An Efficient CAD based Design System for Spatial Cam Reducer

Yu Tao[1] , Wu Yafeng[2] , Leiyu Yan[3] and Ashutosh Sharma[4]

[1]Xi'an Aeronautical Polytechnic Institute Shaanxi Xi'an, 710089, China, rongchuanLin09@gmail.com
[2]Northwetern Polytechnical University   Shaanxi Xi'an 710072, China, wuyaf01@gmail.com
[3]Technical equipment design institute of Manufacturing Engineering Department of AVIC aircraft Co., Ltd, Xi'an Shaanxi ,710089, China, yanleiyu629@gmail.com
[4]Institute of Computer Technology and Information Security, Southern Federal University, Russia, ashutosh@sfedu.ru

Corresponding author: Ashutosh Sharma, ashutosh@sfedu.ru

Abstract. The mechanism of spatial Cam offers excellent Kinetic characteristics, based on these characteristics a spatial mechanism is designed. To study the CAD (Computer Aided Design) design of spatial cam deceleration device based on Creo3.0, two parameterization methods and general parameterization steps of spatial cam deceleration mechanism are studied. Relevant knowledge and parameterization ideas of program parameterization design are introduced in detail. Initially a prototype of reducer is designed. The parameterization of each part of two spatial cam deceleration mechanisms is realized, and then the parameterization of the whole mechanism is completed. The three-dimensional model of spatial cam deceleration mechanism with different transmission ratios is established and its installation is realized in the later stage. Based on the basic parameters of the spatial cam deceleration device and the design principle of the spatial cam deceleration mechanism, the design and selection of the power source, transmission mechanism and other accessories of the deceleration device are completed. The digital prototype of the spatial cam deceleration device is established by Creo3.0, and the development of the CAD system of the spatial cam deceleration device is realized.

Keywords: spatial cam reduction, parametric model, serial design, CAD system
DOI: https://doi.org/10.14733/cadaps.2022.S2.134-143

1   INTRODUCTION

The spatial cam reducer presents high efficiency less consumption and efficient transmission. The transmission mechanism can utilize the friction among the roller and cam in order to replace the

---

sliding friction which is capable for reduction in transmission parts and thus improve the working efficiency. Workflow is based on power source of motor which is driving from a camshaft and rotating at constant speed. Spatial cam deceleration mechanism is a new type of cam mechanism with zero stop period and constant speed motion law. Spatial indexing cam mechanism has a long history of theoretical research, and its design (including follower disc motion law, cam profile equation, pressure angle and curvature of the mechanism) and manufacturing has a fairly mature theoretical system [1]. Spatial indexing cam mechanism not only can realize indexing, but also has the function of positioning and self-locking. Therefore, there is no need for additional braking and positioning devices when using spatial indexing cam mechanism, which greatly reduces the complexity of mechanical equipment; moreover, the contact between spatial indexing cam and driven roller is rolling friction motion [2], so its overall transmission efficiency is high, and the meshing wear of mechanism is small and it has long life.

There are many kinds of spatial cam deceleration mechanisms, such as single-head, multi-head, left-hand and right-hand. In the actual application process, the left-handed single-head spatial cam deceleration mechanism is often used [3]. Sometimes, because of the different transmission ratio requirements, two-head cams are also used, but the outline of three-head and more than three-head cam mechanism is complex, and seldom used [4]. Usually when the transmission ratio is less than 6, two or even multi-head cams are often used to avoid the large pressure angle caused by too small cam mechanism, which reduces the transmission performance of the mechanism. When the transmission ratio is greater than 6, single-head cams are mostly used; the follower rollers of the mechanism have more shapes, usually cylindrical and conical [5].

Following is a brief introduction to the characteristics of two types of spatial cam deceleration mechanism. Cylindrical cam deceleration mechanism is suitable for medium and low speed motion occasions, and its characteristics are: large transmission ratio range, high transmission accuracy, good rigidity performance, and large bearing capacity [6], suitability for use in large torque transmission, good kinematics and dynamics characteristics of the mechanism, low noise, and low manufacturing cost. Tapered roller and cylindrical cam can eliminate the backlash of contact parts when meshing and achieve accurate positioning [7]. The outcomes of the study are concentrated on the following outcomes given as:

- The parameterization of whole mechanism is completed by completing series mechanism of two spatial cam deceleration mechanisms.
- The selection of power source, transmission mechanism and other accessories of deceleration device is realized by using basic principles and design selection.
- The Creo3.0 is used for the realization of digital prototype of spatial cam deceleration device.

