-based application program of parametric design [23]. Moreover, the VB6.0 used in this paper is trial version. The trial version of VB6.0 imposes no restrictions on core API functionalities, ensuring full compatibility with SolidWorks for parametric model generation. Within the secondary development environment of SolidWorks and windows-based application program of VB6.0, it is possible to drive the 3D drawing engine and then generate parametric models of components of gear reducer [24], which serves as the foundation for parameterization.

2.3. Design processing

The model of gear reducer was used for exhibiting the rapid parametric design about mechanical parts. By analyzing the structural sizes of the chosen part, the data tables and sizes were selected and then inputted to establish the foundation of the new part model. Based on the data tables and sizes, the new part model would be created and saved, and the drawings would be generated.

The design procedure was presented and separated in modeling and programming, as shown in **Figure 1**. In the modeling procedure, the model was analyzed to ascertain the active sizes and passive sizes of the components in SolidWorks. Based on the analysis of model parts, the active sizes and passive sizes were set. Then the model parts were established with different sizes and constraints. And active sizes can be modified to match with the whole model. Each model is adaptable to diverse design requirements and assembly needs by adjusting the active sizes in operation interface constructed by VB6.0. For the programming process, the procedure was divided into five phases, namely, "install and operate programming software", "create windows and design interfaces", "input sizes, buttons and data sheets", "programming, testing and debugging", "record, save and text the macros". The model generated by SolidWorks is connected to the user interface through the programming language of VB6. The user can regulate the model by adjusting the input of size data.

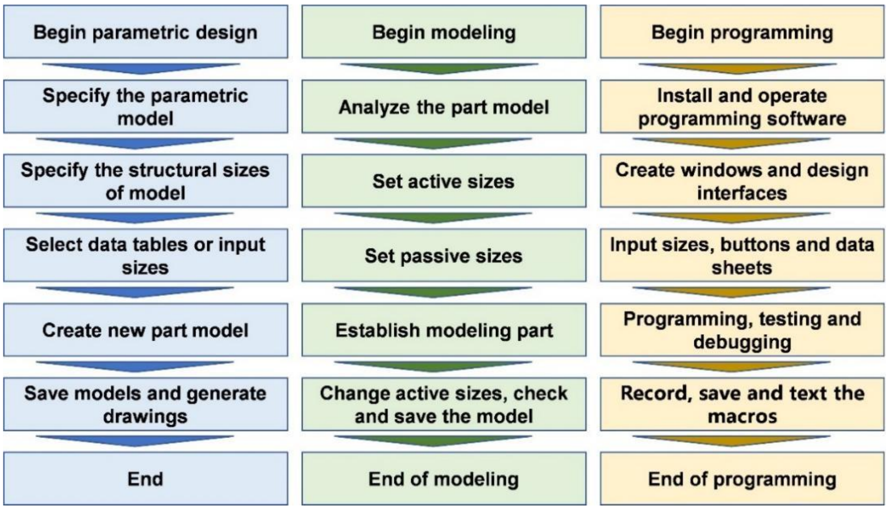


Figure 1. Parametric design.

3. Results

3.1. Design of the user interface

Firstly, the interface was designed for students and engineers to login and identity verification, as shown in **Figure 2**. It is essential to input the corrected number for identity verification. The code of identity verification was employed to check user identity and then to the next step. The interface is designed to record the design results of each student and engineer.

Figure 2. The interface of login.

If the entered account and password are correct, the design interface will be displayed, as shown in **Figure 3a**. Otherwise, an error reminder interface will pop up, showing "Invalid Username" or "Incorrect code", as shown in **Figure 3b**. And the button of back was provided within the interface of validation failure. The interface of part selection was adopted to design the parts and assembly of gear reducer. Furthermore, the interface of part selection serves as a comprehensive platform for the design and assembly of various machinery and equipment components. This interface can help students and engineers understand the composition of mechanical devices.

