

**МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ**

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**Тема: «Аванпроект вантажного літака скороченого зльоту і посадки
вантажопідйомністю до 30 тон»**

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«___» _____ 2021

**MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND AEROSPACE TECHNOLOGIES "**

Topic: "Preliminary design of short take-off and landing cargo airplane with capacity up to 30 tons"

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ЗАВДАННЯ

на виконання дипломної роботи студента

Фен Цянуї

1. Тема роботи: «Аванпроект вантажного літака скороченого зльоту і посадки вантажопідйомністю до 30 тон», затверджена наказом ректора від 8 жовтня 2021 року № 2173/ст.
2. Термін виконання роботи: з 11 жовтня 2021 р. по 31 грудня 2021 р.
3. Вихідні дані до роботи: максимальне навантаження 47000 кг, максимальна дальність 1500 км, крейсерська швидкість 750 км/год, висота польоту 10 км.
4. Зміст пояснювальної записки: Розрахунок питомої витрати палива, відносний розрахунок палива, розрахунок відносної ваги, Аналіз кінцевих елементів та оптимізація конструкції передньої кромки ребра крила.

6. Календарний план-графік:

№	Завдання	Термін виконання	Відмітка про виконання
1	Перевірити літературу з питань роботи. Аналіз параметрів вантажного літака.	11.10.2021– 13.10.2021	
2	Вивчити параметризацію передньої кромки вартості крила.	14.10.2021– 20.10.2021	
3	Вивчити параметри оптимізації товщини ребер і зменшення ваги отвору.	21.10.2021– 24.10.2021	
4	Дослідження з оптимізації топології отворів, що зменшують вагу ребра.	25.10.2021– 15.11.2021	
5	Виконання частин, присвячених охороні навколишнього середовища та охорони праці.	16.11.2021– 21.11.2021	
6	Підготовка ілюстративного матеріалу, написання пояснювальної записки.	22.11.2021– 29.11.2021	
7	Перевірка, редагування та виправлення пояснювальної записки.	30.11.2021– 31.12.2021	

7. Консультанти з окремих розділів:

Розділ	Консультант	Дата, підпис	
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8. Дата видачі завдання: 8 жовтня 2021 року

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Head of Department,
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«___» _____ 2021

TASK

for the master degree thesis

Feng Qianyu

1. Topic: «Preliminary design of short take-off and landing cargo airplane with capacity up to 30 tons», approved by the Rector's order № 2173/CT from 8 October 2021.
2. Period of work: since 11 October 2021 till 31 December 2021.
3. Initial data: maximum load 47,000 kg, maximum commercial load range 1500 km, cruising speed 750 km / h, altitude 10 km.
4. Content: Calculation of specific fuel consumption, relative fuel calculation, calculation of relative weight, Finite element analysis and optimization of the design of the leading edge of the wing rib.

6. Thesis schedule:

№	Task	Time limits	Done
1	Check the literature on work issues. Analyze cargo aircraft parameters.	11.10.2021–13.10.2021	
2	Study the parameterization of the leading edge of the wing cost.	14.10.2021–20.10.2021	
3	To study the parameters of optimizing the thickness of the ribs and reducing the weight of the hole.	21.10.2021–24.10.2021	
4	Research to optimize the topology of holes that reduce the weight of the rib.	25.10.2021–15.11.2021	
5	Execution of the parts, devoted to environmental and labor protection.	16.11.2021–21.11.2021	
6	Preparation of illustrative material, writing the report.	22.11.2021–29.11.2021	
7	Explanatory note checking, editing and correction.	30.11.2021–31.12.2021	

7. Special chapter advisers:

Chapter	Adviser	Date, signature	
		Task issued	Task received
Labor protection	PhD, associate professor Victoria KOVALENKO		
Environmental protection	PhD, associate professor Tamara DUDAR		

8. Date of issue of the task: 8 October 2021 year

Supervisor: _____

Volodymyr Krasnopolskyi

Student: _____

Feng Qianyu

РЕФЕРАТ

Пояснювальна записка дипломної роботи магістра «Аванпроект вантажного літака скороченого зльоту і посадки вантажопідйомністю до 30 тон»:

85 с., 35 рис., 4 табл., 10 джерел

Ця дипломна робота присвячена розробці ескізного проекту вантажного літака ближнього зльоту та посадки, що відповідає міжнародним стандартам польотів, безпечним, ефективним та надійним можливостям перевезення вантажів. Товщина переднього краю ребра крила і оптимізована конструкція отворів для зменшення ваги, а також полегшена конструкція ребра крила.

У дисертації використовуються скінченно-елементний аналіз, оптимізація параметрів, оптимізація топології, моделювання системи ДМ за допомогою системи Ansys, а також модулі аналізу та оптимізації кінцевих елементів.

Практичне значення результатів магістерської роботи полягає в тому, щоб зробити літак легшим, збільшити дальність польоту літака.

Матеріали магістерської роботи можуть бути використані в навчальному процесі та практичній діяльності конструкторів професійних проектних установ.

Дипломна робота, аванпроект літака, ребра, оптимізація параметрів, оптимізація топології, ребро крила

ABSTRACT

Master degree thesis "Transportation of oversized cargo by short-range aircraft"

85 pages, 35 figures, 4 tables, 10 references

This thesis is devoted to the development of a preliminary design of a cargo plane for short takeoff and landing, which meets international flight standards, safe, efficient and reliable cargo transportation capabilities. The thickness of the front edge of the wing rib and the optimized design of the holes to reduce weight, as well as a lightweight design of the wing rib.

The dissertation uses finite element analysis, parameter optimization, topology optimization, DM system modeling using the Ansys system, as well as finite element analysis and optimization modules.

The practical significance of the results of the master's thesis is to make the aircraft lighter, to increase the range of the aircraft.

The materials of the master's thesis can be used in the educational process and practical activities of designers of professional design institutions.

Master thesis, preliminary design, cabin layout, ribs, parameter optimization, topology optimization, wing rib

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Introduction

The research topic of this paper is the preliminary design of short-distance take-off and landing cargo aircraft, which includes the calculation and statistics of preliminary parameters of the aircraft, the finite element analysis of some component structures, and the research of parameters and topology optimization technology. This topic will calculate some parameters of the short-distance takeoff and landing transport aircraft, use ANSYS Workbench to analyze the force on the front edge of the wing rib, parameterize the two weight reduction holes on the wing rib and the thickness of the wing rib, and optimize their size and position. Then complete the topological optimization and final modeling of the rib. Finally, compare the stress, deformation and quality of the three models under the same force. It is expected that relevant research will provide guidance for structural optimization design.

1. Technical description of the airplane

1.1 Brief description of prototype analysis and design aircraft

Flight performance is various parameters that describe the motion law of the aircraft's center of mass, including the aircraft's speed, altitude, range, flight time, take-off, landing, and maneuver flight (such as somersaults, circling, combat turns, etc.). The performance of the aircraft taking off and landing mainly depends on the length of the aircraft's taxiing distance during take-off and landing. The shorter the distance, the better the performance.

The performance of an airplane in a steady (zero acceleration) linear motion is called basic flight performance, including maximum horizontal flight speed, minimum horizontal flight speed, rate of climb, ceiling and ascent time, etc. The maximum horizontal flight speed is the maximum steady horizontal flight speed that an aircraft can reach at a certain flying altitude, which is often expressed in Mach number. It is one of the important performance indicators of the aircraft, and is particularly important for military aircraft.

The aerodynamic layout design of the aircraft is not limited to the design of the aerodynamic shape of the aircraft, but also includes the selection of various aerodynamic parameters, as well as some comprehensive designs related to aerodynamic characteristics. Aircraft aerodynamic layout design is the overall design of aircraft aerodynamics.

In wing design, wing area is a parameter that needs to be optimized. Due to the different aerodynamic characteristics, the wing area required for different aerodynamic layout forms or different wing plane shapes is also different, and the

area of the tail wing has a certain relationship with the area of the wing, so the wing area (wing load) and its Shape selection is a parameter that needs to be determined at the same time in the aerodynamic layout design of the aircraft.

The choice of engine type and engine cycle parameters is generally the content of conceptual design research. In the program design stage, the thrust of the engine is mainly determined (but may include the afterburner ratio or fine adjustment of other engine cycle parameters), that is, the thrust-to-weight ratio of the aircraft is determined, due to the different aerodynamic characteristics of various layout schemes and the different effects on the weight of the aircraft. In the aerodynamic layout design of the aircraft, the thrust-to-weight ratio is also a parameter that needs to be optimized at the same time.

In fact, although the starting point of the aircraft aerodynamic layout design is aerodynamics, the impact on weight must be considered at the same time. This impact comes from two aspects: aerodynamic efficiency and fuel requirements, and different layout parameters affect the weight of the structure. The effect of structural weight on performance in turn affects the choice of aerodynamic layout.

Designing an aircraft needs to comply with a series of design requirements and design specifications. The calculation of aircraft related parameters is very important in each design stage. Therefore, in the preliminary stage of aircraft design, the parameters of the aircraft's main components are reasonably estimated, which also provides a reliable basis for the subsequent optimization design.

In the early stages of aircraft design, in order to meet the performance requirements of the aircraft, it is necessary to estimate the maximum take-off weight

(MTOW) of the aircraft. The maximum take-off weight is composed of empty weight, fuel weight and loaded weight. Using formulas, the empty weight of the aircraft can be broken down into the weight of each component. The calculation of component weight can make the aircraft's empty weight more accurate. In the early design stage, only a few overall parameters of the aircraft are known, such as maximum take-off weight, range, lift-to-drag ratio, etc. The designer does not know the detailed data and can only estimate the weight.

Regarding the aircraft I designed, I chose a short-distance take-off and landing transport aircraft that can carry up to 47,000 kg of cargo. Aircraft like the An-70 will compete with designed aircraft in selected market segments. The performance of the prototype is shown in Table 1.1.

Table 1.1

Performances of prototype – An-70

Performance data	
Airport conditions	Conventional airport concrete runway
Maximum cargo capacity	47 tons (conventional airport runway) 20 tons (field airfield)
Required runway length	1 550-1 800 meters (regular airport runway) 600~700 meters (field battle airport)
Voyage	

Under a load of 47 tons	3 000 km
Under 35 tons load	5 100 km
Under 20 tons load	6 600 km
Empty voyage	8 000 km
Fuel consumption per kilometer	150kg
Speed/height	
Cruising speed	700-750 m
Maximum speed	780 meters
Cruising altitude	12 000 meters
Power	
Engine type	ТВВДД-27 (D-2)
Power	4 × 10 300kWt
Crew	3-5

1.2 Brief description of the main components of the aircraft

1.2.1 Wing

The airfoil of An-70 is a supercritical airfoil. The wing surface structure of this airfoil can delay the wave resistance generated when the aircraft is in the transonic speed range.

The upper surface of the wing of this airfoil is flat. The thickness distribution and camber of the wing affect the air flow around the wing. When the flying speed of the aircraft is close to the speed of sound, and the ambient air pressure and humidity are appropriate, the air velocity near the surface of the wing reaches Mach 1 and a

shock wave is generated. This kind of conical shock wave creates resistance. The flat upper surface of the supercritical airfoil wing can reduce the impact of shock waves.

1.2.2 Cargo hold

The An-70 has a total length of 40.07 meters, a wingspan of 44.06 meters, and a height of 16.38 meters. The aircraft has an empty weight of 73 tons and a maximum take-off weight of 130 tons. As a transport aircraft, the cargo hold of An-70 is 36 meters in length, 6.4 meters in width and 4.4 meters in height.

1.2.3 Tail unit

The An-70's tail is composed of a pair of horizontal tails directly connected to the tail of the fuselage and a vertical tail.

1.2.4 Landing gear

The landing gear part of the aircraft consists of a multi-wheeled landing gear under the fuselage and a two-wheeled nose landing gear under the cockpit.

1.2.5 Control system

The An-70 is equipped with advanced digital airborne equipment, allowing the aircraft to fly day and night at various altitudes, and has advanced electronic countermeasures and self-defense equipment. A multi-channel information transmission system can be installed on the aircraft, and western airborne electronic equipment can also be used. The working environment of the crew is comfortable,

and the cockpit uses a multi-function color display. An-70's electronic navigation and flight control equipment can automatically take off and land in unpaved airports without the help of the ground. During the airdrop and loading and unloading of various items, the machine can operate by itself through the electrical system. The loading and unloading equipment on board is 4 electric cable cars with a total towing capacity of 12 tons. According to customer requirements, roller conveyors can be quickly installed to facilitate loading and unloading of box-shaped goods.

1.2.6 Choice and description of power plant

The aircraft engine adopts D-27 engine and D-27 is a Three-shaft geared tractor-configuration propfan engine. The length is 4.205 m, the width is 1.259 m, the height is 1.37 m, the diameter of the propeller is 4.5 m, and the net weight: 1,650 kg. The propeller weighs 1,100 kg. The engine has a maximum thrust of 12,100 kgf and a speed of 1,000 rpm.

1.3 Geometric calculation of aircraft components

1.3.1 Wing geometry calculation

The geometric characteristics of the computer wing need to know the take-off weight m_0 of the aircraft and the wing load p_0 .

The calculation formula of the wing area is:

$$S_w = \frac{m_0 \cdot g}{P_0} = \frac{146781 \cdot 9.8}{5200} = 276.6 \text{ m}^2$$

The wingspan is:

$$l_w = \sqrt{S_w \cdot \lambda_w} = \sqrt{276.6 \cdot 12} = 57.6 \text{ m}$$

Where λ_w represents the aspect ratio of the wing.

Root chord formula:

$$b_0 = \frac{2S_w \cdot \eta_w}{(1 + \eta_w) \cdot l_w} = \frac{2 \cdot 276.6 \cdot 3}{(1 + 3) \cdot 57.6} = 7.2 \text{ m}$$

η_w represents the wing taper ratio.

Formula of tip chord is:

$$b_t = \frac{b_0}{\eta_w} = \frac{7.2}{3} = 2.4 \text{ m}$$

The expression for the maximum wing thickness is:

$$c_{\max} = c_w \cdot b_t = 0.12 \cdot 2.4 = 0.288 \text{ m}$$

The expression for the board chord is:

$$b_b = b_0 \cdot \left(1 - \frac{(\eta_w - 1) \cdot D_f}{\eta_w \cdot l_w} \right) = 7.2 \cdot \left(1 - \frac{(3 - 1) \cdot 5.2}{3 \cdot 57.6} \right) = 6.767 \text{ m}$$

D_f expresses fuselage diameter.

The average aerodynamic chord length is equal to 5.13 m.