The rest of paper is organized into different sections: second section explain the literature review and methodology is explained in the third section. Results and discussion is made in section four. In the last section, conclusion is given.

2   LITERATURE REVIEW

The reducer can distribute the rotational speed of the working machine and the actuator reasonably and transfer the torque of the driving machine to the follower. It is an important driving part in the mechanical industry and its performance is related to the efficiency of the machine. The transmission efficiency and service life of the reducer are closely related to the performance of the transmission mechanism [8]. In view of the unavoidable defects of traditional reducers, researchers at home and abroad have applied spatial cam mechanisms with excellent characteristics to the field of reducers and have made some achievements. Next, the research on reducer, spatial indexing cam mechanism and spatial cam reducer by domestic and foreign scholars are elaborated respectively [9].

In China, researchers mastered the manufacturing technology of decelerator through technical research and scientific research on processing equipment imported from abroad, which made the

industry of decelerator develop rapidly and the research of decelerator get more attention. Subsequently, the standardization of the reducer was realized according to some requirements of the reducer [10]. After that, many manufacturers of the reducer emerged one after another. Scholars have also studied and learned from foreign technology and advanced theories. In view of the many shortcomings of the gear reducer, in recent years, many scholars have carried out the optimal design of the gear reducer. Abroad, as early as the 20th century, the Soviet Union had an amazing manufacturing technology of reducers.

At that time, many reducers were manufactured with reference to this technology. Later, they were also developing continuously, but ultimately, they could not meet the international requirements. There are also many enterprises specializing in the research and development of decelerators abroad [11]. So far, the research of gear reducer has never stopped. Because the gear reducer has irrevocable defects, and the gear reducer is an indispensable part in life, scholars are constantly pushing forward to try to replace the gear reducer with other gear reducers in order to achieve better deceleration and torque increase effect [12].

The spatial cam deceleration device is a new type of deceleration device with the spatial cam deceleration mechanism as the core transmission mechanism. In China, many achievements have been made in the field of space cam reducer. Tian et al. put forward the roller gear cam deceleration mechanism, introduced its working principle, deduced the meshing profile curve equation and calculation formula, and completed the development of CAD (Computer Aided Design) application software accordingly [13]. Tan et al. innovated the ultra-thin globoidal cam steel ball deceleration machine, introduced its design process and structural form, explained its superior performance characteristics, and proved its broad application prospects [14]. Difen et al. explained the concept of globoidal cam reducer, summarized the unique advantages of this new reducer, the most significant advantage is that it can achieve no clearance meshing, timely and long-term operation. After fine tuning, it can still require accuracy, and it is more suitable for use in high speed, high precision and high efficiency [15].

Finally, through the introduction of the processing theory, trial production is carried out. The prototype of the reducer has contributed to the later experimental verification [16]. Overseas, some achievements have been made in the research of space cam deceleration device, such as CAMCO Company of the United States. RDM series, FLEX-I-DEX series and E-series cam reducers have been successfully developed, which can achieve zero backlash transmission and meet the requirements of high efficiency and high precision [17]. RDM series products are used for light-load short-range sports, while E-series products are used for heavy-load high-speed sports [18]. Different kinds of backlash-free roller gear reducers have been invented in the literature, which have high accuracy and can completely eliminate meshing clearance in practical operation and improve the assembly efficiency of the reducer [19].

3   ADOPTED METHODOLOGY

3.1   Parametric Driving Method

This design method modifies, and designs graphics based on geometric constraints among dimensions of graphics. It is necessary to establish graphics in the design system first, then convert the characteristics of graphics into data structures and save them in the graphics database. Directed line segments are used to represent dimension marking lines.

In the drawn graphics, dimension marking lines are used to check the relationship between geometric parameters, and then the corresponding driving mode is set for each dimension marking. In the actual modification of graphics, the new constraints can be obtained by changing the parameter values, and then the final graphics can be rebuilt in the graphics database. The principle of this method is shown in Figure 1.

