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A PARAMETRIC APPROACH TO PRELIMINARY DESIGN FOR AIRCRAFT AND SPACECRAFT CONFIGURATION

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Abstract

Based on a few aircraft and spacecraft configuration parameters, a parametric preliminary design system for aircraft configuration has been developed. Contrary to the existing CAD systems, which consider structural and aerodynamics aspects in more detail and even lead to a CAM interface, in the system presented here the initial configurational development is emphsized, with special focus on the utilization of configuration parameters. After configuration development, the next step is to modify the configuration according to the fast area rule computation and to fair it . Thus, an initial configuration obeying the aera rule is established. The system is an interactive, user-friendly, completely menu-driven. Graphic displays are provided to assist the user in the visualization of the effect of each development and modification. The computed configuration may be viewed from any angle by using the code' s three dimensional graphic package. The capabilities of the system are demonstrated in several design examples.

I . Introduction

The design process for aircraft and spacecraft configuration may be subdivided to innovative design and evolutionary design. Innovative design is difficult to computerize, particularly in its early phases, as what the design will consist of is unknown. Evolutionary design on the other hand, uses predictable information in a standard data base. Almost all the existing CAD/CAM systems are amenable to the evolutionary design; examples are CADAM, CATIA, NCAD, IDEAS and so on. They are not in use for the innovative design. In recent years, computer-aided innovative design has become identified within the world aerospace industry as the next significant application of CAD, offering considerable scope for savings on development costs. Yet it is proving difficult to achieve, in part because of the complexity of the aircraft and spacecraft configuration. In especial, the configuration of aircraft and spacecraft is even more complex. Thus, emphasis in this paper is placed on the computer-aided innovative design for the aircraft configuration, which is also called the aircraft initial configuration design in terms of aircraft design. In this design phase, importance is attached to parametric variation of a large number of design variables rather than on detailed analysis, which would require a high degree of computational effort. Therefore, the mathematical model of the aircraft is relatively simple, although all important design elements are included. In this paper, a parametric approach to this design is to use parameters of the aircraft configuration to make the mathematical model easier and faster to create and modify.

Ⅱ . Concept of ACDS

In 1987, a research project to develop the parametric preliminary design system for aircraft and spacecraft configuration (ACDS) was initiated at the CAD/CAM Research Center of the Northwestern Polytechnical University of Xi' an. This development is part of an interactive computer graphic preliminary design system for aircraft and spacecraft that aims to develop a new computer-aided design model for aircraft and spacecraft innovative design. The primary goal is to meet some design requirements which combine many design elements (e. g. , aerodynamics, structures, weight and balance, stability and control, avionics, propulsion, performance requirements, and economics). Therefore, it is possible to decrease the subjectivity of the design process and reduce the content and amount of the wind-tunnel tests. This possibility offers significant potential for improving the quality and the economic efficiency of the preliminary design for aircraft and spacecraft.

For the design plan full of variety in the innovative design for aircraft and spacecraft, the parameters for its configuration change frequently so that this system (ACDS) should select a parametric approach which is simple, fast and direct. As it begins with separate part (radome nose, wing, cabin, airinlet, and fuselage) design, the ACDS enables the designer to change not only the relative location of each part according to his ideas or aircraft and spacecraft layout but also the configuration parameters. At any time, the designer can dynamically modify any or all dimensions and have the ACDS automatically regenerate the configuration. When the designer is satisfied with a part, the ACDS automatically generates fully dimensioned, multi-view drawings. The designer can then modify any or all of a drawing's dimensions; the ACDS updates both the part and associated drawings. Finally, the designer parametrically assembles parts according to his ideas or the layout.

The development of the ACDS consists primarily of the following six special areas:

* the preprocess of configuration parameters of each part

After having specified the flight mission and the operational/airworthiness requirements, the system should analyse the configuration parameters of each part of the aircraft either manually, using the experience and judgment of the designer, or automatically by means of the empirical formulas. Thus, initially optimal data of each part comfiguration are generated and stored in a given data base.

