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AERONAUTICAL KNOWLEDGE (SELECTED ARTICLES).(U)

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

AERONAUTICAL KNOWLEDGE
(SELECTED ARTICLES)

FOREIGN TECHNOLOGY DIVISION

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Table of Contents

[Translator's Note: Throughout document flame control = fire control; head = nose; crack extension = crack propagation.]

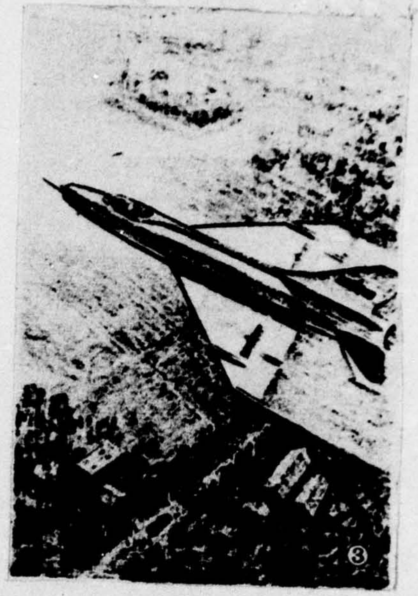
Wang Kuan-yang
A Pilot of Lei Feng Type

by
Shih Feng-huang, Sun Hsu-min and Shih Lan-p'in

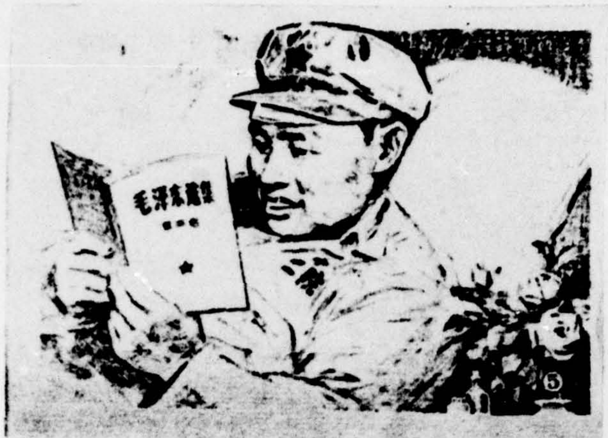
(1) Wang Kuan-yang is a revoluionary, well-experienced and courageous pilot. He fights heroically at the front of science research for national defense,and has many times completed his assignments with excellence. To the task of speeding up the construction of people's air force, he has made great contributions.

(2) Once when he has just completed his flight test and ready to make his return flight, the engine of his aircraft suddenly stopped working. He then decided not to bail out of his aircraft to make a parachuting, instead, he held the craft and made a forced landing.

(3) While his aircraft at an emergency landing altitude was like a wild horse rushing downward, Wang saw a chimmey and a water tower of a factory in front of him. He wanted to make no damage to any part of the factory, he refused the advantageous condition of upwind landing and managed to change his course and successfully spared the factory.



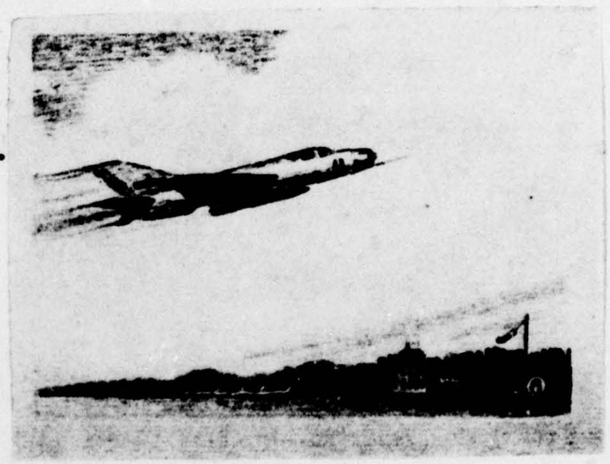
(4) At the moment when his aircraft was coming close to the ground, Wang saw a few people workimg in the cornfield in front of his aircraft. He then hurriedly applied the brake and made a final correction of his course,and thus he saved the workers in the field. His aircraft made a forced landing in a harvested field, but because of the violent shaking, Wang was seriously injured.



(5) Wang Kuan-yang is a diligent pilot and even in the hospital, he never stops working. When the swelling on his eyes has just begun to reduce, he picks up a copy of <u>Volume V of Selected Works of Mao Tsetung</u> as he wants to

inspirations
draw some new revolutionary insirations from it.

(6) As soon as he has completely recovered, he returns to his unit with great determination. He wants, under the guideline of the resolutions of the 11th National Congress of the Chinese Communist Party and following leader Chairman Hua, to make more flight tests.



A Devotee of Science Research and Flight Test

By
Ch'in Ching
Peng Shih-chin Tang Te-sheng
Liu Feng and Tsai Shan-wu

At an altitude of 8000 meters, pilot Wang Kuan-yang had an accident. He refused to parachute and, firmly holding his aircraft, made a forced landing instaed. Thus he successfuly saved some people's ~~peole's~~ life and property. This article attempts to make a profile of such a heroic person.

Wang Kuan-yang is a pilot of one flight test division. He has high degree of sense of responsibility, daring revolutionary spirit, serious attitude toward science and the best flight experiences. In a period of ten years, he has many times achieved excellence in performance of high level science research and flight test, and four times he received official commends from committee members of the Communit Party. On August 8 of last year, the party branch in the air force officially gave him an honorable title of "A Pilot of Lei Feng Type".

Science research and flight test are important links in the programs of speeding up the modernization of air force. New aircrafts must have flight tests, and the newly made instruments of various kinds have to pass flight test as well. The examination of limitation data of new equipment also depend on flight test, and no one of these tests is surely safe. But Wang Kuan-yang is never afraid of danger and always gallantly chooses to take the hardest work. Along with other science researchers, he inceasingly strives to explore new areas and approaches high goals. One hot summer day, the temperature in the airfield was very high, he wore his altitude antigravity suit and a heavy helmet. Stepping off the aircraft, he was all over a sweat. But in order to grasp the favorable time, without taking off his flight suit, he sat down on the parking apron to wait for an order to make another flight test. The other comrades urged him to take a rest, with a gratifying smalling he said, "We want to advance our science research, time is a precious factor. If I can make one more flight, we may have accumulate more data necessary for our science research".

During the time when the "gang of four" tried to delay the development of industrial production and the modernization of national defense, against the tide of the influence of the "gang of four", Wang Kuan-yang completed each flight test assigned to him on time. From 1975 to 1976, in a period of a little more than one year, he together with other comrades completed twenty flight tests for science research.

In the late September, 1976, amidst the sad and solemn atmosphere due to the death of Chairman Mao, the authority assigned a flight test of a science research instrument, which had been a concern of the late Premier Chou En-lai as well as Chairman Hua, to the unit that Wang Kuan-yang was belonging to. Wang Kuan-yang then asked the leader of his unit, saying "Please give this mission to me. I must transform my sorrow into strength and following Chairman Mao's will to complete it."

The unit leader approved his request, and Wang Kuan-yang then began to devote his time and energy, day and night, to the preparation for the test. On the day that Wang planned to make his first flight test, he came to the airfield very early and waited for order standing by his

aircraft. But till noon time, the cloud ceiling remained undesirable for flight. The cloud became thicker and thicker and the visibility became shorter and shorter. All other scheduled flights had been canceled, but Wang Kuan-yang was still waiting by his aircraft. One comrade from a science research unit came over to ask him, "Brother Wang, are you still waiting to fly when the weather is like this?" Wang lifted his head looking at the sky and said, "As soon as it becomes possible, I will try to complete my duty. Then you can have the data you need." As time rolled on, Wang was afraid that he could have no chance to take off if he continued to wait. So once and again he asked his commander saying,"We are still ready and waiting, let's take off." After careful consideration, the commander finally issued an order to let them fly. In the sky, there was a green light signal. Despite the dark clouds, Wang Kuan-yang began to fly in the sky and repeatedly made his tests. As a result, he obtained the much needed data and he really made the best use of this precious time.

There was a new test to be carried out. On that day, the sky was clear and Wang Kuan-yang carrying his new assignment happily flew in the blue sky. He calmly, exquisitely and precisely performed each action and overcame the difficulty of insufficient fuel because more actions than expected must be taken. He continuously reported each practical data to the director in the science research office on the ground, and he victoriously broke the speed and altitude as indicated in the design index. In this test, because of his courageous struggle, Wang succeeded to save 10% of flights as desinged and completed the tests four days ahead schedule.

Before long, China successfully tested another hydrogen bomb under the direction of Chairman Hua. During the test, pilots Pan Kuo-hsing and Sun Jung-hua of China Air Force, using the equipment which Wang Kuan-yang once used and the data collected by Wang Kuan-yang, safely flew through the mushroom clouds and collected the necessary samples. They achieved their distinction. In the final discussion of their meritorious acheivements, they declared that Wang Kuan-yang is the pioneer who passes ~~through~~ through the mushroom cloud.

Wang Kuan-yang is a well experienced pilot, who has been doing science research and flight test for more ~~than~~ than ten years, and from those practices he has accumulated rich experiences. Toward the goal of speeding up the modernization of China's air force, he actively and dutifully studies flight techniques and conscientiously makes flight tests. During the days when he is on duty to carry out science research and flight test, he always in the early morning steps in his aircraft courageously to do various kinds of science research and flight tests. In the evenings when he is off of duty, no matter how tired he is, he always tries to visit other science researchers and discusses his experiences in flights so as to perfect flight techniques.

