RESEARCH ON THE SYNTHESIS OF AIRCRAFT CONFIGURATION PARAMETERS AND COMBAT EFFECTIVENESS

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Abstract

The relationship between aircraft configuration parameters and combat effectiveness is investigated by means of a computer aided aircraft design program developed in our university. The study shows that when the take off weight of aircraft is constant, only 20%-50% of improvement of aircraft combat effectiveness can be made with performance improvement, while more than 150% of combat effectiveness improvement can be achieved by using advanced radar and missiles.

The enhancement of combat effectiveness is always the goal of military aircraft design. The combat effectiveness is related to many factors, such as the aircraft configuration parameters (take off weight of aircraft, payload, engine thrust, specific fuel consumption, wing area, wing aspect ratio, wing thickness ratio, wing sweep angle, wing taper ratio and other geometric parameters), the radar parameters and missile parameters. In this paper, based upon an aircraft improvement design, the relationship between aircraft configuration parameters, radar parameters, missile parameters and combat effectiveness is studied with the computer aided aircraft design program developed in our university[1]. Made were also the optimization of wing geometry and sensitivity analysis of the wing geometry, radar parameters and missile parameters.

1. The Model of Combat Effectiveness

The combat capability of military aircraft can be expressed as follow:

$$F = EX^{B} \qquad (1)$$

Here F is the combat capability of military aircraft. E is the index of combat effectiveness. X is the number of aircraft which take part in the fight. B is an index related to the combat aircraft. The index of combat effectiveness E is composed of air to air combat effectiveness C and air to ground combat effectiveness D:

$$E = a_1 C + k a_2 D \qquad (2)$$

Here a_1, a_2 are sort constant for different kinds of aircraft. The constant k is a balanced number.

1.1 The Air to Air Combat Effectiveness Index

This index is directly related to three factors, such as maneuverability, fire strength and detective capability. Considered are also four factors, such as the reliability of combat, mean flight time of combat, survivability and the effectiveness of flight control system. Expressed with formula as follow:

$$C = [\ln(B) + \ln(A_1) + \ln(A_2)]k_1 k_2 k_3 k_4 \quad (3)$$

Here B is the index of maneuverability for air to air combat flight. A_1 is the index of fire strength for weapon system. A_2 is the index of reliability of combat aircraft. The k_1 is the detective ability for radar and other systems. The k_2 is the endurance ability of combat aircraft. The k_3 is the index of survivability for combat aircraft. The k_4 is the index of the efficiency of flight control system for combat aircraft. The factor B can be expressed as follow:

$$B = Ny_{\max} + Ny_{turn} + 9Vy_{\max}/300 \quad (4)$$

Here the Ny_{max} is the maximum instant load factor. The Ny_{turn} is the maximum load factor in sustained turn. The Vy_{max} is the maximum rate of climb.

1.2 The Index of Air to Ground Combat Effectiveness

The index is influenced by tow factors, i.e. the maximum range and payload of combat aircraft. Considered are also five other factors, i.e. the penetrability, the ability of stand - off weapon, the ability of navigation, the efficiency of air to ground combat and the effectiveness of nuclear weapon. The index can be expressed with formula as follow:

$$D = \ln[RP_c R_m R_n] + \ln[W_b P_a W_n] \quad (5)$$

Here the R is the maximum range of combat aircraft. The P_c is the factor for penetration. The R_m is the factor for the stand-off weapon. The R_n is the factor for navigation. The W_b is the maximum weight of payload(bomb, missile and so on). The P_a is the effectiveness of ground attack. The W_n is the effectiveness of nuclear weapon.

The maximum range R is related to aircraft fuel weight ,aerodynamic characteristics(K_{max}), and flight condition, as follow:

$$R = (KV/Ce)_{\max} \ln[Go/(Go-G_{fuel})] \quad (6)$$

Here the K is the lift to drag ratio. V is the cruise speed. Ce is the specific fuel consumption (SFC) of engine. Go is the aircraft take off weight. G_{fuel} is the aircraft fuel weight.

2. Aircraft Conceptual Design Model

The Aircraft Conceptual Design Model (ACDM) is composed of sub-models ,such as geometric model, weight model, aerodynamic model, propulsion model, flight performance model and so on.

