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An Anatomy of a Warning Aircraft

Chao Shu-min

We already know that an aircraft which carries a huge disk on its back is a warning aircraft. What is inside the disk? What is the effect of the disk on the aircraft and its filght? What is inside the body of the aircraft which is of the size of a transport plane? We are now trying to answer these questions by anatomizing a warning aircraft.

Aircrafts like to have a smart looking and their appearance is always streamlined and smooth. It is strange,however, a warning aircraft,contrary to most of others, canstantly carries a huge disk, which makes a clumsily outstanding feature of a warning aircraft. We now begin our anatomy with this clumsy disk.

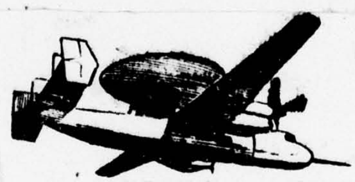


Figure 1

Secret of The Disk

Stripping off the cover of the disk, we can see inside it nothing mysterious but many sets of antennae. For carrying out its duties of reconnaisance and direction,antenna is indispensable to a warning aircraft. There are antennae which are responsible for watching radar and others which are assigned to identify enemy, and there are also antenna auxiliary apparatuses. So people give such a disk a name of radar-antenna cover.

In fact, not every radar-antenna cover looks like a round plate.

many of them are of convex shape or an ellips, but most of them are in the shape of round plate. The corss-section of a disk shows similar shape to that of an airfoil, but their positions on an aircraft are different. The size of radar-antenna cover varies from different aircrafts. Because it must be set up on an aircraft, for not jeopardizing its application, its size is the smaller the better. For minimizing its weight, the thickness of its walls is not even. According to the requirement of its supporting force, the central part is made thicker than marginal part. In order not to affect the electric waves emitted from the antenna, the radar-antenna cover is not made of metal but a kind of glass steel.

There are two different kinds of radar-antenna covers: the fixed one and the spinning one. On the warning aircraft of earlier days, the radar-antenna cover is fixed, such as on EC-121. Later it becomes spinning. The operation of a fixed radar-antenna cover is that the antenna spins within the cover to make search, and the operation of a spinning one is that the antenna is fixed in the cover and it spins to make search following the spinning of the cover. The spinning speed is six rounds per second, and the search direction is 360°, except for some special sector search.

Warning Aircraft and Transport Plane

By appearance, a warning aircraft looks like a product of a combination of a large aircraft and a huge disk, in other words, it looks like a combination of a transport plane and radar-antenna cover. Except for the US warning aircraft E-2A, which is specially desinged, all of the rest are, in fact, transformed from transport planes.

Why are they transformed from transport planes, not other type of aircrafts? We know that the missions of a warning aircraft require it able to make long time flight. This means that it is required to have good ability to make continuous flight. This is the special ability of a transport plane. It can not only make continuous flight and can also carry a great amount of fuel. Moreover, a warning aircraft carries radar, radio equipment, and equipment for data processing, display, operation and control, and all these require a plane with a large stomach. A transport plane just has such a characteristic. So, no wonder most of the warning aircrafts are transformed from transport planes, and their technological requirements are similar, too.

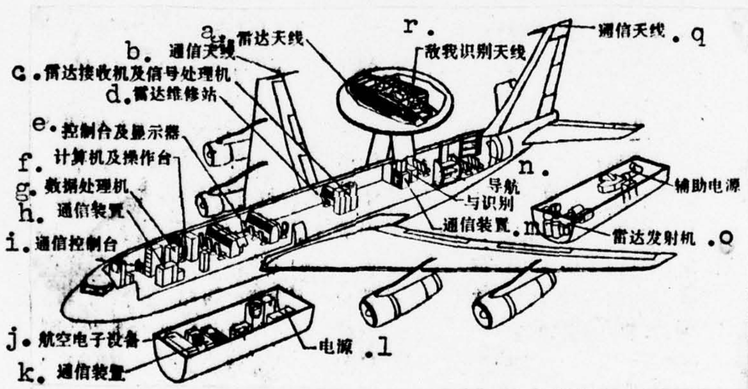


Figure 2

a. radar antenna
b. communication antenna
c. radar receiver and signal processor
d. radar maintenance station
e. control and display
f. computer and operation stand
g. data processor
h. communication equipment
i. communication control stand
j. aviation electronic equipment
k. communication equipment
l. electricity source
m. communication equipment
n. navigation and recogniyion
o. radar emitter
p. auxilary electricity source
q. communication antenna
r. enemy recognition antenna

There is some relationship, but they are not equivalent. Addition of a radar antenna dome leads to some changes in the aircraft itself. The U.S. advanced-warning airplane E-1B, which is converted from the C-1 transport plane, has a dome (9.75 meters) that is relatively long compared to the body (13.8 meters). As the dome is low, a narrow sectional tubular flow forms between the dome and the aircraft body, creating an unfavorable aerodynamic effect. Consequently, the upper surface of the body is made planar such that air can flow without hindrance between the surface and the planar bottom of the dome. To avoid the tail flow of the dome from affecting the aerodynamics of the vertical tail, the single tail is changed into a double vertical tail. In the case of E-2A, the tail assembly is made up of four small ones, as shown in figure 1. Toughened glass is used to avoid interference with the radar.

How does the large dome affect the flight performance? The dome and its support structure increase the air resistance thereby reducing the maximum speed of the plane by about 10%. In flight the dome also generates a lift force equal to its own weight so that the load factor is not affected. Actual performance has proven that the maneuverability and stability of the plane are not affected to any great extent.

Advanced-warning aircrafts generally can refuel in midair as they require even longer cruising ability than transport aircrafts. Some of the advanced-warning aircrafts increase the size of their fuel tanks or change to engines which can produce larger thrust and lower the fuel consumption.

Surveillance and Command

Except for some necessary equipment for the crew, the body of an advanced-warning aircraft is entirely taken up by radar, electronic equipments, analysis and display systems, control units and some accessories, as indicated in figure 2.

An examination of the advanced-warning aircraft leads us to understand that its large size and strange appearance are directly related to its function.

Figure caption: Chang Shi Qi

* The above caption is incomplete.

An Amusing Story of The Physics of
an Aircraft Taking-off and Landing

Wei Hai-tung and Chang Tai-ch'ang

In a civil airfield, there is a silvery white plane, which is loading and ready to take off, and at the same time, there are planes one after the other coming to land on the field. When a landing plane has touched ground, it begins to taxi and stops in front of the waiting building. In a moment, passengers and their baggages come out of the plane and there it becomes a busy and bustling spot of the field. On the platform of the waiting building, there is a group of youngsters and each of them has a red guard armband on his or her arm. They are young scientists and technologists and they add a lively scene to the airfield. While they are watching the planes taking-off or landing, they noisely ask the guide various questions, such as " Why must a plane taxi before taking-off or landing? Why does some plane taxi so long befor it can stop and can the taxi be shortened?" The guide did not answer those questions, instead the youngsters are asked to recollect what they have studied from the physics classes and to discuss and conclude answers to their questions by themselves.

Why does taking-off or landing require taxiing

But the guide randomly picked up a piece of a broken brick and with a controlled speed threw it out. The piece of broken brick following a para-curve fell on the ground and broke into smaller pieces. Then the guide took a model airplane and at the same speed level threw it out. The model plane after a long distance of gliding gently touched the ground. It seems that the model plane was held by a invisible hand, so the track of its movement is different from that of the piece of broken brick. One of the youngsters, without waiting for the guide's question, volunteered his explanation by saying, "It is because that the model plane has wings and the wing can produce climbing force." "You only tell us half of the truth," said the guide smilingly, " for being able to fly in the air, not only must a plane have wings, which can produce climbing force, and the flying speed must also be great enough to enable the climbing force produced by the wings to stand against the gravity of the plane itself. Come on, let's see a demonstration on the analogous flight practice stand".

Soon they entered into a large room, and inside it there is a simulant plane, which represents only the front half of a plane, and it is supported on a stand that is complicatedly composed of pipes, through which liquid pressure is used for operation. The equipment in the pilot's cabin shows no difference from a real plane, and a piece of farmland can be seen through the windsheild glass. But the farmland is not real and it is reflected on a large television screen which stands in the front of the simulant plane. A pilot is demonstrating the operation of taking-off and landing. On the screen, a runway in an airfield appears, and the pilot is slowly closing the fuel gate so he comes closer and closer to the ground. When the guide shouted to the pilot saying "Please close the fuel gate", the pilot so did. Then the engine comes into a state of slow motion and the speed indicator shows from 300km per hour to 100km per hour. At this time, the plane begins to shake.

