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RESEARCH ON PARAMETRIC SIMULATION TECHNOLOGY BASED ON COMPLICATED MECHANISM DESIGN

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ABSTRACT

A new method is proposed, which is the core of parametric simulation based on complicated mechanism design. Furthermore, the connotation of parametric simulation is affirmed and the flow of parametric simulation based on complicated mechanism design is put forward. At last, taking a parallel mechanism as example, the technology of parametric simulation proposed is applied to the simulation study used ADAMS, which consist of analyzing mechanism, parametric modeling, creating GUI, creating menu and parametric simulation. The practice indicates that the method is effectual.

1   INTRODUCTION

The mechanism design is key part of the mechanical design. During the mechanism design, the rationality of the structure parameter decides the comprehensive function of the whole mechanical product directly. Therefore, how to select the structure parameter is a very important problem. Usually, these parameters will be confirmed through the calculation of the kinetics and dynamics. For the complicated construction (for example, the space parallel mechanism), these analytic calculation processes are very complicated. And we usually can't acquire ideal solution because it's hard to establish the correct analytic mathematics model.

The above questions can be resolved by simulation method effectively. Simulation method is that kinematical model is set up according to mechanism kinematical theory and then researched for confirming reasonable structure parameter. However, during the practical design, the structure parameters of the model usually need to be modified constantly and simulated repeatedly for getting ideal solution. The efficiency of simulation study is decreased by fussy operation. If mechanism model and relative constraint are completely parametric, namely by building parametric model, can improve the efficiency of simulation evidently.

In the paper, a new method about mechanism design is proposed, which is the core of parametric simulation. On the basis of it, a 3-TPT parallel mechanism is taken as example, the technology of parametric simulation proposed is applied to the simulation study used ADAMS.

2 THE CONTENT OF PARAMETRIC SIMULATION

The parametric simulation includes two meanings: one is the parametric model, that is the totally parameterization of the shape and constraint to make the whole simulation model completely confirming by a few parameters, so that it is easy to reconstruct the model; The other is the whole parametric simulation flow, namely in the process of simulation, dynamically change the value of parametric variables for determining the optimum parameter in the condition of satisfying constraint. It is clear that the parametric simulation model is the precondition of parametric simulation process.

For the mechanical product, which has the complicated mechanism, it is usually difficult to assure suitable structure parameter at the first stage. But the application of parametric simulation technology can make the dimension as parameter, further establishing parametric simulation model to carry on simulation research. As a result, the parametric simulation is particularly suitable for the complicated mechanism design.

3 THE BASIC FLOW OF PARAMETRIC SIMULATION

Choosing the simulation platform (or the simulation software)

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suitably is the premise of carrying on the parametric simulation. In recent years, some of the scholars have applied the parametric thought to carry on the simulation research. For example, in the literature [1], a kind of multi-functional automobile is in progress of parametric modeling by using Pro/Engineer and Solid Works. And simulation research is done by making use of the DADS system to carry out the target for optimizing the various functions of that automobile. In the literature [2], by the application of parametric modeling software Inventor on the basis of features, the spare parts of the potato harvest machine are parametric modeling. Adopting the ADAMS mechanism simulation software, the key part is carried on kinematics simulation research to acquire the suitable movement parameter. All of the above research is concrete application of parametric simulation; the basic flow of parametric simulation towards complicated mechanism hasn't been given definitely.

In the paper, on the basis of summarizing the predecessors' achievement that can be found in the literature [1-9] and regarding ADAMS as mainly simulation software, the basic flow of parametric simulation research towards complicated mechanism design is proposed, showed as Figure 1

(1)The analysis of the complicated mechanism
The premise of parametric simulation towards complicated mechanism is to analyze this mechanism, including the assurance of the component types and quantity, constraint between components. The target of mechanism analysis is to find out the structure parameter that can describe the whole mechanism model.

(2) Parametric modeling
The abundant basic solid such as connecting rod, cylinder, rectangle are provided by ADAMS software. The whole mechanism model can be set up by basic solid quickly comparing with mechanism models. And then the model will be parameterized by establishing design variables, design points and using the corresponding position and orientation function.

(3) Establish man-machine interaction
In the products developing process, the simulation efficiency will affect directly the design progress of the whole product. For completing simulation efficiently, it is necessary to establish the corresponding dialogue and calling menu around the above-mentioned simulation model in order to make it convenient for the researchers.