Once his unit receives an order to test placing auxiliary fuel tank in a high speed fighter. This test is the preparation for making a new type of aircraft. The research unit and the manufacturer require that this test must be completed in a short period of time and that the data must be accurate. When Wang Kuan-yang has been assigned to this mission, in the night of that day he began to check data, draw flight routes and study flight direction and altitude and the time of fueling. In order to have everything well prepared, he worked till very late.

Next day, immediately after he had arrived at the airfield, using the short time before taking off, he began to check his cabin and recheck his flight plan. In order that his flight plan can be more scientifically prepared, he went to see some of the science researchers and repeatedly explained to them about his flight plan and asked them for correction. Under the asistance of leaders and science researchers, he made a new and more scientific flight plan. After he had completed his mission, he was told that his first taking-off and landing was not perfect. Then, under the approval of his leader, he made three more flights and his mission was completed perfectly.

After the fall of the "gang of four", in the front of national defense, comes a new and good situation. Under the leadership of Chairman Hua, it has been decided to revolutionize and modernize people's air force. Certainly, this gives great aspiration and strength to Wang Kuan-yang. On June 19, 1977, Wang Kuan-yang was assigned to a new flight test. With great ~~excitement~~ (excitement) he pilots a Chinese ~~China~~ made high speed fighter to the blue sky high above. When he has reached an altitude of 8000 meters, following the regulated requirements for flight test, he begins accurately and skillfully to make level flight, circling, diving, rapid climbing and accelerating. After having completed these performances, he is in the process of closing fuel valve, turning off fueling and reducing speed, and suddenly there is a burst of sound in front of his aircraft and the engine begins rapidly to slow down. By this time, it is of no use to release the fuel valve. He now becomes aware that the engine has developed problems. After a calm analysis, he concludes that the engine has stopped working, and from all the phenomena, he realizes that he has no way to pilot his craft any longer. The speed of the craft begins to reduce and the altitude becomes lower and lower. The situation is serious. Wang Kuan-yang calmly and clearly reports the situation to his commander. Under the direction of the commander, Wang coolly and easily tries to adjust his direction and toward the airfield he is ready to make a return flight.

As time passes by second by second, the altitude and speed of Wang Kuan-yang's craft continues to descend. The commander on the ground knows very well the serious consequence as an aircraft has lost its power and the difficulties of its forced landing. So he on the one hand issues detailed directives leading Wang Kuan-yang to return to his original airfield, and on the other hand carefully anaylizes the situation and gets ready to issue his ultimate order. The altitude has reduced from 8000 to 2000 meters, and, by his flight experience, Wang Kuan-yang knows this is the best altitude and condition for making a parachuting and only by a touch of the spring of the parachute, he can then return to the ground. But Wang Kuan-yang realizes that parachuting means to abandon an aircraft and the science research equipment in it. Moreover, the falling of an uncontrolled aircraft will similar to the drop of a heavy bomb and it may fall on a factory or a village, thus it will make great loss. In facing such problems, he makes a quick decision that he refuses the chance of parachuting and tries his best to make a forced landing.

Wang Kuan-yang strives to control his aircraft gliding toward an airfield. The flight is from west to east, and accordingly he should make an eastward forced landing. If so doing, he must pass through the sky over a large factory. In order to avoid the possibility of falling in the factory area, he gives up the favorable condition of making upwind landing, and changes to make a westward forced landing instead. Now his aircraft is only 1000 meters high above the ground and its descending becomes faster and faster, so it has been impossible for him to make a forced landing at an airfield. Under such circumstances, Wang Kuan-yang calmly observes conditions on the ground and tries to avoid any village.

When his aircraft comes very close to the ground, he suddenly sees an elementrary school and some farmers working in the field in front of his right hand side. At this critical moment, Wang Kuan-yang makes a final change of his course and let his aircraft land in a wheat field where the crops have just been harvested.

The aircraft and the science research equipment are saved from wreckage, and the factory, the village , the school and the farmers suffer no damage, but, because of the violent flutter when the aircraft touches the ground, Wang Kuan-yang ~~gets~~ is seriously injured. When people come to his rescue, he seems to forget~~ting~~ his pain and continues to ask, 'Whether he has made damage to any house, hurt any body, and how is his aircraft?' ~~Peeple~~ People who are present are all touched by his courage and patriotism.

On June 20, vice premier Wang Chen and some other leaders of different departments of the central government coincidentally came here to supervise some project. When they heard the story, they rushed to the hospital to see Wang Kuan-yang. Vice premier Wang Chen sent Wang Kuan-yang a bundle of ~~resh~~ fresh red flowers and personally told him, "You are a heroic model pilot.

I am on behalf of Chairman Hua and Vice Chairman Yeh come to see you. When I return to Peking, I will immediately report to Chairman Hua and Vice Chairman Yeh of your heroic deeds". With great excit~~ment.~~ement, Wang Kuan-yang said,"I wholeheartedly support Chairman Hau and Vice Chairman Yeh, and thank you for your concern. I must follow the doctor's ~~the~~ instructions. But I hope that I can be released from the hospital earlier and that I can try to contribute more to our aviation science research."

Fracture Mechanics and Aeroengine

by
Kuo Yi-chi

The study in fracture mechanics of the rules of crack extension of a cracked body when it receives a force is a new breakthrough of the theory of strength, and this study is now showing its great vigorous growth.

In engineering technology, we often use strength to indicate the ability of destruction resistance of a component part when it is under action of external force. In designing of supporting articles, we always make strength calculation. In the past, strength calculation often takes material mechanics and elasticity mechanics as theoretical basis and ~~assume~~ assumes that material is perfect and is homogeneous medium. Now fracture mechanics is a science that deals with the problems of strength and ~~assume~~ assumes that material originally has cracks or it ~~becomes~~ begins to have cracks when it is being used. On such a basis, fracture mechanics studies the strength and useful life of component parts.

If cracks have been found, what will be the theoretical basis for calculation of strength? ~~Using~~ What formula ~~to calculate~~ can be ~~considered scientific?~~ used for calculation? What is the factor that determines crack extension? How is ~~to calculate~~ the life of a component part to be calculated? All these are subjects ~~to~~ for study in fracture mechanics.

Origin and Development

It has been said that in the 1920's, there was a Briton named

Gelifeis* who began to study the calculation of strength of the cracked materials. First, he from theory analyzed the energy change of the crack extension and the relationship between strength of crack and the size of the crack. His theory has been proved true on glass vessels, but because it is applied only to the fragile materials, it failed to attract much attention.

During ~~the~~ World War II, among ~~about~~ 2000 US liberty ships, ~~vessels~~, there were ~~happened~~ more than one thousand incidents of fragile fractures. At that time, because of the urgency of war, no serious study of the incidents took place.

In 1960, the solid rocket engine shell of US polaris missile exploded during testing. According to the traditional strength calculation, the breaking stress is far smaller than the yield limit (damaging stress), ~~so~~ this incident caused wide attention. Through many times of tests and fragile fracture analyses of the shell, it has been discovered that the fragile fracture is always caused by crack extension. In 1969, ~~there was~~ an aircraft F-111 crashed because of the break of its wing axis and at the time ~~when~~ the incident took place, the velocity, weight and loading coefficient of the craft were all within the designed range. Through analyses, it was then found ~~out~~ that the break of the wing axis was caused by a crack which was made when the axis was cast. Aircraft C-5A, helicopter S-61 and the fan rotor disk of RB.221 engine had incidents ~~and~~ all because of cracks on them.

* Gelifeis is a Chinese transliteration of an English name, which may be Griffith. Except for some internationally renowned personalities and places, it is rather difficult to identify a Chinese transliteration of a foreign proper name because of the different pronunciation system of English and Chinese. Worse still, if the transliteration is made on the basis of some local dialect.

The fracture incidents mentioned above are all phenomena of "braking", but those of only "cracking" not "breaking apart" are widespread. In checking an aircraft and its component parts, cracks are often found~~, there~~. It always seems to be a new discovery when a crack is found in some parts, but, in fact, however, the crack has existed before it is discovered. Only after a certain period of time the parts are being used and the crack extended to such a degree that it can be seen by damage detecting instrument or naked eyes. The damage detecting instruments presently used in factories have their own limits. Some of them cannot discover any crack ~~even~~ if there are cracks on the sample. ~~So~~ Many component parts ~~which are~~ detected by damage detecting instruments ~~and~~ prove perfectly fissureless and are often found bearing cracks. This is because of ~~the~~ limitation of ~~the~~ sensitivity of the damage detecting instrument that cannot discover the cracks. It is therefore proper to say that many parts of engines and aircrafts which are now flying in the sky are being operated under the condition that they have cracks. From the fracture mechanics point of ~~veiw~~ view, it is a normal phenomenon and there ~~is~~ are nothingwhich should cause alarm.

The problems of fracture in engine and aircraft are problems which are old, great and ~~difficlut~~ difficult, especially the fatigue fracture which is ~~the~~ number one among the fracture incidents. It is not exaggerated when someone says that the fatigue fracture is the "cancer" of an engine or an aircraft and it metaphorically implies the danger.