The Physics of Aircraft Take-off and Landing

The alarm sounded! The red light on the display panel lit up with the warning signal " Lost of speed! Danger! " "Ping!" " The plane has gone down! " While the students looked startled, the instructor laughed, " Don't worry. This is just a demonstration on the flight simulator. As a plane approaches landing, the landing speed must be such that the lift is equal to the gravity. Only then can the plane attain a safe and soft landing. In an actual flight, the incorrect landing procedure that we just demonstrated cannot be allowed. Otherwise the plane will fall like a piece of rock."

Only when the lift exceeds the gravitational force can the airplane leaves the ground. Similarly, as the airplane descends, it must still have sufficient speed so as to reduce the lift gradually in order to attain soft landing. Therefore take-off run and landing run are needed. During take-off, the run increases speed until the airplane reaches the lift-off speed. On landing, the run reduces speed and momentum, eventually halting the airplane.

How Long is the Run

Early-model airplane usually had large wings. Sufficient lift force is attained under very small speed. Hence the run is usually only in tens of meters. Even the biplanes used for agricultural purposes require a run of about a hundred and seventy meters only. Modern high speed airplanes have small and thin wings. Their take-off and landing require higher speed and hence longer runways. For example, the maximum speed of MG-21 is 2100 kilometers per hour, its landing speed is 290 kilometers per hour and the run required is 1200 to 1300 meters long; while the Soviet commercial airplane Ilyushin 62 has a flight speed of 900 kilometers per hour, its larger mass results in a slower acceleration so that the run can be as long as 2750 meters.

How to Reduce the Run Distance

If we approximate the run as a constant-acceleration (deceleration) motion, the distance is given by the formula:

$$L = V_o t + \frac{1}{2} a t^2$$

where L = distance of run

V_o = initial speed (V_o equals 0 during take-off; on landing, V_o equals the plane speed when it touches the ground)

a = acceleration (deceleration)

t = time of run

From this formula, one sees that the shorter the run time, the shorter the run distance. How to reduce the run time? The speed at the end of the run, V_f, is given by

$$V_f = V_o + at$$

where V_f equals 0 on landing and during take-off, it is the lift-off speed. Hence a short run time is obtained with a small V_f on take-off, a small V_o on landing and a large acceleration (deceleration) during the run.

In the past ten years, extensive research has been done on mechanisms of increasing speed and lift force so that on take-off and landing, an airplane will not stall and fall down at low speed. Figure 1 shows one such mechanism for high speed airplanes. The top figure indicates that with back-swept and small curvature wings which are suitable for high speed flying, the lift is too small at low speed to allow safe landing and take-off. The bottom figure shows the airplane with extended wings and lowered fore and hind flaps. As the wings become large and curved, they generate a large lift even at low speed. So safe take-off and lnding are possible.

Today we shall attempt to increase the rate of acceleration (deceleration) as a means of reducing the run distance. To simplify the problem, let's take landing as an example and look at various methods of stopping the airplane more quickly on the landing run.

A discussion began. " Braking! Just like sudden braking in automobiles. " " Use a big parachute to increase the air resistance." " How about halting the airplane with arresting cables! " * * *

Well, let us demonstrate the various situations on the flight simulator!

The pilot began to simulate the landing procedure: lowering the landing gear and the flaps and slowly releasing the gas. The airplane glided towards the runway. With a slight vibration, the airplane touched the ground. Hua, who proposed to use braking, started to yell, "Use the brake! Use the brake!" The pilot applied a sudden braking. Following a loud noise, smoke began to emerge in the cockpit. The alarm sounded again. On the display panel, a red signal indicated. " Fire " !

What has happened? Well, as the plane brakes suddenly, the tires explode and burst into flames, resulting in a fire alarm.

Why is that we can apply a sudden braking in automobiles but not in airplanes? The reason is that the plane still has a relatively high speed when it touches the ground, and its momentum is hundreds to thousands times greater than that of an automobile.

If a transport plane lands with a weight of 100 tons and a velocity of 300 kilometers per hour, its total kinetic energy prior to the landing run is E_K and

$$E_K = 1/2\ mV^2$$

where E_K = kinetic energy (joule)

m = mass (kilogram)

V = landing speed (meters/second)

In the example of a transport plane, the energy $E_K = 3.5 \times 10^8$ joules. If this amount of energy converts completely to heat due to friction as the wheels brake, it equals 8.3×10^7 calories. This quantity of heat is sufficient to vaporize one and a half tons of water. The heat generated by sudden braking can cause the rubber tires to sublimate or to burst into flames. In modern airplanes, the braking system regulates the braking force automatically to prevent the danger of excessive braking force.

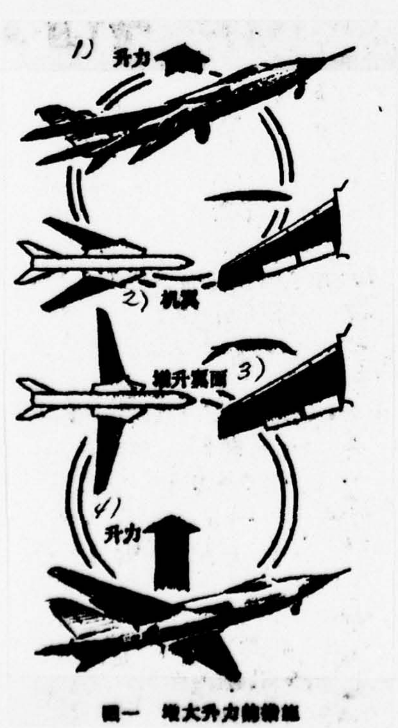
The use of a parachute to decelerate an airplane requires a large-size parachute. Besides the problem of where to store it, the shock generated by the sudden opening of the parachute could result in structural damage to the plane. Hence large planes generally use a combined mechanism of wheel-braking, deceleration-parachute or reversed engine. On landing, the kinetic energy of the plane is dissipated through friction of the wheels, air resistance and reversing of the engine. The disadvantage of these methods is that they complicate the design of the plane. On air carriers, arresting cables and a energy conversion system are used. The large amount of kinetic energy of a landing plane is transmitted to the energy conversion system through the arresting cables. In this way, the structural design of the plane can be simplified.

The take-off run of the plane has a similar purpose. It aims at gaining kinetic energy in the shortest possible time, increasing acceleration and reaching lift-off speed.

One method of shortening the take-off run is to use the engine of the plane or rockets to convert chemical reaction into kinetic energy, such as accelerated combustion chamber or rocket booster. Another method would be to rely on ground facilities, such as the catapult on air carriers which utilizes high pressure steam to accelerate planes. One light-plane launcher, sixty to seventy meters long, also uses high pressure air to push a piston in a cylinder to jet off the plane. In this way, the run distance is less than a hundred meters. All these mechanisms depend on complicated ground facilities to generate energy, which is then transmitted to the plane through a launcher. This simplifies the structural design of the plane and reduces the run distance.

The students agreed that they have learnt a lot. After this visit and discussion, they no longer consider aeronautical engineering to be a complicated and mysterious subject. The problem of how to shorten the run distance of a plane turns out to be just a commonly encountered issue in physics, which is the problem of the conservation and conversion of energy.