3. The Synthesis of Aircraft Conceptual Design Model and Combat Effectiveness Model

As shown in Fig.1 ,given the aircraft configuration parameters, radar parameters and missile parameters, the aerodynamics , weights, performance of corresponding aircraft can be analyzed with the Aircraft Conceptual Design Model(ACDM). From the performance results of the maximum load factor Ny_{max} during instantaneous turn, Ny_{turn} during sustained turn, maximum climb rate Vy_{max} and maximum range R, also with the radar and missile parameters , the index of air to air combat effectiveness C, the index of air to ground combat effectiveness D and the total index of combat effectiveness E can be obtained through the model of combat effectiveness. From the combat effectiveness E, the calculated maximum speed Vmax, ceiling $Hmax$, accelerate time Ta and design specifications ($V'max$, $H'max$, $T'a$ and so on.) , the objective function for aircraft conceptual optimization can be achieved as follow:

$$AMB = E - \Sigma DD_i \quad (i=1,10) \quad (7)$$

Here AMB is the synthesis objective function. The DD_i is the penalty factor for performance constraints. If one performance is satisfied ,then the DD_i equals zero. Otherwise, the DD_i is a big number.

With the Synthesis Model, the relationship between aircraft configuration parameters and combat effectiveness can be studied. It is also possible to optimize the aircraft configuration parameters for combat effectiveness.

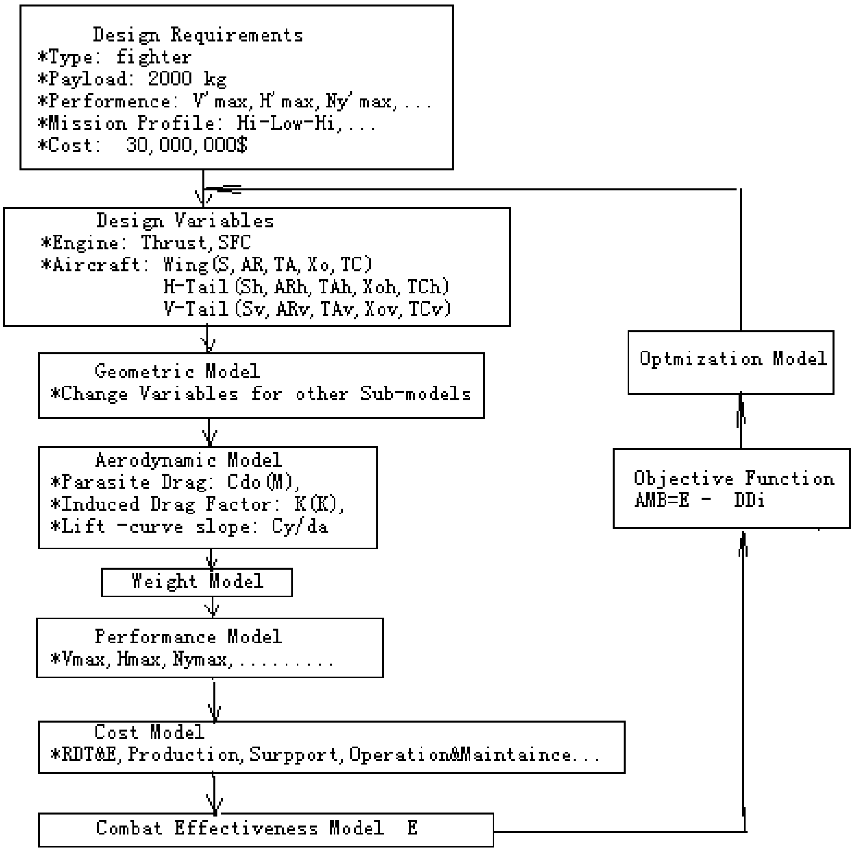

Fig.1 SYNTHESIS OF AIRCRAFT CONFIGURATION MODEL AND COMBAT EFFECTIVENESS MODEL

4. Sensitivity Analysis of Combat Effectiveness to Aircraft Configuration Parameters

Taken a light supersonic fighter as an example, studied is the relationship between combat effectiveness and aircraft configuration parameters (take off weight *Go*, engine thrust *To*, the specific fuel consumption *Ce*, wing area *S*, wing aspect ratio *AR*, wing sweep angle *Xo*, wing thickness ratio *t/c* or *TC*, wing taper ratio *TA*).