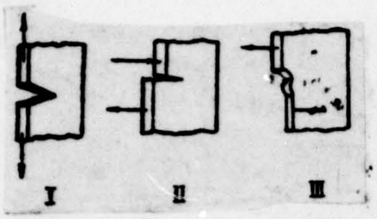
To solve the fracture problem must begin with the study of the causes of fracture, then find out the rules of fracture. From these rules some solution may be found. The present need is to help the advancement of science and technology. The basic theory of elasticity mechanics and plasticity mechanics has reached its required level. So, in the 1960's, the practice and theory of fracture mechanics became mature and soon fracture mechanics was an independent and new science. It can be anticipated as long as there is fracture incident in aviation, this new science will continue to grow.

The New Concepts Generated from Fracture Mechanics

Fracture mechanics is a new science and the achievements it has attained can be summarized as follows:

The concept of "cracking" and "breaking-apart". The incident of breaking-apart is a result of the development of cracks. Because of the seriousness of a breaking-apart, a crack is cause for alarm. It is felt that a crack will lead to a breaking-apart. Obviously such an idea tries to equate a crack with a breaking-apart. It has long been the practice not to try to repair a crack in an aircraft engine, but instead to abandon the engine completely. Thus a staggering quantity of aircraft engine components is abandoned simply because of cracks in engines. Obviously this handling of engines occurs because of the misleading notion that a crack will necessarily result in a breaking apart. This belief is so strong that few people try to study the rules of crack extension, and the study is considered meaningless and useless because as long as there is a crack, there must follow a breaking apart. Although such an idea prevailed for a period of years, the fracture incidents during this period never ceased to happen, and no solution to the problem of fracture was found. Fortunately, at long last, from the unfortunate flight incidents, time and again, people have learned a lesson and begun trying to analyze the cause of the incidents and to explore a new way to solve the problem. For instance, after the explosion of the US polaris missile, they organized more than twenty units to analyze the causes of the incident.

In 1959, a special committee was established to study the fracture strength of materials (further explanation will be given later on). Since then the study of fracture mechanics began to develop.



Open-ing   Tearing   Glide cutting

Figure 1. Types of cracks.

Since the development of the theory of crack surface energy in fracture mechanics, it has been recognized that a crack will not necessarily become a breaking-apart and it may never become so. There is a certain condition in which a crack develops into a breaking-apart. What is the condition? The condition is determined by the exchange relationship between the adaptation energy (explanation will be given later) released from parts when they are working and surface energy absorbed by the crack after it has come into being. If the adaptation energy is larger than the surface energy, the crack will extend; otherwise, the crack becomes stable and will not extend. If both of them are almost equal to each other, the crack will be stable for a period of time. But when it is under some external impact, it will rapidly extend. The concept that a crack must be followed by a breaking-apart is but one of the three possible tendencies of a crack development and it is not a natural tendency. This shows the partiality of the traditional concept.

The dealing with crack in fracture mechanics must face the reality and deals with it individually. In order to reach such a degree, it requires a precise understanding of the rules of crack extension. The individual dealing can be realized only by means of thorough study and various kinds of theoretical calculation and practical experiment.

For proving the practical significance of studying the rules of crack extension to the aircraft engine, we would like to provide the following facts as example. In an aircraft engine, the exhaustion edge of directing blade of the turbine often has cracks. This is almost a common phenomenon of all aircraft turbo-engine. The cause that causes cracks is the uneven distribution of the temperature of combusting air entered into the turbine, and thus it creates an uneven distribution of surface thermal stress (for the concept of stress, see " The Techniques of Strengthening Jet Pellet" in No.10 of this journal, 1976). Through the repeated heat circulations,it is easy to have fatigue cracks on the exhaustion edge. Because the directing blade is static and, unlike the revolving ones, it is not affected by the centrifugal action. So its negative loading and the degree of transformation is insignificant and the amount of adaptation energy it released is also small. But the fatigue cracks always comes in the form of multi-line simultaneously, so the amount of surface energy they want to absorb is not small. Thus it creates a situation that the amount of surface energy the cracks absorbed is larger than that of the adaptation energy the directing blade released when it is working. According to the point of view of fracture mechanics, under such a conditeon, the cracks will not extend. So if there are cracks on the exhaustion edge of the directing blade, the blade is still useable, and there is no necessity to replace it hastely.

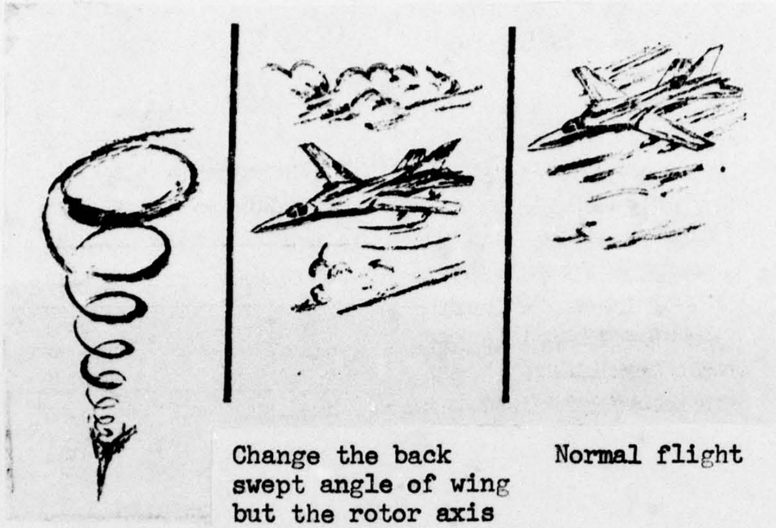
As a consequence, there is no risk of having any incident of breaking-apart, but it prevents the unnecessary waste of material and ~~manpoer~~ manpower caused by replacing the blades.

According to what has so far been known, of the British "Szubei"* engine, if the length of a crack on the blade exhaustion edge is no more than 7.6mm, it is permisable to continue using the engine. The Czechoslovakia engine M701C-500 can continued to be used if a crack on the directing blade exhaustion edge is found no longer than 10mm. These examples suffice to prove that cracking does not necessarily mean breaking-apart. In retrospect, during the years when the thinking that a crack must be followed by a breaking-apart prevails, the way of handling this problem is entirely different. Whenever a crack is found on the directing blade, the whole engine must be taken off from the aircraft and sent back to the factory to replace the blade and only then it is considered useable and safe. But before long, crack is found again and the engine is taken off again. Thus the waste of material and manpower is tremendous. So the study of cracking and breaking-apart is indeed very important. It is not merely a matter of whether the concept is correct or not, but it is a matter concerning flight ~~safty~~ safety, the loss of nation's property and the waste of material and manpower.

Stress Strengthening Factor K_1 and Fracture Tenacity K_{1c}. Generally in the field of fracture mechanics, cracks, according to the condition under which they receive force are divided into three different types. As illustrated in Figure 1, type 1 is an opening; type 11 is a tearing; and

* "Szubei" is a Chinese transliteration of an English name.

type lll is a glide-cutting. Because type l is the one which is very easy to make, it is usually taken as an example.



Change the back swept angle of wing but the rotor axis is cracking

Normal flight

Because of the breaking of rotor axis of the wing, the aircraft is falling down

When a component part has had a crack, under the action of working load, the stress close to the pointed end of the crack is always greater than the average stress the component part received. So the average stress before the crack occurred is not representing, and we must use some other formula to calculate. Because the stress close to the tip of the crack has special characterisitcs, the distribution of stress is called stress field of crack tip. According to the inference of fracture mechanics theory, this stress must be described by using a new concept, which is called stress strengthening factor K_1. Crack extension is, in fact, determined by stress strengthening factor K_1. But K_1 is related to external force, geometrical length, material characteristics and the crack half length a. Based on the inference of fracture mechanics, it can be approximately expressed by the following formula:

$$K_1 = \sigma\sqrt{a\pi}f(w)$$

a is application stress

a is crack half length

f(w) is geometrical shape function

From the above formula, it can be seen that if the external force and the crack length are increased, K_1 will become larger. But the numerical value of K_1 cannot be infinitely increased and it has its limited value. When K_1 reaches the limiting value of K_{1c}, the crack will become unstable and begin to extend. It may rapidly extend to a degree of breaking-apart, and an incident of breaking-apart can happen immediately.

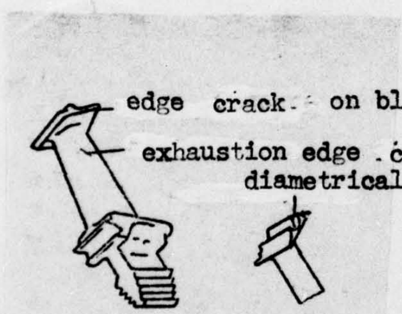


Figure 2. Cracks of three different natures appears on the blade

Where is the demarcation line between a crack stable extension and unstable extension? The line is the limit value K_{1c} of K_1. This limit value is called fracture tenacity K_{1c}, which is closely related to the characteristics of the material. As fracture tenacity K_{1c} varies from different materials, it can be found out through testing by using some instrument. The judgment of fracture resistance ability, therefore, is not made by strength but by fracture tenacity K_{1c} of the material. The higher the numerical value of K_{1c} is, the less chance to have fracture. It is a new concept to measure the fracture resistance ability by using fracture tenacity. Based on the numerical value of K_{1c} which has been obtained, we have found a special rule that is materials of higher pulling resistance strength have lower fracture tenacity K_{1c} (see the following table).