Figure caption: Li Jia
Figure: Zhang Tai



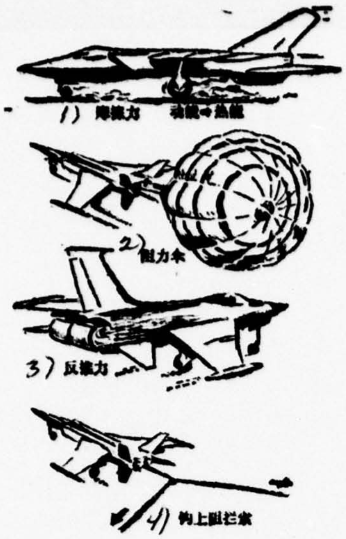
1) lift

2) wing

3) increase wingspan

4) lift

Figure 1. A way of increasing the lift



图二 缩短降落滑跑距离的手段

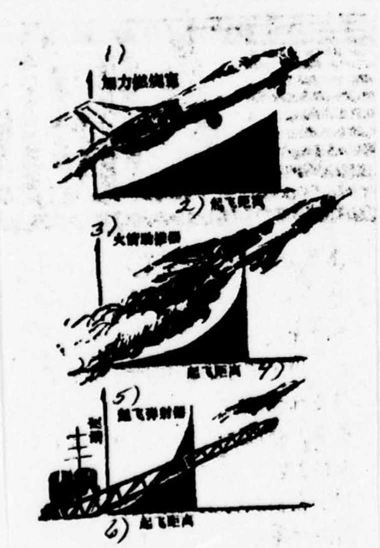
1) friction kinetic energy → heat

2) deceleration-parachute

3) reversed push

4) hooked up to arresting cable

Figure 2. Methods of shortening the landing run



图三 缩短起飞滑跑距离的手段

1) accelerated combustion chamber

2) take-off distance

3) rocket booster

4) take-off distance

5) catapult

6) take-off distance

Figure 3. Methods of shortening the take-off run

Fracture Mechanics and Aircraft Engine

Kuo Yi-chi

The application of fracture mechanics to aircraft design has already made great leeway, but the application to aircraft engine has become a subject of research in recent years. In last issue of this journal, we introduced the origin, development and some basic concepts of fracture mechanics. Now we try to discuss the fracture problem in aircraft engine and the application of fracture mechanics.

The Fracture Problem in Aircraft Engine

For aircraft engine, should we study fracture mechanics, to this question, the answer is definitely positive. According to the statistics of aircraft incident, the cases of engine problem constitute about 9.1% in civil aircraft incidents and the percentage is even higher in military aircraft incidents. Of these engine problems, 60% are caused by structural fracture. In many countries, the cases of engine fracture are rather serious. For instance, in April, 1974, a civil airplane DC-9, due to the breaking of low pressure air compressor axle in the engine had an incident. Through investigation, it was found out that the breaking of the axle was caused by the extension of a crack on the axle. In US the production of engine J85GE21 for military use was forced to stop because of the breaking of blades of the air compressor. Because of the breaking of fan wheel of engine RB.211, there have happened quite a number of aircraft incidents. It is a fact, however, that there are cracks on the parts of engine and the conditions of the cracks are rather complicated. From both theory and practice, we can say that these problems should be studied by applying fracture mechanics. In the following, we are trying to discuss the gap between the level of fracture mechanics and the practical fracture problems in engine.

First of all, it is the temperature factor that is the operation charcteristic of the parts in an engine. The hot end parts of an engine such as combustion chamber, turbine and reinforced combustion chamber ,all work under high temperature. What effect temperature can have on stress strengthening factor and fracture tenacity, it has remained unknown.

Because of high temperature, the stress distribution is intricate and there are also oscillations, the shapes of fracture of the parts are of a great variety and they are more complicated than aircraft. The occurrence of a crack is often out of anyone's imagination. Here we only touch the problems of microscopic cracks because the problems of microscopic cracks are even more difficult. According to the practical experiences that have so far been accumulated, the shapes of microscopic cracks, as we know. include single crack, multicrack, closed crack and cluster of surface crack and underneath skin crack (Figure right below). Among them, for single crack and multicrack at normal temperature, corresponding stress formula (basis of judgment) can be found and their critical crack length can be calculated. It is rather difficult for the rest of them because there is no adequate basis of judgment, so there is no way to determine their critical crack length. It is therefore fair to say that in theory and practical test, fracture mechanics cannot solve any of the problems of crack aircraft engine as yet. It is an urgent task to make further study in this field.

The determination of stress strengthening factor and the tenacity of crack so far can be made only at normal temperature level, and those at high temperature level cannot yet be completely solved. The numerical value at the high temperature state is what the parts of an engine need, so we must make further study on the determination of stress strengthening factor and the tenacity of fracture at high tempearture.

The high temperature parts of an engine are all made of heat resistant alloy. The changes of fracture tenacity of this material under the effect of temperature has not been thoroughly understood.

The important subject in the study of fracture mechanics is how to use fracture mechanics to predict the life span. Many of aircraft engines at the present time have no design life, and the service life cannot be predicted by fracture mechanics, it is often determined by service test, instead. The prediction of life span nevertheless remains to be a subject to study.

Of engines in design as well as those in service, the critical crack length still cannot be determined by using fracture mechanics. The determination of the controlled crack length on a small part of the parts is made by tests. A theorectical calculation method which can be practically applied has not yet been created.

Those practical examples mentioned above are but segmental suggestions which do not cover the whole series of problems. Hereupon we can see that the gap between the level of fracture mechanics and the practical situation of aircraft engines is considerably wide and we must from now on try to do our best to narrow this gap.

The Application of Fracture Mechanics to Aircraft Engine

The purpose of studying fracture mechanics is to solve some practical problems. Fracture mechanics has been applied to matel materials, metallurgy and high pressure vessels. It can be anticipated that, in the near future, fracture tenacity K_{1c} will become a new index of materials. In the following, we will discuss the application of fracture mechanics to aircraft engine.

Strength Calculation in Engine Design. As we have mentioned above, the strength calculation in the past is limited only to static strength or fatigue strength. In theory, those strength calculations are reliable, but in practical application, they can by no mean prevent the occurence of cracks. The main reason of such shortcomings is that it does not pay attention to the problem of strength after cracks have taken place. Now in engine design in some countries, fracture strength calculation has been taken into account. In material selection, fracture tenacity has become a calibration. For instance, in the United States, when titanium alloy is used to make compressor wheel the requirement of fracture tenacity value is 175 $kg/mm^{3/2}$; when it is used to make blade, the requrement is 122.5$kg/mm^{3'2}$.

After the incident in which the fly wheel of a British RB 211 engine fractured, an investigation of the fracture toughness and the rate of crack propogation of the wheel was undertaken. Subsequently, a titanium alloy with the required strength and a better fracture toughness is used to substitute the original high strength material. In some countries, the fracture strength is also being considered in the design of large rotors. More emphasis is also being made on requirements in toughness and plasticity, properties once considered to be of secondary importance.

Design Lifespan and Service Lifespan of Components

In the past, many aeronautical engines do not have an estimate of design lifespan. The service lifespan was also determined experimentally. Nowadays fracture mechanics is being applied to study engine lifespans.

Development of High Temperature Fracture Mechanics

This research area is directed at areonautical engines. There are some positive results. However some difficulties are also encountered in practice. More work is needed.

Determine the Nature of Service-related Cracks

The use of fracture mechanics to predict crack initiation while the component is in service or under repair might be able to control some of the fracture problems which are not solved during the design and manufacturing stages. This would guarantee flight safety, increase the lifespan of the component and avoid frequent replacement of components. Foreign engines with long lifespan have standards of permissible crack lengths for the essential components to remain in service, to undergo repair and to be junked. These requirements generally lengthen the lifespan of engines, sometimes to the extent of several times the design lifespan. However to popularize this method requires extensive research in fracture mechanics.

Techniques for Improving the Fracture Toughness of Components

It is more effective to prevent crack initiation by improving the fracture toughness of components through new techniques. Prevention of cracking through structural changes does not produce good results. It also involves changes in the design of molds, the compatibility of parts, etc. Observations also suggest that cracks can migrate. If structural changes are made in one part of the component which had cracks before, cracks might initiate in aonther area of the component. Actually, any structure has its weak areas and cracks usually initiate there. Redesigning might result in overall improvement, but there are still weak areas. Cracks just appear in alternte forms and at a different weak area. There is no perfect engine which does not crack. The migration of cracks is quite common among engine components. For example, if the radius of curvature R at an axial junction is increased to allow a smoother connection, cracks might disappear there and migrate to other junctions. Cracks on the outflow side of turbine blades are due to fatique resulting from mechanical vibration. If "crown-shaped" blades are used to reduced vibration, cracks just migrate to the "crown". Cracks on the outflow side of guide blades are results of thermal fatigue. If air-cooled guide blades are used to reduce the heat load, cracks simply migrate to the air outlets. Sometimes cracks could migrate from one component to another. This kind of migration is frightening. A concentrated effort should be directed towards improving the fracture toughness of materials so that cracks disappear and do not migrate. Techniques of improving fracture toughness such as special heat treatment, spray-pellet strengthening and vapor deposition are attracting wide attention.

