5D modeliranje mehaničkih sistema

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U radu je prikazan novi pristup u složenom istraživanju mehaničkih sistema uz korišćenje savremenih računarskih sistema - 5D modeliranje. Ovaj pristup omogućava visok nivo složenog istraživanja mehaničkih sistema, uključujući i prezentaciju dobijenih rezultata. Ovo je posebno važno u najranijim fazama projektovanja mehaničkih sistema.

Ključne reči: mehanički sistem, modeliranje, dinamička analiza, analiza konačnim elementima

1. UVODNO RAZMATRANJE

Poznato je da pogrešne tehničke odluke u ranim fazama dizajniranja mehaničkih sistema mogu dovesti do ozbiljnih troškova u svim narednim fazama životnog ciklusa proizvoda. Procena troškova otklanjanja jedne takve greške u različitim fazama pripreme proizvodnje (Gartner Group) data je kroz:

- 1 \$ - preliminarna faza projektovanja;
- 10 \$ - faza projektovanja;
- 100 \$ - izrada modela proizvoda;
- 1000 \$ - projektovanje industrijske opreme;
- 10000 \$ - proizvodnja opreme;
- 100000 \$ - serijska proizvodnja prototipa;
- 1000000 \$ - serijska proizvodnja.

2. FAZE MODELIRANJA

5D modeliranje mehaničkih sistema uključuje tri faze:

- 1) kreiranje trodimenzionalnog modela (3D) mehaničkog sistema, na primer, u sistemu KOMPAS-3D, Solid Vorks, itd. [1 - 8];
- 2) modeliranje funkcionisanja mehaničkog sistema u vremenu (dinamička analiza + 1D), na primer, u sistemu UMEkpress (Univerzalni mehanizam), UM 7.0, itd. ;
- 3) istraživanje intenzivnog deformisanog stanja mehaničkog sistema uzimajući u obzir opterećenja definisana u prethodnoj fazi (analiza konačnih elemenata + 1D), na primer, u sistemu APM FEM ili APM Struktura 3D [9], itd.

Proces složenog modeliranja ima iterativni karakter, s mogućnošću prelaska na bilo koju od gore navedenih faza modeliranja. Na primer, prisustvo pritiska u odvojenim elementima mehaničkog sistema, može zahtevati ozbiljne promene u trodimenzionalnom modelu sistema - prva faza modeliranja ili promenu režima rada sistema - druga faza modeliranja. Konačno, nakon nekoliko ponavljanja, omogućuje se stvaranje vrlo efikasnog mehaničkog sistema. Na primer, tokom dinamičke analize trodimenzionalnog modela mehaničkog sistema mogu se javiti neprihvatljivi nivoi rezonantnih oscilacija. To može zahtevati ozbiljne promene u režimu rada sistema - druga faza modeliranja ili povratak na prvu fazu i sprovođenje odgovarajuće modernizacije trodimenzionalnog modela itd. Proces operativnog razvoja modela proizvoda može zauzeti neke iteracije.

3. FORMIRANJE 3D MODELA

Stvaranje trodimenzionalnog modela mehaničkih sistema može se obaviti korišćenjem različitih CAD sistema: AutoCAD, Solid Vork, Solid Edge, Inventor, T-Flek, APM Vin Machine, KOMPAS-3D, itd.

5D modeliranje mehaničkih sistema je izvršavanje sistema KOMPAS-3D, poslednje verzije firme ASCON. Pre svega, ovaj sistem je povezan da bi pružio potpunu podršku sistemima ESKD, SPDS i ISO. Pored toga, poseduje zadovoljavajuću količinu biblioteka delova, modela i primenjenih biblioteka, što 10 puta olakšava performanse dizajnera i istraživača [5 - 8].

Slika 1: Primeri delova i sklopova

Slika 2: Primer mehaničkog sistema

4. FORMIRANJE I ISTRAŽIVANJE DINAMIČKOG MODELA

Za sprovođenje statičkih, kinematičkih i dinamičkih proračuna mehaničkih sistema korišćen je sistem Univerzalni mehanizam (UMEkpress), koji je ugrađen

direktno u sistem KOMPAS - 3D ili UM-7. Ovi sistemi mogu imati potpuno parametrizovane objekte.

UMExpress menja konfiguraciju mehaničkog sistema i takve parametre, kao što su veličina veza, faktori u izražavanju sila, itd. Ovaj sistem zapravo menja parametre mehaničkih sistema bez ponavljanja zaključaka jednačina kretanja. Jednačine su izvučene u potpunom simboličkom obliku, a odgovarajući parametri su uključeni u njih u obliku identifikatora.