The geometric parameters of the ailerons are calculated in the following order:

Ailerons span:

$$l_{ail} = 0.4 \cdot \frac{l_w}{2} = 0.4 \cdot \frac{57.6}{2} = 11.52 \text{ m}$$

Aileron chord:

$$b_{ail} = 0.44 \cdot b_t = 0.44 \cdot 2.4 = 1.056 \text{ m}$$

Aileron area:

$$S_{ail} = 0.06 \cdot \frac{S_w}{2} = 0.06 \cdot \frac{276.6}{2} = 8.3 \text{ m}^2$$

As l_{atl} increases beyond a given value, the increase in aileron coefficient decreases and the span of the high-lift device decreases. As b_{atl} increases, the width of the chord decreases.

1.3.2 Fuselage layout

The layout of the fuselage is closely related to the shape and structure of the aircraft. The circular shape of the nose of the fuselage reduces the drag caused by the air in flight. Nose part length is:

$$l_{np} = 1.35 \cdot D_f = 1.35 \cdot 5.2 = 7.02 \text{ m}$$

Fuselage length is:

$$l_f = \lambda_f \cdot D_f = 8 \cdot 5.2 = 41.6 \text{ m}$$

Fuselage nose part:

$$\lambda_{np} = \frac{l_{np}}{D_f} = \frac{7.02}{5.2} = 1.35$$

Fuselage rear part's length:

$$l_{rp} = \lambda_{rp} \cdot D_f = 3.1 \cdot 5.2 = 16.12 \text{ m}$$

The height of the cargo hold is:

$$H_{car} = 2.5 \text{ m}$$

1.3.3 Galleys and buffets

Volume of galleys is:

$$V_{galley} = 0.1 \cdot n_{pass} = 0.1 \cdot 3 = 0.3 \text{ m}^3$$

where V – volume of buffets; n_{pass} – number of passengers.

The galleys area is:

$$S_{galley} = \frac{V_{galley}}{H_{cab}} = \frac{0.3}{2.5} = 0.12 \text{ m}^2$$

The number of meals for breakfast, lunch and dinner for each driver-0.8 kg, and tea and water-0.5 kg.

1.3.4 Layout and calculation of basic parameters of tail unit

The determination of the tail unit scheme is conventional. This selection is based on all three prototype tail wing schemes.

In order to estimate the general tail unit profile, it is necessary to calculate the geometric dimensions of the vertical and horizontal tail and the dimensions of the tail rudder. The tail wing must ensure the stability and controllability of the aircraft.

The area of the vertical tail is:

$$S_{VTU} = \frac{l_{wx} \cdot S_w}{L_{VTU}} \cdot A_{VTU} = \frac{24.7 \cdot 276.6}{16.44} \cdot 0.1 = 41.561 \text{ m}^2$$

where L_{VTU} – length of vertical tail unit; A_{VTU} – coefficient of static momentum of vertical tail unit.

The horizontal tail area is:

$$S_{HTU} = \frac{b_{MAC} \cdot S_w}{L_{HTU}} \cdot A_{HTU} = \frac{2.3 \cdot 276.6}{16.44} \cdot 0.8 = 30.5 \text{ m}^2$$

where L_{HTU} – length of horizontal tail unit; A_{HTU} – coefficient of static momentum of horizontal tail unit.

The area of the rudder is:

$$S_{tr} = k_{tr} \cdot S_{rud} = 0.04 \cdot 36.125 = 14.45 \text{ m}^2$$

where k_{tr} – relative trim tab area coefficient.

Root chord of horizontal stabilizer is:

$$b_{0HTU} = \frac{2 \cdot S_{HTU} \cdot \eta_{HTU}}{(1 + \eta_{HTU}) \cdot L_{HTU}} = \frac{2 \cdot 30.5 \cdot 2.2}{(1 + 2.2) \cdot 16.44} = 4.378 \text{ m}$$

where η_{HTU} – horizontal tail unit taper ratio; L_{HTU} – horizontal tail unit span.

Tip chord of horizontal stabilizer is:

$$b_{iHTU} = \frac{b_{0HTU}}{\eta_{HTU}} = \frac{4.378}{2.2} = 1.99 \text{ m}$$

The root chord of the vertical tail is:

$$b_{0VTU} = \frac{2 \cdot S_{VTU} \cdot \eta_{VTU}}{(1 + \eta_{VTU}) \cdot L_{VTU}} = \frac{2 \cdot 41.561 \cdot 3.25}{(1 + 3.25) \cdot 16.44} = 12.031 \text{ m}$$

where η_{VTU} – vertical tail unit taper ratio; L_{VTU} – vertical tail unit span.

Tip chord of vertical stabilizer is:

$$b_{iVTU} = \frac{b_{0VTU}}{\eta_{VTU}} = \frac{12.031}{3.25} = 3.7 \text{ m}$$

1.3.5 Landing gear design

In order to design the landing gear profile, it is necessary to calculate the relative position of each strut to each other, determine the load on the landing gear system, and consider the position of the aircraft's center of gravity. In this layout, the main scheme of the landing gear is based entirely on prototype data.

Like the tail device, it is necessary to provide a stable and controllable base for the aircraft during ground operations including landing and take-off.

The offset of the main axle is:

$$e = k_e \cdot b_{MAC} = 0.3 \cdot 2.5 = 0.75 \text{ m}$$

where k_e – coefficient of axes offset; b_{MAC} – mean aerodynamic chord.

The wheelbase of the landing gear is:

$$B = k_b \cdot L_f = 0.38 \cdot 3.88 = 1.475 \text{ m}$$

where k_b – wheel base calculation coefficient.

From the above, it can be inferred that the nose pillar can bear 5...11% of the aircraft's weight.

The formula for the axial offset of the front wheel is:

$$d_n = B - e = 1.475 - 0.75 = 0.725 \text{ m}$$

The wheelbase is:

$$T = k_T \cdot B = 3.221 \cdot 1.475 = 4.751 \text{ m}$$

where k_T – wheel track calculation coefficient.

The front wheel load is:

$$P_n = \frac{9.81 \cdot e \cdot k_d \cdot m_0}{B \cdot z} = \frac{9.81 \cdot 0.75 \cdot 1.75 \cdot 47000}{8.9 \cdot 2} = 33620 \text{ N}$$

where k_d – dynamics coefficient; z – number of wheels.

The main wheel load is equal to:

$$P_m = \frac{9.81 \cdot (B - e) \cdot m_0}{B \cdot n \cdot z} = \frac{9.81 \cdot (1.475 - 0.75) \cdot 47000}{1.475 \cdot 6 \cdot 12} = 31476 \text{ N}$$

where n - the number of main landing gear pillars.

After calculating the wheel load and take-off speed, select the tires of the landing gear:

For nose landing gear:

Aircraft Rib 461B-3434-TL with parameters Prated = 9000 lbf; Vrated = 250 MPH; size 18×5.7-8.

for main landing gear

Aircraft Rib 461B-2728-TL with parameters Prated =12000 lbf; Vrated =195 MPH; size 22×7.75-10.

Wheel load ratio:

$$\text{for nose wheel } \frac{9000 - 8513}{9000} \cdot 100\% = 5.41\%$$

$$\text{for main wheel } \frac{12000 - 11750}{12000} \cdot 100\% = 2.08\%$$

Both values are less than 10%, so these tires can be used on this aircraft.

1.4 Calculation of the position of the aircraft's center of gravity

1.4.1 Wing centering calculation

The quality of the wing includes the quality of its internal structure, the quality of the skin

And the quality of fuel. The mass register includes the name of the object, the mass itself, and their center of gravity coordinates. The origin of a given centroid coordinate is selected by the nose projection of the average aerodynamic chord (MAC) for the surface XOY. The positive meaning of the center of mass coordinate is accepted as the tail of the airplane.

The equipment wing is defined by the following formula.

$$X'_w = \frac{\sum m'_i \cdot x_i}{\sum m'_i}$$

1.4.2 Determine the center of the fuselage

The weight ratio of each part of the aircraft is given in Table 1.2.

The coordinates of the center of gravity of the fuselage are:

$$X'_f = \frac{\sum m'_i \cdot x_i}{\sum m'_i}$$

List of equipped fuselage masses

Objects	Units	Total(kg)	Center of gravity coordinates, (m)	Momentum (kg*m)
Wing	0.09794	4603.18	16.866	77637.23388
Horizontal tail	0.01103	518.41	36.015	18670.53615
Vertical tail	0.01105	519.35	35.799	18592.21065
Chassis	0.04701	2209.47	16.974	37503.54378
Power plant	0.15722	7389.34	2.160	15960.9744
Fuselage	0.11216	5271.52	16.974	89478.78048
Equipment and management	0.12158	5714.26	2.325	13285.6545
Additional equipment	0.00102	47.94	15.324	734.63256
Overhead	0.01056	496.32	4.406	2186.78592
Fuel and lpa	0.11022	5180.34	18.057	93541.39938
Commerical load	0.32020	15049.4	16.805	252905.167

1.4.3 Calculate the center of gravity positioning variable

After confirming the data of each part of the fuselage, balance the equation.

$$X_{MAC} = \frac{m_f \cdot X_f + m_w \cdot X_w - m_0 \cdot c_n}{m_0 - m_w}$$

where m_0 – aircraft take-off mass, kg

m_f – mass of equipped fuselage, kg

m_w – mass of equipped wing, kg

Table 1.3

Calculate the position variable of the center of gravity

Name	Mass, kg	Coordinates	Moment
1	2	3	4
Object	m_i	m	kgm
Equipped wing	4603.180	16.866	77637.23388
Nose landing gear	432.142	4.289	1853.457038
Main landing gear	727.900	18.214	13257.9706
Fuel	5180.340	18.057	93541.39938
Equipped fuselage	6034.425	16.974	102428.33
Cargo	29772.013	14.593	434462.9857
Crew	250.000	2.027	506.75
Nose landing gear	432.142	4.289	1853.457038
Main landing gear	727.900	18.214	13257.9706

Table 1.4

Aircraft's center of gravity position variants

Variants of the loading	Mass, kg	Momentum of the mass,	Center of mass, m	Centering, %
Take-off mass (nose)	146781	629543.709	4.289	13.78966659
Take-off mass (nose)	146781	631451.862	4.302	13.8314632
Landing variant (main)	80540.975	1466973.319	18.214	58.5602675
Transportation variant	80852.881	1637594.252	20.254	65.11912034
Parking variant	57066.081	1157414.255	20.282	65.20914381

1.5 Summary of this chapter

This chapter preliminarily designs the main parts of the aircraft, preliminarily calculates the basic geometric parameters of the memory and the fuselage, and calculates specific costs, relative fuel masses, and values of relative masses with the help of a computer.

2. Optimal design of rib thickness and weight-reducing holes

All processes will be carried out in Ansys workbench. The steps are preprocessing, parameter analysis and optimization, and topology optimization.

Optimization consists of three elements: optimization variables, constraints, and optimization goals. Optimizing variables is the same as solving equations, that is, converting a geometric problem into a mathematical model and then solving it. For example, there is an equation containing x and y , the variable is x , the constraint is the range of x , and the solution target is y .

There are three main categories of optimization classification:

1. Divided according to the system: component optimization, assembly optimization.
2. Divided by performance: strength, vibration, mass, fluid, thermal, electromagnetic, etc.
3. Divided by function: material, structure, operating conditions, etc.

The optimization analysis tools in the workbench include:

1. Topology optimization
2. Parameter analysis → parameter correlation analysis
3. Parameter optimization → direct optimization + proxy model optimization
4. Reliability analysis → Six Sigma reliability analysis → Reliability optimization (Isight optimization)

2.1 Structure optimization

Optimum structural design finds the best design scheme based on certain goals (such as the lightest weight, the lowest cost, the greatest rigidity, etc.) under the given constraints. It was once called the structural optimal design or the structural optimal design. In terms of "structural analysis", it is also called "structural synthesis"; if the goal is to minimize the weight of the structure, it is called the minimum weight design.[1]

2.1.1 Definition

Definition of scientific and technological terms: Chinese name: structural optimization design;

Definition: The design method of the engineering structure to find the optimal scheme according to the predetermined goal under the constraint conditions;

Applied disciplines: water conservancy science and technology (first-level discipline); engineering mechanics, engineering structure, building materials (second-level discipline); engineering structure (water conservancy) (third-level discipline).

Traditional structural optimization design refers to structural analysis, and the process is roughly hypothesis-calculation-check-redesign. The purpose of the redesign is to be able to obtain suitable results and solutions, but all calculation and analysis processes are limited to the scope of analysis; and according to the designer's experience, it needs to be repeated many times to obtain qualified results. Structural optimization in the modern sense is more inclined to comprehensive optimization

design, and its process can be roughly summarized into four stages: hypothesis-calculation-screening-optimization design. The screening process is a process of modification and optimization. It can select one or several excellent schemes from multiple sample schemes (including satisfying various given conditions). If the required sample scheme cannot be screened out, it will be modified according to certain rules to gradually reach the predetermined optimum index.

2.1.2 Basic concept

1. Mathematical model of structural optimization design

The structural optimization design can be defined as: for the given parameters, find the solution of the design variables that satisfy all the constraints and minimize the objective function.

2. design variable

The design variable refers to the quantity to be selected in the design process to describe the structural characteristics, and its value is variable. The design variables can be the geometric parameters of the design section such as the cross-sectional size, area, and moment of inertia of each component, or the overall geometric parameters of the structure such as the height of the column, the spacing of the beams, the vector height of the arch, and the coordinates of the nodes. Design variables usually have two types: continuous design variables and discrete design variables.

(1) Continuous design variables. Such variables are continuously changing during the optimization process, such as the arch vector height and node coordinates.

(2) Discrete design variables. Such variables change in a leaping manner during optimization. For example, the cross-sectional area of the available section steel and the diameter of the steel bar are discontinuous.

3. Objective function

The objective function is an index used to measure the quality of the design. Which index is used to reflect the quality of the design is related to the technical and economic characteristics of the structure itself. The commonly used objective functions are: structure weight, structure volume, and structure cost.

4. Restrictions

Generally, there are two types of constraints for structural optimization: geometric constraints and behavior constraints.

(1) Geometric constraints. That is, the design variables are restricted in terms of geometric dimensions. Such as the minimum thickness of the web and flange of the I-shaped section.

(2) Constraint conditions of behavior. That is, some restrictions imposed on the working behavior of the structure. Such as the strength of the components, stability constraints, and the overall rigidity and natural frequency of the structure.

2.1.3 Mathematical model

The ultimate goal of light steel structure design is to give an economical and reasonable design plan. The optimized design method can better meet the requirements in this respect. The optimized design of the light steel structure has obvious significance for reducing the weight of the structure, reducing the amount of

steel used and the cost of the structure. At present, some researches and applications have been carried out on the optimization design of light steel structures in China, corresponding calculation programs have been compiled, and the automatic optimization of cross-sections has been realized by computers in order to obtain the design scheme with the smallest weight, the most economical materials, or the lowest cost. This has played a certain role in improving the design quality of light steel structures and speeding up the design process. The mathematical model for the optimal design of light steel structure is established below.