Techniques of Controlling the Crack Propagation Velocity

By controlling the velocity at which cracks propagate, components can be used for a longer period of time. Obviously techniques achieving this goal are also important in solving the fracture problem. Spray-pellet strengthening (see the issue of October,1976) and rolling can accomplish this goal.

A study using vapor deposition to improve metal surface showed a reduction in the crack propagation velocity. It is suggested that a combination of vapor deposition and spray-pellet strengthening produce the most desirable result.

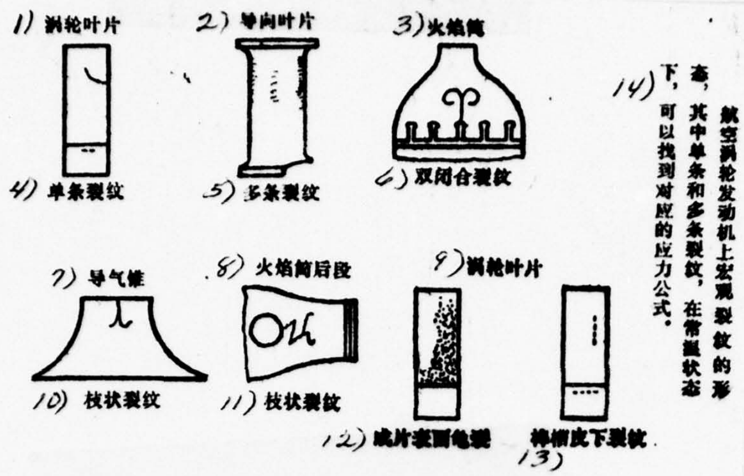
Application in the area of Fatigue

Engine fracture is induced by fatigue. So the study of the initiation and propagation of fatigue cracks by fracture mechanics is called micro-fracture mechanics. Stress cycling develops fatigue nucleus which is followed by macrocrack formation, resulting in unstable propagation and fracture. The entire process is being studied on the basis of fracture mechanics and important advances are predicted.

Detection of Cracks

Because crack propagation produces sound, equiments are now under development to detect this sound as a mean of surveillance. The use of acoustic waves to detect microcracks is also being investigated. These efforts are drawing the attention of the aeronautical industry.

Figure caption: Li Long-rui



1) turbine blade
2) guide blade
3) flame cylinder
4) single crack
5) multiple crack
6) two converging cracks
7) tapered air guide
8) the bottom part of flame cylinder
9) turbine blade
10) branched crack
11) branched crack
12) surface crackle
13) cracks under the skin of groove

14) Under isothermal condition, single and multiple macro-cracks on areo-turboengines can be described by stress formula.

Question and Answer

(The answers are provided by Mechanic Team of Szechwan Province Civil Aviation Administration)

Q: Of a single propeller aircraft, when the propeller is running, what effect it has to the flight and control of an aircraft?

A: The main effect of the running of a propeller is to produce pulling force, but there are two noticeable side-effects to a single-propellered aircraft:

1. The Reaction Moment of a Propeller

When a propeller is running, the resistance acting on each blade will form a reaction moment, which through the revolving axle of the propeller reaches first the engine and then the aircraft. Finally the craft is made incline to a reversed direction of the running of the propeller. If the propeller is revolving to right, the craft incline to left (Figure 1). The greater is the revolving speed of the propeller, the greater is the inclination of the craft.

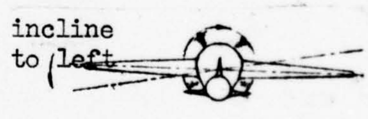


Figure 1

2. The Twisting Airflow of a Propeller. When a propeller is revolving, the airflow that is forced to the rare part of the aircraft is not in the shape of a flat-plate flowing along the body of the craft ,but it goes around the body of a craft. The direction of twisting of the airflow is same as that of the revolving of the propeller. When the airflow is passing the wing, it is divided into upper and lower two parts. If the propeller is running to right, the upper part of the airflow will flow to the right back and the lower part

to the left back. When this twisting airflow touches the vertical tail of the craft, it will make the craft incline to left (Figure 2). If the propeller is running to left, the situation is just contrary to this.

These two sideeffects of the propeller damage the balance of an aircraft in the air, so they must be overcome.

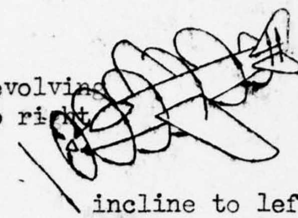


Figure 2

In aircraft design, especially the design of a single propeller aircraft, the impact of the side-effect of the propeller to the flight and control of an aircraft must be taken into acount, and try to overcome these side-effects. For instance, there are aircrafts of which the vertical tail is not set at the fore-and-aft axis but at point that makes an angle with the axis so that the slope and inclination of the aircraft caused by the reaction moment of the propeller and twisting airflow can be offset. On some aircrafts, there is a correction blade on the direction rudder or aileron to adjust the inclination. The correction blade is operated by the mechanical personnel on the ground by using some instrument, so the correction blade is also called fixed adjusting blade. There is another method that is to set up a airflow conducting blade, airflow adjusting blade, bottom fin and back fin on an aircraft. All these measures are for the purpose of maintaining stability of an aircraft in flight and reducing the impact of side-effect of the propeller.

As the reaction moment of the propeller and the magnitude of the twisting airflow change following revolving speed of the propeller, only a fixed adjusting blade is not enough and there must be something that can be operated on the aircraft. In many instances, there are adjusting blades which can be operated by the pilot when necessary. They are usually set up at the direction rudder, lifting rudder or aileron. Some of those blades are set to work mechanically and some electrically.

Q: Of a double-propeller (double engine) aircraft, why the revolving direction of the propellers is not the same but symmetrical?

A: Among civil aircrafts, those which use propeller as pulling force are of many different kinds. Whether they are double-propellered (double engine) or multi-engined,on one and the same craft, the propellers are revolving toward same direction, as indicated in Figure 3.

The propellers of a double-propellered aircraft are set up at the engine on the wing on each side of its body, and not at the fore-and-aft axis. The impact of the reaction moment on the craft is not so serious as that of a single propellered craft.

The rotary flow generated by the propellers in a twin-propeller plane does not blow directly onto the vertical tail. Thus the effect is not as large as in a single-propeller plane. By adding flow guide flaps and flow correction flaps to the airplane, the pilot can adjust these flaps in flight to overcome the adverse air flow created by the propellers.

The propellers create a reaction force moment on the plane and a rotary air flow around the plane. These adverse effects could be overcome by letting the propellers to rotate in opposite directions. However, this would create serious problems in engine design, manufacture, maintenance and storage of spare parts. For example, both left-handed and right-handed engines* have to be designed and manufactured, and their maintenance and usage require careful distinction. Serious incidents will result if a mistake is made. Therefore, two sets of non-interchangeable spare parts have to be stockpiled. And this is uneconomical.

Because of the above reasons, airplanes with two or more engines generally use the same model and the propellers also rotate in the same direction.

* The direction of rotation of the propeller is defined in the following way: looking towards the propeller from the tail section, a clockwise rotation is termed right-handed; otherwise, it is termed left-handed.

Question: If a multi-engine plane uses only one engine in flight, what are the problems and how to overcome them?

Answer: If one engine malfunctions in flight, a twin-engine plane could use a single engine for a short flight. Special attention should be paid to the following two points:

1. Maintain altitude

In single-engine flight, the pull on the plane is reduced. Only by maintaining high altitude can the plane stay in the air for a longer period of time. This gives the pilot more time to evaluate the situation and select a suitable airport to land.

If the plane is not at full load, one can maintain the altitude by increasing the power of the good engine and at the same time, quickly find an airport to land. The plane should return to the departing airport if it is less than half way towards the destination. Otherwise, in the case where no airport is available nearby and no climbing is required along the orginial route, the plane should proceed to the original destination for repair. With only an single engine working, the plane does not have sufficient pull. Maneuvering is difficult and climbing should be avoided. The plane should land in an airport where no climbing is needed.

If the plane is at full load, it becomes necessary to jettison some inessential cargo (record the position so that ground recovery may be attempted) to reduce the weight and to maintain the altitude. At the same time, select an airport with good weather.