Slika 3: Primer mehaničkog sistema u UMExpress-u

Da bi se smanjilo vreme izvođenja statičke, kinematike i dinamičke analize projektant može da:

- transformiše strukturu sklopa u skup tela udruživanjem detalja što omogućava smanjenje broja ugrađenih tela za 10 puta;
- kompletira kinematske šeme vizuelnim dodavanjem ili uklanjanjem potrebnih pokretnih veza;
- kreira grafičke slike opruga itd. pogonskih elemenata ako postoji takva potreba;
- podešavanje interakcije moći između tela, itd. akcije.

Slika 4: Primer postavljanja parametarskih tačaka

Slika 5: Rezultati istraživanja (Interaktivne sile u ozubljenju)

Upotreba programskog paketa UMExpress (Univerzalni mehanizam) omogućava:

- pojednostavljenje procesa stvaranja dinamičkih modela i njihove numeričke analize, omogućavajući dinamičko modeliranje tela širokom spektru inženjera-istraživača i projektanata;
- što je više moguće niže troškove projektovanja koji će omogućiti da se transformiše u široko primenljiv softverski proizvod (alat);
- pripremu širokog spektra korisnika za upotrebu težih i funkcionalno potpuno sličnih programa, uključujući programe UM (vidi www.umlub.ru);
- automatsko formiranje avi datoteke.

5. ISTRAŽIVANJE DEFORMISANOG STANJA

Istraživanje intenzivnog deformisanog stanja najviše opterećenih čvorova mehaničkih sistema metodom konačnih elemenata (FEM) sprovedeno je u sistemu APM FEM, koji je ugrađen u sistem KOMPAS 3D. Međutim, može se izvršiti i pomoću drugih sistema, na primer, Mehanički Desktop Pover Pack [8], APM Struktura 3D [9], itd.

Slika 6: Primer rezultata istraživanja

Svaki od FEM sistema omogućava da se razne vrste opterećenja postave u trodimenzionalni model, da se odrede granični uslovi, napravi mreža konačnih elemenata i izvrši proračun. Takav postupak generisanja konačnih elemenata, omogućava automatsko formiranje sistema jednačina i njihovo rešavanje.

Po pravilu, takvi sistemi omogućavaju sprovođenje sledeće vrste proračuna:

- statički proračun;
- proračun stabilnosti;
- izračunavanje sopstvenih frekvencija i oblika oscilovanja;
- termičke i druge vrste proračuna.

Upotreba programskog paketa APM FEM omogućava:

- pojednostavljenje procesa kreiranja modela konačnih elementa i njihove numeričke analize, omogućavajući sprovođenje istraživanja intenzivno deformisanog stanja različitih čvorova SIPTM, studentima i širokom spektru inženjera-istraživača i projekatanta;
- što je moguće više smanjenje troškova dizajniranja što će omogućiti transformaciju APM FEM-a u široko primenjen softverski proizvod (alat);
- pripremu širokog spektra korisnika za upotrebu težih i funkcionalno potpunih sličnih programa, uključujući APM Structure 3D (vidi APM VinMachine).

2. ZAKLJUČAK

5D modeliranje mehaničkih sistema omogućava visok nivo složenih istraživanja, uključujući i prezentaciju dobijenih rezultata. Ova činjenica je od posebnog značaja u najranijim fazama projektovanja mehaničkih sistema. Kao što je

prikazano u radu, pogrešna tehnička odluka u ranim fazama projektovanja mehaničkog sistema može dovesti do ozbiljnih troškova u svim narednim fazama životnog ciklusa proizvoda.

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5D Modelling of Mechanical Systems

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It is offered the new approach to complex research of mechanical systems with use of a certain set of modern computer systems - 5D modelling. This approach provides high level of complex research of mechanical systems, including and presentation of received results. It is especially important at the earliest design stages of mechanical systems.

Keywords: Mechanical system, modeling, dynamic analysis, final-element analysis

1. INTRODUCTION

It is known, that wrong technical decisions at early design stages of mechanical systems can entail serious expenses at all subsequent stages of life cycle of a product. Estimation of cost of correction of one error at various stages preparation of manufacturing (Gartner Group):

- 1 \$ - preliminary design phase;
- 10 \$ - design stage;
- 100 \$ - manufacturing of a breadboard model of a product;
- 1000 \$ - industrial equipment designing;
- 10000 \$ - equipment manufacturing;
- 100000 \$ - prototype serial production;
- 1000000 \$ - serial production.

2. MODELLING STAGES

5D modelling of mechanical systems includes three stages:

- 1) creation of three-dimensional model (3D) of mechanical system, for example, in system KOMPAS-3D, Solid Works, etc. [1 - 8];
- 2) modelling of functioning of mechanical system in time (the dynamic analysis +1D), for example, in system UMEExpress (the Universal mechanism), UM 7.0, etc.;
- 3) research of the intense deformed condition of mechanical system taking into account loadings defined at the previous stage (the is final-element analysis +1D), for example, in system APM FEM or APM Structure 3D [9], etc.