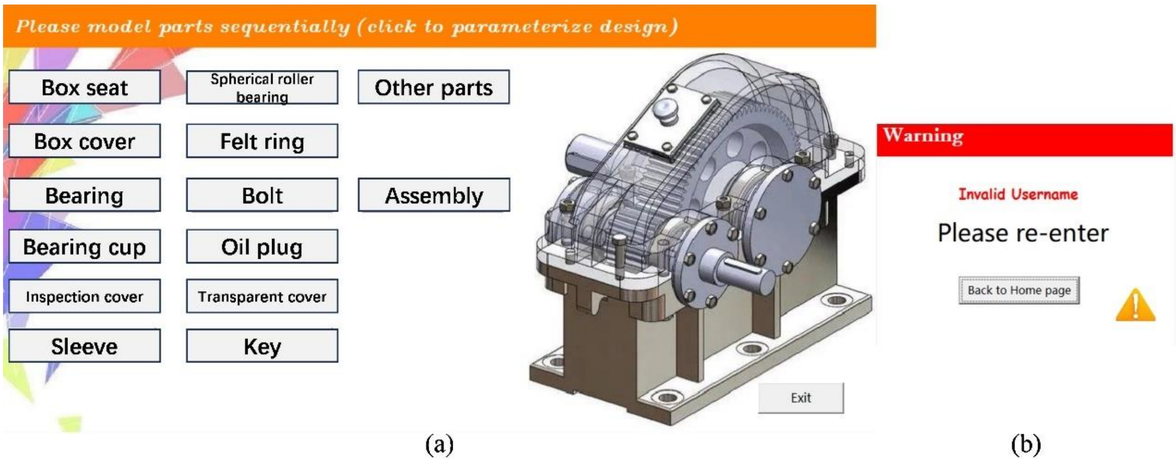


Figure 3. (a) The interface of part selection; **(b)** the interface of validation failure.

As presented in **Figure 4**, the interface of termination will appear by clicking the exit button after using the interface of part selection and finishing the design.

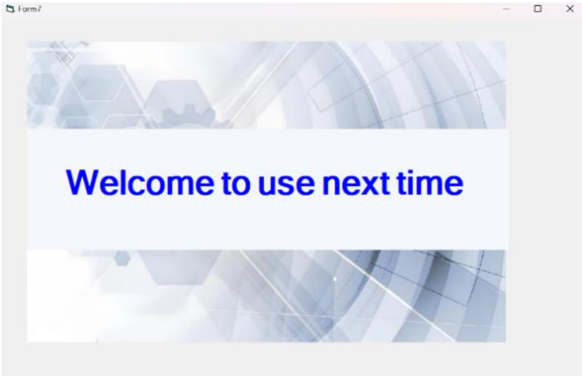


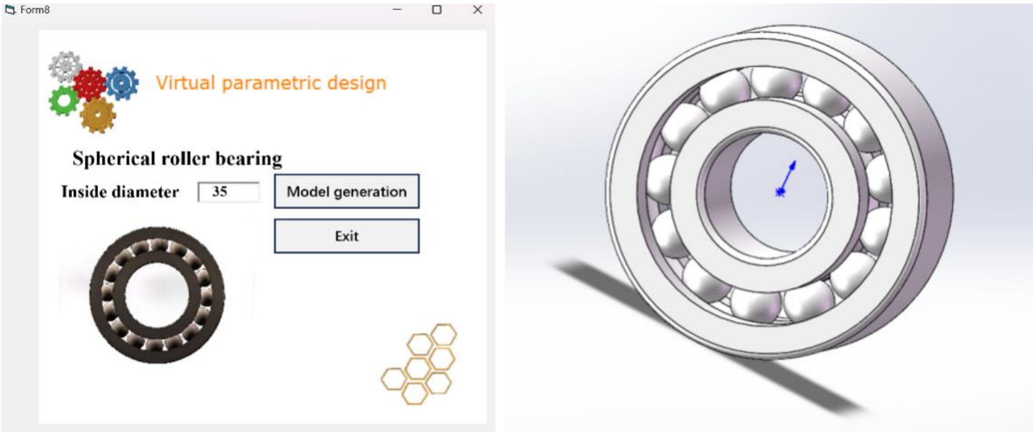
Figure 4. The interface of termination.

3.2. Rapid parametric design of mechanical parts

A mechanical device has many parts which need to be designed based on the requirements of user. Some parts only need design one parameter, and some parts need design two parameters, others need design three or more parameters. Therefore, it is necessary to classify the parametric design and compare the design efficiency depending on the number of design parameters.

3.2.1. One parameter design for models

A 3D model of the bearing was adjusted by selecting the inside diameter in the interface, as shown in **Figure 5**. The new bearing will be generated with alternative parameters. For one parameter design, it can be outside diameter, thickness, and other structural parameters. And the design interface is flexible and adjustable, which can largely meet the various needs and adjustments of users for mechanical design.



(a) (b)

Figure 5. (a) The design interface of bearing; **(b)** the three-dimensional model of bearing.

As shown in **Figure 6**, the inside diameter of bearing was optimized by parametric design in response to the requirements of working condition. The inside diameter of 25 mm can be adjusted to 30 mm immediately after only clicking on the button of “Model generation”. There is no limit to the adjustment of parameters, and the one parameter rapid design can be used for the design of standard parts and non-standard parts. This will allow students and engineers to design certain components individually.