Brand No. of material	Pulling resistance strength limit σ_b(kg/mm^2)	fracture tenacity K_{1c}(kg/mm$^{-3/2}$)
2024—T4	45	202
2024—T851	46.4	81.6
4340	182.6	188
Ti6—4	118.8	167
Ti6—2	129.2	110

Thus we can conclude that in order to prevent cracks on component parts, the parts cannot be made of materials which are of high strength. Because the higher the strength is, the easier the fragile fracture occurs. Such an idea is contrary to the traditional thinking. In the past, based on traditional thinking, when a part cracked, it is always thought that the strength of that part is not high enough. In order to solve such a crack problem, materials of high strength are often sought. The result of so doing is, in fact, to make it easier to have cracks. The factual instances of this case are often seen in daily life.

In summary, crack extension is determined by stress strengthening factor K_1 close to the crack tip when a component part is receiving external force. If K_1 is greater than fracture tenacity K_{1c} of the material, cracks, under the condition of receiving no more external force, will rapidly extend themselves, and results in an incident of breaking-apart. The inference of fracture mechanics by using stress as basis to determine that cracks will not produce unstable extension can be expressed by the following relation formula: $K_1 \leq K_{1c}$.

The above formula is an important conclusion deduced from the study of the stress field close to the crack tip in fracture mechanics. From the combination of K_{1c} numerical value and the state of stress when a crack produces unstable extension, we can calculate the maximum crack length of a component part, and this length is called critical crack length a_c. If the critical crack length a_c of every kind of component parts can be obtained through calculation, then, based on the existing crack length a and the speed of crack extension, the time needed to extend to the length of a_c can be determined. Thereupon, the life of a component part which has had cracks can be determined. If the crack length a is much shorter than the critical crack, there is no need to replace the component part which has had cracks. Such a conclusion is in accordance with the points mentioned above. At the present time, in some countries, when an engine is being designed, they consider the initial crack a_o of a component part at a certain period of its life. Obviously, this is to apply fracture mechanics theory to make strength design and life design. For instance, the life prediction of the turbine disk of an engine by Pratt.Whitney Co. in the United States is through a number of working cycles. The life of turbine disk is determined by the working cycle at which a crack of 0.794mm is found on the turbine disk. Of course, this numerical value cannot be just the critical length a_c of the crack, and it can be smaller, so the reliability of the engine still has its guarantee. Obviously, however, the guideline of making such a technical standard is to take the concept of crack critical length a_c and crack initial length a_o in fracture mechanics as theoretical basis.

The Surface Energy and Adaptation Energy of Cracks. In fracture mechanics, it is believed that when a crack is extending, there must be some energy to support it. In the process of extending, the crack absorbs energy. When Gelifeis suggets his theory of surface energy, he believes that once a component part has a crack, the surface of the part at the crack has been divided into two. If the crack continues to extend, the two surfaces will continue to be augmented, and at the same time they absorb energy. The energy thus absorbed is called surface energy. The amount of energy absorbed will be in direct ratio to the size of the crack and the absorption rate of surface energy is usually indicated by using G_{1c}. Through repeated comparison, it has been discovered that the crack surface energy absorption rate is closely related to the crack tenacity K_{1c} of the material. Of the material, the higher K_{1c} is, the higher is G_{1c}. This means that a crack cannot extend unless it has absorbed enough surface energy. G_{1c} is therefore also called crack extension resitance force.

Adaptation energy has been discussed in material mechanics. When the main parts of an engine are working, some kind of distortion will take place, and at the same time, they release a certain amount of energy. This is adaptation energy. A displacement always takes place when a component part receives external force, and this displacement inevitably brings about distortion. The origin of adaptation energy is external force, so it is also called potential energy. On the other hand, a part of the adaptation energy is stored in the materials of which the component part is made, and this part of adaptation energy is released through displacement when the parts are working. When a part has crack, the displacement while it is working will be different and the adaptation energy released will also increase. This part of energy absorbed by the two split surfaces changes into surface energy. The release rate of adaptation energy G_1 is the energy that determines the crack extension.

According to Gelifeis' theory of surface energy, if the adaptation energy release rate G_1 is larger than surface absorption rate G_{1c}, the crack will extend; otherwise, there will be no extension. G_1 can therefore be called force of crack extension, and G_{1c}, the force of crack extension resistance. From this we can reach a conclusion of the energy in fracture mechanics that will not cause crack extension. The conclusion can be expressed in the following form:

$$G_1 \leq G_{1c}$$

This is the condition that makes a crack stable and not extend. In our foregoing discussion of the point that a crack is not necessarily followed by a breaking-apart, we mention that for many engines, it is permisable to have crack of a certain length on the exhaustion edge of directing blade and the condition is $G_{1c} \gg G_1$. Cracks will be unstable and rapidly extend if the condition is $G_1 > G_{1c}$. There is another kind of cracks which at beginning is stable and not extends (extension may be very slow), but when it reaches a certain length, it will become unstable and rapidly extends. The condition for this is $G_1 \approx G_{1c}$, which gradually becomes $G_1 > G_{1c}$. The extension of this kind is of transitional nature. These three different kinds of cracks can be summarized as: stable crack, unstable crack and transitional crack.

These three different types of cracks can be found from many engines being used in China as well as other countries. For instance, The British Szubei engine permits to have crack of no more than 2.54mm at the blade top edge of first class high pressure turbine operation blade. Obviously, within this limit, the crack is stable. When it is over this length, the crack will become transitional in nature. On the sealing tooth at the top of this kind of blade, one crack is permissible and the engine can continue to be in use. There is even no regulation concerning the length of crack because the crack is positively a stable one. But if a crack is found at the exhaustion edge of this kind of blade, the whole engine will become useless (Figure 2), because the crack is definitely unstable. Once it is found, it will rapidly develop into a breaking-apart of the blade, so the engine becomes useless.

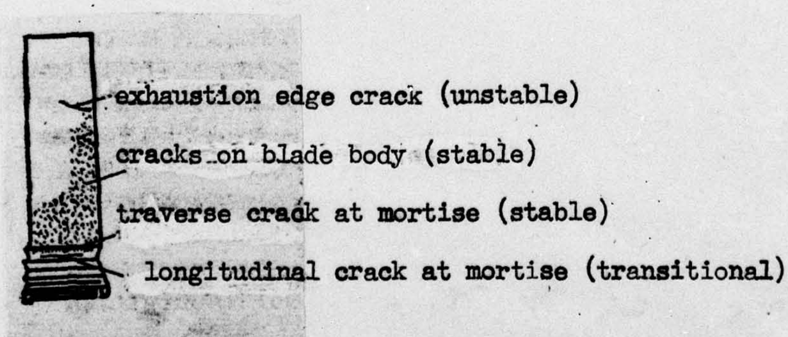


Figure 3 Cracks of three different natures are found on a turbine blade of a turbine engine made in China

There is another example, of one type of engine made in China, there are found many cracks on blades of the turbine blade, and the cracks are stable. But the traverse cracks at the mortise are transitional and the longitudinal ones are stable, and the cracks at the exhaustion edge are unstable (see Figure 3).

The above examples manifest a fact that on turbine operation blades of same type, the three different kinds of cracks can all be found. Turbine blade is one important component part of aeroengine, if it can have crack, it will be no surprise to find cracks on component parts of other positions of an engine.

Speed of Crack Extension. The speed of crack extension is one important topic in the study of fracture mechanics. When a component part begins to have crack, the crack will develop from stable extension to unstable extension. As soon as the crack reaches critical length a_c, the unstable extension will begin. What is the extension speed when a crack loses its stability. According to the results of various tests, the speed is surprisingly great and it is almost equal to sound speed. But before the crack reaches the critical length a_c, the speed of extension is slow. So the extension speed within the limit of critical length is called crack extension hypocritical speed. At the present time, in the study of fracture mechanics, the crack extension speed after the critical length has been known,the point of emphasis of the study should be the hypocritical area. Cracks which are all in the hypocritical length area are different from each other. Some simply stops developing; some develops but in a very slow speed; some are in great speed; some develops at beginning very slow and then becomes fast; and some develops at beginning rather fast and then becomes slow. Up to date, there have been numerous formulas describing crack extension speed in this area and this is obviously because ~~that~~ there are so many factors which affect the speed of extension, such stress distribution, elasticity of material, plasticity, elasto-plasticity and work hardening. However, it is a general recognition that crack extension speed is determined by the amplitude of stress strength factor ΔK.

The value of ΔK is concerning circulation stress. If there is no intricate changes of stress, cracks will not extend. There is a crack on a static article, if its ΔK value is zero, the crack will not extend. The necessary condition that causes crack extension is the action of external force which has cyclar changes. When a component part is acted upon by the external force, within the part there will be a circulation of stress. Since there has been a circulation of stress, the maximum value of stress strength factor is K_{1max} and its minimum value is K_{1min}, and their difference is $K_{1max} - K_{1min} = \Delta K$, which is called amplitude of stress strength factor. Crack extension speed is related to stress strength factor and also related to fracture tenacity K_{1c} of the material. It can therefore be said that the main factors that affect crack extension speed are stress circulation, stress distribution and fracture resistance ability of the material. In addition, the work technique of the component part can affect crack extension speed as well. Of component parts that are made of same material and are of same stress circulation and stress distribution, those which have been given a jet pellet strengthening technique can reduce their crack extension speed noticeably. So, besides ΔK, there may be some other factors which can equally affect crack extension speed. It is therefore impossible to make a complete formula to calculate the crack extension speed of the hypocritical area.