(4) Parametric simulation
Various simulation models that are activated dialogue by menu can be made up rapidly. Aim at these models, different drive can be added and all kinds of measurement can be established. From the result for measurement, every structure parameter can be investigated to acquire the superior structure parameter. The functions of ADAMS, such as design analysis and design research, may be applied in the simulation to accelerate process of acquiring suitable parameters.

4 A RESEARCH EXAMPLE
For demonstrating the basic process of parametric simulation, a kind of 3-TPT parallel mechanism is taken as an example. The 3-TPT parallel mechanism is a kind of mechanism that can move with pure 3D translation, which has 3 driving arms and has 3 degree of freedom. Each driving arm's kinematic pairs separately are hook joint, translation joint and hook joint. The kinematics model of the 3-TPT parallel mechanism can be presented by Figure 2[10].
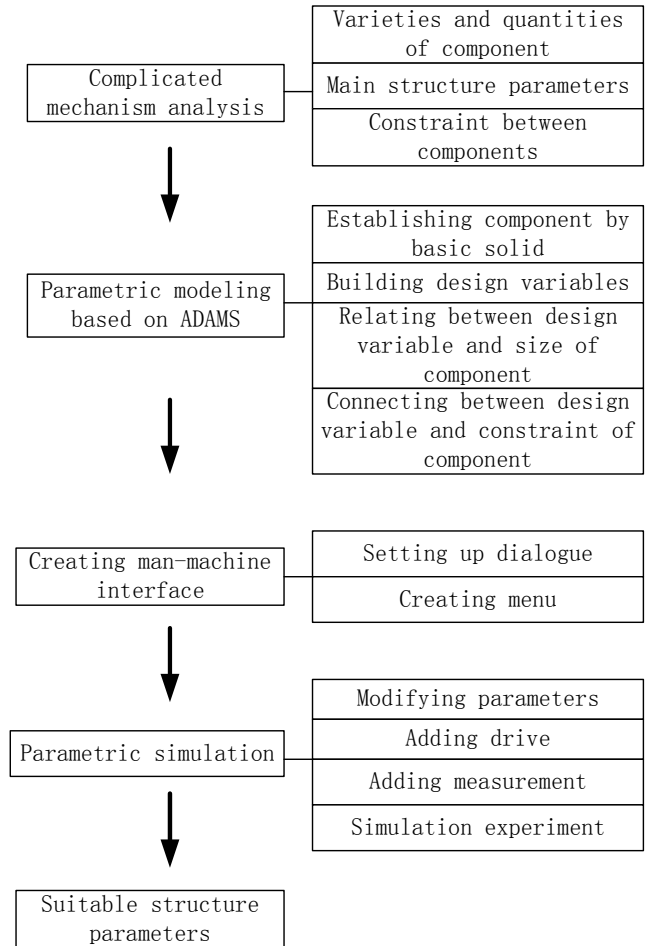

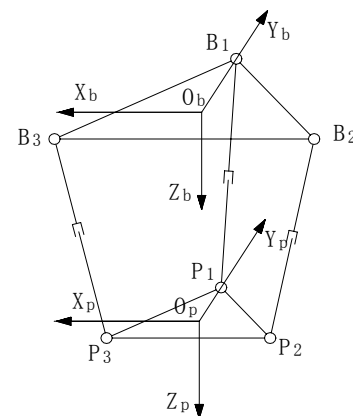**Figure 1.** Parametric simulation flow of complicated mechanism

Figure 2. Kinemics model of parallel machine tool

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The parallel mechanism is carried on parametric simulation research by ADAMS software. The main work is mechanism analysis, parametric modeling, building dialogue and menu, mechanism movement simulation, etc.

4.1 Mechanism analysis

According to the kinematics model, the parallel mechanism can be divided four parts, namely fixed platform, moving platform, sleeve and flexing rod. The model composing with these four parts can simulate all the movement of real mechanism.

Establish 6 design points. The ex-three design points B_1, B_2, B_3 means fixed platform. The last three design points P_1, P_2, P_3 means moving platform. From formula (1) and (2), the position coordinates are demarcated by circumcircle radius of moving platform (Ry) and the distance (H) between the two platforms. According to the six design points, fixed platform and moving platform can be created by using Plate of ADAMS. By connecting the three end points (B_i, P_i, i=1,2,3) between the two platforms separately, sleeve model can be established that its length is TL by Cylinder of ADAMS. In accordance with the same method, the flexing rod model that the length is SL can be created. For convenience, the diameters of sleeve and flexing rod can be appointed a fixed value. By the above analysis, the model of basic mechanism is entirely decided by design variable of Rd, Ry, H, Tl and SL. And the model can be carried on parametric modeling taking these five design variables as parameters.