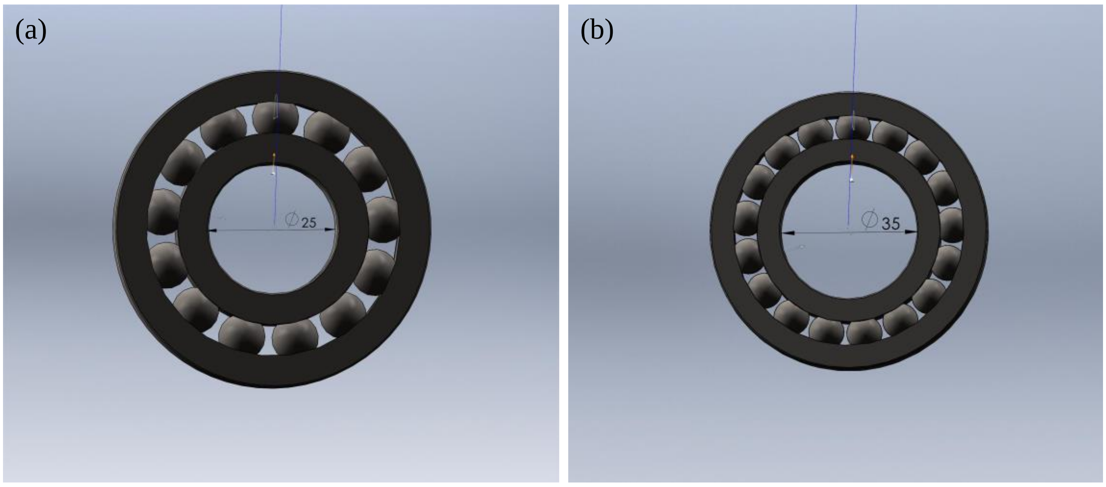
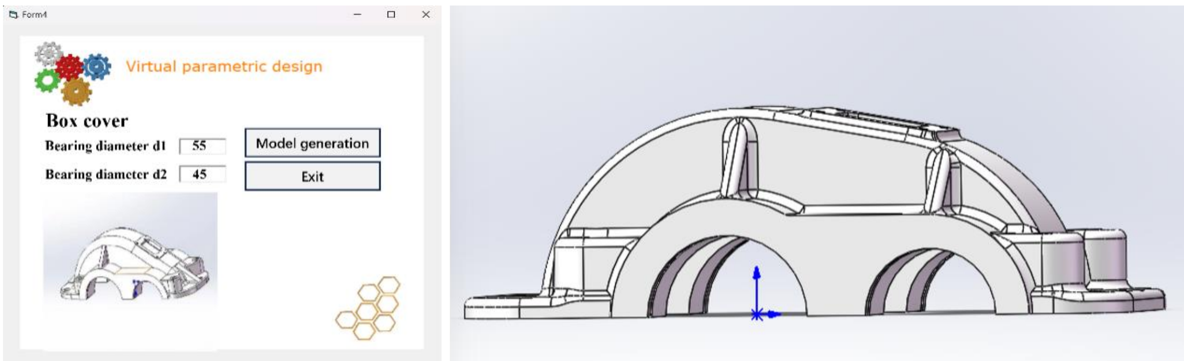


Figure 6. Three-dimensional model with different inside diameters. **(a)** Three-dimensional model with 25 mm inside diameters; **(b)** three-dimensional model with 35 mm inside diameters.

3.2.2. Two parameters design for models

Compared with one parameter design, two parameter design is more difficult. The complex relationships between parameters need to be established on account of the complexity of the models. The main parameters that affect the function of the gear reducer are four bearing semi-cylinders of two gear shafts. For the box cover, the parameter of parametric design is the diameter of the four bearing semi-cylinders based on the two gear shafts. The design interface is presented in **Figure 7a**. There are two input boxes for parameter design and adjustment in the interface. d1 and d2 are diameters of gear shafts. The adjusted model is shown in **Figure 7b**. The adjustment of the two parameters is independent of each other. Under the requirements, it is convenient to adjust one of the parameters or two parameters at a time. Similar to one parameter design, the parameters of parametric design are not unchangeable, but relying on the target model. For box cover, the parameters also can be aggregate thickness or width of the edge that affects the strength and rigidity of the box cover and ensures good sealing performance and installation stability.



(a) (b)

Figure 7. (a) The design interface of box cover; **(b)** the three-dimensional model of box cover.

As shown in **Figure 8a**, the originally designed model of box cover was generated with two parameters of d1 = 55 mm and d2 = 45 mm. The two parameters can be flexibly adjusted to different values on the basis of the diameter of the four bearing semi-cylinders, such as d1 = 60 mm and d2 = 50 mm, as displayed in **Figure 8b**. Since there are no dependencies, the two parameters can be adjusted without fixed proportion but considering the design standards and scope of application. This gives students and engineers the flexibility to select bearing diameters when designing gear reducers.

