Computer Sizing of Fighter Aircraft

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Abstract

A COMPUTER technique for determining the performance of fighter aircraft on military missions has been modified to provide an option for preliminary sizing. This Synoptic describes the performance program and the development of the new sizing capability. Included are descriptions of the military mission profiles that the program can represent and the methods used to calculate the performance data. The use of the sizing technique to define a minimum gross weight configuration and the determination of additional performance and sensitivity data for the sized configuration is described. The discussion is illustrated through examples taken from a conceptual design study performed at the NASA Langley Research Center.

Contents

Computerized performance and sizing techniques provide a method of quickly evaluating the merits of large numbers of conceptual aircraft configurations. The effect of applying new technologies to a concept can also be rapidly determined. An existing technique[1] for determining the mission radius and maneuverability characteristics of fighter aircraft has been modified to provide a preliminary sizing option. The original program has a number of unique features and forms the core of the new sizing option. The assumptions and methods used in the program are discussed in greater detail in Refs. 1 and 2. The following sections endeavor to present an outline of the important features of the program and the sizing logic.

Description of the Program

All military missions have similar segments, such as takeoff climb, cruise, and reserves; thus, a modular approach to computing the mission performance was adopted. In this approach, each mission module is an executive routine that controls the calculation of the performance data for the segments of the profile it represents. This performance data is calculated in other specialized modules which represent particular segments. If the performance in a segment is known to be sensitive to aircraft weight, that segment module will automatically calculate the performance for a series of weights that might be encountered during the mission. The performance as a function of weight is stored and later interpolated in the mission module based on the actual weight during a particular segment. In this way, as the segment weight changes while the inbound and outbound mission radii are being balanced, the performance data does not have to be recomputed.

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Segment Data Modules

Takeoff Segment

This module uses an approximate solution to the equations of motion to compute the takeoff distance and velocity. The technique is described in detail in Ref. 3. Takeoff performance can include the effects of high lift devices, vectored thrust, gear drag, ground proximity, and hot day conditions.

Climb Segment

The fuel, time, and range required to climb to the start of cruise altitude are computed in this module. An approximation to the aircraft equations of motion[4] is used to determine these quantities. The start of cruise altitude is determined by one of three options: Minimum fuel burn for a specified radius, aircraft rate of climb limitations, or program input (fixed altitude cruise).

Cruise Segment

The cruise Brequet factor and fuel burn for the specified cruise radius are determined during the search for the cruise altitude. The cruise segment data is calculated using the Brequet range equation.[5]

For missions which carry external stores or fuel tanks, the program automatically calculates an increment in the Brequet factor corresponding to the drag penalty of these items. If the stores are expended or the tanks dropped, the appropriate increment is added to the cruise Brequet factor to reflect the change in performance due to this configuration change.

Combat Segment

Military missions include a wide variety of specifications for the combat fuel allowance. One of the important features of this program is the number of options available to handle this variety of allowances.

These options include the fuel required for an increase in specific energy; engine operation for a specified time, Mach, altitude and power setting; level acceleration; and sustained turn maneuvers. Combinations of these combat allowances are possible.

Loiter Segment

Loiter is defined as steady flight at a fixed altitude for a specified period of time. The loiter module determines the Mach number for minimum fuel flow at the specified altitude.

Dash Segment

A dash segment is flight at a constant Mach number and altitude. This module computes the aircraft's specific range factor corresponding to these flight conditions. The mission module uses this parameter to determine the fuel used during a dash of the required length.

Descent Segment

There are two options for this segment. The first consists of predetermined increments for range, weight, and time during the descent. The second option uses a technique similar to that of the climb segment to determine these increments.

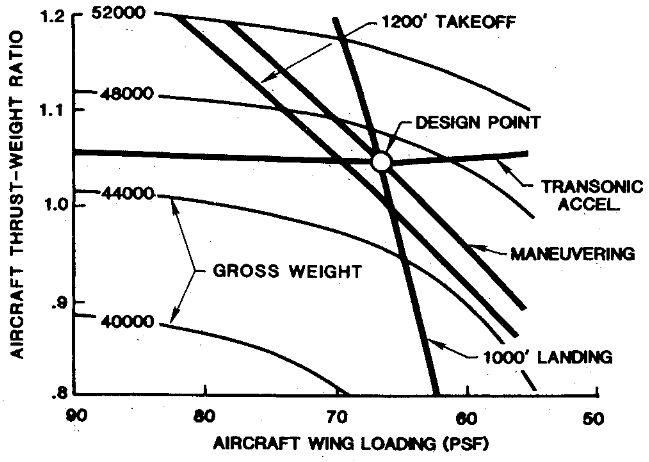

Fig. 1 Thumbprint plot for supersonic intercept mission.