* the mathematical model of each part configuration

For the optimal initial configuration of each part, a mathematical model was developed to generate the part surfaces. The geometric information corresponding to the surfaces is stored selectively in several data files and meantime stored in chosen data items.

* the development of the integral configruation

After having the surfaces of each part, the designer can call them interactively from a computer and assemble them according to his ideas of the design layout. Therefore, the integral configuration will be developed. While the designer gives no requirements, the ACDS will complete implicitly this step according to the usual layout. In the meantime, the relative transformation information corresponding to each part will be recorded so that the data of the integral configuration will be generated.

* the intersection and the area distribution of the integral configuration

For the application of the tran/supersomic area rule, the ACDS includes a certain program which can calculate the intersection of the integral configuration and any plane. the area enclosured by the intersection curve can be calculated and then the projected area from the intersection curve on to the plane perpendicular to the axial direction will be generated. Thus, the area distribution can be obtained at various axial locations along the fuselage.

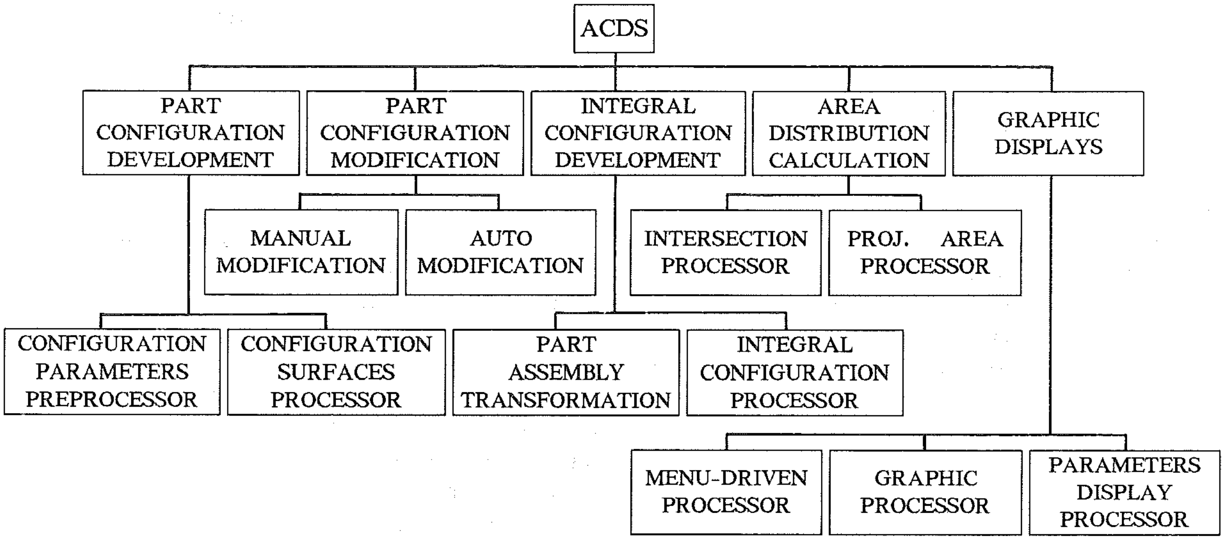

Fig. 1 Structure of ACDS

* the interactive modification for the design process

As the design process for aircraft and spacecraft is not a straight forward process, the ACDS should permit easy and fast modification of the configuration. Carrying out the modification interactively eliminates the need for the designer to construct lengthy input file, which can increase the initial setup time for the configurations. According to the designer' s ideas or the tran/supersonic area rule, whether a part configuration or the integral configuration can be interactively modefied by varying the corresponding parameters.

* the function of graphic displays

The ACDS provides not only menus but also superior visualization of the effect of the design or modification process. The graphic displays are: simple three-view drawings, complex three-view drawings and wire-frame model, as well as displays for the visualization of the development of the design parameters.

The structure of the ACDS is outlined in Fig. 1 that corresponding to those six areas given above.