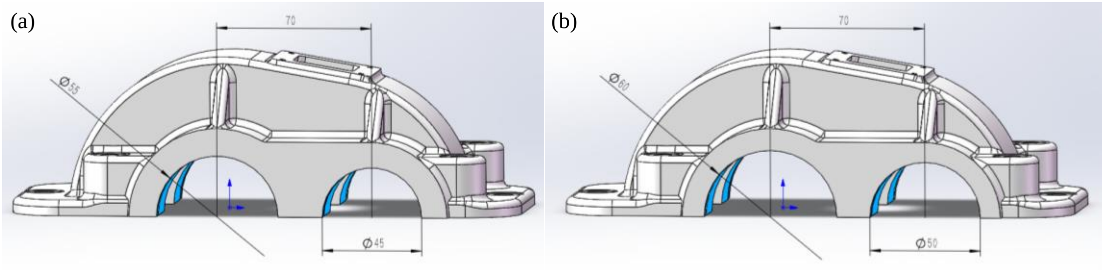


Figure 8. (a) Three-dimensional model with d1 = 55 mm and d2 = 45 mm; **(b)** three-dimensional model with d1 = 60 mm and d2 = 50 mm.

3.2.3. Three parameters design for models

It is imperative to consider relationships between parameters in a three-parameter design, which is more complex by comparison with a two-parameter design. For more complex mechanical parts, the number of parameters can be further increased in multiple parametric design. For the box seat, the parameters of parametric design are similar to those of the box cover, but the parameter of bottom slope is added. The input boxes for three parameters and the buttons are shown in **Figure 9a**. Elements of the design interface can be modified by students to become more aesthetically pleasing. The completed model of the box seat is presented in **Figure 9b**. Similar to two-parameter design, the three parameters are unrelated to each other and can be substituted by other dimensional features. The three-parameter design has the same advantages as the two-parameter design. It should be noted that all three parameters are active parameters, which can control the passive parameters to generate a new model.

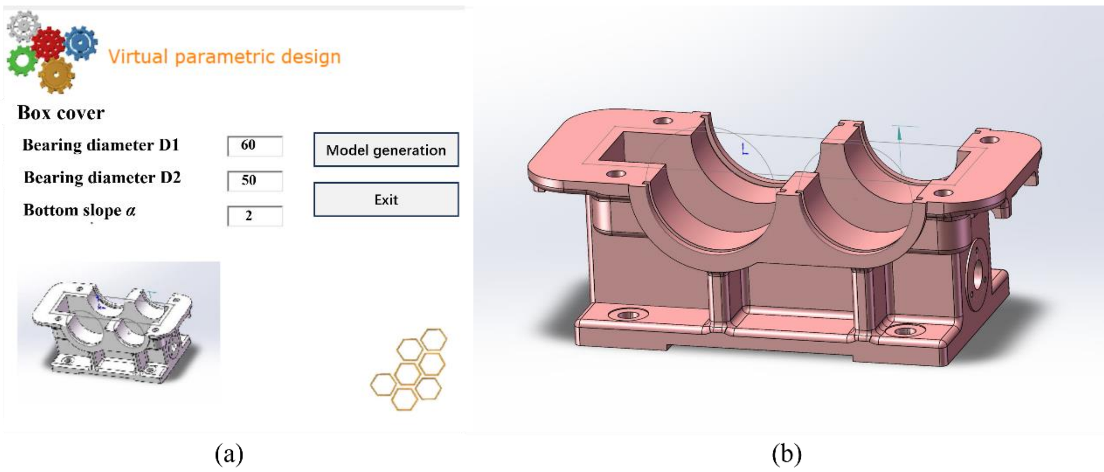


Figure 9. (a) The design interface of box seat; **(b)** the three-dimensional model of box seat.

The three-dimensional model of the box seat with D1 = 55 mm and D2 = 48 mm was presented in **Figure 10a**. With the convenience, flexibility and simplicity for complex models, D1 and D2 can be adjusted to generate new model directly. For example, D1 was changed to 60 mm, and D2 was adjusted to 50 mm, as shown in **Figure 10b**. The flexibility and tunability of the three-parameter design are similar to those of the two-parameter design. As more parameters are added, restrictions between parameters should be noted. That the sum of the radii of the two bearings should be less than the center distance between two bearings. In the processing of rapid parametric design of mechanical models, students and engineers will be capable of designing parametric parts with more parameters and then equipped with a comprehensive understanding of the adjustability of parameters and their limitations between parameters.