When such an emergency arises, the pilot must remain calm and deal with the situation decisively. For example, one of our ~~two~~ twin-engine planes was on route from Kun-ming to Chung-king when the right engine suddenly stopped. Because of full load, the remaining engine did not have sufficient power to maintain altitude. The plane was losing altitude. What can be done? The crew calmly analysed the geography along the route, the altitude and the rate of descending. It ~~is~~ was not possible to return to Kun-ming because the plane would have to climb to higher altitude. Chung-king however, is at a lower altitude. With the present rate of descend, the plane should reach Chong-qing safely even without jettisoning any cargo. With careful handling by the pilot, the plane finally reached the destination. Thus it is extremely important to maintain the flying altitude in such emergency.

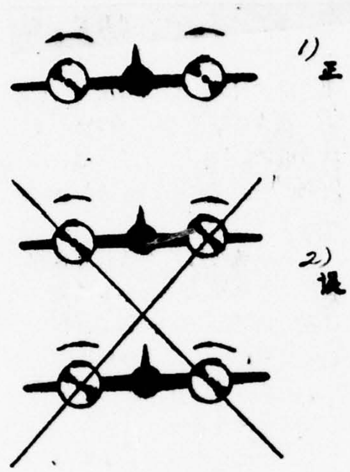
2. Maintain the direction of flight

In single-engine flight, the pull of the engine exerts a torsional moment on the center of gravity of the plane, causing the plane to twist towards the malfunctioned engine. To maintain course and to prevent twisting, the pilot needs to use the rudder and correction flaps more often. The amount of steering required depends on the speed of the plane, the air flow and the torsional moment on the plane.

When the plane approaches landing, it is extremely important to maintain the flight direction. With its head down and decelerating, the plane is not too stable. Additional use of the rudder to counteract the torsional moment requires careful control. Otherwise, the plane might skid out of the runway.

Besides the above two points, it is also necessary to align the propeller blades of the faulty engine. The fore edge of the blades (blade face) should be parallel to the longitudinal axis of the plane. This reduces the air resistance against the blades and consequently, the torsional moment. This alignment is usually carried out by a combination of electrical, mechanical and hydraulic mechanisms. In modern airplanes, this has been automated. When the engine stops, the propellers are aligned automatically.

Airplanes with three or more engines are generally large and heavy. It is impossible to fly with a single engine. How about using two engines? The answer is yes for three-engine planes. For four-engine planes, it depends on the location of the engines. With two engines on each wing, flight is possible if one engine on each wing is disabled. But if both engines on one wing malfunction, flight would be impossible because even if the remaining two engines can pull (push) the plane, the larger torsional moment cannot be counteracted by the use of the rudder. Even a short flight under this circumstance should not be permitted. The plane can crash at any moment. The only choice is to land immediately.



圖三

1) correct

2)incorrect

Figure 3

Q: In the vast sky, why there must be regulated air routes?

A: Air routes are of two different kinds: the fixed and the unfixed. The routes of fighters of an air force are unfixed, and they can change at any time according to necessity of the fighting as well as training. Now what we are going to discuss is the civil air routes which are fixed.

An air route is that which is preset for an aircraft to fly from one point (starting point) to another point (terminal point) on the surface of the earth.

Between two or more populated points, a transport plane can fly regularly, and on the ground, there are airports and installations which quarantee the flights of air transportation. And the approved fixed air routes are called regular air routes.

The ground corresponding to the regular air routes (projection to the earth) is called air road of the regular air routes. Its width is regulated to be 50 km. Taking the air route as a central line, it is 25km on each side.

Some areas in the sky in which the civil planes can fly back and forth are over important cities and these areas require limitations. Some other areas where airports are many and the flights of aircrafts are busy and frequent, in order to avoid interference with each other and to quarantee the safety of the flights, also require limitations. Thus in the sky above the air road on the ground, a certain width of the space is regulated to provide aircrafts for their flights from and onto stations. Such an area in space is called "air corridor", of which the width is usually 8km.

In some areas in the sky over some political, military and industrial centers, flights are forbidden. These areas are called flight forbidden region.

From these limitations and regulations, we can known that flights of aircrafts are very strictly organized. In the vast sky no one can fly freely or take whatever route as one likes, but one must follow the regulated routes to fly. Now we try to answer the question of why it must be so.

1. Every nation has its own territorial space, which is a sovereignty and no other nation has the right to come to invade. But, however, one nation must do business with others, and aircrafts must fly internationally. So there is a necessity of signing air agreements among nations to regulate routes by which foreign aircrafts can fly within one's native territory and use air stations. If the regulations are violated by a foreign aircraft, the sovereignty nation can take appropriate and necessary measures. If the case is serious, such as military reconnaissance and other destructive activities, the sovereignty nation has the right to shoot the aircraft down. Evidently the regulations of air routes are very important.

2. National economic development requires air transportation of goods as well as passagers, so there must be suitable air stations. By regulated air routes, these stations can be connected into an air transportation network. Regular flights must have a fixed flight number and definite route and stations (in order to load and disload good and passengers, and to refill fuel) and definite schedule. It seems impossible without a regulated route to carry out the missions of transporting goods and passengers. The regulated route should take a straight line so that the flight distance and time required can all be short and the consumption of fuel is low. So the cost of flight is low and the transportation rate will be high.

3. For flight safty it is absolutely necessary to have a regulated

route.

An aircraft flying in the sky is always conducted by ground personnel. Following a regulated route, the ground personnel will feel easy to know where is the aircraft and its flight position anf altitude. Thus they can guide the craft to reach the preset station without any mistake.

When an aircraft is flying in the sky, it needs navigation from the ground. If there is a regulated route, there can be navigation stations, direction finding stations and radar station along the route. So the aircraft cannot be lost and will safely reach its destination.

Along a regulated route, the flight altitude and time of various crafts can be well arranged, so they have no danger of collision. On the other hand, an aircraft along a regulated route can at the right time know the weather in the sky. Thus it can try to aviod any of the storms and safeguard the flight.

An air route must not encounter natural obstacles, such as the mountainous area which is very high and bad weather areas in a year. Following a regulated route,an aircraft can aviod such areas.

Moreover, a regulated route can let an aircraft keep away from some forbidden regions, such as military base, ground-to-air shooting range. It will be also good for national security and national secrecy if an aircraft can keep away from major political, econmic and military centers. From all these, we can know that an air route is very important. Although the sky is vast, it is still necessary to regulate air routes.

A Random Talk on the ClimbingCeiling of an Aircraft

Chu Pao-liu

To begin with the development of aircrafts. In the earliest days, the highest altitude that an aircraft with piston engine can reach by using its full power is called climbing ceiling. In other words, it is the altitude where the climbing rate of an aircraft is zero. But in later days, the number of flights become more and more and the theories of flight have been enormously proliferated. The time that an aircraft requires to reach a certain altitude is in inverse ratio to its climbing rate (altitude reached in a unit time), so the altitude becomes higher and higher and the climbing rate becomes smaller and smaller, as a result , the time required for climbing each meter becomes more and more. Calculation indicates that the time required for reaching an altitude where the climbing rate is zero will be infinitely great. In practice, there is no way to reach such a climbing ceiling. But there is a regulation saying that climbing ceiling is an altitude in climbing when the climbing rate is 0.5m per second. In order to distinguish this climbing ceiling from the original unreachable one. This one is called applicable (or practical) climbing ceiling and the one which requires that the climbing rate is zero is called absolute climbing ceiling or theoretical climbing ceiling. These two terms have been used ever since.

Since the advent of jet plane, flight speed has been greatly increased and it can surpass the sound speed. There comes a new phenomenon in climbing performance, that is the altitude an aircraft can reach is related to its flight speed.

Ceiling Height of Airplanes

[illegible]

If an airplane ascend at the proper speed, it can reach the service ceiling. However, if before reaching this height, the airplane increases its speed through horizontal flight, the maximum altitude it can reach on the subsequent climb will exceed the service ceiling. Therefore, there are two different ceiling limits: static and dynamic. The dynamic situation is similar to the projection of a piece of rock (figure1). The greater the initial velocity of the rock, the higher the altitude it can reach. At the dynamic ceiling, the lift force is less than the gravitational force. So it is difficult to maintain horizontal flight. The situation is different at the static ceiling. During the climb, the lift on the aiplane is equal to its weight. The airplane can maintain horizontal flight. Both the absolute ceiling and the service ceiling belong to this category. Similar to the problem of a projectile, the dynamic ceiling of airplane is closely related to the final speed during the climb. Thus the highest altitude record frequently reported requires close examination. Take the record set by the U.S. F-4 Phantom in 1962. It was reported to have reached 30040 meters. The airplane started the climb after exceeding Mach 2 speed at an altitude of 15240 meters. At a height of 30040 meters, the speed is only 72 kilometers per hour. Both engines had stopped. Then the plane just fell like a piece of rock to a low altitude before the engines were restarted. Most of the world altitude records were set under similar conditions. So the dynamic ceiling is the highest altitude attained by an airplane which starts climbing with high speed till it reaches almost zero speed. The dynamic ceiling of supersonic jets often far exceed the absolute ceiling. The present record is around 39000 meters. At the dynamic ceiling, the airplane is virtually out of control.