1. design variable

The main geometric parameters of light steel structure such as span, cornice height, roof slope, longitudinal column spacing, etc. are usually determined by the owner or architect. The variables that can be optimized are mainly section parameters. Specifically, it is the width and thickness of the flange of each I-beam section, and the height and thickness of the web. The thickness of the steel plate is a discrete variable, and the height (width) of the web and flange is generally selected from a series of regular numbers, so the design variables of light steel structures are usually discrete variables.

2. Objective function

Structural weight is an important indicator for the optimal design of light steel structures, and it is easier to write a function of design variables. Therefore, light steel structures usually use the least amount of steel as the optimization goal.

3. Restrictions

The optimal design of light steel structure must meet the following constraints:

(1) Strength and stability constraints.

Light steel structural members must meet the requirements of strength and stability.

(2) Stiffness constraints.

When the component size of the light steel structure is optimized, the overall rigidity of the structure must meet the requirements of deformation control. Specifically, the maximum vertical displacement of the beam, the maximum horizontal displacement of the top of the column, and the maximum horizontal displacement of the top of the crane rail must meet the deformation control values specified by the relevant specifications.

(3) Constraint condition of section size.

The selection of section size of light steel structure must meet the structural requirements and use requirements of relevant specifications. For example, the height of the web of all sections must be greater than the width of the flange, and the thickness of the flange of all sections must be greater than the thickness of the web by more than 2mm.

(4) Constraints on the overall structure.

The optimal design of the light steel structure must meet the overall constraints of the structure, that is, the selection of the component section size must ensure the continuity and rationality of the beam and column sections, and meet the conventional processing and use requirements.

(5) Constraints on the upper and lower limits of variables.

2.2 Topology optimization

Topology optimization is a mathematical method for optimizing material distribution in a given area according to given load conditions, constraints and performance indicators. It is a kind of structural optimization.[2]

2.2.1 Basic concept

Size optimization: Taking the shape of structural parts or the shape of holes as the optimization object, such as the shape of the transition chamfer of the boss.

Shape optimization: Finding new boss distributions on existing thin plates to improve local stiffness.

2.2.2 Optimization ways

The continuum topology optimization methods mainly include homogenization method, variable density method, progressive structure optimization method (ESO) level set method, MMV, etc. Discrete structure topology optimization is mainly based on the basic structure method using different optimization strategies (algorithms) to solve, such as Cheng Gengdong's relaxation method, topology optimization based on genetic algorithm, etc.

2.2.3 Commercial software

The research on continuum topology optimization has been relatively mature. Among them, the variable density method has been applied to commercial optimization software. The most famous ones are Optistruct from the Hyperworks

series software of Altair in the United States and Tosca from Fe-design in Germany. The former can use Hypermesh as the pre-processor, and it has been widely used in various industries; the latter only focused on optimization design at the beginning, supporting all mainstream solvers, and pre-processing, and the operation is very simple.

2.3 Pretreatment

2.3.1 Modeling

There are many software options for modeling. CATIA, as a modeling software, can build complex surface models. It is the most ideal and best modeling software. I used it to build models from the beginning. However, if the CATIA modeling model is directly imported into the workbench, the size of the model cannot be parameterized. It is necessary to manually import the parameters into the workbench through a third-party software. This operation is time-consuming and complicated. Finally, I chose to use the Design Modeler that comes with the workbench to model. Although I encountered many problems with curves and constraints when modeling with this software, its model size can be directly parameterized to lay the foundation for subsequent research and used in this research. Medium is barely enough.

Create a static structure module in the workbench, then use DM (Design Modeler) to open the geometric structure options and start modeling.

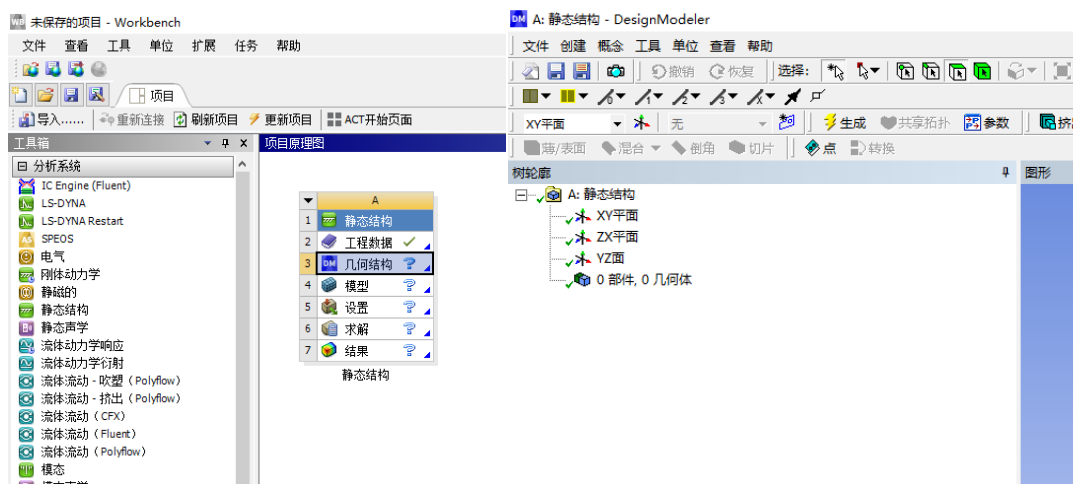


Fig. 3.1 Working interface

Draw sketches with commands such as lines, circles, and splines, and then extrude the sketches into a solid body.

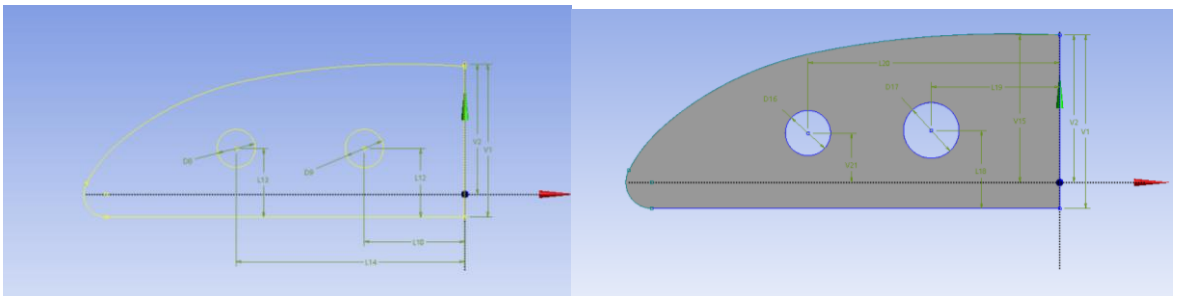


Fig. 3.2 Sketch

Define the diameter of the two weight-reducing holes and the distance between the center of the circle and the right and lower borders and the thickness of the plate as parameters, so that a parameter set will be generated under the "Static Structure" module.

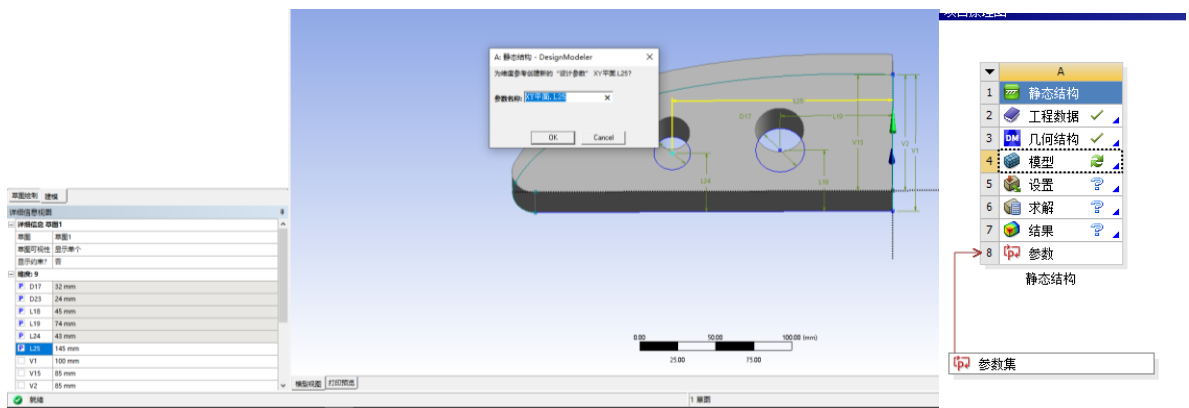


Fig 3.3 Extrude the sketch

Finally, the model material is defined as structural steel.

2.3.2 Meshing

The finite element theory is to discretize the complete geometry into finite nodes and elements, then construct the element matrix, and then perform mathematical calculations to obtain the required results.

Open the model in the model module and divide the mesh. Because the structure of the plate is not complicated, there are no sharp angles, and the size is small, the quality of the mesh is not high, so the default method is used to automatically divide the mesh. If the model is more complicated, when the automatic meshing function is used, a highly distorted element will be generated at the sudden change position of the model. If the element appears in the assembly contact position, it is prone to non-convergence.

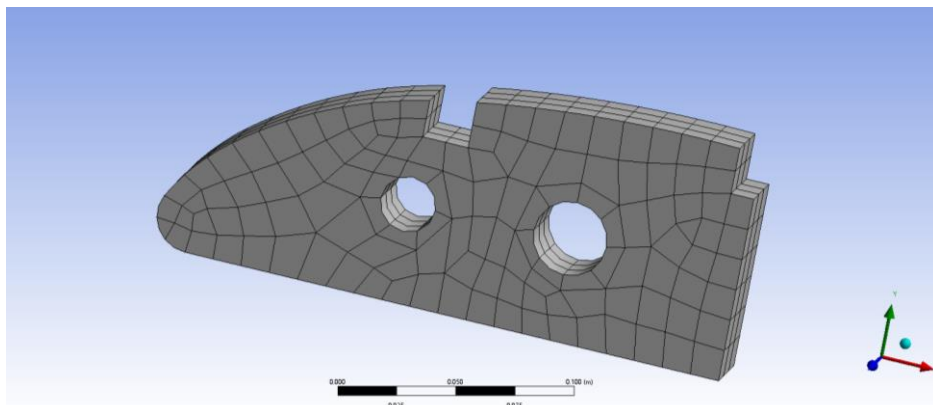


Fig 3.4 Meshing

Check the grid quality and show low-quality grid cells. It can be seen that the grid cells are all high-quality cells greater than 5.0.

As long as the unit quality is greater than 0.3, the software can calculate it. If the unit quality is between 0.3 and 0.7, the software can calculate it. If the unit quality is below 0.3, a warning or even an error will be issued.

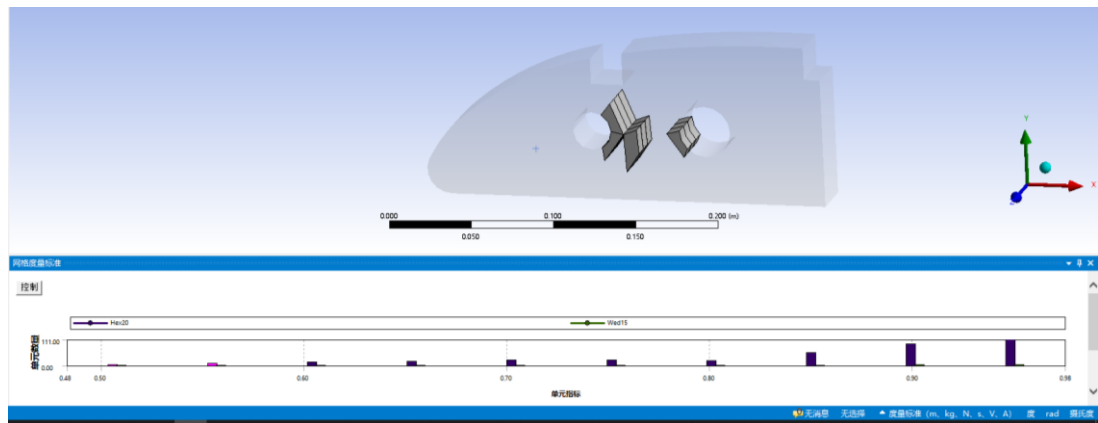


Fig 3.5 Mesh quality

2.4 Finite element analysis of the model

Optimum structural design finds the best design scheme based on certain goals (such as the lightest weight, the lowest cost, the greatest rigidity, etc.) under the given constraints. It was once called the structural optimal design or the structural optimal design. In terms of "structural analysis", it is also called "structural synthesis"; if the goal is to minimize the weight of the structure, it is called the minimum weight design.

After a simple calculation, we can see the force of the model when flying at the highest speed under the maximum load of the aircraft: the grooves of the upper two support beams are the fixed parts, the lower surface of the wing rib is subjected to an upward pressure of $6.0133e+005\text{Pa}$, and the front end of the wing rib and the upper The backward force on the surface is 60N.

2.4.1 Boundary conditions

Fix the two grooves on the upper side and the right cross section, and set the bottom pressure and the pressure on the upper edge of the front edge.

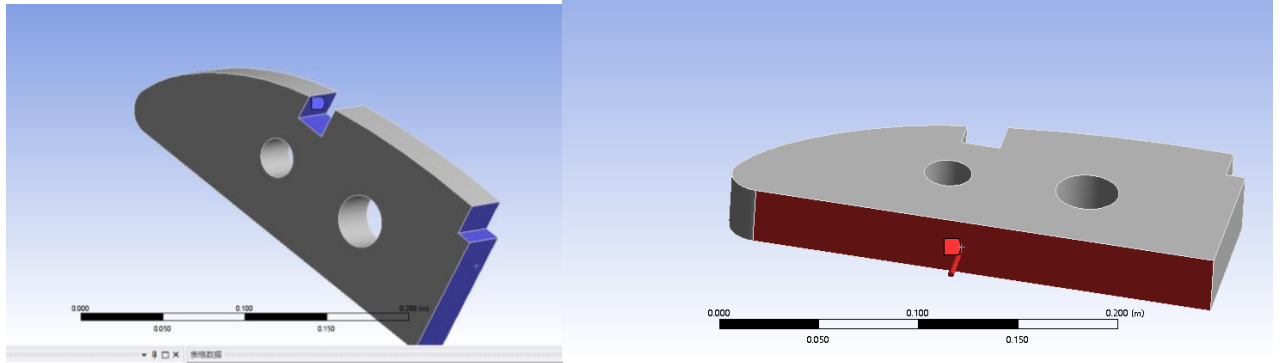


Fig 3.6 Define boundary conditions

2.4.2 Solve

The deformation and equivalent stress are selected as the calculation results, and the maximum deformation is $2.8997\text{E-}06$ meters, and the maximum equivalent stress is $6.6604\text{E+}06$ Pa. It can be seen that the largest deformation is concentrated on the front edge part, which will tilt up when subjected to force, and the largest stress is concentrated on the left side groove.