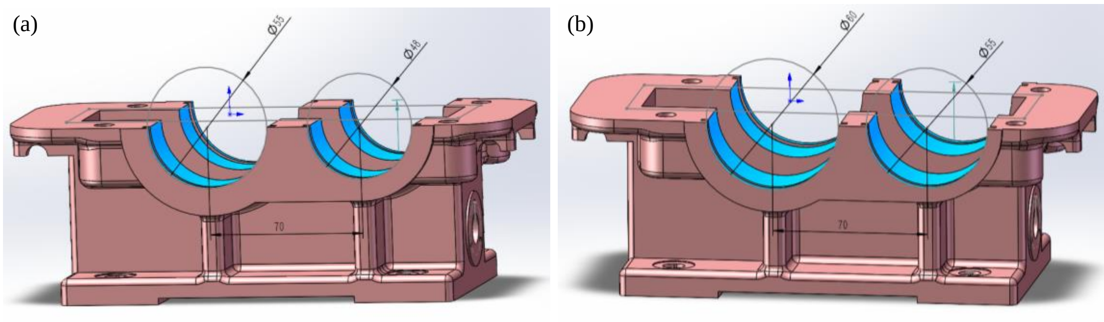


Figure 10. (a) Three-dimensional model with D1 = 55 mm and D2 = 48 mm; **(b)** three-dimensional model with D1 = 60 mm and D2 = 50 mm.

3.2.4. Comparison of traditional design and rapid parametric design

The time of designing a new model is compared between the traditional design and the rapid parametric design, as shown in **Table 1**. The parametric design is classified and compared according to the different number of parameters. The number of parameters for the same design model can be different. And users can adjust the number of parameters for the models to meet individual requirements. For those who are not skilled in modeling software or inexperienced in design, it will take a lot of time to design and adjust the models in the traditional way, which is to adjust the model step by step in the CAD software. The minimum time required by the traditional design and the rapid parametric design is recorded. The time of traditional design is more than 45 s, more than 30 s, and more than 18 s for box seat, box cover, and bearing/bolt, respectively. And the time of rapid parametric design is about 19 s, 17 s, and 13 s for box seat, box cover, and bearing/bolt, respectively. As the number of parameters is increased from one to two, the minimum time required by the traditional design increases by about 67%. And when the number of parameters is increased from two to three, the minimum time increases around 50%. Compared with traditional design methods, the rapid parametric design is more efficient for the inexperienced engineers and students and requires less time to complete the design and adjust the mechanical model. As the parameter number of rapid parametric design increases from one to two, the average time increases approximately 31%, and from two to three, the average time increases only 12%. Comparing with traditional design, the rapid parametric design methodology saves about 28% design time for one parameter and 43% and 57% for two parameters and three parameters, respectively. In terms of multi-parameter and complex model design, rapid parametric design has a more obvious effect on improving efficiency. The rapid parametric design method is helpful for engineers and mechanical students to better understand mechanical parts and devices and to have a new understanding of model design, which can help them solve practical engineering problems more efficiently.

Table 1. Time used for model design by traditional design and rapid parametric design.

Number of parameters	Parts	Time of traditional design (s)	Time of rapid parametric design (s)
3	Box seat	>45	18–20
2	Box cover	>30	16–18
1	Bearing Bolt Other parts	>18	12–14

3.3. Rapid parametric design of mechanical assembly

3.3.1. Rapid parametric design of reducer assembly

The three-dimensional model assembly of reducer was constructed by constraints and the generated parts, as shown in **Figure 11**. The assembly process starts with the basic components, including the box seat, the box cover and the bearings on account of the complexity of assembling the reducer.

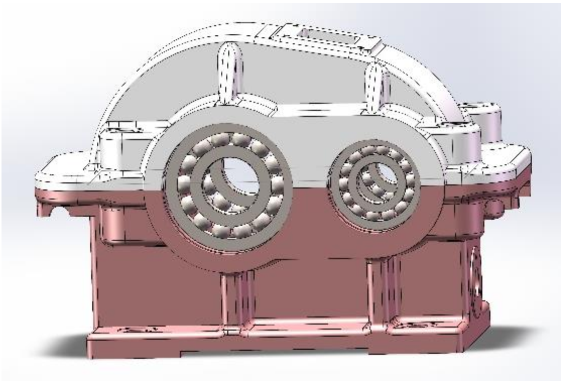
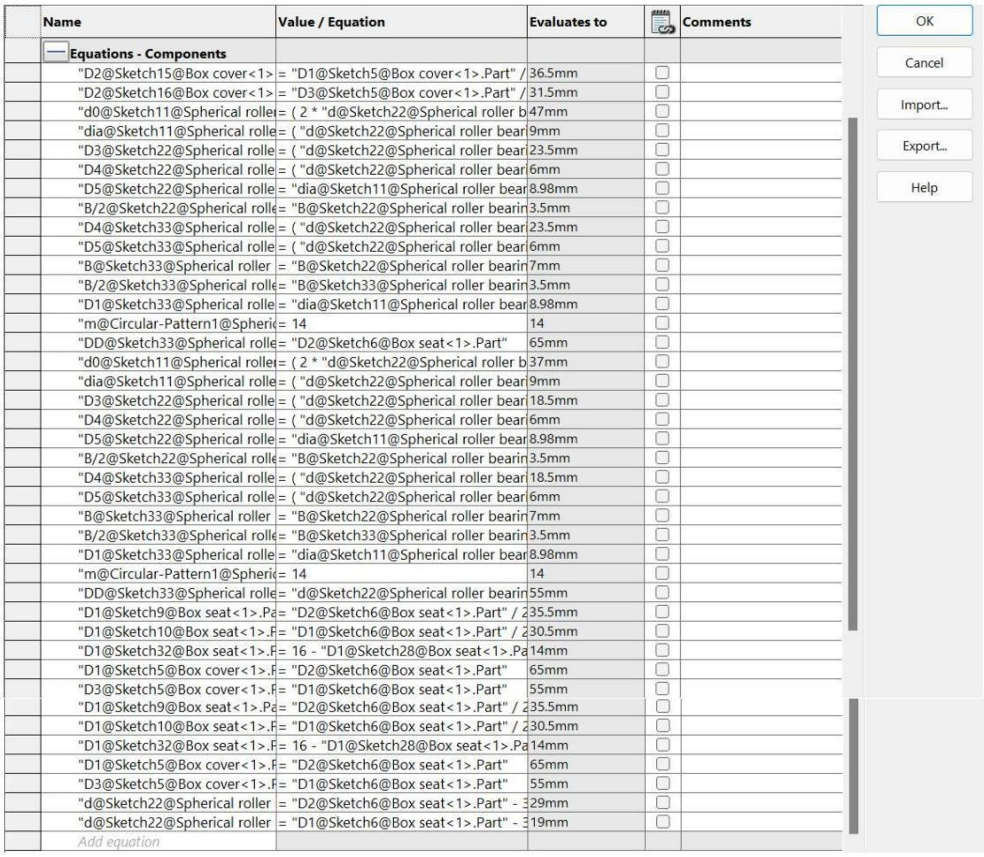