3.2   Variable Geometry Method

This method is an algebraic method based on constraints. Generally, geometric models are represented in the form of feature points, and then a set of non-linear constrained equations are established.
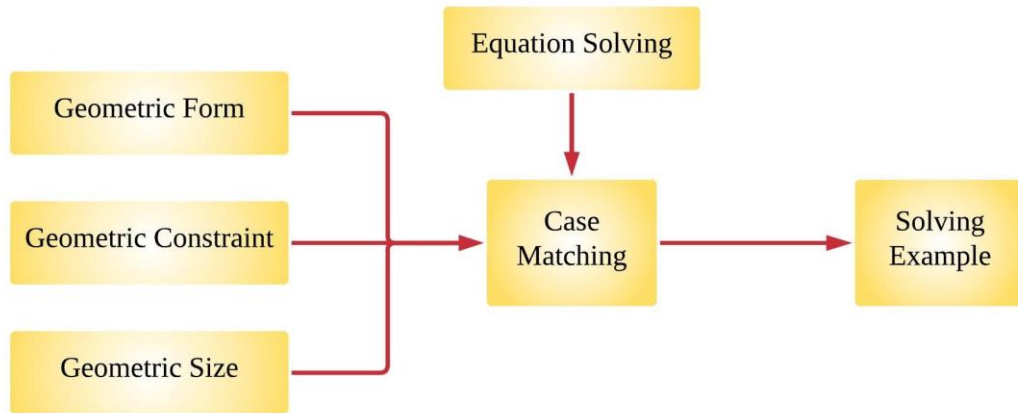

Figure 1: Parametric drive principle.

New feature points are obtained by solving the above non-linear constrained equations by iteration method, and then geometric models are generated from these feature points. This method can classify many constraints in the design process, making the design process more free, flexible and simple. The basic principle of variable geometry is shown in Figure 2.
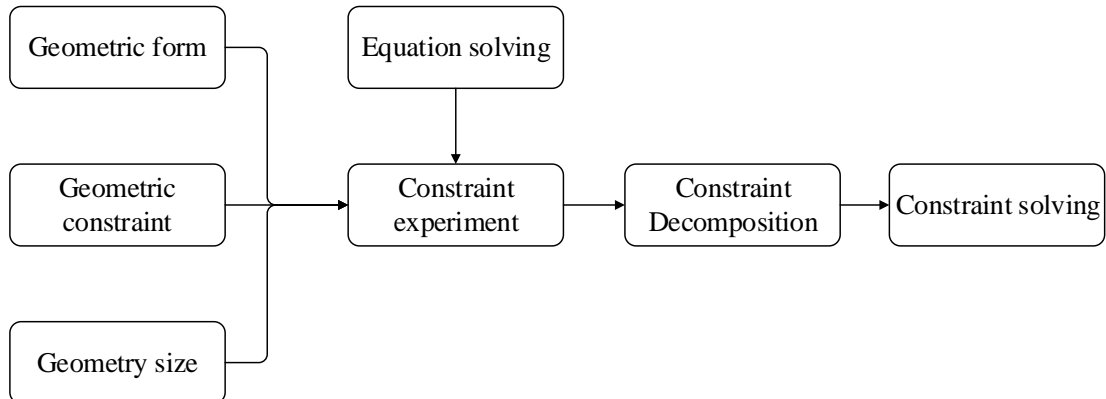

Figure 2: Basic principle of variable method.

The essence of parameterization is the combination of model and program. Before parameterization, the template model should be built with three-dimensional modeling software, and then the correct control program should be established among the parameters of the template model. Finally, a new model can be generated by modifying the design parameters. The parameterization process is shown in Figure 3. The following points should be paid attention to when building model:

- Graphics must be in the state of full constraint, that is, to add a complete dimension and constraint relationship to the graphics.