Ⅲ. Configuration Mathematical Model

It is essential for the success of any computer-aided design system to properly coordinate system the underlying mathematical model. The model consists of two sets of coordinate system. One is local coordinate system for individual configuration and the other is absolute coordinate system for the integral configuration. For the model should permit calculation of surface areas, volume, e. g. positions, and cross-section area distributions of individual compents, the following model was chosen. In accordance with the principle of variant programming, the surface in the model is described by parametric, piecemeal analytical functions. The parameters of these variants are mainly geometrical demensions. e. g. , fuselage length, wing position, kink position, sweep angle. Furthermore, this approach allows convencient cataloging of the geometry of existing aircraft and spacecraft in the statistical data base by simply determining the necessary parameters rather than digitizing the whole geometry.

As a first step, the wing parametric design is described. The description of the wing geometry (Fig. 2) is derived from the methodology for conventional wing design. From the given wing paramters, the airfoil is obtained. Therefore, the surface of the wing, and of the vertical and horizontal tail, is generated by projection of the given profile along the leading and trailing edges and the line of maxium thickness. By this approach, the surface is completely described when the basic geometry parameters of Fig. 2 and the spanwise destribution of relative thickness and twist are given. Analog parameters are defined for the tail surfaces. In this approach, a data base of airfoils has to be attached. The data base includes a variety of standard airfoil coordinates, from which the profile of the wing section can be calculated when a airfoil is chosen.

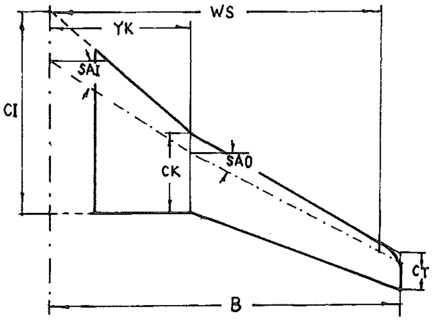

Fig. 2 Wing Geometry: Definition of Planform Parameters.

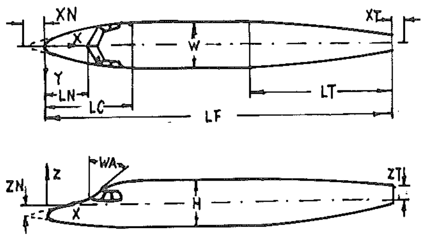

Fig. 3 Fuselage Geometry Definition of Shape Parameters.

The fuselage cross section can be approximated by hyperelliptic or conic functions of fuselage width, height, and centerline position. Common elliptical and circular cross sections, as well as the more hyperelliptical cross sections can thereby be generated. When all of the fuselage cross sections have been satisfied, the next step is to blend the fuselage cross sections in the longitudinal direction. This yields a set of equations that describe the entire fuselage surface. The longitudinal blending process is carried out by means of piecemeal, controlled cubic fuctions. Remaining free parameters are either user-controlled — i. e, they are design parameters such as length and diameter (Fig. 3) — or determined by design requirements. This approach is also used for the cabin and air inlet.

The nose region of the fuselage is treated separately from the remainder of the fuselage. The approach taken here allows for a unique specification of the nose region based on a cross section (e. g. , width, height, and centerline position), the conic curves are generated. For a given meridional half-plane, the intersections between this half-plane and the conic curves are found. These intersection points, along with the nose point, are curve fit in the meridional half-plane using a conic equation constrained to pass through the nose point with an infinite value. Thus, the surface of the entire nose region can be calculated.

Ⅳ. Configuration Optimization

The aircraft and spacecraft design process primarily demands the search for a solution that is compatible with the design speciafications. On the other hand, it is desirable to find configurations that are optimal in regard to a certain objective function. For any optimal design parameters, the *configuration can be varied either manually*, using the experience and judgment of the designer, or automatically by means of the empirical formulas.

It is worthly pointed out that the configuration of the wing-body combination may be modified automatically to obey the tran/supersonic area rule. The approach is based on the simplification of the each part configuration for aircraft and spacecraft, e. g. , a regular geometric model can be substituted for a corresponding irregular geometric model. The regular model is the only one for the application of the area rule to the parametric design. A fast area rule method is provided, as the regular model serves as original conditions, to calculate a series of normal sections of the integeral configuration and plane, so that an area distribution along the fuselage can be generated. From the area distribution, the zero-lift wave drag can be derived which will be used to decide whether the area distribution is most favourable. If the area distribution is not satisfactory, the iteration sequence will continue and the configuration will be modified by varying the remaining free parameters and controlled factors. The iteration will be over as soon as the result achives the optimal state.