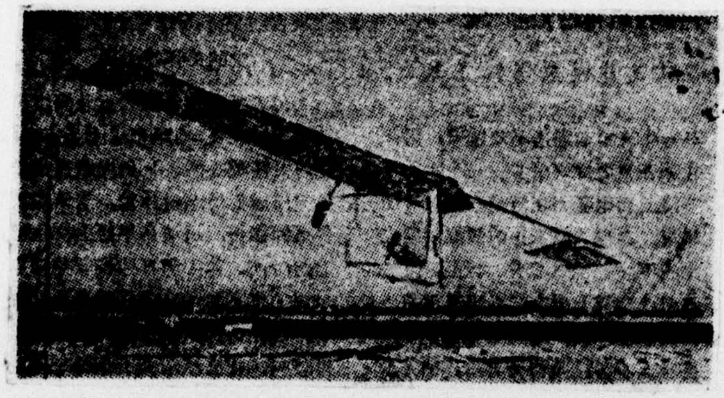
Sound Emission. In the study of fracture mechanics, it has been discovered that in the process of crack extension there is always a kind of sound. This is called sound emission. It is transformed from the energy released due to crystal shifting when a crack is extending. From a large construction, this kind of sound can be heard by human ears. From a component part of an aeroengine, it cannot be heard unless it is magnified by a special instrument. This principle has been applied in aviation to detect crack extension and it has also been used by some one as means to detect micro-crack. It is a new technique and it has caught wide attention.

In next issue of this journal, we shall discuss crack problems in aeroengine.

The First Flight of a Man-powered
Aircraft Following a 8-shaped Air Route

by
Hsieh Chu

In January, 1975, this journal published an article "The Recent Development in The Study of Man-powered Aircraft", by which we introduced how the man-powered aircraft designers abroad have tried to make a successful flight following a 8-shaped air route. Now this goal has been reached.



Title Picture. This is the picture of man-powered aircraft "Floating Bald Eagle" taken at the time when it is successfully making a record-making flight following a 8-shaped air route. From the picture, it can be seen that the aircraft is passing by the guide post at left corner and trying to make a turn. On the ground there are a few persons on bicycle to observe the flight. The pilot sits reclining backward and is pushing the pedal to keep the propeller running. In front of the seat, there is a wind shield and the pilot is protected by a transparent plastic box.

In a ~~summer~~ summer morning, the sky is clear and the breeze is gentle. On the runway of Shafter Airfield in California parked a strange aircraft. It has two long wings, the length of which is 30m, and they are almost transparent, for they are covered by a very thin cover which shows the ribs very clearly. Underneath the wing, there is a very simple pilot cabin. It seems somewhat exaggerated to say a pilot cabin because there is no cabin but a single seat. In front of the seat there is streamlined wind shield, and the seat is connected with a pedal, which resembles the one used in a bicycle. Its gearing chain can start the double-blade propeller in the rear of the craft. On the head of the craft, there is a long and thin aluminum pipe, on which a duck type forward wing is set. This wing controls the flight of the craft.

At seven o'clock in the morning, a young man named Bruce Allen steps on the pilot seat. He is a 24 year~~s~~ old athlete, of a height 1.82m and a weight 62kg, and wearing large-framed eyeglasses. He has experience of taking part in a bicycle race and practicing gliding. After waving to the people surrounding the scene, he sits on the pilot seat reclining backwardly and begins to start the craft by using the pedal. Soon the propeller behind the wing begins to revolve by a speed of 100 turns per minute and produces forward force, forcing the aircraft taxiing on the runway. Gradually the craft lifts from the ground and flies high above. This ~~is an~~ event ~~which~~ took place on August 23 last year. In this test, besides straight flight, the aircraft can make turns of 180°. Between two guide posts which are separated by a distance of 800m, the craft successfully made a 8-shaped flight. The flight takes 7 minutes and 28 seconds with an average speed of about 18 km. The flight altitude is above 3m and the average operating rate is 0.35- 0.4 horse power.

When the aircraft successfully lands on the ground, it has completed a record-making flight in aviation history and for this flight the prize is the highest in aviation history, too. This is a record of a man-powered aircraft successfully made a 8-shaped flight. The prize was made by British

Royal Aeronautics Society and the money was donated by an English industrialist. The prize was ~~estabilshed~~ established in 1959, since then in a period of 18 years, there was no one proven qualified to win the prize and the final amount of the prize reached 50,000 pounds.

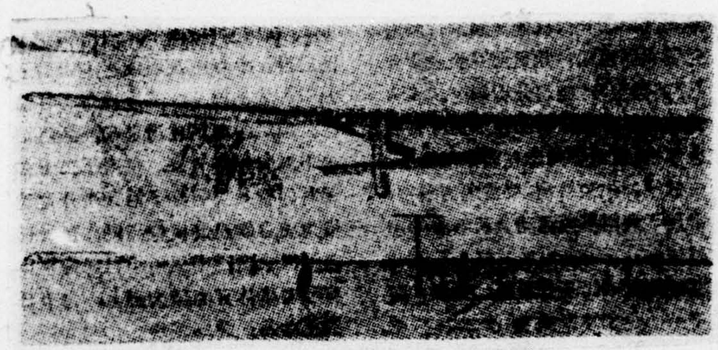
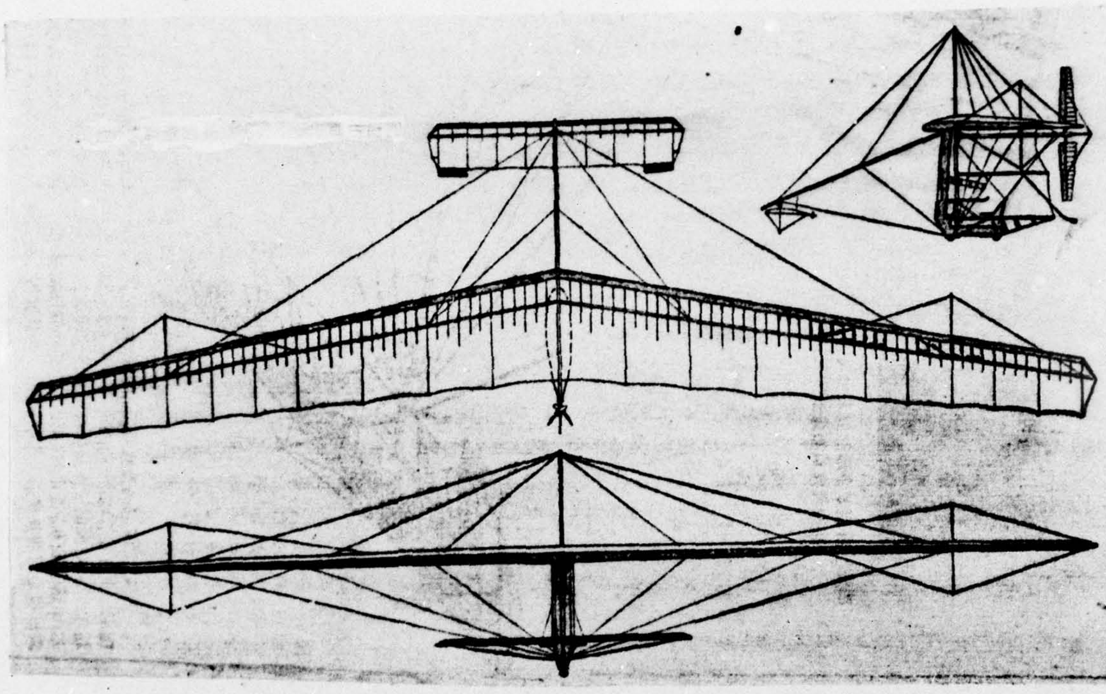


Illustration Picture 2. The man-powered aircraft successfully passed the guide posts on the ground and made a turn of 180°.

The designer of this man-powered aircraft is a well known American glide athlete and his name is Bill Mcleed*. In 1956, he was a winner in the world gliding contest, and the instrument he invented has been widely used by glide athletes. Later, he changed to work in the field of industrial aerodynamics and in 1976, he began his study of man-powered aircraft. By that time, many designers of man-powered aircraft have failed in their attempts to achieve 8-shaped flight. Most of their reasons are that the long wing touches the ground and forces the craft to fall down when it is trying to make a turn. The aerodynamical arrangement on the surface of those man-powered aircrafts is made following the model of a general aircraft. They resemble a general glider which has long wings (for providing enough lifting force) and short body. The ratio between

* A Chinese transliteration of an English name.

wingspan and the length of the aircraft (longitude-traverse ratio) is 20 ~ 30. On the other hand, they usually have tail wing and control plane, so the structure is bond to be complicated.



Picture 4. A three-facet diagram of man-powered aircraft "Floating Bald Eagle".