Reserve Segment

The reserve fuel allowance for a military mission may be specified in a number of ways. The program has six reserve segment options that encompass the majority of these requirements.

Landing Segment

The principal output of the landing segment module is the landing ground-roll distance. An iterative method is used to solve the airplane equations of motion as the aircraft slows from the touchdown velocity to a stop. The landing performance can include the effects of approach velocity, glide slope angle, thrust reversing, braking, and lift spoiling devices.

Mission Profile Modules

The program contains five mission modules, each representing a different military mission. These missions are air superiority, fleet air defense, supersonic penetration, long range penetration, and long range cruise. The mission modules use the previously described segment modules to assemble the appropriate mission segment data and determine the maximum mission radius or range. All radius type missions are balanced; that is, the total outbound radius equals the total inbound radius.

External fuel can be carried on all missions. Program logic determines when the tanks are empty and when they are to be dropped. The tanks can also be retained until the end of the mission. The long range penetration mission is unique in that it contains logic to represent air-air refueling accurately.

In addition to computing the overall mission performance, each module controls the calculation of two special performance items. The first of these is the time and fuel required for a level acceleration following a required Mach number schedule. The second item involves maneuverability parameters. For a required combination of Mach number, altitude, and power setting, the program will compute the aircraft's maximum instantaneous specific power and maximum sustained load factor and turn rate. These parameters are important in comparing performance of fighter designs. Certain acceleration and maneuver performance is usually part of the mission specifications.

Sizing Logic

A new sizing option has been added to all the mission profiles, except the long range penetration profile. The sizing logic provides the capability of repeating the previously described performance calculations in such a manner as to provide information that will be useful in identifying the minimum gross weight required to perform a particular mission.

Before any sizing is done, a well-defined baseline configuration must be developed. The program does not synthesize any aerodynamic, propulsion, or weight data. This information must be contained in a detailed set of program inputs that is developed by configuration specialists.

During the sizing process, the program automatically selects combinations of wing loading and thrust-weight ratio, and for each, estimates the takeoff gross weight. These three quantities are used to scale the baseline aerodynamic and propulsion data, and to determine the empty weight and fuel available. This information is then used by the selected mission module to compute the maximum balanced mission radius. An iterative process is then used to find the TOGW required to just meet the mission radius.

The final output of this process is the size and performance data for a 25 element "matrix" of airplanes which can be used to develop a "thumbprint plot" or performance map. The thumbprint plot takes a number of forms. Figure 1 shows a sample thumbprint for a conceptual supersonic fighter configuration. The figure shows contours of constant gross weight on a grid of aircraft thrust-weight ratio and wing loading. Curves representing performance constraints are also shown. The constraints correspond to the performance requirements specified in the design mission. All of the aircraft above the constraint curves meet the design mission radius, and meet or exceed the performance requirements. The design point aircraft is the one with the minimum gross weight that meets all the mission requirements.

During the sizing process, caution must be used if the design point varies far from the original baseline. The program does not generate new aerodynamic data to reflect changes in the relative size of the wing, engines, and fuselage. If the design point is far from the baseline, a new baseline should be developed and the sizing process should be repeated.

The size and performance data generated during the sizing process can be used to investigate various trends. For example, a vertical cross section of the thumbprint plot shows the effect of aircraft thrust weight ratio on takeoff gross weight for aircraft with a fixed wing loading. Alternately, the sizing process can be repeated to establish trends due to changing mission requirements. An example would be the effect of changing the required mission radius on takeoff gross weight.

The sizing program can also be used to perform sensitivity studies and investigate the impact of new technology. These studies can be handled incrementally within the program or by modification of the data base.

Concluding Remarks

A computer program has been developed for use in the preliminary sizing and performance analysis of fighter aircraft. The program can be used to rapidly identify the minimum gross weight required to meet a specified set of military mission requirements. The program can be used to develop trend data and perform sensitivity studies. The effects of applying advanced technologies can also be investigated.

References

[1]Foss, W. E. Jr., "A Computer Technique for Detailed Analysis of Mission Radius and Maneuverability Characteristics of Fighter Aircraft," NASA TP 1837, 1981.

[2]Coen, P. G. and Foss, W. E. Jr., "Computer Sizing of Fighter Aircraft," AIAA Paper 85-0212, Jan. 1985.

[3]Foss, W. E. Jr., "A Computer Program for Detailed Analysis of the Takeoff and Approach Performance Capabilities of Transport Category Aircraft," NASA TM 80120, 1979.

[4]Jackson, C. M. Jr., "Estimation of Flight Performance with Closed Form Approximations to the Equations of Motion," NASA TR R-228, 1966.

[5]Perkins, C. D. and Hage, R. E., *Airplane Performance Stability and Control,* John Wiley & Sons, Inc., New York, 1949, Chap. 4.