Figure 11. The three-dimensional model of reducer assembly.

The constraints, which govern the relationships between the components of the reducer in SolidWorks, were formulated by equations, as shown in **Figure 12**. The equation relationship in the process of gearbox assembly is verified by various sizes. Finally, after completing assembly and activating the exit button in the interface of part selection, the interface of termination was presented to finish the parametric design.



Name	Value / Equation	Evaluates to		Comments
Equations - Components				
"D2@Sketch15@Box cover<1>	= "D1@Sketch5@Box cover<1>.Part" /	36.5mm	☐	
"D2@Sketch16@Box cover<1>	= "D3@Sketch5@Box cover<1>.Part" /	31.5mm	☐	
"d0@Sketch11@Spherical roller	= (2 * "d@Sketch22@Spherical roller b	47mm	☐	
"dia@Sketch11@Spherical rolle	= ("d@Sketch22@Spherical roller bear	9mm	☐	
"D3@Sketch22@Spherical rolle	= ("d@Sketch22@Spherical roller bear	23.5mm	☐	
"D4@Sketch22@Spherical rolle	= ("d@Sketch22@Spherical roller bear	6mm	☐	
"D5@Sketch22@Spherical rolle	= "dia@Sketch11@Spherical roller bear	8.98mm	☐	
"B/2@Sketch22@Spherical rolle	= "B@Sketch22@Spherical roller bearin	3.5mm	☐	
"D4@Sketch33@Spherical rolle	= ("d@Sketch22@Spherical roller bear	23.5mm	☐	
"D5@Sketch33@Spherical rolle	= ("d@Sketch22@Spherical roller bear	6mm	☐	
"B@Sketch33@Spherical roller	= "B@Sketch22@Spherical roller bearin	7mm	☐	
"B/2@Sketch33@Spherical rolle	= "B@Sketch33@Spherical roller bearin	3.5mm	☐	
"D1@Sketch33@Spherical rolle	= "dia@Sketch11@Spherical roller bear	8.98mm	☐	
"m@Circular-Pattern1@Spheric	= 14	14	☐	
"DD@Sketch33@Spherical rolle	= "D2@Sketch6@Box seat<1>.Part"	65mm	☐	
"d0@Sketch11@Spherical roller	= (2 * "d@Sketch22@Spherical roller b	37mm	☐	
"dia@Sketch11@Spherical rolle	= ("d@Sketch22@Spherical roller bear	9mm	☐	
"D3@Sketch22@Spherical rolle	= ("d@Sketch22@Spherical roller bear	18.5mm	☐	
"D4@Sketch22@Spherical rolle	= ("d@Sketch22@Spherical roller bear	6mm	☐	
"D5@Sketch22@Spherical rolle	= "dia@Sketch11@Spherical roller bear	8.98mm	☐	
"B/2@Sketch22@Spherical rolle	= "B@Sketch22@Spherical roller bearin	3.5mm	☐	
"D4@Sketch33@Spherical rolle	= ("d@Sketch22@Spherical roller bear	18.5mm	☐	
"D5@Sketch33@Spherical rolle	= ("d@Sketch22@Spherical roller bear	6mm	☐	
"B@Sketch33@Spherical roller	= "B@Sketch22@Spherical roller bearin	7mm	☐	
"B/2@Sketch33@Spherical rolle	= "B@Sketch33@Spherical roller bearin	3.5mm	☐	
"D1@Sketch33@Spherical rolle	= "dia@Sketch11@Spherical roller bear	8.98mm	☐	
"m@Circular-Pattern1@Spheric	= 14	14	☐	
"DD@Sketch33@Spherical rolle	= "d@Sketch22@Spherical roller bearin	55mm	☐	
"D1@Sketch9@Box seat<1>.Pa	= "D2@Sketch6@Box seat<1>.Part" / 2	35.5mm	☐	
"D1@Sketch10@Box seat<1>.F	= "D1@Sketch6@Box seat<1>.Part" / 2	30.5mm	☐	
"D1@Sketch32@Box seat<1>.F	= 16 - "D1@Sketch28@Box seat<1>.Pa	14mm	☐	
"D1@Sketch5@Box cover<1>.F	= "D2@Sketch6@Box seat<1>.Part"	65mm	☐	
"D3@Sketch5@Box cover<1>.F	= "D1@Sketch6@Box seat<1>.Part"	55mm	☐	
"D1@Sketch9@Box seat<1>.Pa	= "D2@Sketch6@Box seat<1>.Part" / 2	35.5mm	☐	
"D1@Sketch10@Box seat<1>.F	= "D1@Sketch6@Box seat<1>.Part" / 2	30.5mm	☐	
"D1@Sketch32@Box seat<1>.F	= 16 - "D1@Sketch28@Box seat<1>.Pa	14mm	☐	
"D1@Sketch5@Box cover<1>.F	= "D2@Sketch6@Box seat<1>.Part"	65mm	☐	
"D3@Sketch5@Box cover<1>.F	= "D1@Sketch6@Box seat<1>.Part"	55mm	☐	
"d@Sketch22@Spherical roller	= "D2@Sketch6@Box seat<1>.Part" - 3	29mm	☐	
"d@Sketch22@Spherical roller	= "D1@Sketch6@Box seat<1>.Part" - 3	19mm	☐	
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Figure 12. The equations of constraints.

