APPLICATION OF CAD SYSTEM IN GEOMETRIC MODELING FOR HELICOPTER PRELIMINARY DESIGN

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Abstract

A Computer program HEGMCAD (Helicopter Geometric Model Computer-Aided Design) has been developed with CAD system for automatic geometric modeling. This paper introduces HEGMCAD in detail. HEGMCAD is capable of rapidly generating various helicopter models and corresponding sizing data. Three orthographic views and a 3-D wireframe are produced for four helicopter configurations—— single-rotor, tandem-rotor, coaxial-rotor and titl-rotor. In order to generate more smooth fuselage, a new cross-section shape called super-ellipse was introducted into HEGMCAD. In addition to the four views, a solid model is produced. From the solid model, designers can get more informations than from the 3-D wireframe model. With HEGMCAD, desigeners also can arrange the location of mission equipment packages (such as avionics), crew stations and passenger stations.

Ⅰ. Introduction

Helicopter geometric modeling is an important step in helicopter preliminary design. It directly reflects the design parameters. Traditional geometric model is designed on paper with pencils and rubbers. This method inevitably brings about some limitations. First, it is difficult to get informations of 3-D model from traditional geometric model, such as relative location of each component in 3-D space. Second, the efficiency is very low. Someone describes the traditional method as the struggle between pencils and rubbers. The problem of efficiency is more important in the preliminary design which may be modified again and again.

Moreover, between existing helicopter preliminary parameters optimizing program to audio-visual 3-D geometric model, it lacks an interface which can rapidly transform the output of the former into the latter. So, to raise the efficiency of geometric modeling, break the limitations of traditional method and use the optimizing program more efficiently, it is necessary to develop a CAD tool which should have the following functions:

1. It can rapidly generate the geometric models corresponding to the output of the preliminary parameters optimizing program.

2. The above graphical output should also be a CAD/CAM design model.

3. It should have a library which includes various small components, such as rotor hub, auxiliary propulsion, landing gear etc., so that designers can add them to the basic model.

4. It should enable arrangement of mission equipment packages, crew stations and passenger stations.

To satisfy these needs, an automatic geometric modeling program for helicopters called HEGMCAD was designed. HEGMCAD functions as the interface which integrates the optimizing program and the CAD/CAM system. HEGMCAD will be described below.

Ⅱ. Development and Features of HEGMCAD

Main Idea of HEGMCAD

HEGMCAD was developed with the CDS4001 system of Computer Vision Corporation. CDS4001 system is a computer-aided design and manufacturing system supported by the software CADDS4. This system allows 2-D and 3-D model design to be interactive. Although helicopter models can be created by inputing the detail dimensions step by step, and then using the interactive commands provided by CADDS4, this requires a highly skilled operator, may take several days (though it is more advanced than drawing by hands), and is easy to make errors. More importantly, such a procedure does not satisfy the needs which are mentioned above.

To solve this problem, we adopted the special purpose program language of CDS4001 system——CVMAC macrolanguage. This language is capable of processing a series of design commands for geometric modeling, and it also can be related with the date base and FORTRAN subroutines. Thus much time is saved for geometric modeling with HEGMCAD, and preliminary helicopter designs with various shape and size can be generated in a short time.

No matter which configuration a helicopter is, it is simply composed of main rotor, tail rotor, fuselage, engine, landing gear and stub wing etc., thus HEGMCAD is made up of the subroutine blocks which can generate the above components. Designers can make various combinations conveniently with these blocks, like building toy bricks. Some geometric parameters are not included in the output of the optimizing program, such as rotor hub di-

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mensions, the radii of some corners, then they will be calculated from proportional relationships with the main parameters. So the number of inputs is decreased. For example, a rotor model can be generated only with inputing the rotor radius, number of blades, blade chord and airfoil. Fig. 3 shows the flowchart of HEGMCAD.