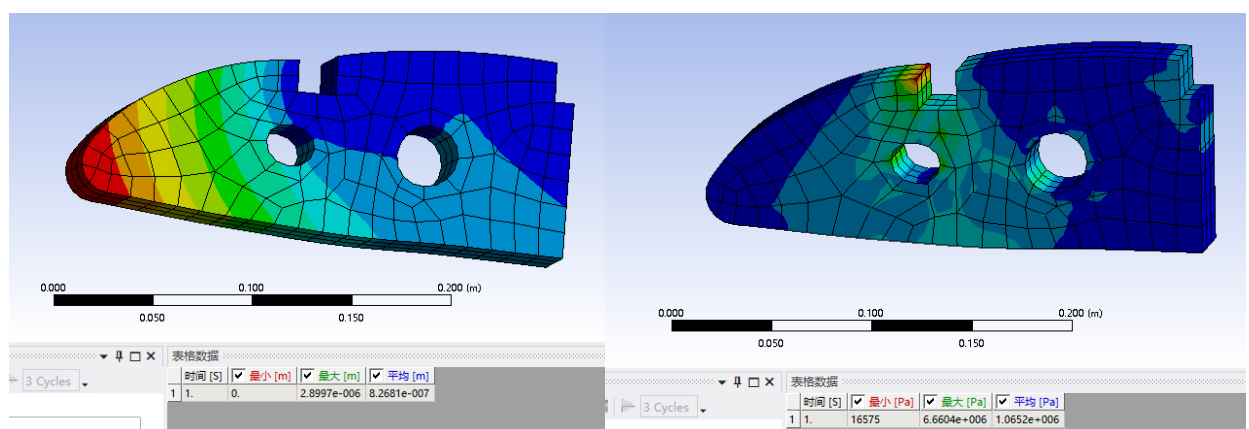


Fig 3.7 Finite element analysis

The largest deformation, largest composition, and quality parameterization are regarded as one of the optimization goals.

2.5 Parameter optimization

The parameter optimization steps are:

1. First rough calculation and optimization;
2. Reduce the parameter range according to the results;
3. Secondary optimization;
4. Pick candidate samples.
5. Data import

The reason for adding the first rough calculation is that the computer memory is 16G, and the upper and lower limits of the first set of parameters are very large. It takes tens of thousands of samples and hundreds of hours of calculation to calculate the best parameters at a time. Therefore, a rough calculation method is used to reduce the number of samples for each calculation to 100 groups, and the calculation time is limited to 2 to 3 hours to ensure the efficiency and quality of the calculation.

2.5.1 First rough calculation and optimization

Link the "response surface optimization" module to the parameter set, open the experimental design window, you can see that the previously defined parameters have been imported and can be analyzed. The type of experimental design is "Latin Hypercube Sampling Design".



Fig 3.8 Experimental design interface

Set the upper and lower limits of the parameters. The first step of parameter optimization is rough calculation, so the upper and lower limits of the parameters are based on the maximum boundary of the model. Define the sample size as 100, and then start the calculation.

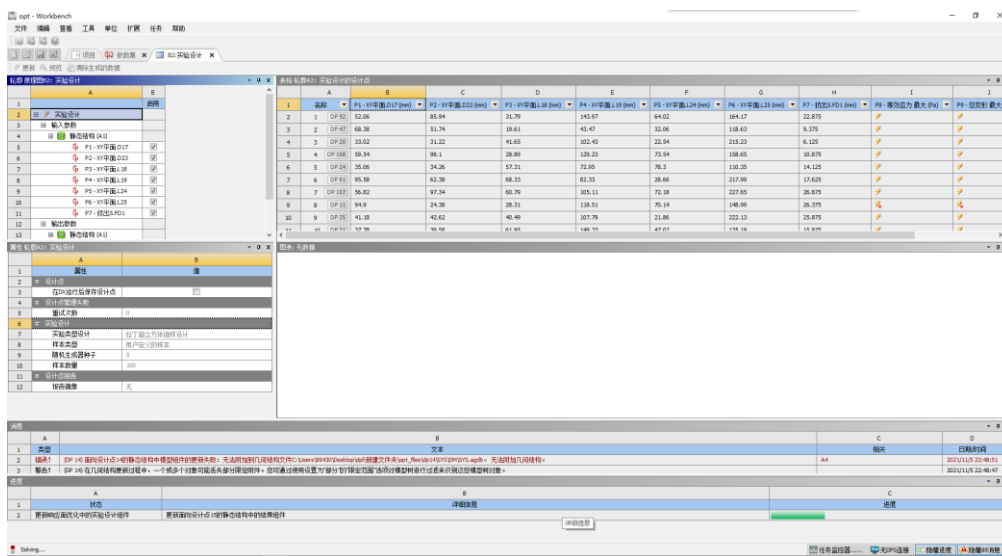


Fig 3.9 Calculation process

2.5.2 Reduce the parameter range according to the results

After three hours of calculation, we obtained 12 sets of available parameters from 100 sets of samples, and the remaining 88 sets reported errors. The reason for the error was that the weight reduction hole destroyed the outer contour of the model, which made it impossible to perform force analysis on the model. Solve. The reason why the weight-reducing hole destroys the model profile is that the relationship between the size and position of the weight-reducing hole and the outer profile of the model is extremely complicated, and it is difficult to associate them through equations, so the weight-reducing hole can only be second. The center of the circle is constrained to be within the smallest rectangle that can be accommodated by the model sketch, and the diameter of the weight reduction hole is constrained to not exceed the maximum height of the model. This will naturally cause a large number of samples to report errors.

	B	C	D	E	F	G	H	I	J	K
1	P1 - XY平面.D17 (mm)	P2 - XY平面.D23 (mm)	P3 - XY平面.L18 (mm)	P4 - XY平面.L19 (mm)	P5 - XY平面.L24 (mm)	P6 - XY平面.L25 (mm)	P7 - 挤出S.FD1 (mm)	P8 - 等效应力 最大 (Pa)	P9 - 总变形最大 (m)	P10 - 固体质量
2	61.58	46.42	31.21	40.79	31.38	122.77	20.375	6.4446E+07	2.072E-05	2.5083
3	84.02	27.42	49.77	83.67	23.22	220.75	6.875	5.9888E+07	3.3579E-05	0.76732
4	50.02	43.38	63.11	52.85	42.26	154.51	5.625	4.6776E+07	2.0609E-05	0.74667
5	66.34	31.98	34.69	127.89	42.94	198.67	21.625	4.4557E+07	1.5989E-05	2.7319
6	41.18	42.62	40.49	107.79	21.86	222.13	25.875	3.7912E+07	2.222E-05	3.5737
7	33.02	31.22	41.65	102.43	22.54	215.23	6.125	3.3079E+07	1.7933E-05	0.90061
8	41.86	35.78	56.73	44.81	57.22	165.55	12.875	1.7474E+07	9.9322E-06	1.8163
9	69.06	32.74	57.89	38.11	44.98	169.69	22.125	1.1882E+07	3.5417E-06	2.7381
10	47.3	28.94	34.11	117.17	32.74	183.49	26.625	9.3784E+06	4.9596E-06	3.7491
11	81.3	37.3	52.09	46.15	38.86	161.41	28.625	8.6758E+06	3.4071E-06	3.1614
12	58.18	30.46	37.01	56.87	23.9	160.03	28.875	7.7946E+06	4.1618E-06	3.8456

Fig 3.10 Sample

2.5.3 Secondary optimization

The new parameter upper and lower limits are defined as the maximum and minimum values of each parameter in the 12 sets of samples. At this time, the upper and lower limits of the parameters are much smaller than the first calculation. Start

the second calculation. After completion, all 100 sets of samples are available. Reduce the number of samples to 30, and continue to repeat the above steps for the third calculation. This calculation obtained 30 sets of more accurate data.

1	A	B	C	D	E	F	G	H	I	J	K
1	名称	P1-X1平直度D17 (mm)	P2-X1平直度D23 (mm)	P3-X1平直度L18 (mm)	P4-X1平直度L19 (mm)	P5-X1平直度L24 (mm)	P6-X1平直度L25 (mm)	P7-扭矩FD1 (mm)	P8-扭矩FD1最大值	P9-扭矩FD1最大值	P10-扭矩
2	5	45.957	30.75	35.5	74.383	31.35	192.65	28.75	6.999E+06	5.72E+06	4.04E2
3	20	44.7	30.517	47.233	72.46	36.15	181.25	27.85	7.209E+06	5.149E+06	3.932E2
4	10	46.507	38.817	46.5	76.483	34.95	190.75	28.05	7.323E+06	4.252E+06	3.84E2
5	15	47.967	36.983	41.367	72.283	35.55	188.35	27.75	7.233E+06	4.229E+06	3.80E2
6	3	44.233	22.217	42.1	72.517	37.68	177.45	27.15	7.267E+06	5.102E+06	3.836E2
7	9	47.5	33.217	36.233	76.017	30.45	194.55	28.55	7.363E+06	4.002E+06	3.969E2
8	25	54.033	28.283	35.167	77.65	37.95	202.15	28.25	7.506E+06	4.072E+06	3.855E2
9	21	49.267	28.517	35.9	71.25	31.65	179.35	26.95	7.448E+06	5.848E+06	3.762E2
10	18	52.967	31.85	32.567	71.117	37.05	183.15	28.95	7.204E+06	4.904E+06	3.935E2
11	4	51.233	37.35	47.967	73.683	33.15	204.05	28.35	7.883E+06	4.648E+06	3.558E2
12	11	48.433	32.95	44.3	77.883	32.25	173.75	27.25	8.033E+06	4.149E+06	3.777E2
13	22	55.9	34.633	45.387	72.883	34.05	196.45	28.25	8.178E+06	4.122E+06	3.766E2
14	30	48.9	38.45	45.033	76.95	35.85	187.95	28.45	8.123E+06	4.212E+06	3.866E2
15	8	56.367	37.717	48.433	74.817	32.55	173.65	28.65	8.238E+06	4.332E+06	3.749E2
16	28	51.7	31.117	31.1	76.25	38.85	176.55	28.25	8.246E+06	4.304E+06	3.893E2
17	6	56.833	28.183	51.633	75.517	33.45	148.95	27.65	8.313E+06	4.085E+06	3.715E2
18	14	53.567	28.55	36.367	77.183	36.45	186.95	28.85	8.303E+06	4.442E+06	3.679E2
19	19	45.833	30.383	38.367	75.517	32.85	154.65	26.45	8.367E+06	4.566E+06	3.725E2
20	16	54.433	32.883	39.8	74.65	31.05	166.05	28.85	8.303E+06	4.205E+06	3.874E2
21	12	46.1	31.483	33.3	75.083	30.75	158.45	26.55	8.208E+06	4.208E+06	3.713E2
22	29	53.1	34.05	34.767	75.783	30.15	200.25	26.15	8.488E+06	4.814E+06	3.525E2
23	23	51.7	36.25	23.7	72.617	31.95	188.05	27.35	8.483E+06	4.808E+06	3.594E2
24	13	49.833	33.683	48.7	71.583	35.25	152.75	27.55	8.513E+06	5.979E+06	3.787E2

Fig 3.11 Calculation results

2.5.4 Pick candidate samples

Check the response surface quality in the response surface module, you can see that the optimization quality of the parameter value is three stars, and all the parameter points are on a straight line, indicating that the optimization result is very good.

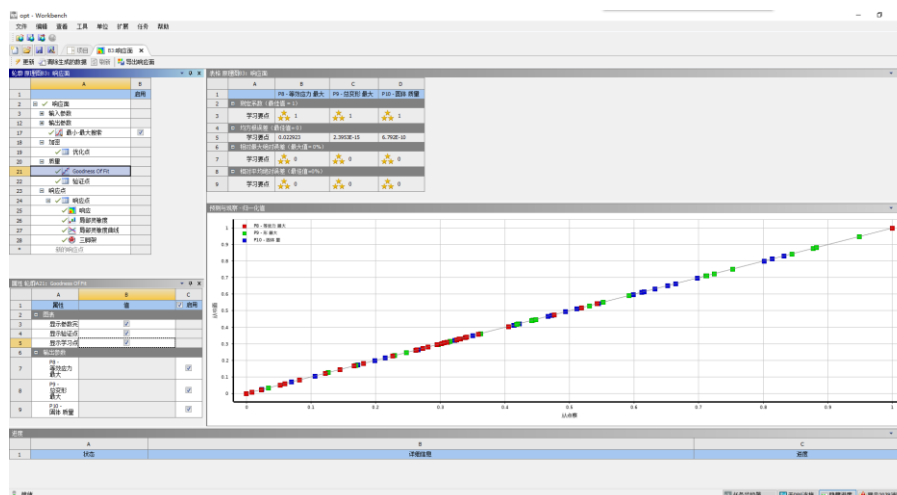


Fig 3.12 Response surface quality

View the local sensitivity graph, the maximum local sensitivity curve of the equivalent stress, the maximum equivalent stress response table and the spider graph.

The final preparation before parameter optimization. This optimization is to select the most suitable parameters from the 30 sets of samples previously obtained. The optimization goal is to minimize the total deformation, quality, and equivalent stress of the plate.

	A	B	C	D	E	F	G	H	I
1	名称	参数	目标			约束			
2			类型	目标	容差	类型	下界	上限	容差
3	最小化P9	P9 - 总变形 最大	最小化	0		无约束			
4	最小化P10	P10 - 固体 质量	最小化	0		无约束			
5	最小化P8	P8 - 等效应力 最大	最小化	0		无约束			
*		选择一个参数							

Fig 3.13 Define optimization conditions

The optimization method is MOGA. In order to ensure the quality of optimization, the estimated number of evaluations, the number of initial samples, and the number of samples in each iteration are all set to default values. Then start the calculation.

	A	B
1	属性	值
2	设计点	
3	在DX运行后保存设计点	<input type="checkbox"/>
4	设计点管理失败	
5	重试次数	0
6	优化	
7	方法选择	手动
8	方法名称	MOGA
9	预计评估数	33600
10	容差设置	<input checked="" type="checkbox"/>
11	验证候选点	<input type="checkbox"/>
12	初始样本数	7000
13	每次迭代的样本数	1400
14	最大允许帕累托百分比	70
15	收敛稳定性百分比	2
16	最大迭代次数	20
17	最大候选数里	3

Fig 3.14 Optimal conditions

After the calculation is completed, three candidate points are obtained. These three candidate points are the most suitable three sets of data calculated by the computer through repeated iterations among the 30 sets of samples.