4.1 Aircraft Take Off Weight

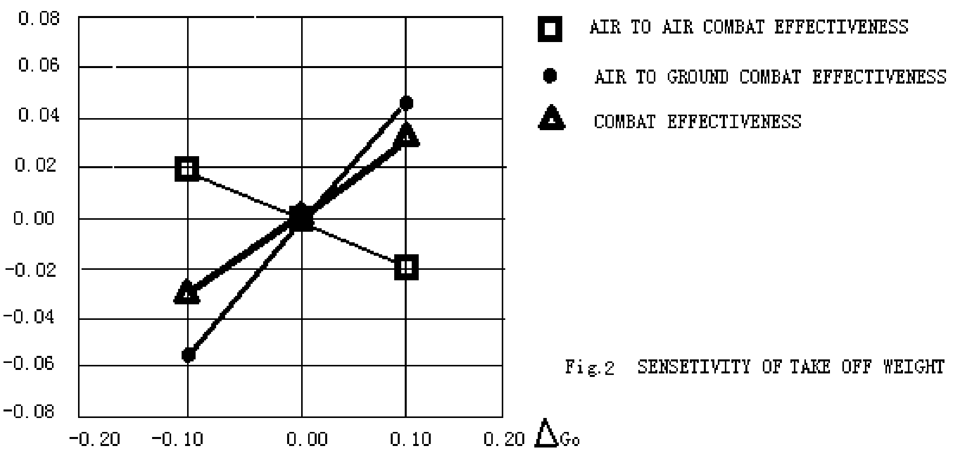

Fig.2 SENSETIVITY OF TAKE OFF WEIGHT

4.2 Engine Thrust

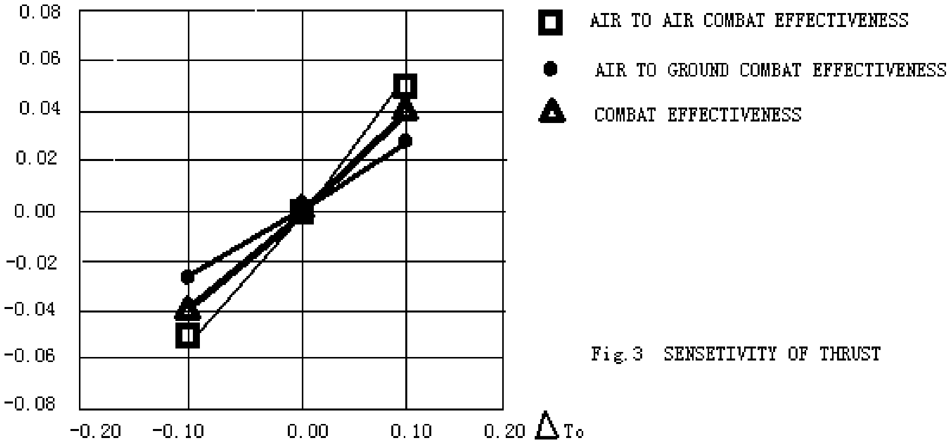

Fig.3 SENSETIVITY OF THRUST

4.3 The Engine Specific Fuel Consumption

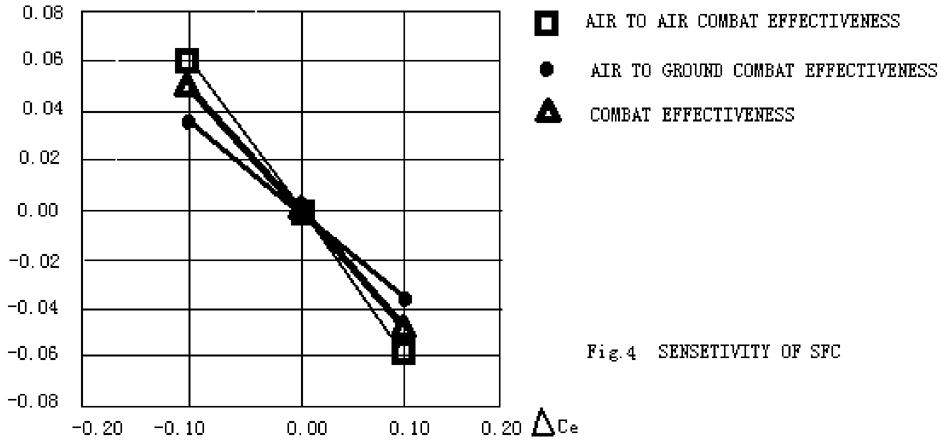

Fig.4 SENSETIVITY OF SFC

4.4 Wing Area

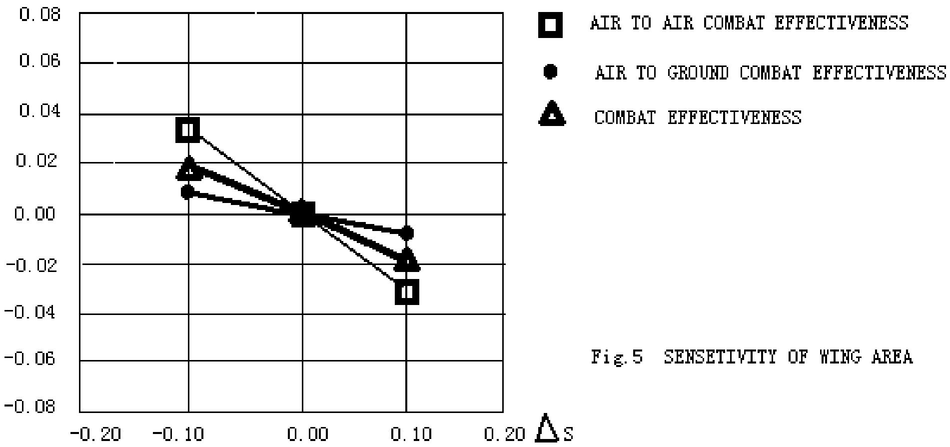

Fig.5 SENSETIVITY OF WING AREA

4.5 Wing Aspect Ratio

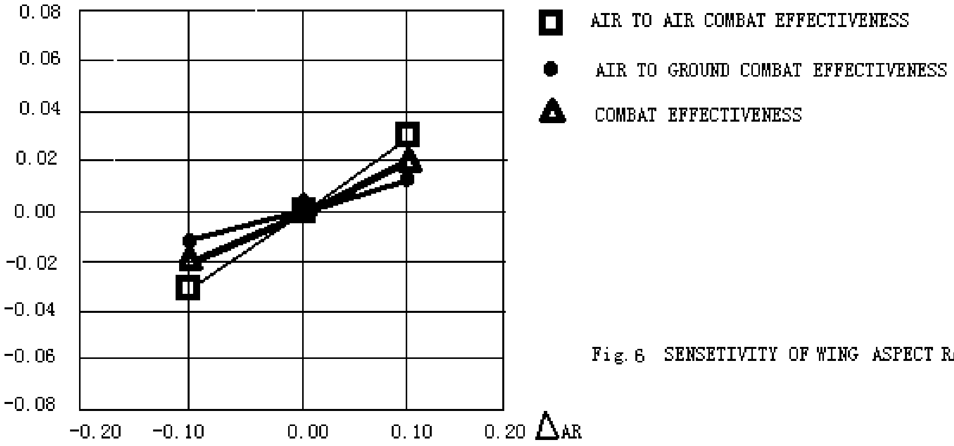

Fig. 6 SENSETIVITY OF WING ASPECT RATIO

4.6 Wing Sweep Angle

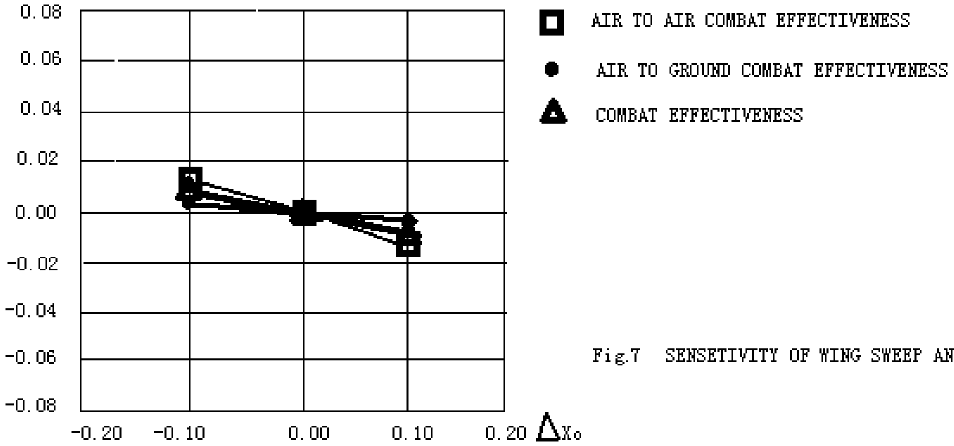

Fig.7 SENSETIVITY OF WING SWEEP ANGLE

4.7 Wing Thickness Ratio