3.3.2. Comparison of parametric assemblies

Similarly to the rapid parametric design of parts, the rapid parametric design of assemblies is classified by the different number of designed parts, as presented in **Figure 13**. The comparisons of designing times between traditional and rapid parametric design are shown in **Table 2**.

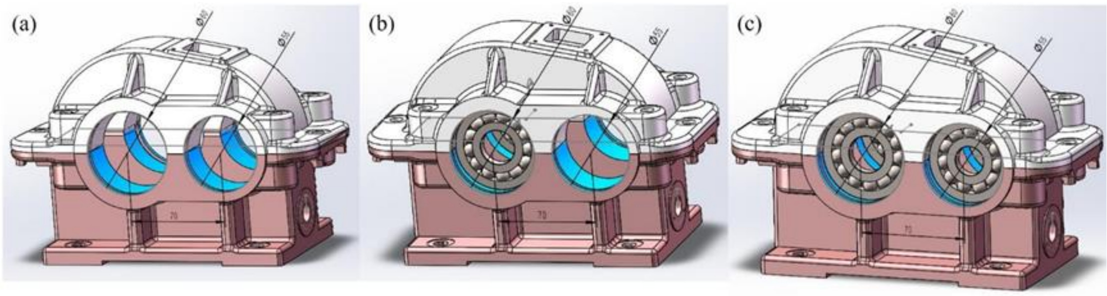

Figure 13. (a) Parametric assemblies with two parts; **(b)** parametric assemblies with three parts; **(c)** parametric assemblies with four parts.

For assembling four parts, the traditional design method necessitates 58 s to complete the assembly process, while the rapid parametric design only needs 30 s. It demonstrates that the fast parametric design method takes 48% less time to assemble the model than the traditional design method. The assemblies with three components use 55 s and 30 s by traditional design and rapid parametric design method, respectively. The fast parametric design method is 45% more efficient in model design than the traditional design method. For simpler assemblies with two components, the parametric method also gives efficient process, reducing the assembly time from 46 s of traditional design to 28 s, which means 39% reduction in design time. The design time of the traditional design and rapid parametric design perform 20% and 7% raise when the number of parts grows from two to three, respectively. And while the parts in the assembly are added from three to four, the time required by traditional design and rapid parametric design increases by 5% and 0%, respectively. With the increase of the number of assembly parts, the time spent on rapid parametric design in the assembly process increases less. In the process of assembly, the interference between parts will increase, and then the complexity of assembly increases simultaneously with the increasing number of parts. The rapid parametric design is less affected by the number of assembly parts, mainly due to the fact that the parameter relationship between parts has been established in advance during the adjustment of part parameters and assembly, so that the parts can be directly matched and the assembly task can be quickly completed. The rapid parametric design is not limited to the assembly of four parts, and allows more parts to be assembled on account of the complexity of the assembly in engineering field. The comparison of the assembly time of the models shows that the fast parametric design method is effective and feasible.