Another dynamic ceiling is associated with warplanes. Instead of dropping to zero speed, the airplane begins to assume a horizontal position before reaching the stalling speed (250 to 300 kilometers per hour). After that, it can maintain a horizontal flight for a short period of time, allowing it to open fire on enemy planes. In order that the target is within the firing range after the climb, the direction of approach and the position at which the ascending begins have to be accurately determined. Otherwise, at high altitude and low speed, it is difficult to correct the direction of flight and any difference in altitude. So attacking high altitude targets by rapid climbing requires good coordination with ground guidance.

Thus the dynamic ceiling can be of two kinds: one with almost zero terminal speed (absolute dynamic ceiling) and the other with terminal speed close to the stalling speed. There is a great difference between them. For F-4 Phamtom, the former ceiling is 30040 meters while the latter (temporarily call combat dynamic ceiling) is only 22000 meters. The absolute static ceiling is 18000 meters. For slow planes such as piston planes, jump-climbing does not increase the maximum attainable altitude to any great extent. Therefore the static and dynamic ceilings are almost identical.

The weight of an airplane is closely related to the ceiling height. In older planes, fuel only accounted for a small fraction of the total weight. The ceilings are generally quoted without specifying the weight. The advent of jets, especially the long-range ones, fuel could acount for as much as half of the total weight. The ceilings are different at full tank versus an empty tank. For example, a B-52 has a service ceiling of 11500 meters when it weighs 208650 kilograms and 14470 meters when it weighs 127000 kilograms. When a ceiling height is given without specifying the weight, it is generally considered to be either at take-off weight or at half-filled tank.

Because jets have a fast climb rate, it is difficult to maintain a climb rate of just 0.5 meter per second. Thus some countries have defined service ceiling as the altitude attained with a climb rate of five meters per second, although there is no international standard. Even within the same country, both standards of 0.5 meter per second and 5 meters per second are often used. Unless it is specified, piston planes generally use the standard of 0.5 meter per second while jets could use either standard. (U.S. still uses 0.5 meter per second)

Some countries have two static ceilings: the combat ceiling and the cruise ceiling. The former refers to the altitude at which the climb rate has dropped to 2.5 meter/sec (500 feet/sec) when climbing under maximum thrust. Cruise ceiling refers to the altitude at which the climb rate has dropped to 1.5 meters per second (300 feet per second) when climbing with cruising thrust. This is higher than the optimum cruising altitude (altitude with maximum range). At 13600 kilograms, the A-7 aircraft has an absolute ceiling of 12500 meters, a service ceiling of 12280 meters, a combat ceiling of 11580 meters and a cruise ceiling of 11520 meters.

The maximum altitude attained by a plane climbing with subsonic speed is called the subsonic ceiling. If a plane attains supersonic speed at a certain altitude before climbing, the maximum altitude reached is called the supersonic ceiling. With a supersonic speed of Mach 1.5 to 2, the supersonic ceiling is much higher than the subsonic ceiling.

So far, eight different ceilings have been mentioned. Both the supersonic and subsonic ceilings can be divided into absolute, service and combat ceilings. Normally five are used as supersonic ceiling ceiling ~~which~~ generally means service ceiling. There is only one dynamic ceiling.

The above discussion only covers military aircrafts. A different set of ceilings exists for commercial airplanes. According to the rules for commercial flight (such as the British Requirements for Long Distance Commercial Flight), the maximum permissible flying altitude is limited by two factors: the excess maneuverability and the safety or structural limitation of the airplane. The British law requires a certain degree of maneuverability at the maximum flying altitude to insure against turbulent air flows. This means that the ratio of the lift coefficient at wing vibration to that at the maximum flying altitude is greater than 1.5. With a weight of 56818 kilograms, the Trident 2E has a maximum flight altitude of 11590 meters (38,000 feet), a flight Mach number 0.78, a wing span of 135.7 square meters. The wing life coefficient is 0.467 while the wing vibration lift coefficient is 0.7, with a ratio of 1.5.

The strucutural limitations can be manifold. An example is the pressure difference inside and outside the airtight cabin. This criterion dictates that under no circumstances can the Trident 2E airplane exceeds an altitude of 12200 meters. This height limit has nothing to do with the weight. To safeguard passengers, some countries forbid flying at altitudes exceeding 10670 meters if the airplane is not equipped with automatic falling oxygen supply system (for passenger use in case of oxygen deficiency at high altitude).

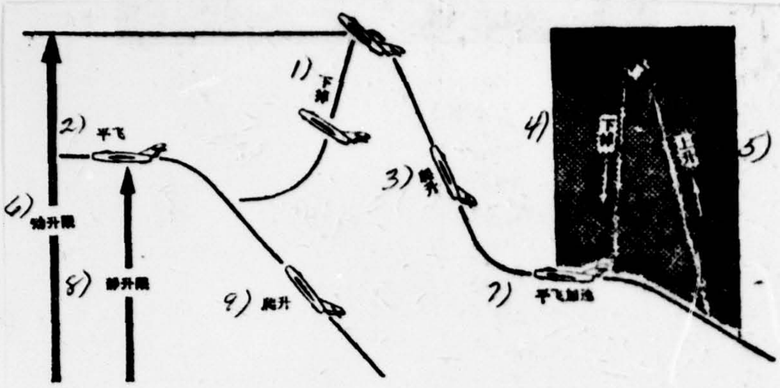
Normally only the first two types of maximum altitude are referred to as ceilings. Official data on commercial aircrafts generally do not list values on ceilings. If it is to be listed, the criteria should be specified to ensure a clear meaning.

We have discussed the various definitions of ceiling. Sometimes aircraft ceiling reported in magazines are unclear in their meaning. Is there a simple test? An attachment in this issue presents a quick and simple method based on the requirement that the lift force equaling the weight of the aircraft. It reflects the relation between the flight altitude, the lift coefficient, the flight Mach number and the wing load, allowing one to estimate the static ceiling of modern jet aircrafts.

The light-red colored areas of the diagram, in the region of ceiling Mach number and lift coefficient, is arrived at after the analysis of a large quantity of statistical data. This simplifies its use. Otherwise, it is not easy to calculate the flight Mach number and the lift coefficient. At the subsonic ceiling, military jets generally have a flight Mach number between 0.75 and 0.95 (between 0.75 and 0.85 for bomber and subsonic attack plane and between 0.9 and 0.95 for fighters). Lift coefficient ranges between 0.55 and 0.65 (for fighters, it is between 0.55 and 0.6; for bombers between 0.6 to 0.65). At the supersonic ceiling, the flight Mach number is between 1.5 and 2, the lift coefficient between 0.15 and 0.2. Airplanes with very small thrust power (the ratio of thrust to gravity less than 0.4) are exceptions.

With this diagram, and knowing the ceiling flight Mach number and lift coefficient, the ceiling of a certain type of aircraft can be found out quickly. For example, at half fuel tank, the B-1 bomber has a wing load of 830 kilograms per square meter. Assuming a ceiling Mach number of 1.8, lift coefficient of 0.2, the ceiling is found to be 12500 meters. The value of 18000 meters reported by magazines abroad the B-1 is clearly an exaggeration.

Lastly, it should be noted that there are limitations to the use of this diagram. For example, with insufficient engine thrust power, the actual ceiling will be less than the value indicated by the diagram. Also it is not applicable to other types of aircrafts (propeller airplane and helicopter).