- The parameters must be correct and reasonable, and independent parameters independent of other parameters should be used to control the geometric size and topological relationship of the model.
- The relationship between parameters and variables must be correct. This relationship is established by Pro/Program, which links the external design parameters with Creo system constraints so that the three-dimensional model can be controlled according to the external design parameters.
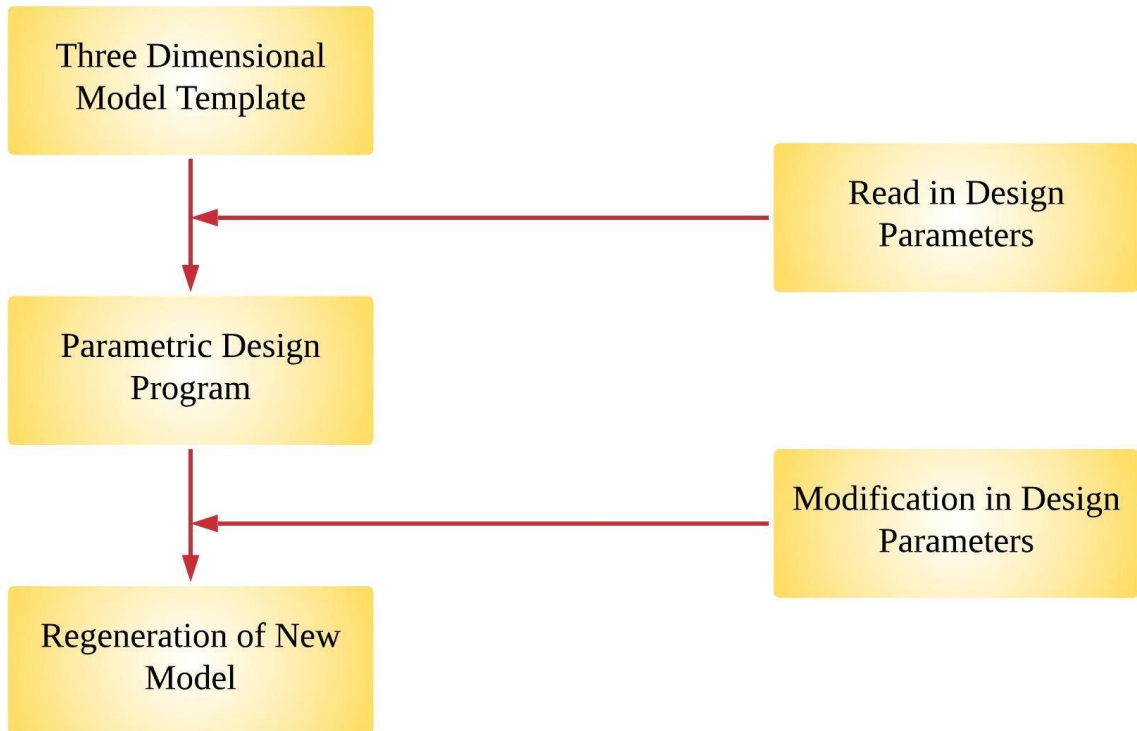

Figure 3: Process of parametric design.

4   RESULTS AND DISCUSSION

4.1   System Design Ideas

The system will adopt object-oriented design method, encapsulate all the design process into the system background, and only show the simple operation interface to the user. The user can modify or input the parameters appropriately in the interface according to the design need to obtain the corresponding device. The design idea of the spatial cam reducer system is shown in Figure 4.

4.2   Development of Device Design System

System development process: The Creo3.0 engineering software developed by PTC Company is selected for the development of this system. The development environment is Visual C++ and the development tool is Pro/toolkit that Creo brings with it. Pro/toolkit is a customized development toolkit for Creo3.0 software.