What was in Mcleed's mind was the parasol wing glider which was fashionable at that time in the United States (see "Single Seat Glider" in January Issue of this journal, 1976). That glider has no tail wing and control plane, and the pilot is suspended underneath the wing (or parasol wing). The operation totally depends upon the shape-change of the parasol wing or flexible wing and incidence, so it is also called "swing gliding". Thus the structure of a glider is simple and its weight is light but the lifting force is thereby increased. Mcleed was originally an enthusiastic participant of parasol gliding and he had been convinced that if a man-powered aircraft wants to succeed in making a 8-shaped flight, it must not use the aerodynamical arrangement which a general aircraft or a glider has, and it must use the principles of parasol gliding. He went to ask an aerodynamic engineer for help in his calculation and they together proved that a man-powered aircraft as he had devised could make a 8-shape flight, and that such a craft could meet the requirements for a prize from the British Royal Aeronautics Society. They organized a small group for the task of design, manufacturing and flight test. That aerodynamic engineer through electronic calculation found out the best form of wing and propeller. By using the lightest materials they sucessfully worked out their first aircraft in a period of only one month. The wingspan of this craft is 27m and its weight is 23kg. In September, 1976, they began their test flights. The three sons (age 17, 14 and 10) of the designer all tried this craft. Although the youngest son seemed not strong enough to start the propeller, it flew up because it was so light. After a period of one year for adjustment and experiment and improvement, they finally made a man-powered aircraft (for a three-facet diagram and structural disection, see Picture 4 and 5), and ready for their trial to make a 8-shaped flight. They invited an athlete Bruce Allen (as mentioned above) to be the pilot. Through Allen's patient tests, it proved that the craft could continue to fly for 7 minutes and produce power of 0.45 horse power. The wingspan of this craft is 30m, the longitude-traverse ratio is 12.8 (one half as smaller as other man-powered aircrafts),air-borne weight is 32kg (one third or one half lighter than other man-powered aircrafts) and the wing load is 14kg/sq.m (only one third of that of other man-powered aircrafts). Due to its light weight and small wing load, it is easy to lift and easy to control. All these create helpful

Picture 3, Bruce Allen, a pioneer of operating a man-powered aircraft to make a 8-shaped flight

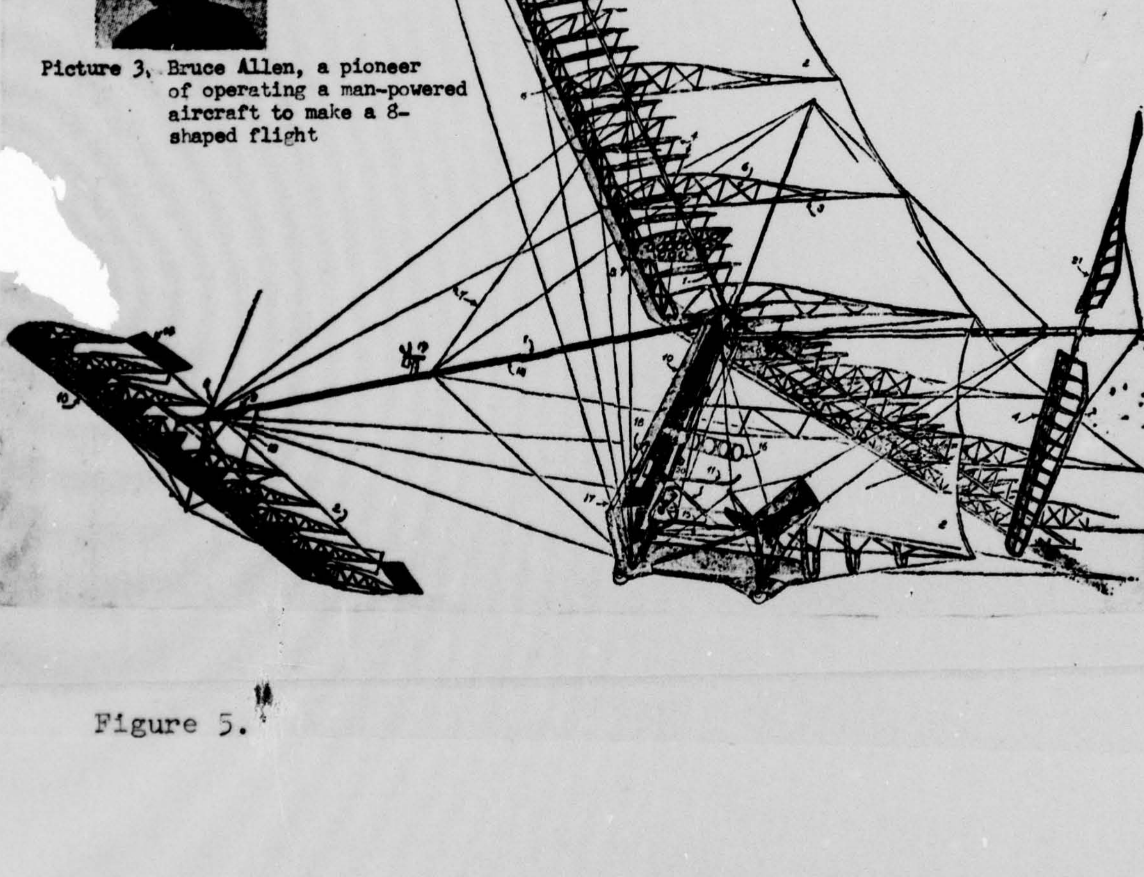


Figure 5.

5.

Picture 5 (preceding page) Diagram of structural dissection of man-powered aircraft "Floating Bald Eagle". This picture was originally published in a weekly, Feihsing Kuochi (Flight International), in England.

(1) Aluminum pipe, its diameter is 5 centimeter and the thickness of its walls is 0.3~0.5 mm. It connects the main body of the aircraft with the duck type forward wing.

(2) The cover skin of ~~thw ing~~ the wing, which is made of thin film (the thickness of upper cover is 0.05mm and that of underneath cover is 0.025mm.

(3) The framework of wing ribs is made of thin aluminum pipe, of which the diameter is 6.5mm.

(4) The minor wing ribs are made of light wood.

(5) The front edge of the wing is made of card paper.

(6) Ribbon to tie the frames.

(7) Stay cord,of which the thickness is0.5~0.7mm.

(8)The adjusting ring on the stay cord.

(9) ~~Safty~~ Safety belt.

(10) Wind shield in front of the pilot seat.

(11) Steering bar, which can control the aircraft up and down, Dutch roll and side slipping.

(12) Control gearing cord.

(13) Gearing cord to control upward and downward.

(14) Control blade.

(15) Control cord used at the wing tip.

(16) Ventilated set-up.

(17) Ventilating nozzles.

(18) Pilot observing window.

(19) Speed detector.

(20) Instruments.

(21) Pusher propeller, of which the diameter is 3.65m and which revolves 115~120 turns per minute.

conditions for the craft to make turn of 180°. Picture 5 and the descriptions give the structure of this aircraft in detail. The wing is flexible and through the control its end can go upward or downward. Thus it can make trasverse control(turning flight). The pitch control of the craft (goes up or down) is made by using the control cord to connect the duck type forward wing.

After having completed the 8-shaped flight, the craft slowly lands on the ground, and Allen stepped off the cabin and smilingly told his friends saying "This is really a miraculous flight".

The study of man-powered aircraft has begun since the late 1920's and there has been record of flying over a distance of 200-300 meters. In the past half of a century,however, satiafactory result remains lacking although continuous studies are carried on by quite a few people. The establishment of prize by the British Royal Aeronautics Society is obviously intended to encourage such studies. In the 1960's, in Italy, the government established similar prize. The best outcome of such studies in recent years was the man-powered aircraft made by ~~profesors~~ professors and students in a Japanese university in February last year, and the craft made a record of straight flight over a distance of 2,094 meters. Of course, this 8-shaped flight is an important milestone in the development of man-powered aircaft. Nevertheless, it still has a long way to go when man-powered aircraft can be in practical use. Someone predicts that if a small engine of 1.5~2 horse power is set up there, a man-powered aircraft may become useful. And he further says, "Please think it over, consuming 10 litres of gasoline, and by a speed of 40-50 km per hour, you can fly over a distance of more than 1,000 km. Isn't it of great worth?"

News in Aviation Science and Technology

The Correlation Techniques of a Pilot and an Aircraft

The correlation techniques of a pilot and an aircraft are techniques which facilitate the cooperation between a pilot and an aircraft. The aim of studying such techniques is to search a way as how to improve the design of aircarft in order to enable a pilot to operate the craft more conveniently. The scope of these techniques covers the setup of pilot cabin, design of the seat, the best processing of information and forms of display. The work efficiency of a pilot can be promoted, the operation error can be diminished and the aircraft can show its best performance if the items mentioned above are found in perfection. For instance, a pilot of a fighter needs a viewing field which is the wider the better. To meet such a need, the seat must be higher. If the seat is set higher, the cover of the pilot cabin must be made convex. Thus the resistance of the craft will be increased. To have a satisfactory solution to such correlated problems needs the correlation techniques of a pilot and an aircraft. Again, in order to promote the mobility of the aircraft, it often produces a phenomenon of overload. As a result, the craft will need a new model pilot cabin, which is called overload pilot cabin, because the pilot, due to his physical limitation, cannot stand such a great overload. In this new model pilot cabin, when it is overlaoding, the pilot seat will automatically recline backward by 60-65°. Thus the pilot's ~~black~~ back view overload value can elevate to 11.5g. Some other types of fighters use other means to overcome such an inconvenience instead of having higher seat. At the present time, the pilot seat in F-16 reclines backward by 25° and the pilot's ability to stand overload can be inceased by 0.6-1g. For compensating the loss of pilot's operating ability due to overload, the steering bar and fueling bar and other control buttons are set on the arms of the seat to replace the steering bar which is usually set at the center of the pilot cabin.