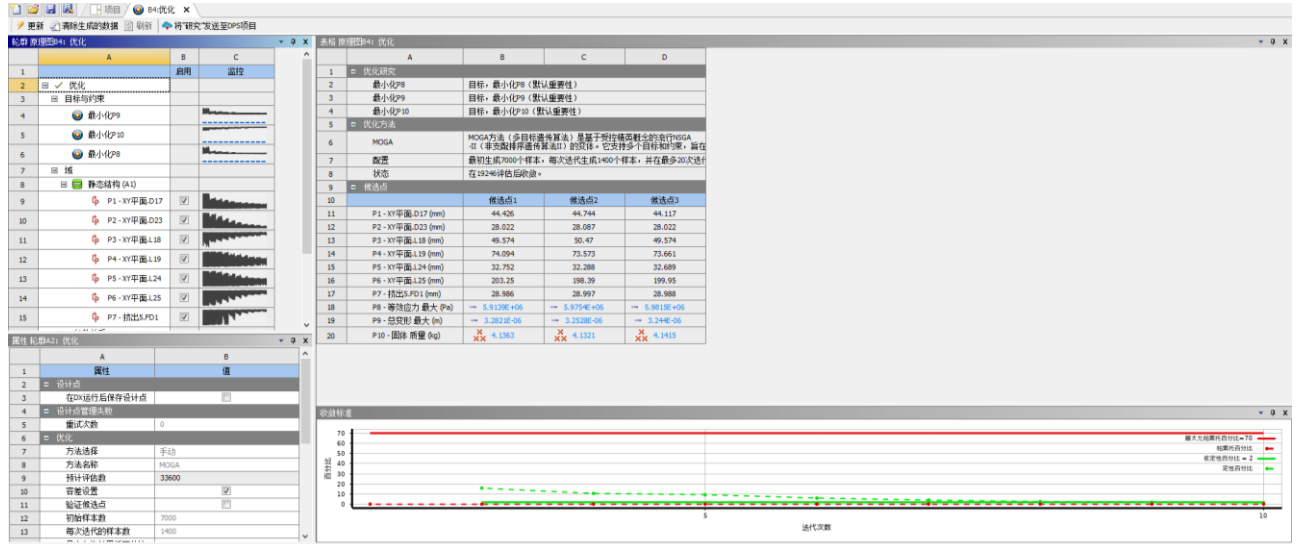


Fig 3.15 Iterative display

View the iterative curve of the parameters, the curve gradually decreases from the up and down fluctuations until it approaches a certain value.



Fig 3.16 Parameter iteration

Looking at the trade-off diagram of the maximum equivalent stress and the total deformation, it can be found that most of the feasible points are concentrated on

a straight line, and it can be seen that the equivalent stress is inversely proportional to the total deformation.

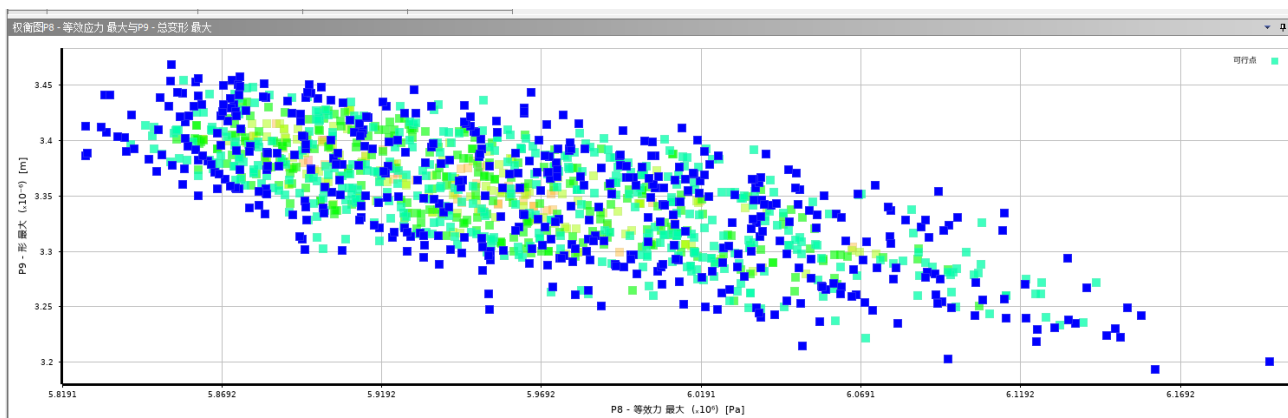


Fig 3.17 Trade-off diagram

The figure below is a parallel table of parameters. It shows the difference between calculation and value of all sample parameters participating in the calculation. Each color line represents a set of sample parameters. The bottom and top of the icon are the preset minimum values and maximum value of these parameters.

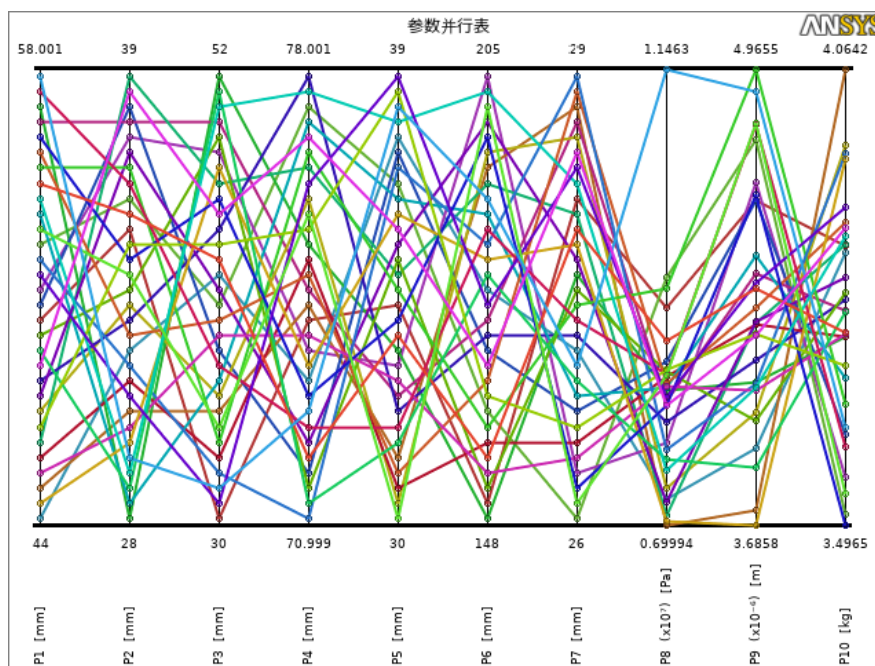


Fig 3.18 Parallel table of parameters

The following three graphs are iterative graphs of the three optimization parameter goals. After a certain number of iterations, the numerical fluctuation will decrease and tend to a smaller interval.

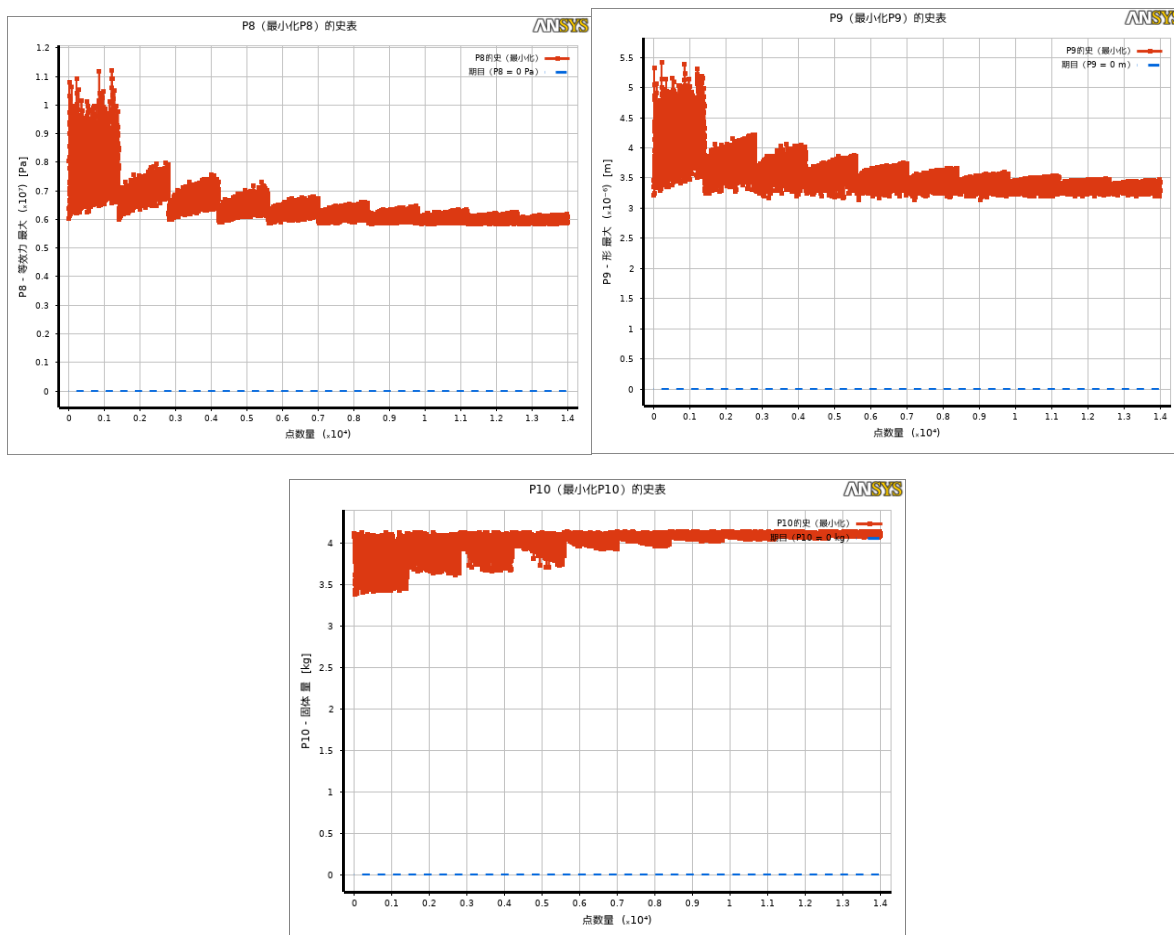


Fig 3.19 Iterative graph

View the maximum equivalent stress 3D response table. The coordinate system of this chart is three-dimensional, where the x-axis and the y-axis represent the diameters of the two weight-reducing holes D17 and D23 respectively, and the z-axis represents the maximum equivalent stress of the model. We can see that the diameter of the two weight-reducing holes With the increase of, the maximum equivalent stress also increases. This can be understood as the increase in the circular hole will

reduce the material of the part, and the decrease in the pressure resistance will naturally increase the stress.

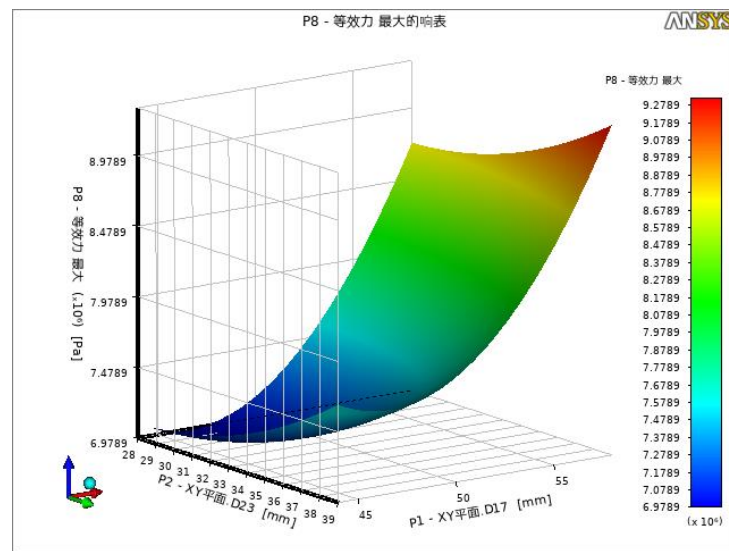


Fig 3.20 Maximum equivalent stress

View the normalized value of the sample. Normalization is a way to simplify calculations, that is, a dimensional expression is transformed into a non-dimensional expression and becomes a scalar. The three sets of parameters (maximum equivalent stress, maximum deformation, and solid mass) after normalization are on a straight line in the normalized coordinate system.

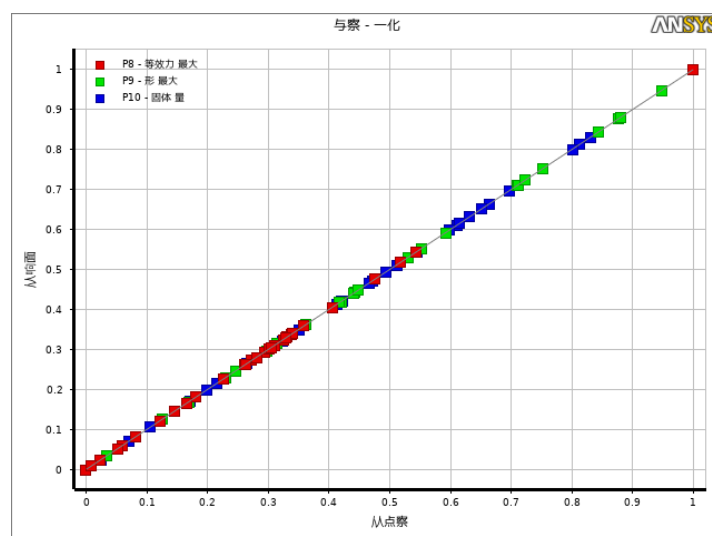


Fig 3.21 normalized value of the sample

View the parameter comparison curve of the three candidate points. The values at the bottom and top of this icon respectively indicate the minimum and maximum values of various parameter settings. By observing the three candidate points, we can know that the size and position of the weight reduction holes on the right side of the three sets of data and the positions of the weight reduction holes on the left side near the front edge of the wing rib are quite different, while their left side The size of the weight-reducing hole, the thickness of the part, the weight of the part, the maximum equivalent stress, and the maximum deformation are all very similar. The performance in the chart is that the similar parameters are superimposed together, and the parameters with larger differences will be staggered up and down. .

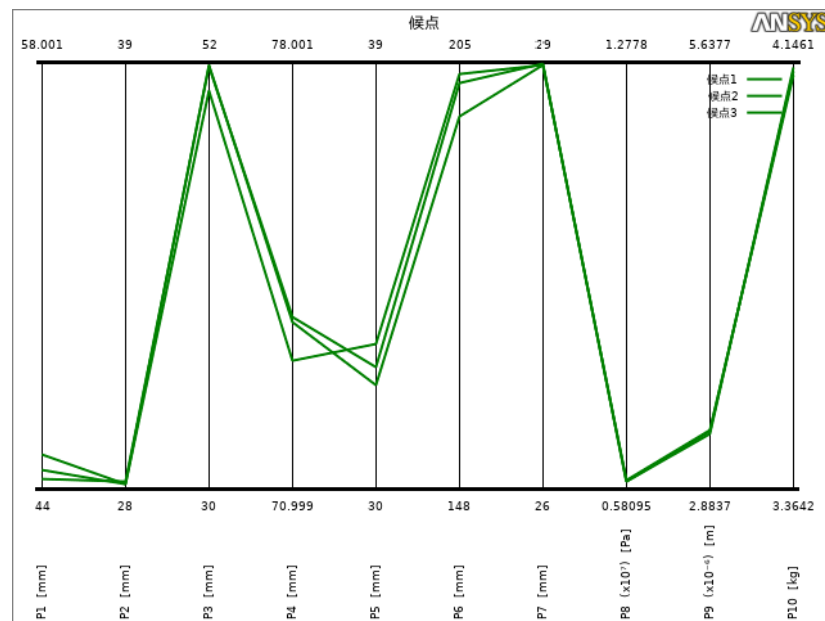


Fig 3.22 Three candidate points

After selecting the parameters, you can view the spider graph of the three sets of data as the optimization target. The icon shows the relationship between the three parameters to a certain extent.