$$B_1 = \begin{bmatrix} 0 \\ Rd \\ 0 \end{bmatrix} \quad B_2 = \begin{bmatrix} -\sqrt{3}Rd/2 \\ -Rd/2 \\ 0 \end{bmatrix} \quad B_3 = \begin{bmatrix} \sqrt{3}Rd/2 \\ -Rd/2 \\ 0 \end{bmatrix} \quad (1)$$

$$P_1 = \begin{bmatrix} 0 \\ Ry \\ H \end{bmatrix} \quad P_2 = \begin{bmatrix} -\sqrt{3}Ry/2 \\ -Ry/2 \\ H \end{bmatrix} \quad P_3 = \begin{bmatrix} \sqrt{3}Ry/2 \\ -Ry/2 \\ H \end{bmatrix} \quad (2)$$

4.2 Parametric modeling

In ADAMS, design variable can be set up by dialogue. The above five design variables can be created by clicking the menu of Build\ design variable\new. The condition of every variable can be viewed at Table 1. Next, every design variable and the corresponding object should be related. For instance, Rd, Ry and H relate with coordinates of the six design points (See formula (1) and formula (2)), TL and SL relate with the length of sleeve and flexing rod. Finally, the two platforms showed by plate and sleeve and flexing rod showed by Cylinder relate with six design points for controlling the position and orientation of the above geometry body. During the process of relating geometry body and design points, position function and orientation function of ADAMS should be used. For example,

LOC_RELATIVE_TO({0,0, 0} , .ground.B2)
ORI_ALONG_AXIS(.ground.B2, .model_1.ground.P2, "Z")
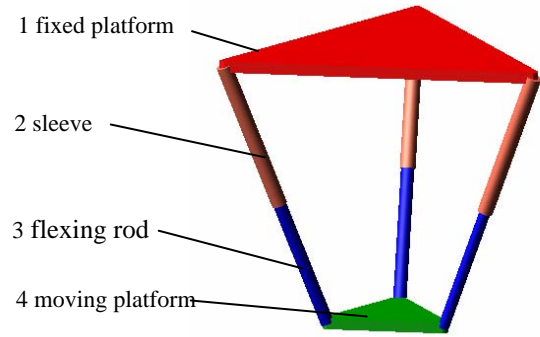Figure 3 is parametric model that is finally completed.

Figure 3. Parametric model with basic geometry entity

Table 1. Defining design variables

Variable name	Basic value(mm)	Value range(mm)
Circumcircle Radius of fixed platform Rd	800	600—1000
Circumcircle Radius of Moving platform Ry	300	200—600
Distance of two platforms Hh	1200	700—1500
Length of sleeve TL	700	600—1000
Length of flexing rod SL	700	600—1000

4.3 Establishing dialogue

The parametric model is driven by creating dialogue box in ADAMS. The process that establishes the dialogue is as follows:

(1) Establishing own database

In ADAMS, the content including all kinds of model object, constraint, dialogue can be saved with database. If the own database cannot be established, the dialogue would be saved in the database of gui. It isn't favorable for data management. The method of setting up database is to click Tools/Command Navigator/ library/create in ADAMS interface. The name of own database is .Bing_Ku.

(2) Setting up a macro to modify position of six design points

It is convenient to make the position of structure point parametric by setting up macro. And the dialogue box that is nominated by macro command can be also automatically produced by macro. The process of establishing macro is as follows: click Tools/Macro/Edit/new in ADAMS interface and enter the following macro command.

!$RdC: t=real: D=800: C=1
variable modify variable_name=. model_1.Rd real_value=$RdC

The sentence means the original value of fixed platform circumradius (Rd) is 800. Similarly the original value of other design variables can be entered.

(3) The realization of the dialogue

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The dialogue box, which is produced automatically by macro, can be found in the database of gui. It is moved and renamed into the own database. The dialogue can be revised by dialogue editor providing by ADAMS. The process, which starts the dialogue editor, is as follows: click Tools/Dialog Box/Modify in ADAMS interface. The revised content includes the revision to the relevant name and command of text label, data area and command button. Figure 4 is the completed dialogue.
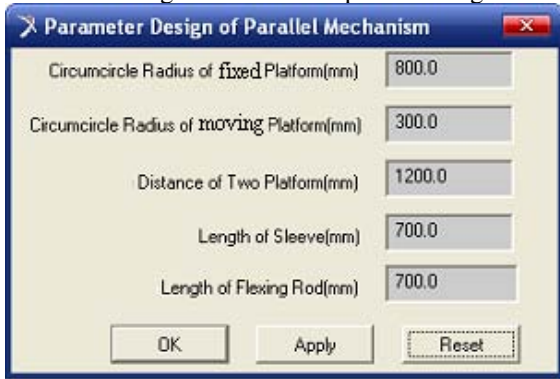
Figure 4. Dialog box of parametric modeling