图一 动升限和静升限的比较

1) fall

2) horizontal flight

3) climb

4) fall

5) climb

6) dynamic ceiling

7) horizontal flight and acceleration

8) static ceiling

9) climb

Figure 1. Comparison between the dynamic and static ceilings

Table Criteria of ceiling heights for military aircrafts

type	name	engine condition	terminal climb rate
subsonic speed static ceiling	absolute ceiling	maximum thrust	zero
	service ceiling		0.5 m/s or 5 m/s
	combat ceiling		2.5 m/s
	cruise ceiling	cruising thrust	1.5 m/s
supersonic speed static ceiling	service ceiling	maximum thrust	0.5 m/s
dynamic ceiling	absolute ceiling	maximum thrust	terminal speed almost zero
	combat ceiling		terminal speed close to stalling speed

A Review of the Development of Detonators Abroad

Shang Wen Zhou

A detail discussion on aerial bomb detonators was published in the number 11 issue of 1977. This article presents a survey of the development of bomb detonators abroad.

After the Second World War, there had been rapid development of detonators abroad, both in quality and quantity. The U. S. alone had increased its detonators from less than ten types to 40 ~ 50 types during the War and to several hundred after the War. Standardization was also introduced. Japan used at least fifty-one different types of detonators and Fascist Germany used a minimum of eighty-six during the War. These include impact-explode, aerial-explode, set-time, anti-dismantling detonators, etc. Of the total, 64% are electric detonators while the rest are mechanical detonators.

Many mechanical detonators are designed to guard against accidental explosion during transportation or while in service. There is a device separating the primer from the base charge. When it is activated, the detonator will not explode even if the primer does.

There is also adjustable delay mechanism in many detonators. This permits the setting of either delay or instantaneous explosion according to the requirement of the bombing mission. Some detonators have a set of deceleration gear coupled to the rotating wing (flap). After a certain number of turns of the wing, the delay mechanism will be deactivated. This ensures the safety of the airplane.

At the moment, the following types of new detonators are under development abroad:

1. Low altitude

This type of detonator is mounted on low altitude parachute-decelerated bombs. To ensure the safety of the plane, the bombing factors (altitude, speed, parachute opening time) must have the correct values when the bomb is released. When this happens, a control device on the bomb will cause both the front and tail detonator cartridges to change from a delay-explode to an instantaneous-explode condition. On ground impact, the bomb will be detonated. If the bomb parachute is not functioning properly, or if there is an error in the launching, the control device on the bomb will shut off. The instantaneous-explode condition will not be activated. After a delay of fifteen seconds, the front cartridge will detonate the bomb. This ensures the safety of the bomber.

2. New set-time detonators

In addition to mechanical set-time detonators, the U. S. has developed both chemical and electrical set-time detonators.

One type of chemical detonator, called ionic solution capsule, uses electric current to change the concentration of ions in different parts of the solution to achieve set-time explosion. Another type uses the rotating wing to break open a bottle of acetone. The acetone dissolves a celluloid ring which is used to limit the movement of an impact pin. When the ring softens, the pin punctures the primer to induce detonation. Changing the concentration of the acetone or the thickness of the celluloid ring alters the set-time for detonation.

Electronic set-time detonator uses semiconductor integrated circuit and principles of high frequency oscillation to determine the pulsing capacity of the circuit at a given time. After a fixed time period, a pulse is generated to ignite the electric detonator.

3. Piezoelectric detonator

This detonator, made up of piezoelectric crystals, has a simple design and high sensitivity. It can be ignited at the front end and detonate at the tail end of the bomb. It is generally used on air-to-ground antitank bombs.

4. Mechanical detonator with a long and pointed rod

This detonator has a long, pointed and hollow rod attached to the front end. Before the bomb touches the ground, the rod first makes contact to ignite the detonator. Thus the bomb explodes before hitting the target. This increases the damage capability of aerial fragmentation bombs.

5. Micro-detonators in cluster bombs

During the Vietnam War, the U. S. used a variety of small bombs and steel-pellet bombs. New detonators were specially designed: mechanical detonator which uses centrifugal force and electrical detonator which uses self-capacitance to activate.

6. Dense forest detonators

In response to the Vietnam War, two types of detonators were designed for bombing use on dense forest.

The radio detonators rely on the different reflectivity of radio waves from the tree leaves and from the ground. By increasing the size of the antenna so that it has better reception for waves reflected from the ground, the bomb can penetrate the forest before exploding.

A second type involves a special device attached to the centrifugal mechanical detonator on small fragmentation bombs. When the bomb comes into contact with tree branches, it does not explode. As the axial rotation of the bomb slows down, the special device activates the detonator so that it detonates the bomb when it hits the target or the ground.

(7) Doppler Radar Fuse

It is a skew moment fuse made according to Doppler principles. When a measurement numerical value and a preset numerical value are equal, the fuse will lead to explode a bomb.

(8) Infrared Proximity Fuse

It is a completely active fuse and there are infrared launcher and receiver set at its two sides respectively. When a proximity fuse goes close to a certain height of the target, it will lead to explode the bomb. If this fuse is used at a fragmentation bomb, it can make the killing rate of the bomb three times larger than using a fuse of impact type. If it is used at an incendiary bomb, it can help to widen the spread area of the incendiary agent. One more merit the infrared proximity fuse is that it cannot be easily interfered by enemy, but its weakness is that it is easily affected by the sun.

(9) Shooting Fuse

It is composed of fluidic generator, fluidic oscillator and calculator. Its merit is that it has good reliability and accuracy and its weakness is that its structure is somewhat too complicated.

(10) Laser Fuse

Following the development of laser guided weapons, laser fuse has correspondingly developed. The one that is used at US solid petrol bomb is a laser fuse.

A Brief Talk on the Equipment of
Bomb Loading and Transporting

Han Chen-tsung

It would be an unbearable labor to load bombs on an aircraft by not using machineries but depending on man power or simple machine,and sometimes it is simply impossible to complete the task by man power only. The task must be done by the help of machines, which can easily load the necessary bombs on an aircraft. Thus not only are the ground personnel in an air field released from the unbearable labor, and the aircrafts can take off on time without missing the opportunity of fighting,and consequently the usefulness of the aircrafts is promoted. This article is trying to introduce the equipment of bomb loading and transporting which has been widely used by air force in various countries.

It is everyone's common knowledge that a bomb is dropped from an aircraft. Even if someone never has the chance to witness the dropping of a bomb from an aircraft, one must understand it from one's readings or movies. But how to load a bomb, which is sometimes weighted several tens, hundreds and thousands of kilograms, is not something that everyone can understand. Those who have had the experience of serving in the bomber division of air force may know that bombs are always suspended on holders in the bomb cabin or underneath the wings for aircraft to transport, and customarily the work of loading the bombs is called "bomb suspending". As bombs are dangerous, in peace time, they can only be stored in the ammunition depot away from airfield. For safty sake, bombs and their ignitors (such as fuse) are stored separately, and only shortly before loading, they are transported from the ammunition depot to a special area called ammuniation operation zone in the airfield, where they receive the service of cleaning and checking.

For loading, the bombs first are carted to a spot underneath the aircraft and then they are suspended on the craft. Practically the loading work includes two parts: 1. to transport the bomb from an ammunition depot to the ammunition operation zone then to the spot underneath an aircraft, and 2. to suspend the bomb on the aircraft. Equipment used in these operations is generally called equipment of bomb loading and transporting.

In the earlier days, the work of bomb loading and transporting depends mainly on man power, because the bombs at that time are weighted only several or several tens of kilograms and the loading of an aircraft is also limited to a small amount, so it can be done perfectly by man power. But since the size of bombs has greatly increased (from several hundreds to several thousands of kilograms), and the loading amount of an aircraft has increased (from several to several ten tons), It has become impossible to complete the task of bomb loading and transporting by man power only. So some simple machanic installations have begun to develop, and through continuous improvement, they have been developed into a set of special equipment of bomb loading and transporting. At the present time, this equipment generally includes two parts: the soft elevation transporting system and the ammunition loading carts.

The basic technical requirements for equipment of bomb loading and transporting are safty, power saving and promptitude.

Safty, Power Saving and Promptitude

(Basic requirements for equipment of bomb loading and transporting)

Bombs are dangerous. The length of a big bomb can reach two to four meters and its weight can be several hundreds to several thousands kilograms, and its charging coefficient can be 50% (charging coefficient: the ratio of the weight of poder charged in the bomb and the total weight of the bomb). The charging coefficient varies from different bombs, and it ranges from 15% to 70-80%.

Most of the commonly used bombs have a filling coefficient around 50%. With high explosive taking up half of the total weight of a bomb, accidental explosion in an area of large quantity of explosive is unthinkable. Thus both loading and transportation facilities must include devices to secure the bombs (figure 1) in order to prevent them from falling, leading to an explosion or wounding of workers.