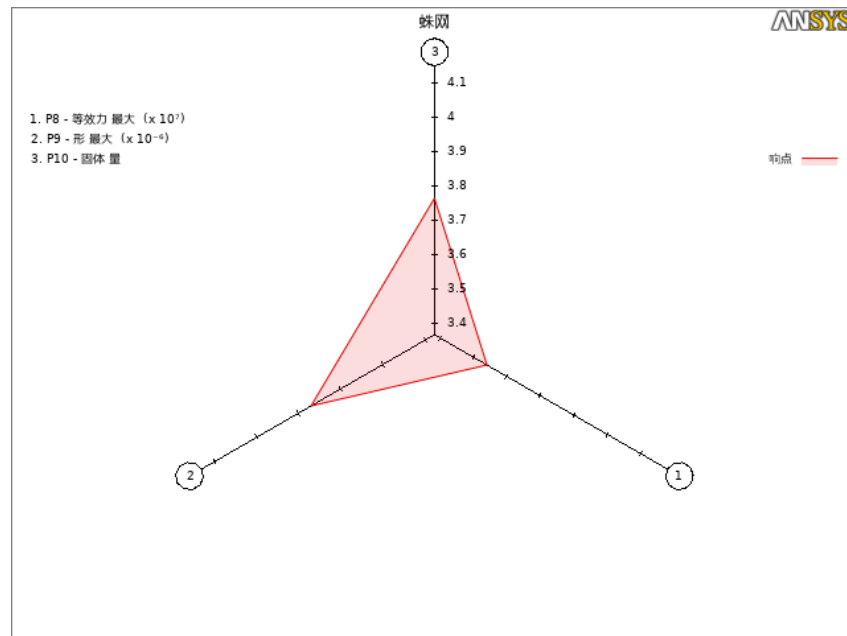


Fig 3.23 Cobweb

View the local sensitivity graph. Sensitivity analysis is used to qualitatively or quantitatively evaluate the influence of model parameter errors on model results. It is a useful tool in the process of model parameterization and model correction, and has important ecological significance. Sensitivity analysis includes local sensitivity analysis and global sensitivity analysis. Local sensitivity analysis only examines the degree of influence of a single parameter change on the model results; global sensitivity analysis examines the total influence of multiple parameter changes on the model's running results, and analyzes each parameter The effect of the interaction between its parameters on the model results. At present, in the sensitivity analysis of ecological models, the method of global sensitivity analysis is more and more inclined.

It can be seen from the figure that the increase of the weight reduction hole on the right side of the part will make it easier to increase the values of the two parameters of maximum equivalent stress and maximum deformation, making it

easier to reduce the quality of the part, and the increase in the thickness of the part is more than other parameters. It is easy to increase the weight of parts.

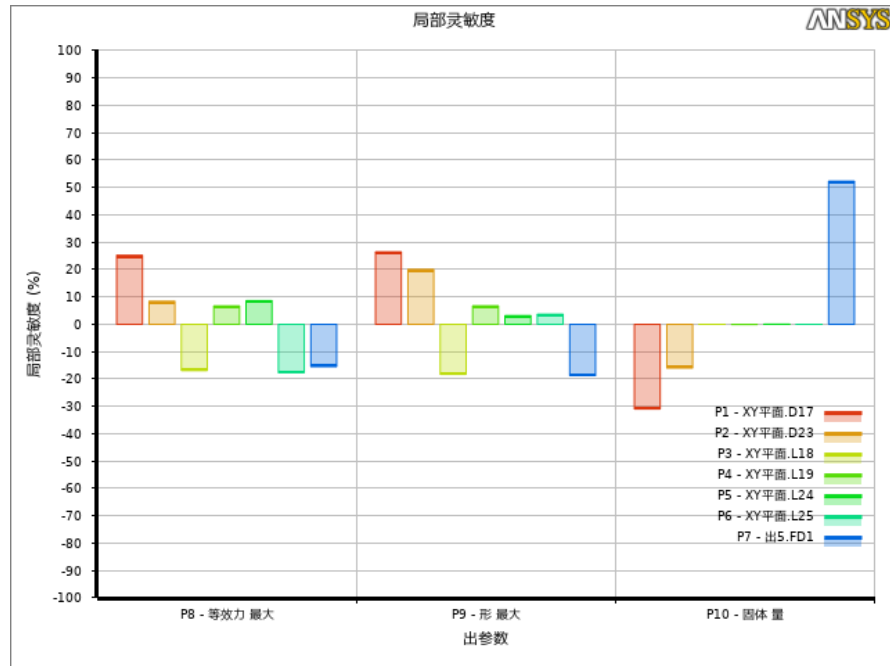


Fig 3.24 Local sensitivity

Check the sensitivity chart. Sensitivity is a way to quantitatively describe the importance of model input variables to output variables. Suppose the model is expressed as $y=f(x_1, x_2, \dots, x_n)$ (x_i is the i -th attribute value of the model), so that each attribute changes within the possible range of values, and research and predict changes in these attributes will affect the model. The degree of influence of the output value. We call the degree of influence the sensitivity coefficient of the attribute. The larger the sensitivity coefficient, the greater the influence of the attribute on the model output. The core purpose of sensitivity analysis is to analyze the attributes of the model to obtain the sensitivity coefficients of each attribute. In practical applications, attributes with small sensitivity coefficients are removed based on experience, and attributes with larger sensitivity coefficients are considered. This can greatly reduce the complexity of the model, reduce the workload of data analysis and

processing, and improve the accuracy of the model to a large extent. At the same time, researchers can use the ranking results of the sensitivity coefficients of various attributes to solve corresponding problems.

It can be seen from the figure that the maximum equivalent stress of a part is most affected by the lateral position of the weight-reducing hole on the right and the position of the weight-reducing hole on the left, and the maximum deformation and weight of the part is most affected by the diameter of the weight-reducing hole on the right.

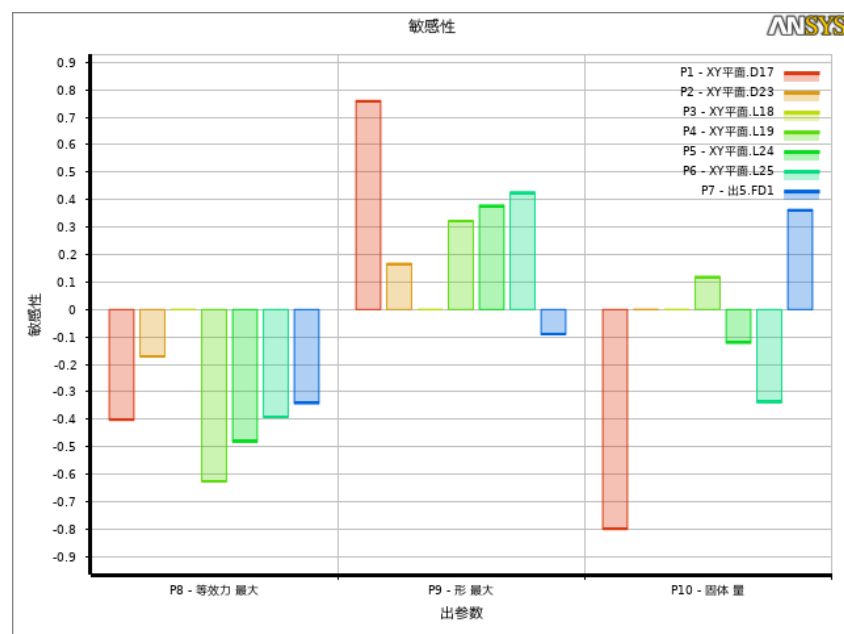


Fig 3.25 Sensitivity

View the maximum equivalent stress at the design point. This chart visually shows the maximum equivalent stress value and gap between the thirty sets of sample parameters.

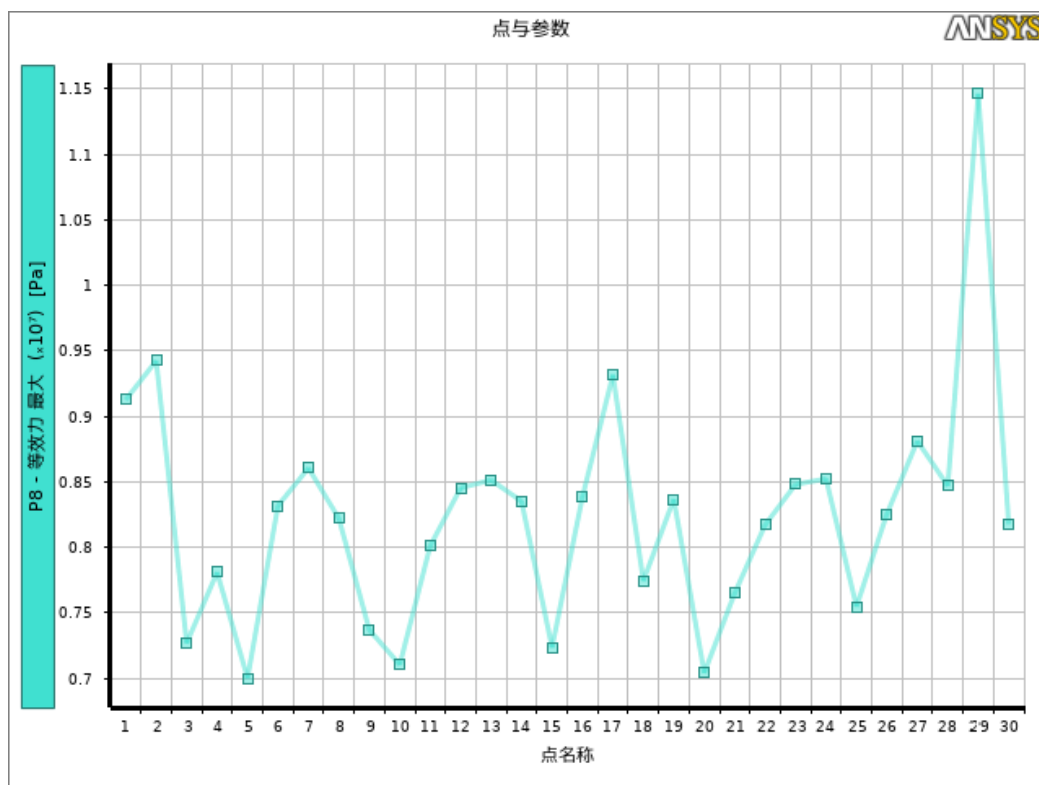


Fig 3.26 Maximum equivalent stress

Since the subsequent topology optimization can greatly reduce the quality of the solid, and the maximum deformation is in the micrometer range, the third set of parameters with the smallest maximum equivalent stress value is selected from the three candidate points as the optimal solution.

	A	B	C	D	E	F	G	H	I	J	K	L
1	名称	P1 - XY平面.D17	P2 - XY平面.D23	P3 - XY平面.L18	P4 - XY平面.L19	P5 - XY平面.L24	P6 - XY平面.L25	P7 - 挤出5.FD1	P8 - 等效应力最大	P9 - 总变形最大	P10 - 固体质量	保留
2	单位	mm	mm	mm	mm	mm	mm	mm	Pa	m	kg	
3	DP 0	32	24	45	74	43	145	30	7.086E+06	3.086E-06	4.4972	<input checked="" type="checkbox"/>
4	DP 211(当前)	44.426	28.022	49.574	74.094	32.752	203.25	28.986	6.7238E+06	3.4629E-06	4.1381	<input checked="" type="checkbox"/>
5	DP 212	56.833	28.183	51.633	75.317	33.45	148.95	27.65	8.3176E+06	4.0896E-06	3.7316	<input type="checkbox"/>
6	DP 213	44.643	28.151	50.563	73.126	33.089	203.46	28.983	6.584E+06	3.4448E-06	4.1328	<input type="checkbox"/>
*												<input type="checkbox"/>

Fig 3.27 Select candidate points

2.5.5 Data import

Import the selected parameters into the parameter set and update the geometric structure module, so that the size and position of the model's weight reduction holes are also updated to the optimized look. Comparing the model before and after

optimization will find that the size and layout of the weight reduction holes are more reasonable.

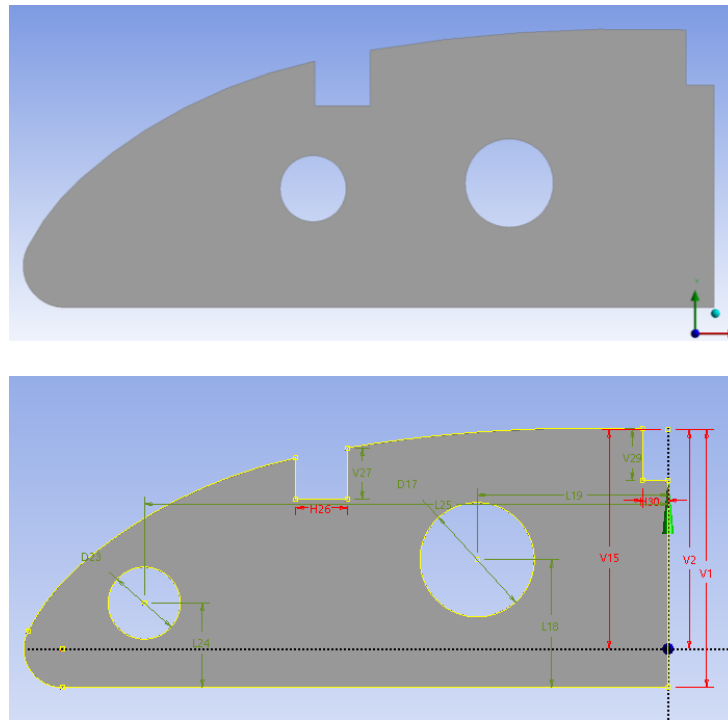


Fig 3.28 Comparison of No. 1 model and No. 2 model

Finally, the performance parameters of this model are collected: the maximum equivalent stress is $6.584\text{E}+06$ Pa, the maximum deformation is $3.4448\text{E}-06$ meters, and the solid mass is 4.1328 kg.