It can expand the functions of Creo through object-oriented method. Its powerful function library can realize the conversion of system information with Creo 3.0. VC++ provides an object-oriented interactive visual integrated development environment for the secondary development of software, which integrates editing, compiling, connecting and debugging.
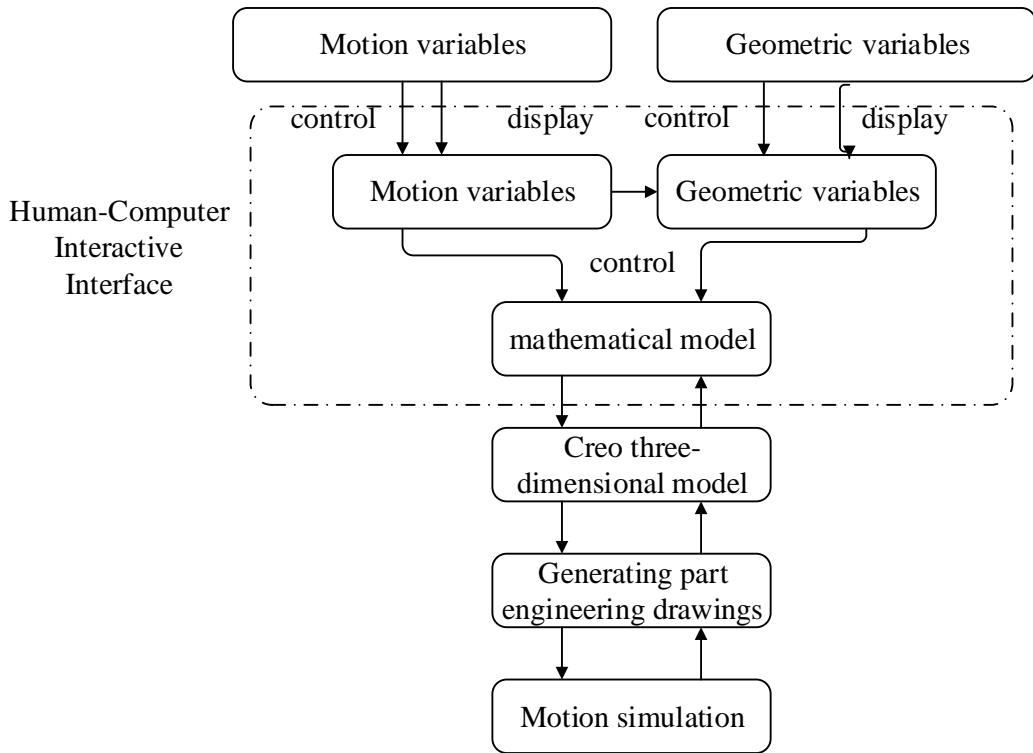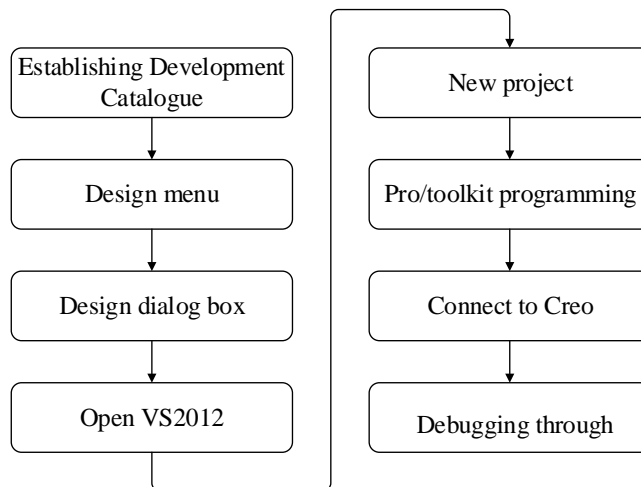

Figure 4: General design of system.

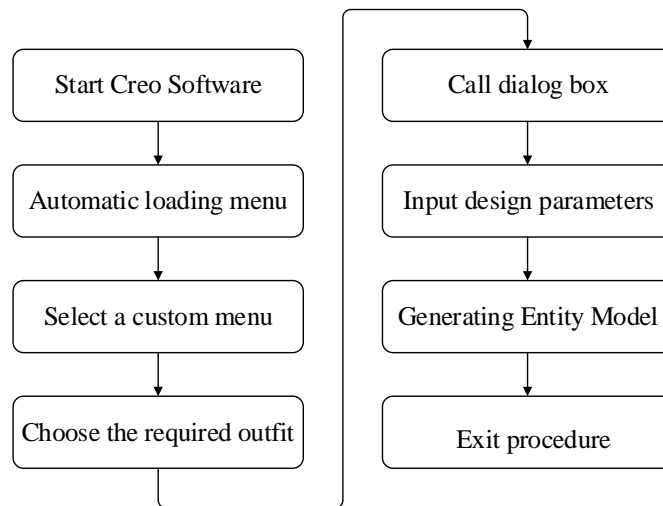**Figure 5**: The development process.