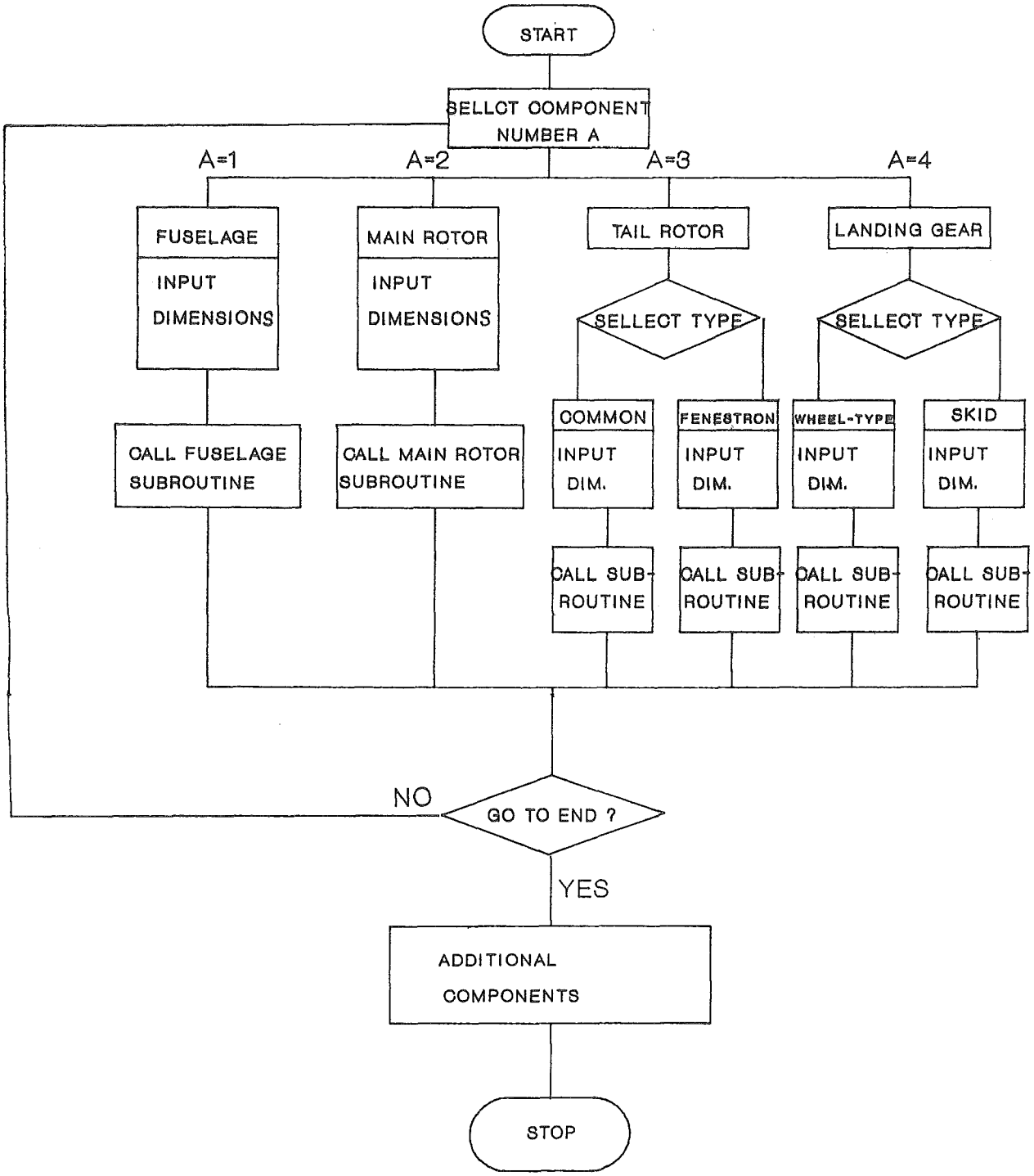

Fig. 1 Flowchart of HEGMCAD.

Generation of Fuselage

Among all the components, it is the most difficult to generate a fuselage, because its surface is very complicated. After the shape, location and dimensions of each cross-section are input, then the B-spline curve of each cross-section will be generated. Points on the B-spline curve must be equally spaced and equal in number on the different cross-section, otherwise the splines on the surface of fuselage will be skew.