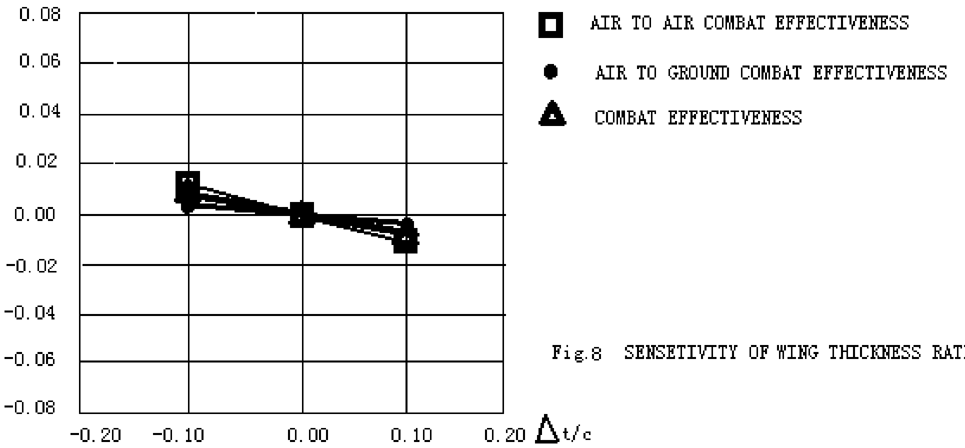

Fig.8 SENSETIVITY OF WING THICKNESS RATIO

4.8 Wing Taper Ratio

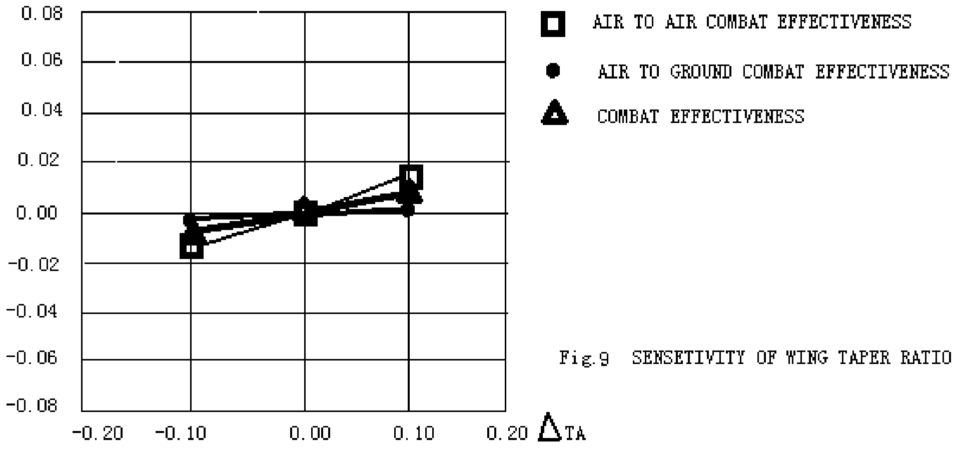

Fig.9 SENSETIVITY OF WING TAPER RATIO

5. Sensitivity Analysis of Combat Effectiveness to Radar and Missile Parameters

5.1 Radar Detective Range

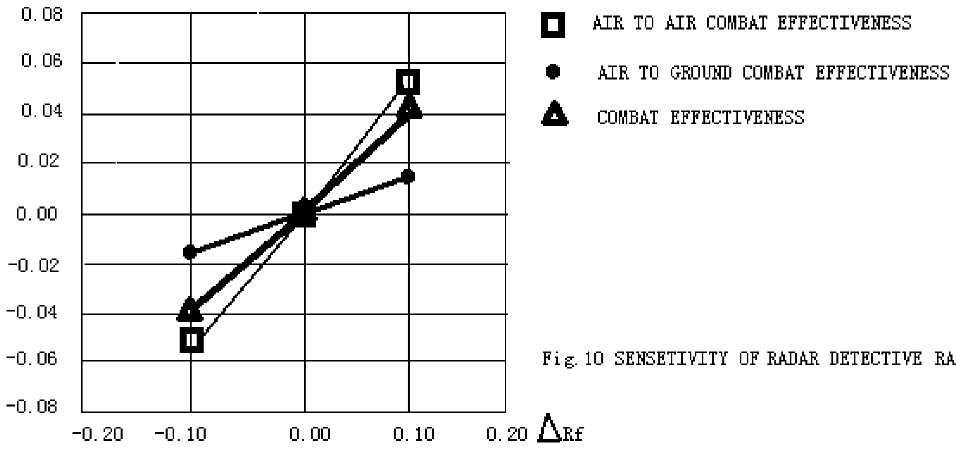

Fig.10 SENSETIVITY OF RADAR DETECTIVE RANGE

5.2 Radar Search Angle

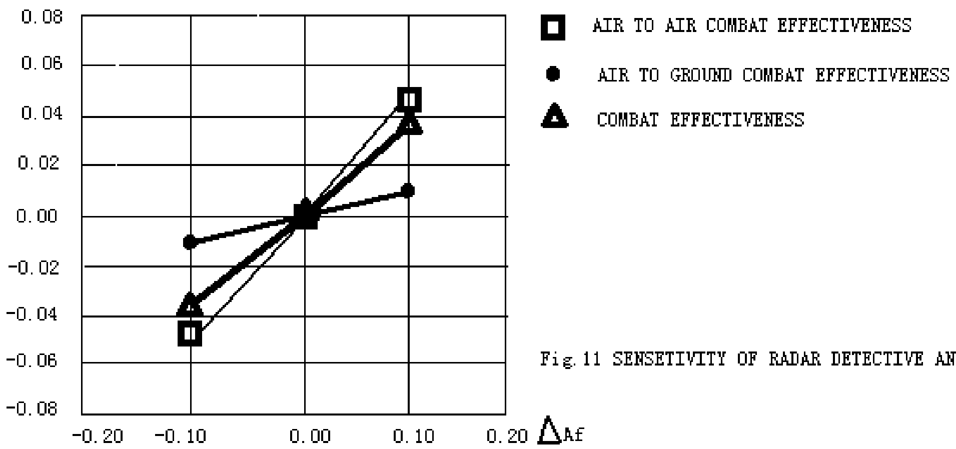

Fig.11 SENSETIVITY OF RADAR DETECTIVE ANGLE

5.3 Missile Range

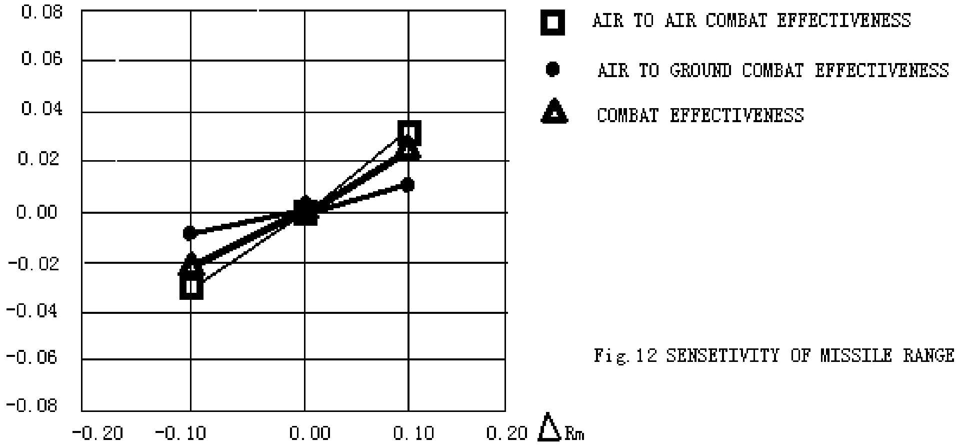

Fig.12 SENSETIVITY OF MISSILE RANGE

5.4 Missile Attack Angle

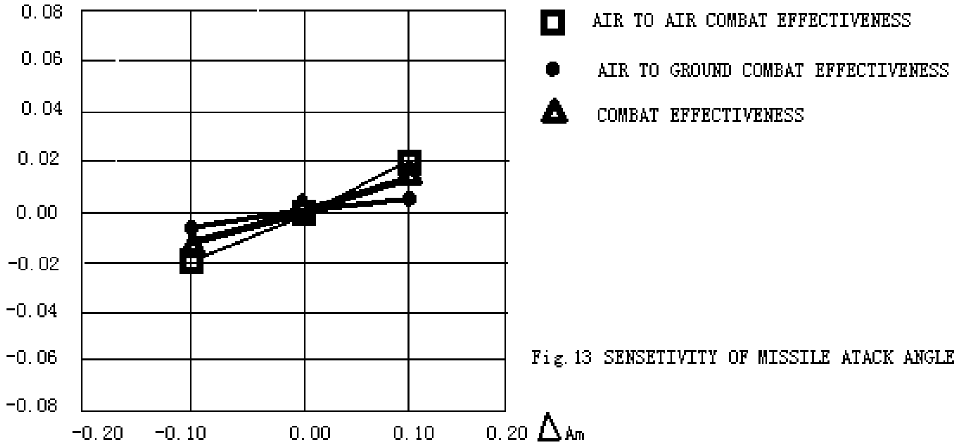