4.4 Establish menu

After the dialogue is established, the corresponding applied menu should be built for being convenient to activate the dialogue. Establishing customized menu is carried on the menu editor and management tool proving by ADAMS. Click Tools/Menu/Modify and enter the relevant code to achieve the menu item for activating dialogue. The main command is

CMD=int dia dis dia=.Bing_Ku.bing_make_model_dlg

It is for starting dialogue.

4.5 Parallel mechanism simulation

The main work of parametric simulation on the parallel mechanism is including the key steps as follows: add constraint, add drive, establish measurement and demonstrate result, etc.

The constraints include Universal Joint, Translational Joint, Fixed Joint and Parallel Axis Primitive Joint. The detailed conditions are showed in Table 2. For realizing rapidly the visual simulation of different structure parameter, every constraint joint is also parameterized. The method is the two Marker points, which decides position and orientation of constraint joint, should also be parameterized separately by using the position and orientation function.

For the 3-TPT parallel mechanism can do pure translation movement in the workspace, so the position analysis of contra-solution is mainly done. In the center of moving platform, we put on a point drive. The method is clicking General Motion button in the toolbox. The moving platform can do line, circle, spiral and other complicated movement by setting the movement of x, y, z orientation. Taking spiral movement as examples, the operation process is as follows: set up rotation movement about x, y, z axis as 0 and translation movement along x, y, z direction as formula (3),

$$x= 200*\cos(\text{time})$$

$$y= 200*\sin(\text{time})$$
$$z= 10*\text{time} \tag{3}$$

and then spiral movement can be realized.

Table 2. Restraint between components

Name of part	Fixed platform	Moving platform	Sleeve	Flexing rod
Fixed platform		Translation-al Joint	Universal Joint	
Moving platform	Parallel Axis Primitive Joint			Universal Joint
Sleeve	Universal Joint			Translation-al Joint
Flexing rod		Universal Joint	Translation-al Joint	

During the process of simulation, every running parameter should be measured for judging the rationality of every structure parameter. In view of the example, the changing situation of every working parameter can be obtained by establishing measure function. For example, for measuring the changing situation of the displacement and speed of every driving arm, the method can be realized as follows: click Build/Measure/Function/new in ADAMS interface for creating measure function. For instance, if we want to build the function of measuring displace and velocity, the grammar is as follow:

DM(To_Marker , From_Marker)

VR(To_Marker , From_Marker , Ref_Frame)

The measurement result can be expressed with figure by using PostProcessor by ADAMS. The rationality of the parallel mechanism design value can be judged by determined the corresponding curve. Figure 5 is showing changing condition of velocity of every drive arm with the parameter of Figure 4, when moving platform is doing circle movement that radius is 200mm and angle velocity is 0.5rad/s.
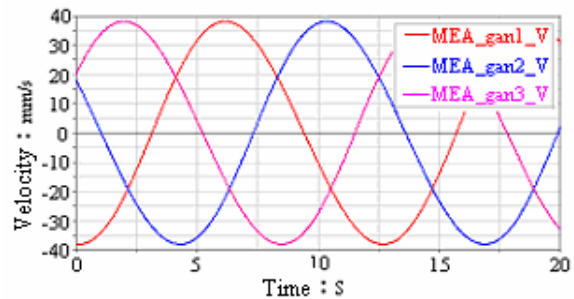
Figure 5. Velocity change of every drive arm

With changing the every design parameter in dialogue box, the above steps of simulation are repeated for ensuring rationally the relevant parameter of the mechanism.

5 CONCLUSION

The efficiency of simulation research can be increased by parameterization of completed mechanism model and parametric simulation for accelerating the speed of product development. In the paper, on the basis of the summaries and analysis of relevant research achievement, the connotation of

parametric simulation is definite. Furthermore, the basic process on parametric simulation technology based on complicated mechanism design is presented by ADAMS as the simulation software. In the end, illustrating a kind of parallel mechanism with example, the process of parametric simulation on the mechanism is discussed in detail, including the steps of mechanism analysis, parametric modeling, establishing dialogue box, starting menu and concrete simulation, etc. The above research can be the reference of other completed mechanism design.

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