HEGMCAD can provide four types of cross-section shape—— circle, ellipse, rectangle with small round corners and super-ellipse. The reason of introduction of super-ellipse is that the former three types of shape do not exactly represent some very smooth helicopter fuselage. The expression of super-ellipse is

$$\begin{cases} x = a\ (\cos\theta)^{2/n} \\ y = b\ (\sin\theta)^{2/n} \end{cases}$$

where, a is the length of major semi-axis, and b is the length of minor semi-axis.

When n=1, it is a rhomb;

n=2, it is a ellipse;

n > 6, it is approximate a rectangle with small round corners;

n>14, it is approximate a rectangle. (See Fig. 2)

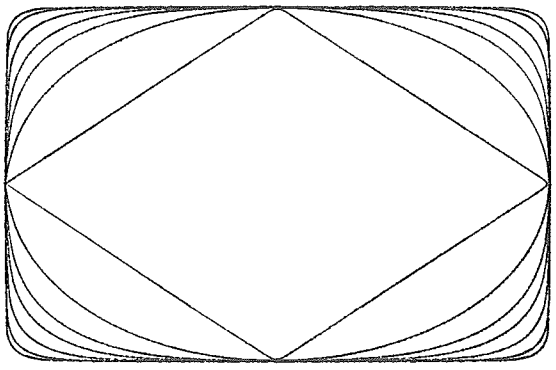

Fig. 2 Super-ellipse (From inside to outside n=1,2,3,4,6,10,14 respectively)

However, the calculation of the arc length of super-ellipse is very difficult. The time spent on calculation is relatively long, even with more effective method. Thus the fir/st step is to generate the nonequal spaced points using the equation of super-ellipse, and then generate a B-spline curve through these points; After these points are deleted, the second step is to generate new equal spaced points using the interactive command, and then generate a new B-spline curve through these new points.

Super-ellipse is very useful, especially in modeling the nose of fuselage. In this section, the shape of cross-section changes eventually from a very small circle to a rectangle with small round corners. Only altering the value of n will simulate the changes from a circle to a rectangle. So the surface of fuselage generated will be more smooth. Fig. 3 shows the fuselage generated automatically.

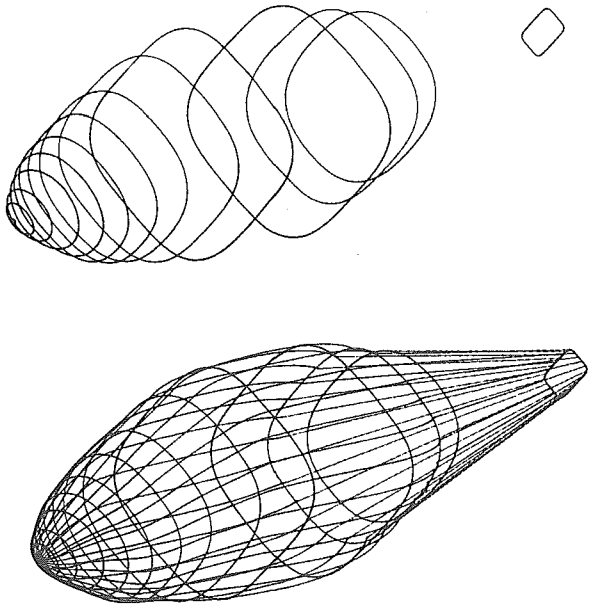

Fig. 3 Generation of A Single-Rotor Helicopter Fuselage 3-D Wireframe

Features of HEGMCAD

HEGMCAD has the following features/functions:

1. It has strong generality and flexibility, it can generate 2-D and 3-D views of various types of helicopter geometric models (single-rotor, tandem-rotor, coaxial-rotor and tilt-rotor). For a single-rotor helicopter, a fenestron tail can be selected besides a common tail. HEGMCAD has a library which includes many small components, designers can conveniently choose them and add them to the basic configuration from this library.

2. In addition to the above views, a solid model can also be generated. From the solid model, designers can get more informations, such as whether the surface of the fuselage is smooth, and whether the components are in harmony with each other, so that evaluate a design from a technological point of views.