2.6 Topology Optimization

After parameter optimization, the model weight reduction hole is still a regular circle, and the part performance is excessive, there is still a lot of room for optimization. At this time, topology optimization is needed to further increase the mechanical properties of the model and reduce the weight of the model by changing the shape of the hole.

The topology optimization module of Ansys Workbench 2020 does a pretty good job. As for what is topology optimization, topology optimization is to let the model automatically perform the topology of the shape.

2.6.1 Pretreatment

In the topology optimization module, the optimized area is defined as the weight reduction hole and its surrounding part, and the percentage of the reserved volume is 50%. The reason for choosing to set the reserved volume to 50% is that the result of topology optimization can only provide a rough shape distribution. Retaining a part of the volume can make the structure shape clearer, which is convenient for subsequent secondary processing and modeling.

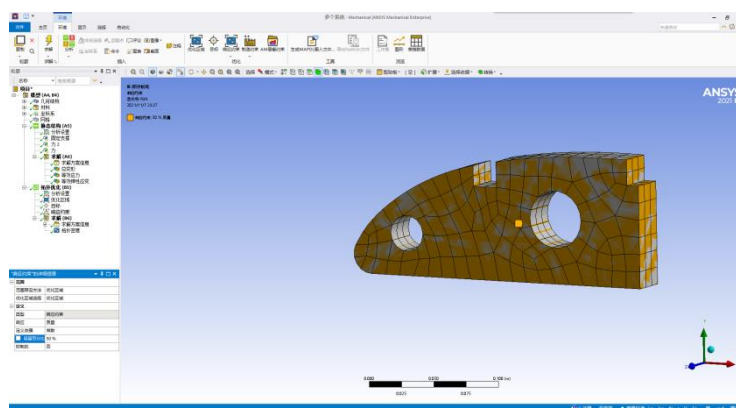


Fig 3.29 Optimize the interface

2.6.2 Solve

After the optimization, the weight-reducing holes of the model obtained become larger and have irregular shapes. At this time, the surface quality of the model is poor, and the mesh cannot be directly divided for force analysis.

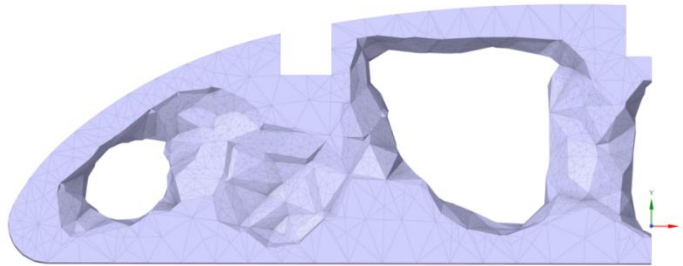


Fig 3.30 Optimization Results

2.6.3 Remodeling

After topology optimization, the model is initially obtained. This model is very rough and needs to be processed twice, that is, re-modeling.

Open the model with the SC (SpaceClaim) module and create a sketch surface on the side of the model. At this time, the contour of the contact part between the model and the sketch surface is automatically outlined with lines.



Fig 3.31 Define the sketch face

Use the fit curve function to copy the contour to the sketch surface. Part of the lines copied to the sketch can be used directly, and the rest of the irregular lines can be deleted one by one.



Fig 3.32 Copy outline

Use the spline curve to draw the outline of the weight reduction hole according to the shape of the model to complete the sketch.

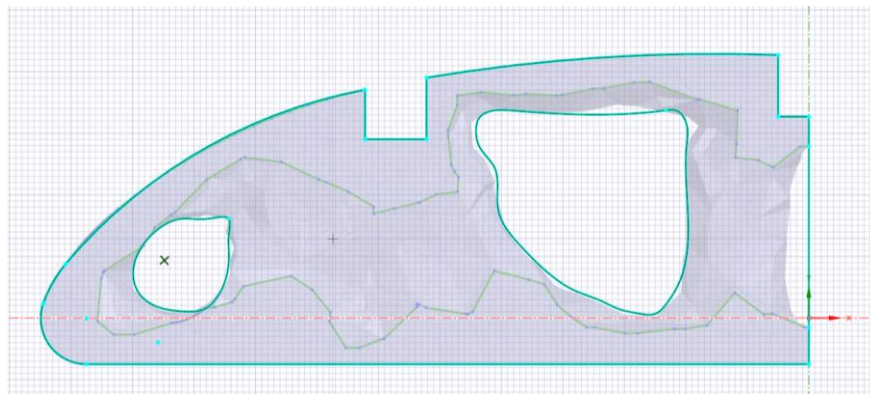


Fig 3.33 Complete the sketch

After extruding the sketch into a body, the final model is obtained.

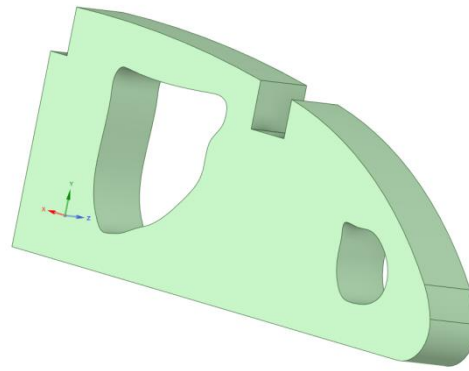


Fig 3.34 Model Three

2.7 Force analysis

Perform the same preprocessing on the new model and then solve it.

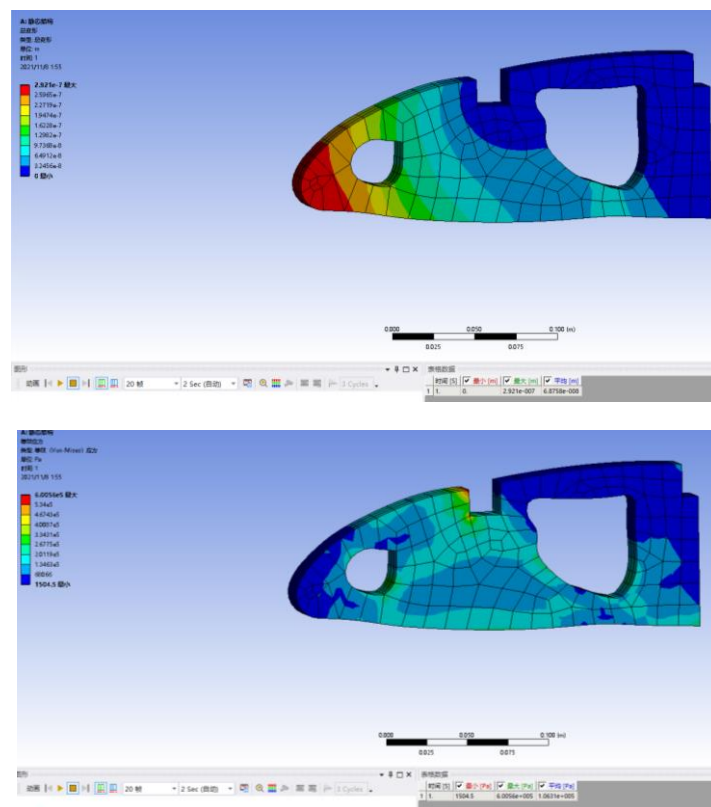


Fig 3.35 Deformation and stress diagram

Collecting data shows that the maximum deformation is $2.921\text{E}-007$ meters, the maximum equivalent stress is $6.056\text{E}+005$ Pa, and the mass is 3.2034 kg.

2.8 Summarize

The mechanical parameters of the three models are compared to get Table 3.1.

Table 3.1

Comparison of three model data

Model number	Maximum deformation(m)	Maximum equivalent stress(Pa)	Weight(kg)
1	2.8997e-006	6.6604e+006	4.4972
2	3.4448e-006	6.5840e+006	4.1328
3	2.9210e-007	6.0560e+005	3.2034

No. 1 is the model created for the first time, No. 2 is the model generated after parameter optimization, and No. 3 is the model after topology optimization.

After the comparison, the maximum deformation of the No. 3 model is reduced by 89.9%, the maximum equivalent stress is reduced by 90.9%, and the weight is reduced by 28.8% compared with the No. 1 model.

3.Environmental protection

3.1 Short takeoff and landing cargo airplane and its impact into environment

Most airplanes that use aviation fuel become pollution sources because of the following main reasons: exhaust emissions, noise generation, and water pollution. Among them, air pollution has the most serious damage to the environment.[4]

Before analyzing environmental pollution, we need to understand the main differences between passenger aircraft and cargo aircraft. These differences will lead to differences in the way they pollute the environment. There are three main differences between passenger and cargo aircraft.

1. Different loads: passenger planes mainly carry passengers, followed by cargo. The cargo plane only transports cargo.

2. The structure of the fuselage doors is different: passenger planes have more boarding doors for human use and escape doors for use in the event of an accident. There are fewer doors for humans to enter and exit cargo planes. The largest cargo doors on cargo planes are distributed in the front and rear cargo compartments of the fuselage and in the lower cargo compartments. These doors are generally more than 2 meters in height and 3 meters in width, all of which are used to load cargo.

3. The transportation method of the load is different: the passenger aircraft cargo transportation method is to first transport the luggage that needs to be checked from the terminal to the apron, and then transport the luggage to the cargo hold of the aircraft by a special conveyor. The cargo loading of cargo planes mainly uses trucks with a larger size and load capacity and a lifting platform. After the truck raises the

cargo to the height of the cabin door, the rollers or conveyor tracks on the platform transport the cargo into the cabin.

It can be seen from the above that passenger planes need more space for passengers to move around, while freight planes have heavier weight, take-off weight, greater fuel consumption, and more exhaust emissions than passenger planes.

3.1.1 Air pollution

During the operation of an aircraft engine, oxygen in the air and aviation fuel are mixed and chemically reacted to produce gas. Vaporized water, carbon oxides, nitrogen oxides. The incomplete combustion of aviation fuel produces fine particles, which are composed of hydrocarbons, sulfur oxides, and carbon. The gas emitted by airplanes can cause the greenhouse effect is carbon dioxide.[5]

Carbon dioxide

Greenhouse gases are the most important substances that can cause changes in the earth's climate. The effects of carbon dioxide are not much different at any altitude. And not just airplanes, the airport where the airplane is located also produces carbon dioxide from land vehicles such as vehicles in the airport.[6]

Nitrogen oxides (nitrogen monoxide and nitrogen dioxide)

Above the troposphere, the emission of nitrogen oxides is conducive to the formation of ozone. At altitudes of 8 to 13 kilometers, nitrogen oxides cause the concentration of ozone in the air to increase, and these reactions will have a greater impact on global warming. The influence of ozone concentration will fluctuate with regional changes, but in the upper and middle troposphere, its concentration is

relatively even on a global scale. The sulfur and water emitted by the aircraft flying at the corresponding altitude will chemically react with ozone, and these reactions offset part of the increase in ozone caused by nitrogen oxides.[7]

Flight trail

The combustion of aviation fuel produces water vapor, which condenses into a stripe cloud visible to the naked eye under conditions of high altitude, low air pressure, low temperature and high humidity, also known as contrails. They are thought to contribute to the greenhouse effect, but they are not as large as aircraft carbon dioxide emissions. The wake may have an additional impact on global warming.[8]

3.1.2 Sound pollution

Noise is the sound produced when an object vibrates irregularly. Sound is produced by vibration and travels through a specific medium. Generally speaking, noise pollution is man-made. Sounds that interfere with people's rest, study, and work, as well as sounds that interfere with people's desire to hear, or unwanted sounds, are collectively called noise. Noise pollution occurs when noise has an adverse effect on people and the surrounding environment. Noise can damage hearing, cause a variety of carcinogenic and fatal diseases, and interfere with people's lives and work.

3.1.3 Water pollution

Water pollution refers to water that reduces the use value of water or pollutes the environment due to harmful chemical substances. The acids, alkalis, oxidants,

heavy metals, organics and other elements in the water can poison aquatic organisms and affect drinking. When organic matter is decomposed by microorganisms in the water, the microorganisms consume oxygen in the water, thereby affecting the life of macro aquatic organisms in the water. After the oxygen elements dissolved in the water are exhausted, microorganisms decompose organic matter anaerobically, producing toxic gases such as hydrogen sulfide, which further deteriorate water quality.

The operation of the airport consumes a lot of fuel, lubricants and other chemicals. If the waste liquid produced by these consumption is not handled properly, it will seriously pollute the water resources of the surrounding large area of land. Chemical spills can be mitigated or prevented by leak containment structures and cleaning equipment (such as tankers, portable berms, and absorbents).

3.2 The ways to reduce pollution

There are many methods such as reducing air travel, distance restrictions, route optimization, regulating emission caps, increasing taxes and reducing subsidies, and aviation's environmental impact will be alleviated.[9]

3.2.1 Reducing air travel

Reducing the number of aircraft flights is the most direct way to reduce pollution. For example, during the new crown epidemic in recent years, many airports have been shut down and flights have been cancelled in large numbers. This has directly improved the air and water quality around the airport. But this method is not

good for the circulation and development of the world economy, so this method is a last resort until humans invent more efficient vehicles.

3.2.2 Taxation and subsidies

Appropriate financial sanctions can reduce the airline's habit of arranging inefficient flights and priority transportation options for passengers and aircraft, and promote aviation-related companies to improve route efficiency.

Existing feasible aviation taxes include: air passenger tax; departure tax; aviation fuel tax.

Reducing subsidies for unsustainable aviation and subsidizing the development of sustainable alternatives can affect consumer behavior. In a poll conducted by the European Investment Bank, between September and October 2019, 72% of EU citizens will support a carbon tax on flights.

Aviation tax can reflect all its external costs and can be included in emissions trading schemes. Until the 2016 ICAO triennial meeting agreed on the CORSIA offset plan, international aviation emissions were not subject to international regulation. Because aviation fuel taxes are low or non-existent, air travel has a competitive advantage over other modes of transportation.

3.2.3 Alternative fuels

Biofuels are usually composed of or converted from living organisms, and generally appear as solids, liquids, or gases. Biofuels are easy to store and transport,

and can replace petroleum fuels to a certain extent. The narrow definition of biofuel mainly includes fuel ethanol, biodiesel and aircraft biofuel.

Since the 1970s, traditional energy prices have soared, people's awareness of environmental protection has increased, and global climate has become warmer. Countries around the world have gradually paid attention to the development of biofuels. Brazil, the United States and the European Union are actively developing biofuel technology. Currently, the United States and Brazil are the two countries with the strongest biofuel production technologies in the world. At the end of the 20th century, China began to promote fuel ethanol in order to solve the problem of spoiled and expired grains and to increase corn production. At present, in order to promote the healthy development of the biofuel industry, the liquid biofuel technology developed in China is mainly based on carbohydrates and lignocellulose from non-food crops such as potatoes and sorghum.

In the aviation field, biofuels are generally produced from biomass such as animal and vegetable oils or agricultural and forestry wastes as raw materials, and hydrogen is added to the fuel during the production process.