Figure 6: The call response diagram of program.

Users can write application statements in the format of basic C language or C++ language in their development environment. The basic process of creating Pro/Toolkit application with VC++ 6.0 is shown in Figure 5, and the program call response in Creo is shown in Figure 6.

Create a Pro/toolkit application. Pro/toolkit applications refer to executable files or dynamic link libraries that can run in Creo3.0 environment. Executable files are named with the suffix ".exe" and dynamic link libraries are named with the suffix ".d11". The basic methods of creating Pro/Toolkit applications are as follows: first, Make file creation method; second, VC wizard creation method. The first method needs to modify the content of template Make file every time it is created. The second method is to create according to VC wizard file, which can directly design, create and debug the application, making full use of VC resources. Therefore, the second method will be used to complete the application creation.

A new Pro/Toolkit application framework project is created by creating a project in VC++ 6.0 and choosing the connection type as the shared dynamic connection DLL type. This framework does not implement any specific functions, but only meets the requirements of Windows operating system. Specific actions are as follows: in the integrated development environment of Visual Studio 2012, select "File-New-Project-Visual C++ MFC", then select MFCDLL project in the module installed by Visual Studio, enter the file name "tulun" in the Name dialog box, and click the "OK" button to create the application project.

The language structure of the Pro/toolkit application program for setting file path consists of three parts: the header file part, the main program part and the user function part. Before compiling the program, it is necessary to set the path of each file. The correct file path is directly related to the successful operation of the program. The steps of setting the file path are: select Tool-Options-Directory-Includes files and add the header file and library file directories respectively.

In the integrated development environment of Visual Studio 2012, select Tools/Options and add header file paths:

D:\ProgramFiles\Creo3.0\Creo3.0\F000\CommonFiles\protoolkit\protk_appls\includes
D:\ProgramFiles\Creo3.0\Creo3.0\F000\CommonFiles\protoolkit\includes

Add:

D:\Program Files\Creo3.0\Creo3.0\F000\Common Files\pro/toolkit\x86e_win64\obj.

Set project properties.

Select Project/Properties in the Visual Studio 2012 menu bar and select "Configure Properties" in the Properties dialog box.

Add "PROUSEVARARGS" library file in "C/C++-Pre-processor - Pre-processor Definition".

In Connector-Input-Additional Dependencies, add:

ws232.1ib

protk_dllmd.lib

wsock32.lib

psapi.lib

netapi32.fib five library files.

Design menus and dialogs: After setting up Visual Studio 2012, start to write programs in the programming interface. First, add menu bars to the Creo system as needed. All menu bars in the Creo interface are menus composed of buttons and submenu items. Call the Pro Menu Bar Menu Push Button Add () function to complete the addition of menu buttons, call the Pro Act Add () function to set the action when clicking the button, call the Pro Menu Bar Menu Add () function to add a menu in the Creo menu bar, and call the Pro Menu Bar Menu Add () function to add submenus in the Creo menu bar.

The window information file is the text description displayed on the screen interface when running the program after the menu design is completed. It is the ASCII text file with the suffix of .txt. The information file is composed of four lines of statements. The first line is a string that prompts information keywords, and it identifies the message when calling the Pro Message Display () function, which is consistent with the relevant string in the information file function; the second line is another string text that replaces the first line of string, which acts when calling the Pro Message Display () function; the third line is the text displayed on the screen; the fourth line is a deliberate blank line, reserved for future expansion, marked with "#". Dialogue box is the interface of human-computer interaction.

Its main function is to realize the effective exchange of information between the system and users. Writing the dialog resource file is the first step in designing the dialog box. In this design, part of the text code of the dialog resource file is used to define the layout of the dialog box and the composition, appearance and attributes of each component, which is called when the program is registered. Application compilation: After completing the compilation of each text, the application program can be compiled by choosing the "tulun - generate - generate tulun" button in the menu of VC++ 6.0 and generating the "dll" dynamic link library file. Registration and operation of the program: If the registration file is loaded into the Creo auxiliary application window, the Pro/toolkit application program can be integrated into the Creo system. The file contains ".dll" file, dialog box file, and the location of information resource file, etc. Click the Start button to run the application.