Ⅲ. Examples of Application

To show features of HEGMCAD, some sample helicopters have been designed. Fig. 4-6 show the 3-D wireframes of single-rotor helicopter, tandem-rotor helicopter and tilt-rotor helicopter respectively. Fig. 7 shows the 2-D views of a single-rotor helicopter with fenestron tail. Using HEGMCAD, a Remotely Piloted Helicopter also has been designed. Fig. 8 shows the arrangement of

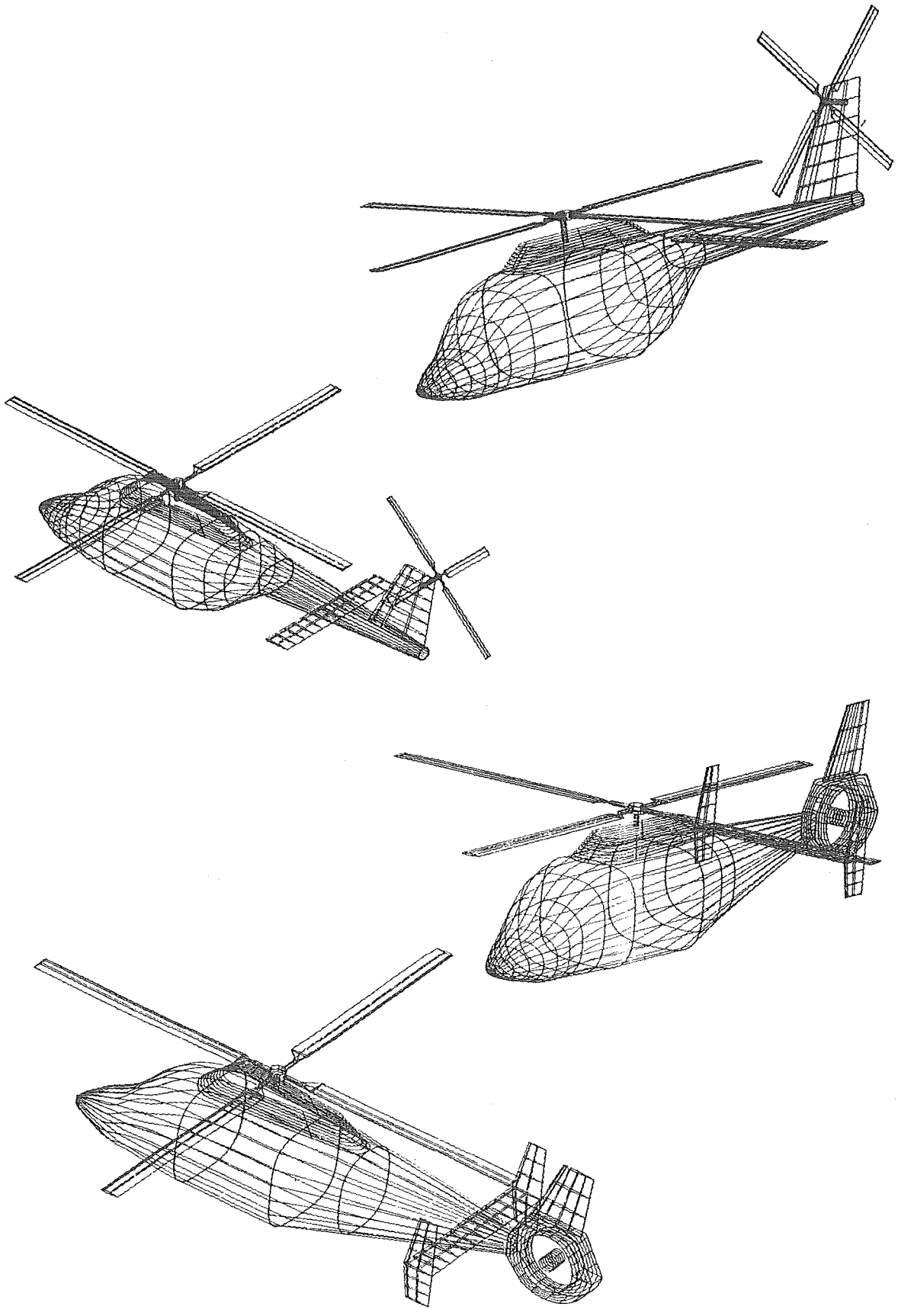

Fig. 4 3-D Wireframes of Two Types of Single-Rotor Helicopter