Process of complex modelling has iterative character, with possibility of transition to any of above listed stages of modelling. For example, presence of other-wordily pressure in separate elements of mechanical system, can demand serious changes in three-dimensional model of system - the first stage of modelling or to change a system operating mode - the second stage of modelling. It, finally, after several iterations it will allow to create the highly effective mechanical system.

For example, in the course of the dynamic analysis of three-dimensional model of mechanical system there can

be inadmissible levels of the resonance oscillations. It can demand serious changes in a system operating mode – the second stage of modelling or to return to the first stage and to spend corresponding modernization of three-dimensional model etc. The process of operational development of model of a product can occupy some iterations.

3. CREATION 3D MODEL

Creation of a three-dimensional model of mechanical systems can be carried out with the use of various CAD systems: AutoCAD, Solid Work, Solid Edge, Inventor, TFlex, APM Win Machine, KOMPAS-3D, etc. 5D modelling of mechanical systems is the execution by the system the KOMPAS-3D, last versions of firm ASCON. It is connected, first of all, by this system to provide complete support of systems of ESKD, SPDS and ISO. Besides, it has a satisfactory quantity of libraries of fragments, models and applied libraries, which by 10 times facilitate performance of designer and researcher [5 - 8].

Figure 1: Samples parts and assemblage

Figure 2: Sample mechanical system

4. CREATION AND RESEARCH DYNAMIC MODEL

For carrying out static, kinematics and dynamic calculations of mechanical systems we used systems Universal mechanism (UMExpress), which is built directly in system the KOMPAS - 3D, or UM-7. These systems can

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to have completely parametrized objects. UMEExpress changes a configuration of mechanical system and such parameters, as the sizes of links, factors in expression of forces, etc. This system actually changes of parameters of mechanical systems without a repeated conclusion of the equations of movement. The equations are deduced in the full symbolical form, and corresponding parameters are included into them in the form of identifiers.

Figure 3: Sample mechanical system in UMEExpress

To reduce time of performance of the static, kinematics and dynamic analysis the designer are used by so as:

- to transform an assemblage tree to a set of bodies by association of details that allows to reduce number of incorporated bodies in 10 times;
- to spend completion of the kinematics scheme by visual addition or removal of necessary hinges;
- to create graphic images of springs, etc. power elements if there is such necessity;
- to set power interactions between bodies, etc. actions.

Figure 4: Sample installations of the parameter points

Figure 5: Some research results (interacting forces in the toothings)

The use of program complex UMEExpress (the Universal mechanism) allows:

- to simplify process of creation of dynamic models and their numerical analysis, having made accessible modelling of dynamics of systems of bodies to a wide range of engineers-researchers and designers;
- as much as possible to lower cost of design workings out that will allow to transform it into mass software product (tool) of the expert;
- to prepare the mass user for use of more difficult and functionally full similar programs, including programs UM (see www.umlub.ru);
- automatically to create avi file.

5. CREATION AND RESEARCH DYNAMIC MODEL

Research of the is intense-deformed condition of the most loaded knots of mechanical systems by a finite element method (FEM) by us it was carried out in system APM FEM, which has been built in system the KOMPAS 3D. However, it can be executed and by means of other systems, for example, Mechanical Desktop Power Pack [8], APM Structure 3D [9], etc.

Figure 6: Some research results

Each of FEM systems allows to put loadings of various types to three-dimensional model, to specify boundary conditions, to create an is final-element grid and to execute calculation. Thus, procedure of generation of final elements, drawing up of systems of the equations and their decision is spent automatically. As a rule, such systems allow to spend following kinds of calculations:

- static calculation;
- calculation on stability;
- calculation of own frequencies and forms of fluctuations;
- thermal and other kinds of calculations.

The use of program complex APM FEM allows:

- to simplify process of creation of is final-element models and their numerical analysis, having made accessible carrying out of research of the is intense deformed condition of various knots СИПТМ to students and a wide range of engineers-researchers and designers;
- as much as possible to lower cost of design workings out that will allow to transform APM FEM into mass software product (tool) of the expert;
- to prepare the mass user for use of more difficult and functionally full similar programs, including АПМ Structure 3D (see APM WinMachine).

6. CONCLUSION

5D modeling of mechanical systems provides high level of complex research, including and presentation of received results. It is especially important at the earliest design stages of mechanical systems. As is shown above, the wrong technical decision at early design stages of mechanical system can entail serious expenses at all subsequent stages of life cycle of a product.

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