Figure 7 presence of simulation results of the design parameters. The feasibility and correctness of proposed parameters are analyzed through the simulation results. The computer aided design for the cam reducer is realized and the prototype of a reducer is established based on these system means. Experimental analysis presents the faster design process of reducer and it is also observed that the handling of repetitive design and complex calculation work is easy.
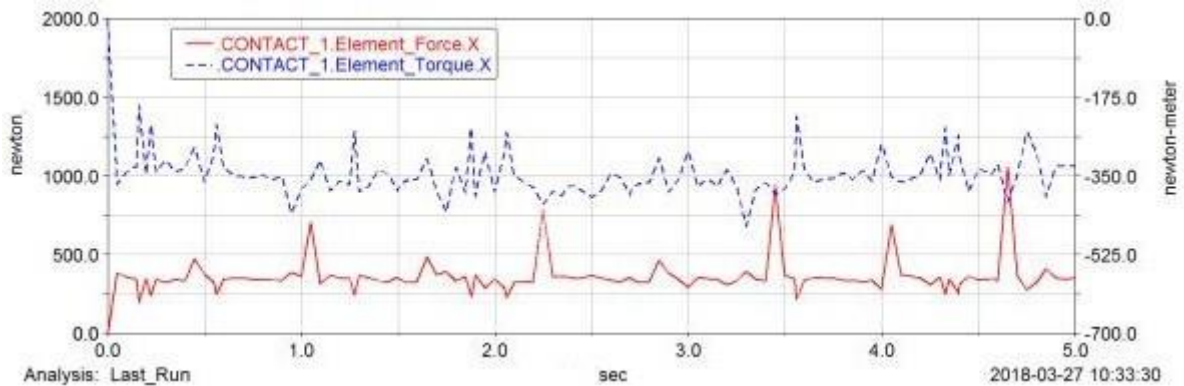
Figure 7: Simulation results of design parameters.

5   CONCLUSION

Spatial cam mechanism has the advantages of smooth motion and compact structure and is widely used in mechanical devices. The spatial cam deceleration device studied is a new type of deceleration device developed on the basis of the research of the existing spatial cam deceleration mechanism. The main research contents and achievements are summarized as follows: firstly, the development platform and tools of the system are briefly introduced, and the development process of the system is designed; the system framework is created based on the development environment of VC++, user-defined menu design and parameter interface design. By running the program on Creo3.0 platform with Pro/toolkit development tool, the system can finally realize the parametric modelling of deceleration device.

Yu Tao, https://orcid.org/0000-0002-2439-0299
Wu Yafeng, https://orcid.org/0000-0002-0004-5626
Leiyu Yan, https://orcid.org/0000-0002-2052-4683
Ashutosh Sharma, https://orcid.org/0000-0002-4990-5252

REFERENCES

[1]   Hu, D.; Guo, J.: Tool path optimization algorithm of spatial cam flank milling based on NURBS surface, Journal of the Brazilian Society of Mechanical Sciences and Engineering, 40(4), 2018, 1-8. https://doi.org/10.1007/s40430-018-1092-x
[2]   Xiao, X.; Yao, Y.; Xie, Y.-M.; Wang, X.-H.; Li, Y. L.: Protecting entanglement from correlated amplitude damping channel using weak measurement and quantum measurement reversal, Quantum Information Processing, 15(9), 2016, 3881-3891. https://doi.org/10.1007/s11128-016-1356-2
[3]   Kohn, F.-E.; Van Ommen, J.-G.; Feijen, J.: The mechanism of the ring-opening polymerization of lactide and glycolide, European polymer journal, 19(12), 1983, 1081-1088. https://doi.org/10.1016/0014-3057(83)90001-0
[4]   Heinrich, G.; Ghadieh, H.-E.; Ghanem, S.-S.; Muturi, H.-T.; Rezaei, K.; Al-Share, Q.-Y.; Najjar, S.-M.: Loss of hepatic CEACAM1: a unifying mechanism linking insulin resistance to obesity and non-alcoholic fatty liver disease, Frontiers in endocrinology, 8, 2017. https://doi.org/10.3389/fendo.2017.00008