Ⅴ. Conclusions

An interactive, user-friendly, completely menu-driven computer-aided innovative design system, e. g. , the parametric preliminary design system for aircraft and spacecraft configuration (ACDS) has been developed. Parametric provisions have been made to handle bodies, wings, cabins, and air inlet, as well as the integral configurations. The present method calculates surface areas, volumes, and cross-section area distributions along the axiel direction. Modifications of configurations can be carried out by means of remaining free parameters and controlled factors. Optimal configurations can be obtained for the application of the fast area rule method. The graphic displays of individual components and integral configurations are provided.

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APPENDIX

Application of ACDS

The ACDS was already used to a certain aircraft design. An airfoil is shown in Fig. 4. The wing with sweeping angle is shown in Fig. 5. Fig. 6 is suselage cross section cruves with different controlled factors. Fig. 7 is a preliminary fuselage surfaces. Fig. 8 is an aircraft integral configuration for preliminary design.

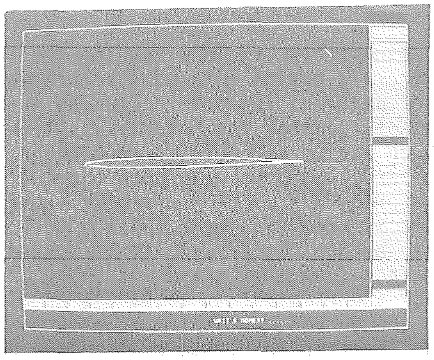

Fig. 4 Airfoil

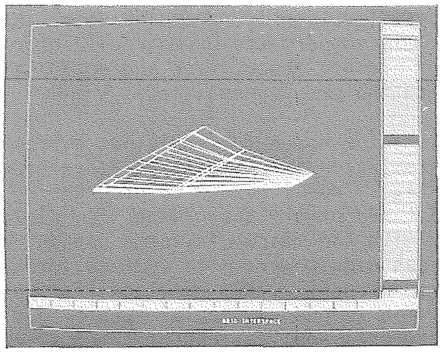

Fig. 5 Wing Surfaces

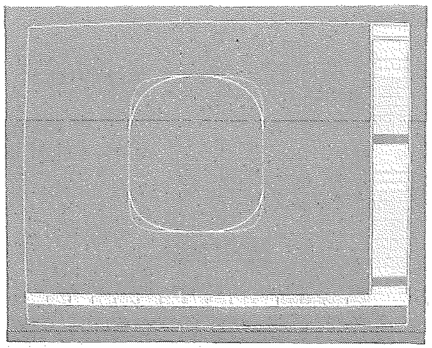

Fig. 6 Fuselage Cross Section Curves

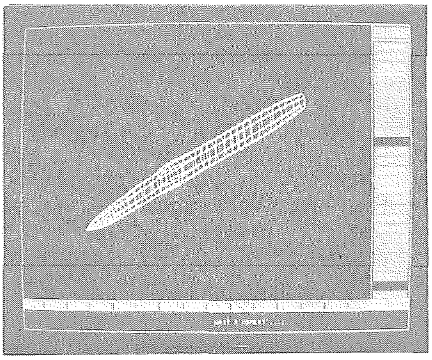

Fig. 7 Fuselage Surfaces

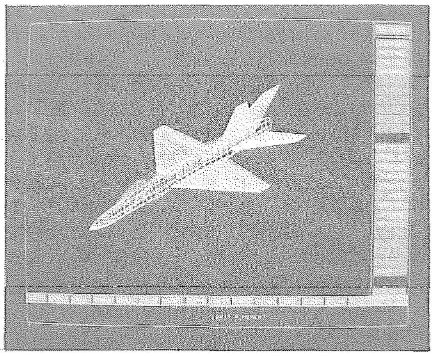

Fig. 8 Integral Configuration