Table 2. Design time used for mechanical assemblies by traditional design and rapid parametric design.

Number of parts	Time of traditional design (s)	Time of rapid parametric design (s)
Four	58	30
Three	55	30
Two	46	28

The results show that the rapid parametric design method can reduce the design time, save the design cost and shorten the design cycle in the assembly process with different complexity. Furthermore, the rapid parametric design method is extensible and flexible, which can be applied to all models and is not limited to the type of model. The high efficiency of rapid parametric design is attributed to the constraint managements and parameter adjustments, greatly minimizing the time required for manual adjustments and modifications. The rapid parametric design shows the similar efficiency in parametric design of parts and assemblies. Therefore, the rapid parametric design method is more adaptable to parameter adjustment than the traditional design model in the current rapid development of teaching and engineering design.

3.4. Rapid parametric design of machines

The rapid parametric design can be applied not only to the design of first-level assembly but also to multilevel assembly. The parametric assembly of the gear reducer is a first-level assembly that comprises three key components, including bearings governed by a single parameter, a box cover designed with two parameters, and a box seat controlled by three parameters. Complex machinery is multilevel assembly, typically composed of multiple interconnected assemblies. That the parameterization of an entire machine is the integration of parametric assemblies, which consist of parametric parts.

To illustrate the rapid parametric design of machines, the belt conveyor is analyzed as a teaching case. The component composition and parameters of the belt conveyor are listed to clarify the details of parametric design, as shown in **Figure 14**. It is a relatively simple mechanical system compared to other machines such as motor vehicles and machine tools. The parameterization of the belt conveyor focuses on its core assemblies, including the driving motor, reducer, and conveyor belt. And the reducer assembly is parametrically modeled using components such as bearings, box covers, and box seats. The parametric components of the reducer are controlled by different parameters. Similarly, the driving motor and conveyor belt are parametrically designed and assembled using their respective parametric parts. This modular case of a belt conveyor enables students and engineers to break down the complex machines into assemblies and components, helping obtain scalability and adaptability for diverse engineering applications.

By adopting this design method, students and engineers can gain insights into the interdependencies between parametric components and assemblies. This fosters a deeper comprehension of parameterization and design flexibility for students and engineers in mechanical engineering.

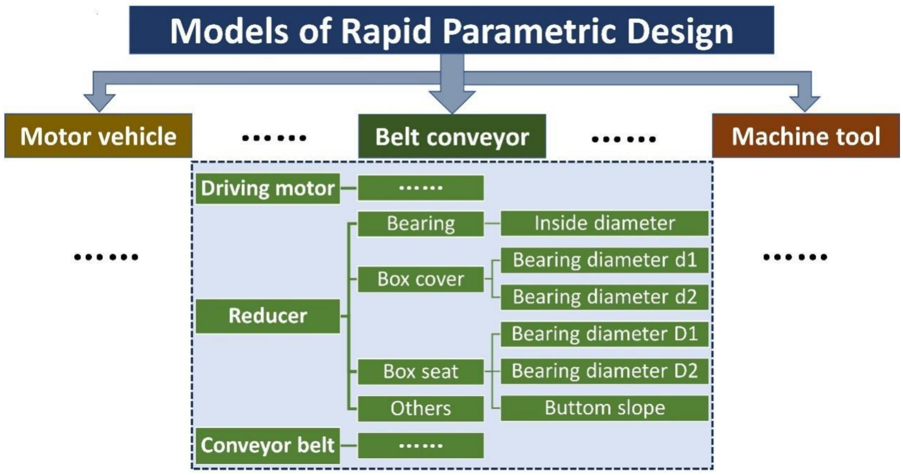

Figure 14. Rapid parametric design of machines.

4. Conclusions

This study focuses on rapid parametric design method to guide students and engineers on constructing gear reducer or other mechanical models quickly, via the rapid parametric design interface. Rapid parametric design method can solve the problems of long design cycle and low design efficiency that come from traditional design. Comparing with traditional design, the rapid parametric design methodology saves about 28% design time for one parameter, and 43% and 57% for two parameters and three parameters, respectively. And the fast parametric design method takes 39%, 45% and 48% less time to assemble the model than the traditional design method in assembling two, three and four parts, respectively. The reduction in assembly time gives the potential application of parametric design to improve productivity in engineering education and industries, particularly for inexperienced designers. The future studies of the rapid parametric design will focus on promoting programs and explore the effects of other variables to achieve better design efficiency.

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