Some indicators of biofuel performance are even better than traditional aviation kerosene. It alone or in combination with petroleum-based aviation kerosene can meet the various requirements of aircraft navigation, and there is no need to design additional engines or aircraft or airports for it, and there is no need to develop new fuel transportation systems for it. This kind of biofuel can be directly used in most civil aircraft turbine engines after being mixed with traditional fossil aviation kerosene in a volume ratio of 1% to 50%.

My country has completed the first verification flight of China's aviation biofuel. PetroChina uses Jatropha oil as the raw material. After refining and conversion, it is blended with petrochemical jet fuel at a ratio of 50% and filled into the fuel tank of a Boeing 747 passenger aircraft. The flight test at the international airport was successful.

3.2.4 Carbon offsetting

Faced with increasingly severe environmental and climate issues, people have gradually realized the significant impact of human activities on climate change. On this basis, the global climate change dialogue came into being. Taking into account the differences in the level of economic development and per capita carbon emissions of various countries, the "United Nations Framework Convention on Climate Change" has established "common but different responsibilities" under this principle. The United Nations Climate Change Conference was held in Kyoto, Japan on December 11, 1997, and the "Kyoto Protocol" was formally adopted. By dividing participating countries into Annex I and non-Annex I Parties, most of the Parties included in Annex I are developed countries. It should also ensure that the total amount of human equivalent carbon dioxide emissions does not exceed the quantitative limit stipulated in the protocol. For non-Annex I parties, there is no mandatory emission reduction target requirement.

At the same time, the "Kyoto Protocol" provides three carbon offset mechanisms to encourage regions outside of Annex 1 and Annex 1 to participate in carbon emission reduction activities in response to environmental changes. Most

international carbon offset mechanisms are mechanisms bound by international climate treaties. Usually managed by an international organization. These include the international emissions trading mechanism, joint action mechanism and clean development mechanism.

1. International Emissions Trading Mechanism: This mechanism mainly exists in developed countries. Developed countries with excess emissions will transfer the excess emission reduction commitment quotas to developed countries that have not fulfilled their emission reduction commitments in the form of trade at the same time, and the relevant transfer amount will be deducted from the transferor's allowable emission limit.

2. Joint action mechanism: through project-level cooperation between developed countries, the emission reductions obtained can be transferred to contracting parties in other developed countries. But at the same time, the corresponding amount of the transferor must change. Subtract from the allocated amount

3. Clean Development Mechanism: Developed countries carry out project-level cooperation with developing countries by providing financial and technical support. Developing countries have achieved "certified emission reductions" by implementing emission reduction plans, and developed countries. The parties will use it to offset the same amount of carbon emissions. Therefore, it has fulfilled its obligations under Article 3 of the Protocol.

3.2.5 Carbon neutrality

Carbon neutrality is a term for energy saving and emission reduction. It refers to the total amount of greenhouse gas emissions produced directly or indirectly by enterprises, groups or individuals in a certain period of time, and the total amount of carbon dioxide emissions that can be offset by means of tree planting, energy saving and emission reduction. In this way, "zero emissions" of carbon dioxide can be achieved.

The means to reduce carbon dioxide emissions is to accumulate carbon elements, which can absorb and store carbon elements in the atmosphere through the soil, forest, ocean and other ecosystems with microorganisms and plants. Then there is carbon offset, which can invest in the development of renewable energy. There are also low-carbon clean technologies that reduce the carbon dioxide emissions of one industry to offset the carbon emissions of another industry. The offset of carbon dioxide can be measured in tons. If the amount of carbon dioxide emitted is offset, people will enter a net-zero carbon society. The currently feasible operation steps are as follows:

Step 1: Calculate the carbon footprint and establish a low-carbon system.

Calculating the carbon footprint of an activity is the first step in managing carbon emissions. The government or company collects data on emission sources, locates the company's greenhouse gas emission sources, and conducts statistics and quantification on the collected data.

Step 2: Reduce carbon emissions

Through the positioning and analysis of the company's carbon emission sources, it is

possible to better understand the company's carbon emissions and formulate a series of effective measures accordingly to reduce the carbon emissions generated by the company's production and operation activities.

Step 3: Achieve carbon neutrality

The offset of carbon emissions is achieved through the purchase of voluntary carbon emission reduction credits. Voluntary is the basic principle, that is, a neutral trading method. The realization of carbon neutrality is usually done jointly by the buyer (emission party), the seller (the emission reduction party) and the trading agency (intermediary).

3.3 Chapter summary

Aircraft pollution is diversified, and solutions are also diversified. As long as the right remedy is applied, combined with the research of national policies and new technologies, it is still very hopeful that the problem of aviation pollution will be solved in this century.

4. Labor protection

4.1 Introduction

In the production and manufacturing process of the aircraft body, it has to go through the processes of process preparation, process equipment manufacturing, blank preparation, parts processing, assembly and testing. In aircraft manufacturing, coordinated technologies that are different from general mechanical manufacturing (such as mold line model work) and a large number of unique process equipment (such as various jigs and fixtures, mold tires and frames, etc.) are used. These technologies and equipment are used to ensure The manufactured airplane has an accurate shape. Process preparation includes the determination of coordination methods and coordination routes in manufacturing, and the design of process equipment.[10]

4.2. Analysis of working conditions in the workplace

(1) Aircraft flat-mounted tail processing workshop

Because there are many kinds of processing equipment in the tail processing workshop, the air will be mixed with the strong paint smell from chemical products and the noise of various drilling machines. The technicians in the workshop need skilled skills, work intensity is relatively high, and they also have certain requirements for physical fitness. For product inspection, workers need to conduct thorough inspections bit by bit, and no one can be missed. The color of work clothes must be uniform. Workers working in some processes must wear protective glasses and masks. There are hundreds of processes for the flat-mounted rear wing of an

airplane. It takes hundreds of times to produce an airplane. It is a very huge project. The potential safety hazards are countless. Most of the current safety regulations and clauses are the injuries or sacrifices of the predecessors. The accumulated experience.

(2) CNC machining workshop

Numerical control processing workshops are full of various large-scale machinery, such as planers, lathes, milling machines, etc., and the equipment in the aircraft manufacturing plant is larger than that in ordinary workshops. They are all super-large machinery. These large-scale machinery are not only in use, but also in workers. It will cause safety hazards during the maintenance and maintenance process.

(3) Sheet metal workshop processing workshop

At present, there are still a lot of manual processing in domestic sheet metal processing workshops, especially fitters, which have a high demand for workers' skills and safety awareness.

4.3 Formulate labor protection measures

1. The purpose of the labor protection regulations is to adopt some compulsory labor protection measures and protections for workers working in the aircraft production and assembly workshops during work, so as to prevent safety accidents caused by accidents during work. Or personal injury accidents can also minimize the occurrence of machine failure incidents.

2. Before the new employee Wang officially enters the workshop to work, he must pass the factory safety operation training and operation skills training and pass

the assessment before he can start operation. Old employees must participate in various safety skills training held in the factory every year for the purpose of continuous Update safety knowledge and reduce the occurrence of safety accidents.

3. Workshop operators must strictly follow the operating procedures of their respective workshops, and must wear tooling, work shoes, safety hats, gloves, protective shields, and earplugs. When operating or overhauling in dangerous areas, they must strictly follow the prescribed procedures. Only after formalities and protective measures have been taken.

4. Employees can take sick leave if they are sick: regular employees can apply for sick leave for treatment or recuperation when they are sick (injury or sickness not due to work). Regular employees are entitled to 12 days of sick leave with full pay each year. If sick leave exceeds 12 days, the excess time can be treated as personal leave with special approval by the general manager.

5. Employees can take work injury leave for work injury. Wages will be paid during work injury leave. Medical expenses will be paid by the company's insurance company. If an employee injured at work needs to be taken care of by someone during the treatment period, the company will send someone to take care of it after confirmation by the company. , The cost of care is paid by the company at \$5 per day.

6. Workshop operators are not allowed to drink alcohol within eight hours before going to work, so as not to cause work-related accidents or machine accidents due to drinking alcohol to work.

7. Employees are not allowed two consecutive shifts to avoid safety accidents or personal injury accidents caused by excessive fatigue.

4.4 Fire safety in production sites

4.4.1 Fire safety education and training system

1. New employees entering the factory must undergo pre-employment training on fire safety. The training content includes: basic knowledge of fire safety, the operation and use of fire extinguishers and hydrants, etc.

2. Conduct fire safety training and education for each employee at least once a year, and record the training situation on file.

3. The company conducts evacuation drills for all employees every quarter, and conducts special training on fire-fighting drills for voluntary firefighters, so that each team member can use fire-fighting equipment proficiently.

4. The company's fire safety responsible person, fire safety manager, full-time and part-time fire management personnel, fire control room operators and other relevant personnel shall receive special training on fire safety.

5. Electric welding, gas welding, boiler workers and others who work in fire-hazardous areas and automatic fire-fighting system operators must undergo fire-fighting training and hold certificates.

6. The fire safety education and training carried out by various workshops, teams and other departments should be based on the characteristics of each department, each stage, and each word.

7. The company conducts regular fire safety publicity and education through various forms.

4.4.2 Fire protection inspection system

1. Establish a gradual fire safety responsibility system and a post fire safety responsibility system, clarify their respective responsibilities, and implement an inspection and inspection system.

2. The company's security department personnel conduct daily fire inspections on the company. The company's safety department and the environmental safety department conduct fire-prevention inspections on the company every month and review and track improvements.

3. When a fire hazard is discovered during the inspection, the inspector should fill in the record, and in accordance with the regulations, require the relevant personnel to sign on the record.

4. The inspection department shall promptly notify the inspected department of the inspection results in written form, and the person in charge of the inspected department shall promptly rectify fire hazards in accordance with the notification requirements.

5. If the hidden fire hazard discovered during the inspection fails to be rectified in a timely manner within the prescribed time, it shall be punished in accordance with the company's regulations.

4.4.3 Safety evacuation facility management system

1. The width of the safety exit doors, evacuation stairs, and evacuation corridors of the workshops, warehouses, and dormitories in the factory must be set according to the specifications.

2. All evacuation exits, stairs and walkways must be equipped with corresponding emergency lighting and evacuation signs.

3. When going to work, production workshops, and warehouses should ensure that safety exits are unblocked, and safety exits must not be locked.

4. Workshops and warehouses shall store items in accordance with regulations and shall not block the passages.

5. The person in charge of each department should regularly check whether the evacuation signs and emergency lighting facilities are in good condition according to regulations, and repair them if they are damaged.

4.4.4 Maintenance and management system for fire-fighting facilities and equipment

1. The company's fire-fighting facilities and equipment are managed by the Safety Department, and the fire-fighting facilities and equipment are regularly inspected and tested.

2. Establish file management for fire-fighting equipment and fire-fighting facilities.

3. Fire-fighting facilities and fire-fighting equipment should be stored at designated locations, maintained by dedicated personnel, and regularly inspected, and the inspection records should be archived.

4. Educate all employees of the company, require employees to take good care of fire-fighting facilities and equipment, and demand compensation and penalties for acts of deliberately destroying or damaging fire-fighting facilities and equipment.

5. In accordance with national legal requirements, the company shall set up fire safety evacuation signs and emergency lighting and other fire-fighting equipment and facilities that comply with national regulations, and keep the fire-fighting facilities in a normal state.

4.4.5 Fire hazard rectification system

1. The management functional department of the company's security department conducts fire prevention inspections on all departments once a month, and orders them to limit changes in writing for the problems found, and supervises the rectification in place.

2. The person in charge of fire safety or the fire safety manager shall organize a fire safety meeting once a month to discuss the hidden fire hazards discovered during the inspection and the corresponding rectification measures to ensure safe production.

3. All departments of the company shall promptly urge relevant personnel to implement rectification measures after receiving the rectification of fire hazards at the same time. Departments that cannot be rectified for a while shall implement preventive measures to ensure fire safety.

4. After the fire hazard rectification is completed, the department in charge of the rectification or the person in charge shall report the rectification situation to the

company's fire safety responsible person or fire safety manager for signature, and file it for future reference after confirmation.

5. For the fire hazard that the fire protection agency is ordered to rectify within a time limit, the company responsible for rectification shall make rectification within the prescribed time limit and issue a fire hazard rectification response letter to the public security fire protection agency.

4.4.6 Fire safety management:

1. Strictly implement the hot fire approval system. When hot work is really necessary, the operating unit shall apply for the "hot license" to the security department and other relevant departments in accordance with the regulations, and the outsourcing construction shall be applied for by the contract issuing unit.

2. Before the operation, the inflammable and explosive dangerous goods within 4 and a half meters of the hot spot should be removed or be properly isolated for safety, and appropriate types and quantities of fire-fighting equipment should be borrowed from the security department for standby at any time. After the operation is completed, the Return immediately, and report truthfully if used. The outsourcing construction unit should bear the cost of refilling the fire extinguisher. If it causes other benefits or losses, it should compensate for the price and bear the responsibility.

3. In the case of on-site hot construction at the operation site, the application shall be signed to the manager-level (including) supervisor of the unit where the operation site is located according to the regulations. The applicant unit needs to send on-site supervision, and the security department also needs to send people from time

to time. Go to patrol. Elevated hot work above 2 meters above the ground must ensure that one person is fully responsible for extinguishing sparks that may ignite other objects at any time.

4. Under the premise of ensuring safety and not affecting the normal production on site, it is required in principle that night fires are prohibited when applying for the "hot work application form", and night fires are strictly prohibited in particularly dangerous work areas.

5. The countersignature and approval of hot work during overtime attendance on holidays and holidays shall be carried out in accordance with the fourth power. Hot work during on-site public holidays should be applied for in advance, and the construction unit will send a person to be responsible for supervision. If the contractor is responsible for hot work, the contracting unit will send a person to be responsible for guardianship.

6. Those who do not apply for the "hot work permit" without authorization will be given a second penalty for minor demerits, and severely fired; for outsourcing construction, a fine of 100 US dollars will be imposed on the outside contractor, and they will be required to complete the formalities. construction.

4.5 Chapter summary

The purpose of labor protection is to protect the health of workers during the labor and production process, avoid the hazards of toxic and harmful substances, and prevent and eliminate occupational poisoning and occupational diseases. Enterprises must meet the labor hygiene standards in accordance with these labor hygiene regulations in order to effectively protect the health of workers.

General conclusion

This paper studies the preliminary design of a 30-ton short-distance take-off and landing cargo aircraft and the optimization design of aircraft parts. First, the basic parameters of the aircraft are calculated, and then the parameter optimization and topology optimization of the aircraft parts are carried out. Finally, the following conclusions are obtained:

1. The size and position of the weight-reducing hole of the part have the greatest influence on the maximum equivalent stress and maximum deformation.

2. The thickness of the model has the greatest influence on the weight of the part.

3. Parameter optimization and topology optimization can significantly improve the mechanical properties of parts and reduce the weight of parts.

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