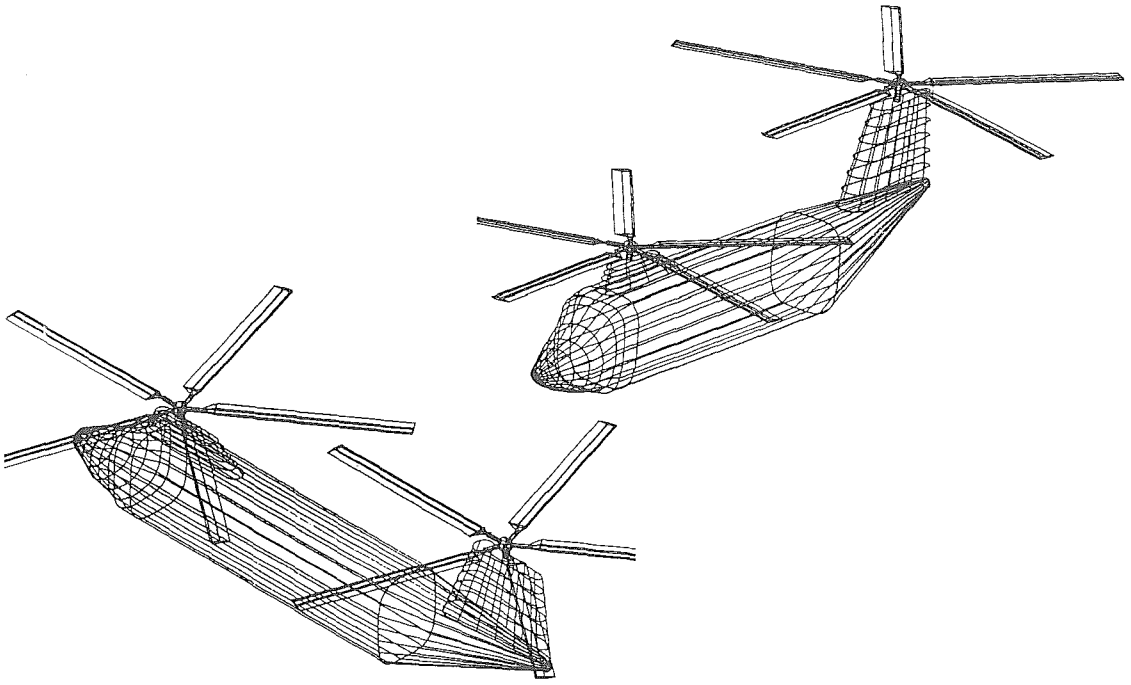

Fig. 5 3-D Wireframes of A Tandem-Rotor Helicopter

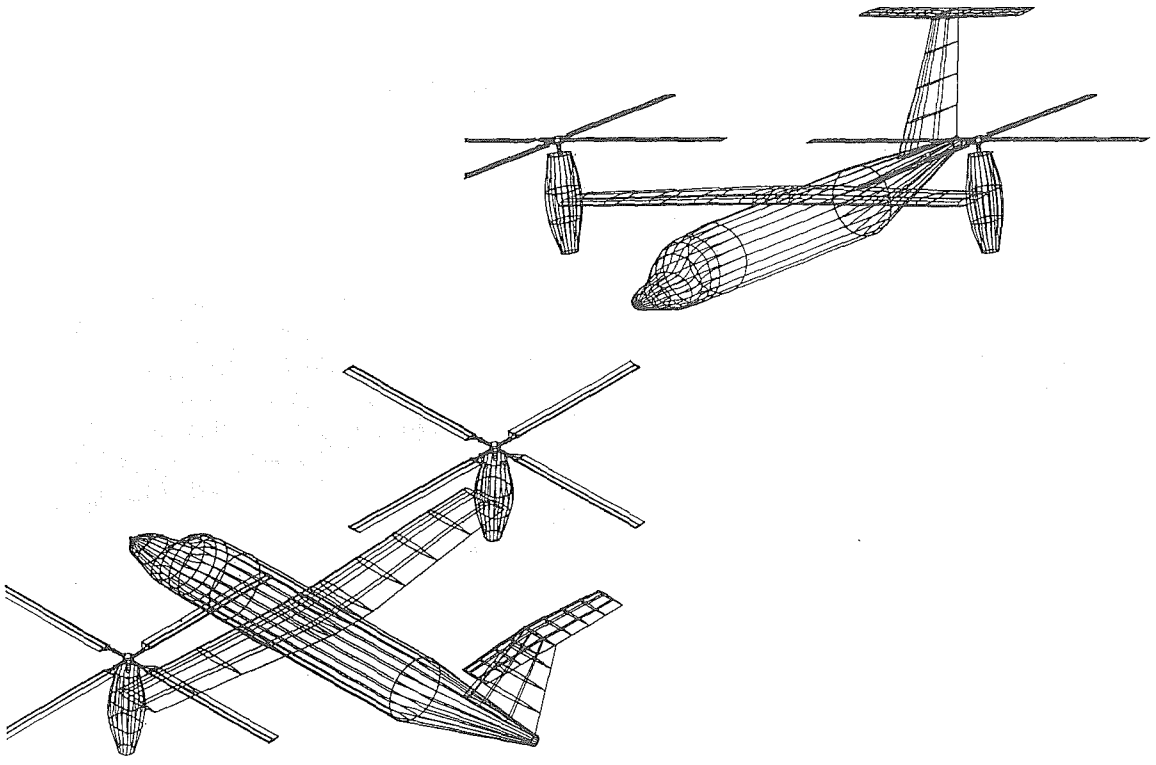

Fig. 6 3-D Wireframes of A Tilt-Rotor Helicopter

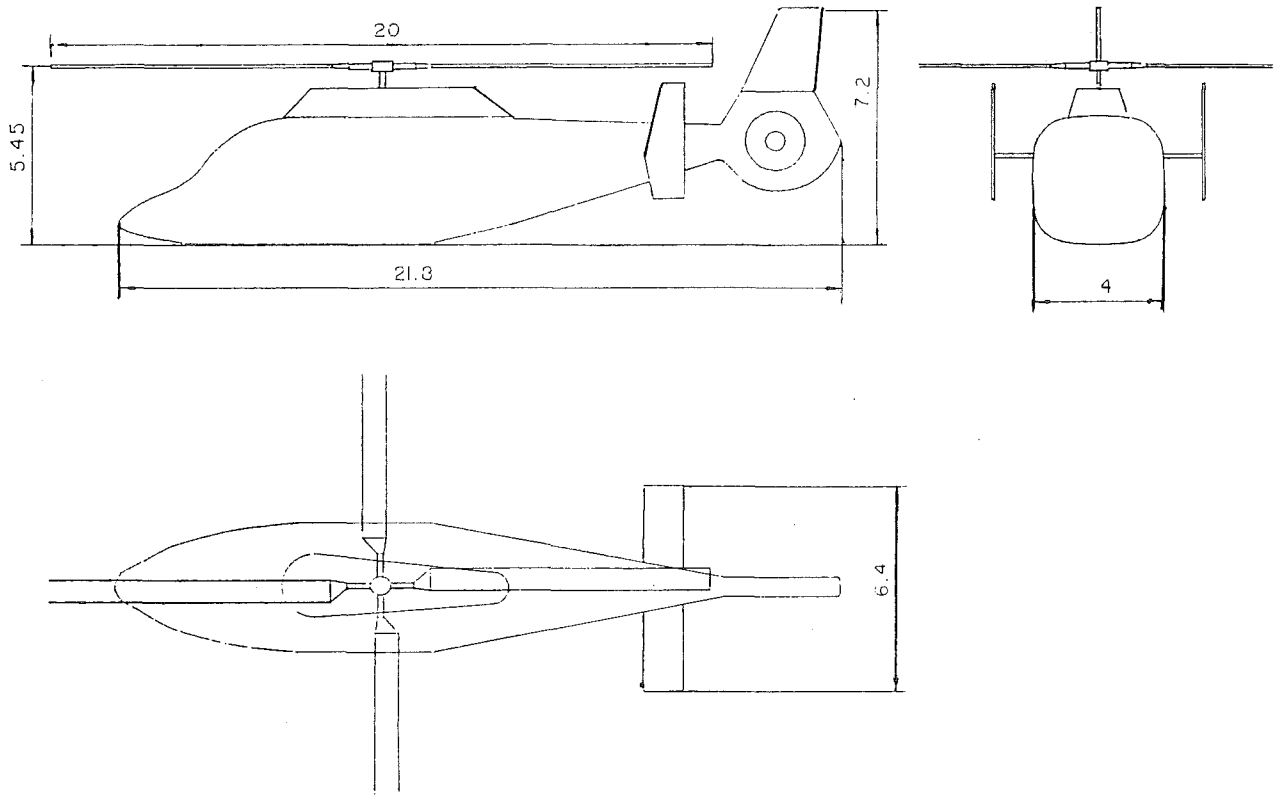