Secondly, loading should minimize human effort, meaning the use of a smaller force to lift and transport a heavy bomb. A man has limited strength. He cannot move a weight heavier than a hundred kilograms. Thus it is impossible for him to manually load a bomb that weighs several hundred kilograms. Electric motors provide greater lifting power. And consideration of efficiency implies that mechanical devices should be coupled in use. The combined use of machines such as pulleys, beam balance, wheel and axle can reduce the force required substantially. From the physical view point, mechanical devices can only minimize the force, but not the amount of work. Generally a smaller force means longer operating time. So speediness and labor saving are two conflicting demands in the loading process. It is necessary to arrive at a compromise solution that saves human energy and allows loading to proceed at a reasonable speed.

Thirdly, speedy loading is required. Modern warfare requires bombing missions be carried out quickly and secretly so that the enemy does not have sufficient time to take defensive measures. As we discussed before, bomb loading can only be carried out immediately before the bombers take off. Then this loading process becomes the crucial factor in determining whether the bombers can take off quickly. For some large bombers which carry up to a hundred bombs, the loading time could take more than ten hours. This leads to the following consequences. First, with the bombers undergoing long period of loading on the airfield, reconnaissance by the enemy usually reveals that an attack mission is in progress. Second, the longer the bombers stay on the ground, the greater the probability of an air attack on the airfield. So speedy loading not only guarantee fast take-off to achieve a surprise attack, it also reduces the chance of an air attack from the enemy.

When aircrafts are on a continuous bombing schedule, speedy loading becomes even more important. Between landing and take-off, refueling and bomb-loading are the two main items of ground work. Speedy loading shortens the time a plane has to spend on the ground and increases the combat usage of aircrafts.

In conclusion, it is easy to see that speedy loading is an important tactical requirement on the loading facilities.

A Soft Lift and Transport System

A soft lift and transport system is made up of cables, pulleys, winches (figure 2) and other accessaries. The steel cables support and transmit forces. Pulleys can be fixed or movable. Fixed pulleys are used to change the direction of a force while movable pulleys reduces the force requirement. The winch is the part of the system which transmits the dynamic force. Its principle is the same as the wheel and axle widely used in villages. The greater the ratio of the radius of the wheel to that of the axle, the smaller is the force required. The winch can be operated by hand or by an electric motor.

The soft lift and transport system is an old model of loading and transport system and is still being used on some airplanes. Actually the lift and transport systems are two separate and independent parts. The lift system is normally mounted on the airplane.

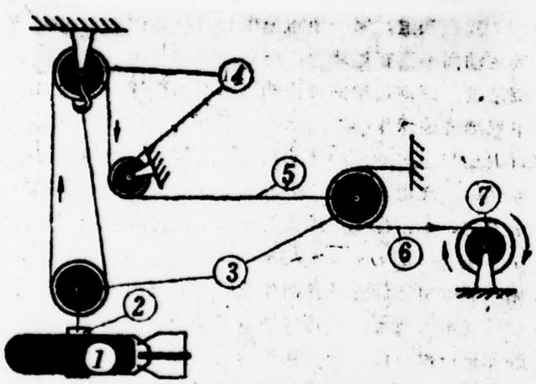
It can be called a pulley-crane. The transport system is a ground vehicle which, pushed by hand or pulled by other vehicles, transports bombs from the storage ares to the airplane.

In general, each bomber carries two to four winches. Each winch can only lift one bomb at a time. For large size bombs, two winches are needed.

The main advantage of this system is its simple set-up. It can be carried on board the plane so that there is no dependence on ground facilities. There are several disadvantages as well. Examples are dislocation between the lifting and transport processes, slow loading, a large working crew and heavy work. It also takes a long time to change cables for different formats of bomb loading. These disadvantages become obvious when an airplane has a large bomb load or when the bombs are of large size. As a result, most countries have abandoned this method of loading and use explosive-loading vechicles instead.

图一 用专门装置固定炸弹

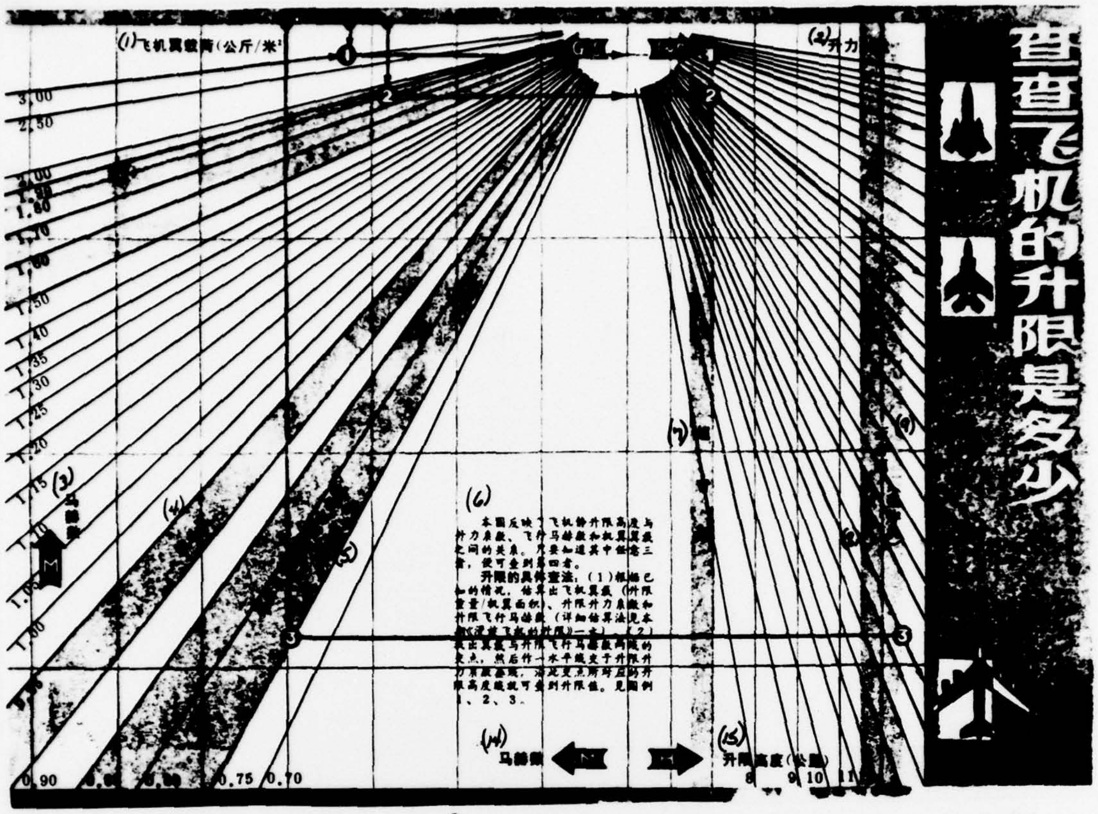
Figure 1. Special device for securing the bombs



图二 软式升降系统起挂炸弹的示意图
①炸弹 ②炸弹钩 ③动滑轮 ④固定在飞机上的定滑轮 ⑤飞机上的钢索 ⑥绞盘机的钢索 ⑦绞盘机

Figure 2. A soft lift system loading a bomb

1. bomb 2. bomb hook 3. movable pulley
4. pulleys fixed on the airplane
5. steel cables on the airplane
6. winch cable 7. winch



Key: (1) Wing load (kg/m^2); (2) Lift coefficient; (3) Mach number, (4) Fighter, (5) Bomber and subsonic attack plane; (6) This diagram illustrates the relationship between the static ceiling and the lift coefficient, the fligh Mach number and the wing load of an airplane. Knowing three allows the fourth quantity to be determined. To determine the ceiling: 1. With given data, estimate the wing load (ceiling weigh/wing area), ceiling lift coefficient and ceiling flight Mach number (see The Ceilings of Aircraft in this issue). 2. From the intersection of lines of constant wing load and flight Mach number, draw a horizontal line to intersect the vertical line of lift coefficient. The altitude corresponding to this intersection is the ceiling of the aircraft. See example 1, 2, 3 in the diagram. (7) Supersonic speed, (8) Subsonic speed; (9) Fighter bomber; (10) Bomber; (11) Fighter; (12) High altitude reconnaissance plane, (13) What is the ceiling of an aircraft; (14) Mach number; (15) Ceiling height (km).

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