Zero-speed Aerodynamics

Aerodynamics has already had many different branches, such as low-speed aerodynamics, high-speed aerodynamics and supersonic aerodynamics. Since the 1950's,there have developed techniques of vertical taking-off and landing,which are followed by the problems of aerodynamics of the aircrafts that make vertical taking-off and landing. As this kind of aircraft can make forward flight from vertical taking-off and can make vertical landing for forward flight, during those two periods of transitional flights, the relative speed of the aircraft and the air stream is equal to or close to zero. So it is called zero-speed aerodynamics, which deals mainly with problems of control and stability when an aircraft is at zero speed.

In the past two decades, there has been a great variety of difficulties in the development of vertical landing techniques. Besides the difficulties in manufacturing engines for vertical taking-off and landing, the understanding of the rules of zero-speed aerodynamics is not adequate. This is because at a flight of zero speed, the relative speed of the aircraft and the air stream is close to zero, but the jetting of the engine gives great impact to the aircarft. The old theories of aerodynamics have become obsolete and the new ones must be developed.

For making experiments and study of this new theory, in the United States there is a setup for making close-to-ground flight. A testing model of vertical taking-off and landing is set upon a moving stand, and let the model by a certain speed move along the ground. In addition, they are now building a low-speed tunnel of 12 x 24 sq.m. In western Europe, they have jointly developed a large type tunnel of 20m level.

Solid State Electricity Distribution System

The electricity distribution system now widely used in aircrafts is a composition of cables and circuit breaker. In a large aircraft, the system requires a tremendous amount of cables and circuit breakers. For instance , the cables used for electricity distribution and control in Boeing-747 reach to a total length of 250km and weigh 2.5 tons and the number of circuit breaker is 950. In order to reduce the weight of electricity distribution system, in the 1960's, a solid state electricity distribution system was made in the United States.

The solid state electricity distribution system is to use a digit computer through multicircuit transmission system and solid state power controller to transduce and protect the charged and automatically controlled electricity distribution system. A digit computer is used to replace air personnel to carry out automatical control, automatic charging control and automatic test; a multicircuit transmission system is to use one cable to transmit various controls and directive information; and a solid state power controller is used to substitute for a thermo-circuit breaker and protect charging. The main merit of this system is the great diminishing of the length and weight of cables and to reduce the

the working load of air personnel. And above all, the system is easy to maintain and easy to change; but it is more complicated and requires various integrated circuits and and semiconductor switches of high reliability. According to the reports in foreign newspapers, this system used in a large aircraft, like the strategy bomber B-1, can reduce the weight of the craft by 900kg, and save conducting wires by a length of 50 km.

New Airborne Cannon and Bullet Powder

The diameter of airborne cannon presently equipped in aircrafts is about 20-30mm, the initial speed is 800-1050m/sec. and the standard firing rate is no more than 6000 shots/min.

The new airborne cannon and bullet powder which are now under study and manufacturing include the following:

Liquid Cannon. This kind of cannon uses liquid charge. Its merit is that under constant highest chamber pressure, the total energy of its charges can be promoted, and consequently its initial speed and firing distance can be increased.

Open-chambered Cannon. This kind of cannon, unlike the presently used airborne cannons, need not lock its chamber when it is fired. It simplifies the structure of cannon, diminishes its weight and increases its firing speed.

Shell-less Bullet Powder. This kind of bullet powder is to set the warhead directly at the powder bar and it has no shell. Thus it reduces the weight of the bullet powder and saves materials used in making the shell.

Helium Ballon as Loading and Unloading Equipment for Ships

According to a report, two US companies have signed a contract with a commercial company of Arab Republic of Yeman to make a helium ballon to be used as loading and unloading equipment for ships.

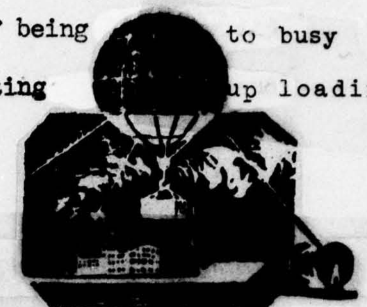
This kind of ballon transportation system is to use a helium ballon to load and unload goods for ocean ships. According to their original plan, the system will begin to operate at Port Hodeida on September 26,1977.

This system can be used to replace the loading and unloading facilities and dock at seaport. The cost of making such a system is about 170-200 million of US dollar and the time used for installation is 3-4 months.

The helium ballon transportation system can move ten tons of goods and transport the goods to a point 1-6 km off the shore. The ballon is equipped with steel-wire rope, pulling wire, pulley block and anchor. The ballon is tied to a holding tower. In operation, the ballon is controlled by the equipment in it. On the dock, there is a diesel engine to start the winch. By pulling-up and releasing the winch, the ballon transports goods back and forth.

The cost of moving each ton of goods is US$23, and it can move 800 tons one day. The good condition for this system to do unloading is the wind speed at 55.5km per hour. If the wind is too strong, the ballon must be tied tightly on the ground. It is said that this system can work 24 hours a day.

The outstanding merit of this system is that it is easy to move and it can be completely dismantled in two days and then it can be moved to a new place to work. It can solve the problems of being to busy and too crowded at one dock and the difficulty of setting up loading and unloading facilities.



New Model Aircraft of Composite Material

According to a report in New Scientists of March 3,1977 in England, fifty years ago, aircrafts made of metal were the most popular, but now the trend goes just the opposite way. The Rockwell International of the US is manufacturing two testing aircrafts of high mobility using compound materials of graphite-fibre and glass-fibre. The weight of this material constitutes 29% of the total weight of the craft. This compound material (graphite-fibre and glass-fibre) is not only lighter, less expensive and easier to come into shape than metal, and it can also make the best wings which will produce great lifting force and small resistance.

These two experimental aircrafts of high mobility and telecontrol has been scheduled to be completed in December 1977 or January 1978. These two aircrafts will carry nobody in them because the testing is one of low cost and high risk. The purpose of the testing is to supply data for making fighters in the 1990's. At an altitude of 9000m, at a speed of 0.9 times of sound speed, the craft can maintain an overload of 8g when it is making stable turn. It doubles what the aircrafts currently used can make. At an altitude of 11,000m, its transonic performance is similar to that of F-16, but the size of its engine is smaller than that of F-16.

These testing telecontrol aircrafts of which the length is about 7m, according to the ~~desingers~~ designers, are closer to the aircrafts of completely compound materials. The materials used for these two crafts are aluminum 26%, graphite-fibre 26%, titanium 18%, glass-fibre 3%, steel 9%, tungsten 4% and other compound materials 14%. The wing and the front small wing frame, cover, heat dispersion blade and the air intake on the engine are made of graphite-fibre. Titanium is used in this kind of aircrafts much more than others, because its expansion coefficient is close to that of graphite. The structure of the body and exhaust pipe are made of superplasticity forming and difussed continuous cast titanium.

By design techniques of high mobility, the craft can provide maximum lifting force at each incidence angle. The control plane of this full size aircraft (including elevating aileron, elevating rudder, revolving tail wing, and the flap on the stable plane) can make the craft slowly fly obliquely forward when it is making forward flight.

This kind of telecontrol aircraft made of compound materials will be dropped by a remodeled bomber B-52 from an altitude of 14,000m. Then it will be controlled to fly by people on the ground through radio direction. The test will begin from the summer of 1978 and subsequently twenty tests will be made in two years.

Holography

Holography is a unique technique, which can record information of every aspect of a subject. It not only records [redacted] photostrength of a subject and it can also record the phase position of a subject. So it is also called stereoscopic photography.

The theorectical basis of this epoch making holography was first mentioned in 1948,but, because such a photography requires interfering photosources, it did not have chance to be practiced. Until the 1960's when the laser techniques were developed, this holography began to have a rapid development. It has life-like and three dimensional effect and can repeatedly record without any interference. It can even piece a broken picture together into a complete and perfect one. So it has been widely applied now. In the United States, England, Russia, Japan and France, holography has been applied to the investigation of tunnel flow, analysis of the vibration of turboblade and the test of the peeling of honeycomb structure.

A Plentiful Aero-exhibition

—A report on some special items and the electronic equipment at the 32nd aero-exhibition in Paris—

by
Li Hsüeh-kuo

For speeding up the modernization of national defense and catching up with the advanced level in the world, and following the principle that we must learn all the useful experiences and science and technology from foreign countries for our own use, we would like to make the following report on some special items and the elecronic equipment at the 32nd aero-exhibition in Paris.

At the 32nd aero-exhibition in Paris, the United States, England, France, West Germany, Italy, Canada, Sweden and Japan all have great many special items and electronic equipment to display.

The special items include instrument and apparatus of aircraft, display devices; automatic flight control system, automatic landing system; inertial navigation system; system of electricity source; and flight simulator and testing equipment.