Fig. 7 2-D Views of A Single-Rotor Helicopter

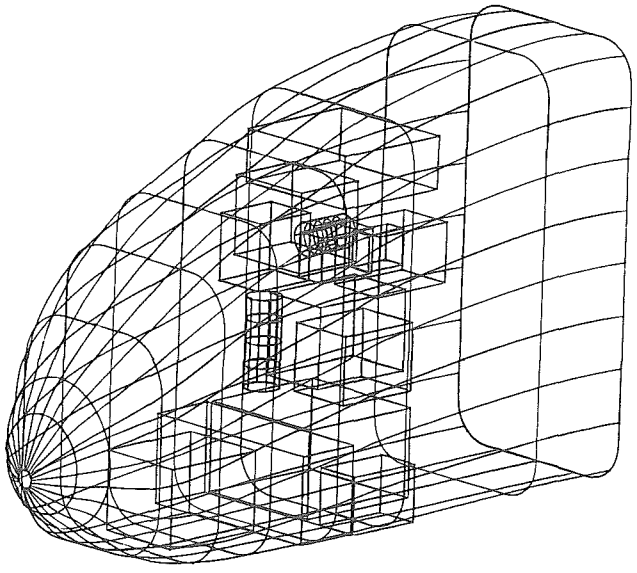

Fig. 8 Arrangement of Avionics in A RPH Helicopter Fuselage

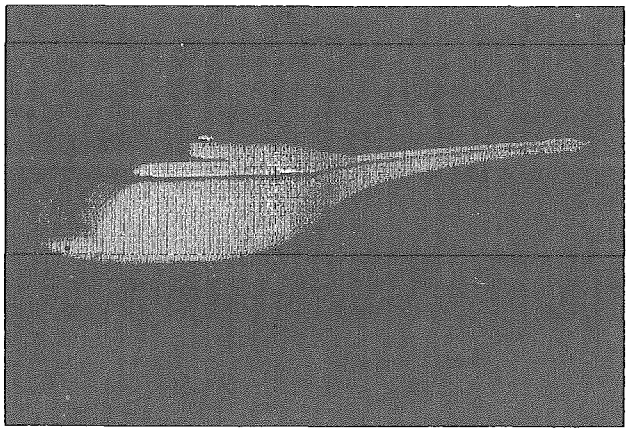

Fig. 9 Solid Model of A Single-Rotor Helicopter Fuselage.