Fig.13 SENSETIVITY OF MISSILE ATACK ANGLE

6. Optimization of Aircraft Configuration Parameters for Combat Effectiveness

Take combat effectiveness E as an objective, using wing parameters (*S, AR, TA,Xo,TC*) as design variables, an objective function can be made by penalty function method.. Performed with Random Point + Random Ray method, the improvement of objective function and design variables is shown in Fig.14. After optimization the combat effectiveness of the example fighter is greatly enhanced(table 1).

Table 1 comparision with the objective and the variables

	Objective E	Wing area S/M^2	Aspect ratio AR	Sweep Xo/ °	Taper ratio TA	Thickness ratio Tc
Before opt.	**1.000**	**29.500**	**2.200**	**47.500**	**0.265**	**0.0475**
After opt.	**1.418**	**24.984**	**3.451**	**42.232**	**0.228**	**0.0591**

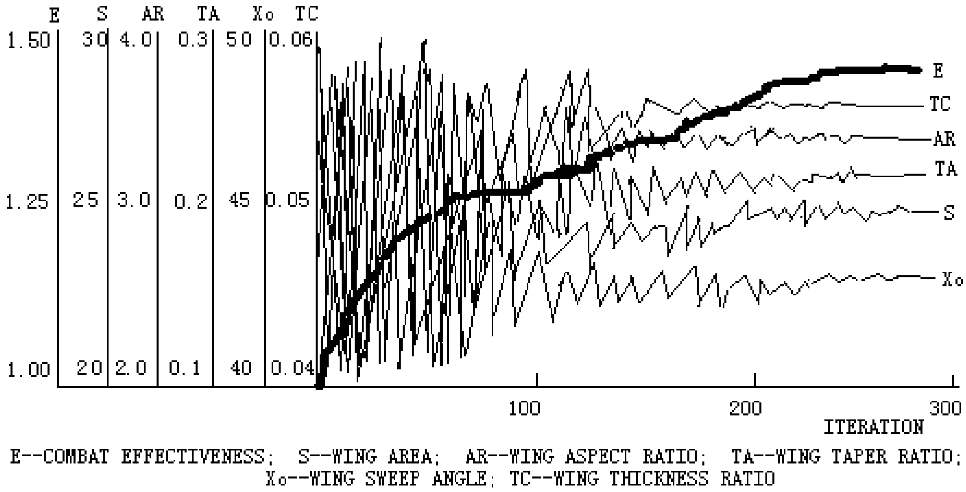

Fig. 14 PROCESS OF COMBAT EFFECTIVENESS OPTIMIZATION

7. Conclusion

(1) The aircraft configuration parameters have great influence on combat effectiveness. For light supersonic fighter the impotent order is take off weight, engine thrust and SFC, wing parameters.

(2) The radar detective range and search angle, the missile range and attack angle have vast influence on combat effectiveness. With advanced radar and missile the combat effectiveness can be enhanced as much as several times.

(3) When the radar detective range and the missile range are limited, the improvement of combat effectiveness can be made with the enlargement of radar search angle and the missile attack angle.

(4) For high combat effectiveness the wing parameters should be chosen as follow: wing aspect ratio(3.0-3.5),wing sweep angle(40°-43°), wing taper ratio(0.2-0.25),wing thickness ratio(0.055-0.060).

References

[1] Wang Heping. Research on the Synthesis of Aircraft Configuration Parameters and Combat Effectiveness. [***Dissertation***], Northwestern Polytechnical University, 1998