[5]   Chen, L.; Yang, Y.; Chen, J.: Spatial-temporal variability and transportation mechanism of polychlorinated biphenyls in the Yangtze River Estuary, Sci Total Environ, 2017, 598: 12-20. https://doi.org/10.1016/j.scitotenv.2017.04.069

[6]   Zhang, H.; Dong, B.; Liu, B.: A Reweighted Joint Spatial-Radon Domain CT Image Reconstruction Model for Metal Artifact Reduction[J], Siam J Imaging Sci, 11(1), 2018, 707-733. https://doi.org/10.1137/17M1140212

[7]   Yan, D.; Yao, J.; Liu, Y.: Tau hyperphosphorylation and P-CREB reduction are involved in acrylamide-induced spatial memory impairment: Suppression by curcumin, Brain Behav Immun, 2018, S0889159118301351. https://doi.org/10.1016/j.bbi.2018.04.014

[8]   Kulaw, D.-H.; Cowan, J.-H.; Jackson, M.-W.: Temporal and spatial comparisons of the reproductive biology of northern Gulf of Mexico (USA) red snapper (Lutjanus campechanus) collected a decade apart, PLOS ONE, 12(3), 2017, e0172360. https://doi.org/10.1371/journal.pone.0172360

[9]   Aouad, G.; Wu, S.; Lee, A.; Onyenobi, T.: Computer aided design guide for architecture, engineering and construction, Routledge, 2013. https://doi.org/10.4324/9780203878750

[10]   STEFANI, L.: Evaluation of Academic Development, Evaluating the Effectiveness of Academic Development: Principles and Practice, 2010. https://doi.org/10.4324/9780203847930

[11]   Kim, J.; Pratt, M.-J.; Iyer, R.-G.; Sriram, R.-D.: Standardized data exchange of CAD models with design intent, Computer-Aided Design, 40(7), 2008, 760-777. https://doi.org/10.1016/j.cad.2007.06.014

[12]   Sinha, R.; Paredis, C.-J.; Liang, V.-C.; Khosla, P.-K.: Modeling and simulation methods for design of engineering systems, J. Comput. Inf. Sci. Eng., 1(1), 2001, 84-91. https://doi.org/10.1115/1.1344877

[13]   Tian, S.; Gong, Q.; Zhang, G.; Hu, M.; Wu, Y.: Extensible Innovation Design of Globoidal Cam Deceleration Mechanism Based on Knowledge, In International Conference on Mechanical Design, Springer, Singapore, 2019, 1054-1069. https://doi.org/10.1007/978-981-32-9941-288

[14]   Tan, J.: Advances in Mechanical Design, Proceedings of the 2019 International Conference on Mechanical Design, ICMD, Springer Nature, 77, 2019. https://doi.org/10.1007/978-981-32-9941-2

[15]   Kondratyev, A.; Lwin, K.: Design of asynchronous circuits using synchronous CAD tools. IEEE Design & Test of Computers, 19(4), 2002, 107-117. https://doi.org/10.1109/MDT.2002.1018139

[16]   Chang, K. H.: Product design modeling using CAD/CAE: the computer aided engineering design series, Academic Press, 2014. https://doi.org/10.1016/B978-0-12-398513-2.00003-8

[17]   Sakao, T.; Shimomura, Y.; Sundin, E.; Comstock, M.: Modeling design objects in CAD system for service/product engineering, Computer-Aided Design, 41(3), 2009, 197-213. https://doi.org/10.1016/j.cad.2008.06.006

[18]   Srivastava, S.; Sharma, N.; Singh, S.-K.; Srivastava, R.: Design, analysis and classifier evaluation for a CAD tool for breast cancer detection from digital mammograms, International journal of Biomedical Engineering and technology, 13(3), 2013, 270-300. https://doi.org/10.1504/IJBET.2013.058447

[19]   Bordegoni, M.; Rizzi, C.: Innovation in product design: from CAD to virtual prototyping, Springer Science & Business Media, 2011. https://doi.org/10.1007/978-0-85729-775-4