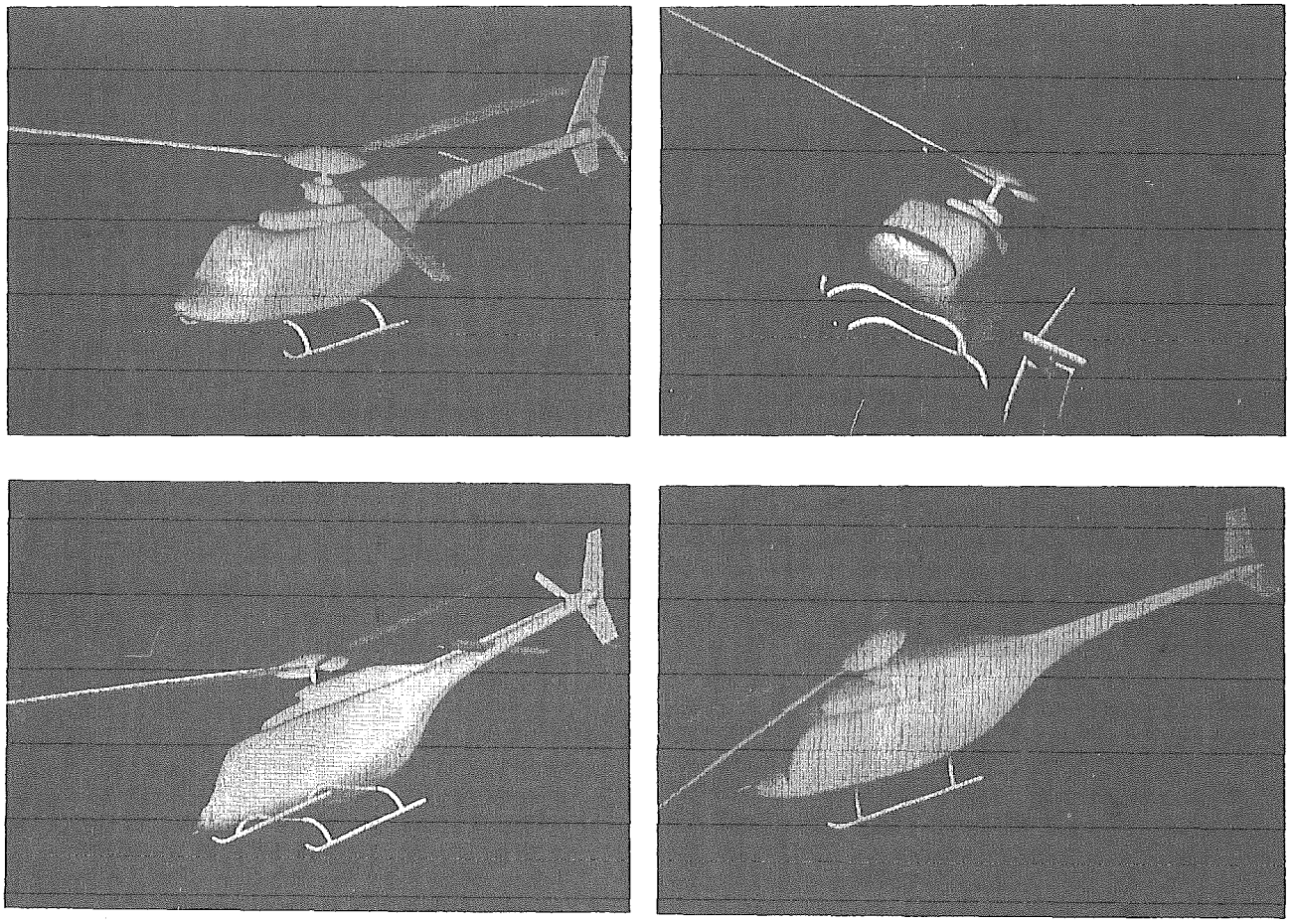

Fig. 10 Solid Models of A Single-Rotor Helicopter in Various Attitude

avionics in this RPH fuselage. The weight, volumes and mass moment of these avionics are then calculated using the functions of CADDS4.

However, it is difficult to evaluate a helicopter design from these 3-D wireframes, even though the hidelines have been removed. Fig. 9 shows a solid model of single-rotor helicopter fuselage. It is almost a real fuselage. Fig. 10 shows some solid models of a single-rotor helicopter in various attitude. These solid models shorten the distance between design models and real helicopters. With these models, designers can assess their designs comprehensively.

Ⅳ. Conclusions

A program HEGMCAD has been described which can automatically generate helicopter geometric models. HEGMCAD is a powerful tool for helicopter preliminary design, it can aid in the helicopter design with great generality and flexibility, save time and reduce cost. Only with inputing the preliminary parameters, various designs will be generated rapidly. The introduction of super-ellipse makes the fuselage generated more smooth.

If HEGMCAD is linked with a helicopter preliminary parameters optimizing program, then a close-loop design system can be set up. In this close-loop procedure, the results of the optimizing program are wrote into HEGMCAD, then the graphical models are displayed; on the other hand, some changes of geometric variables in HEGMCAD are fed back into the optimizing program. This design system can greatly shorten the length of time of holicopter preliminary design. Moreover, a geometric model generated by HEGCAD is also a CAM model.

Acknowledgments

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