The central theme of this exhibition is about the new military aircrafts in the world today, such as F-15, F-16, F-18, Saab-37, Fantasy F1 and 111, America Panther, MRCA, YC-14 and the equipment of Fantsay 2000 which is under study and manufacturing, and a great variety of equipment of transport aircrafts and general aircrafts.

Viewing the special items as well as the electronic equipment, we can conclude that the general characteristics of this exhibition are:

comprehensive, digitization, electronization, in series and micrification. New techniques, new materials and new technology all have had advanced applications.

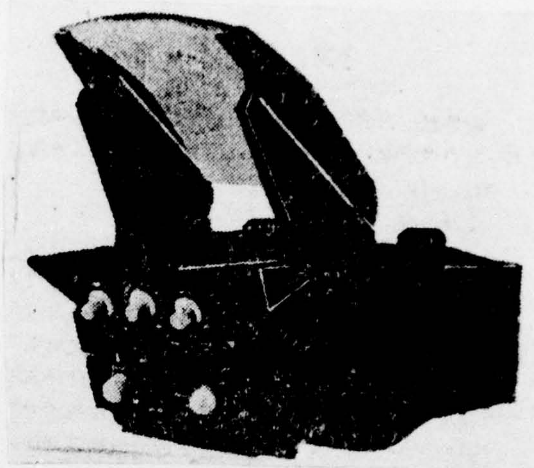


Fig. 1. Level view instrument and weapon aiming system of F-16

Comprehensive. So far as the special items are concerned, each country displays many multi-functional comprehensive systems. For instance, the Smith Company of England displays SEP-10 automatic flight guiding system (AFGS). This system combines the functions of automatic flight control system and automatic flight guiding system together and uses the advanced digit techniques. Thus it promotes the performance and reliability and lowers the cost, and the ~~safty~~ safety of the system is also guaranteed. By combining together the automatic flight control system and VOR/LOC, air traffic control and regional navigation system and the signals of inertial navigation system, the new system can perform more than 20 different functions, such as maintaining pitch attitude, lateral roll attitude, and altitude; preselection of flight direction; maintaining flight direction; and capturing and tracking of VOR/LOC angle. Thereby the automatic landing of an aircraft can reach 11 level. A branch of Szup'ailei* Co. of the United States displays P-140 attitude and flight direction reference system. which contains a gyrocompass (DG), gyro-mag and compass working attitude. The application of this system ranges from a very simple

* A Chinese transliteration of the name of an American aircraft company

unmanned aircraft or a drone aircraft to those of high property(such as F-15 and B-1). The characteristics of this system are that the cost is low; it provides information of complete attitude/flight direction; and it is good for a place where a first order compensation correction system is sufficient. One branch of Macnee*-Elliott Aero-Electron Company exhibits their horizontal viewing device/weapon aiming computer system (HUD/MAC); Smith Company of England shows their weapon aiming/horizontal viewing system (WA/HUD); and Thompson-CSF Company of France dispays their VE type electronic horizontal viewing device/weapon aiming system (HUD/WAS), but these items are basically similar to each other. They combine the functions of horizontal viewing device and weapon aiming system. As a consequence, the horizontal viewing device can not only guide a fighter of high property to land in an airfield, and it can also provide digit symbol display for air-air flame, control and air-ground attacking attitude. On the other hand, they improve the accuracy of weapon dropping and shorten the time of taking aim, and thus they reduce the working burden of the pilot and make him better perform his duties.

Digitization. Presently digit control techniques are widely used in the special equipment of aviation in many countries. For instance, digit computer has become an important component part in comprehensive flight instrument system, flight control system, inertial navigation system, flight simulator system,and comprehensive data collection and processing system, and in flight control, the tendency of digitization is even more obvious. The TERN-100 automatic navigation system of US Szup'ailei Company, for exanmple, uses digital technique and magnetic disc storage of large capacity and it can store 25 million units. In addition to

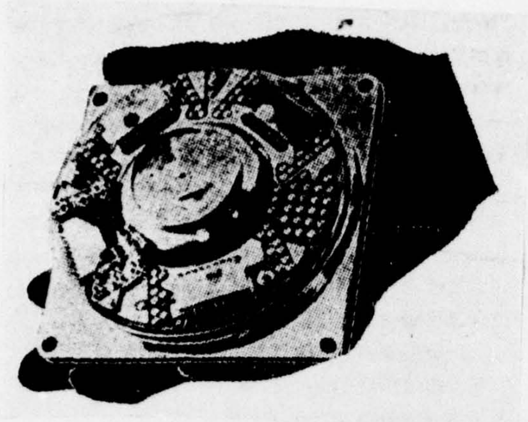


Fig. 2 The magnetic-disc storage exhibited by ~~Saup'ailei~~ Sperry Company

the invariable data bank, the pilot can store 50 selected flight plans and 204 selected flight trace points. The electronic units in SKN-2416 inertial navigation system made by Guilford Company for F-16 all use large and medium scale integrated circuit. The digital electric control system of MRCA (multifunction fighter in Europe) sent to the exhibition by Macnee-Elliott Company of ~~Enland~~ England, and the digital flight control electronic unit made by the same company for US Boeing short distance taking-off and landing military transport aircraft YC-14; and the automatic flight control system made by an aero-navigation equipment company in France for Fantasy 2000, all use digit control technique. The digital electric control system of MRCA uses a quadri-redundancy computer, of which the length of characters is of 16 figures and of 16 instructions and it uses a parallel processor, of which the speed can match the band width of CCV system that has difficulty-work ability. The digital automatic flight control system of Fantasy 2000 uses UMP7800 central computer, which is developed from UMP6800, and its characteristics are that its size is small and the amount of electricity consumed is small, too. This ~~computer~~ computer uses microprogram technique and the number of its inserts is reduced from 5 to 3. According to the explanation made by one attendant on the display stand, this system will be manufactured for sale in 1978. The Boden Lake Instrument and Technology Company of West Germany displays their electronic unit of inertial platform, which uses digital computer to provide input and output signals to the platform. The Szup'ailei Company exhibits a digital atmosphere data computer made for the US new fighters F-15, F-16 and F-18, and Boeing also displays a digital

Fig. 3 HSD-880 digital flight path compass of Pentax Company**

atmosphere data computer. The Klutse* Co. of France exhibits a 70 type digital atmosphere data computer for use in a seaborne aircraft and a 80 type digital atmosphere data computer for use in fighters of new generation. Fighter A-4/weapon system trainer and the flight simulator of B-52 of Szup'ailei Company all use digital computer. Thus the cost becomes lower and the efficiency becomes higher and it can make the simulations of aero-electronic system control, advanced and elementary flight training, navigation, control, anti-submarine tactics training, weapon dropping program and harmonization control. At the exhibition, there is also an electric revolving platform controlled by a digital computer.

Electronization. The development of electronic display system has been very fast in many countries, the comprehensive flight guiding system, horizontal viewing device/weapon aiming systems in particular are almost all electronic. The HSD-880 flight path compass of the Pentax aero-electron Company of US is made of digital diagram navigation and radio magnetic compass. It has no sychronizer, decompossor and gearing unit and its special feature that has arrested much attention is its double-function display.

* A Chinese transliteration of the name of a company in France.
** Based on a Chinese transliteration.

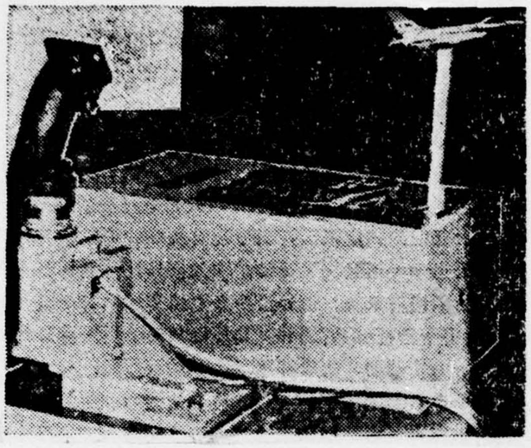


Fig. 4. The controller of the electric
control system of F-16

When a pilot uses his finger to touch the button on the outer edge of the compass,he can then select the instruction of a radio magnetic compass or the information from an automatic directioning instrument through a flight path compass or VOR. When the button is at a center position or a "HSI" position, the instrument can be used as a standard flight path compass. The Smith Company also exhibits a photodiode display instrument. It is mainly used for engine control. Its characteristics are that it does not consume much electricity and has high reliability, its cost is low and its size is small. It is the first time that the Macnee-Elliott Company exhibits a helmet aimer. This is a small type of horizontal viewing device, which is ~~desinged~~ designed to be set on the helmet of pilot, and thus it can make the pilot able to determine the position of target only through a simple observation, and it also gives information of aiming and weapon dropping. The electric control system (FBW) of F-16 is also a new product, which catches great attention of the visitors to the exhibition. It marks the new direction of electronizing the aircraft control system. This system is made by US General Dynamic Company and one branch of Lear Zeagler* Company. F-16 designed according to such a control arrangement uses quadri-redundancy stable control system, so it is quaranteed an effective control all the time. As a result, the aircraft can have the best

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* A Chinese transliteration of the name of a company

performance and mobility. A perfect control system guarantees the completion of flight and its mission. The craft has a side control bar. When it is making a flight of high velocity, it is not the usual central steering bar, but the longitudinal force of this side control bar is used as g instruction. When the pulling force is 14kg it can reach 9g. At low velocity the instruction is received by incidence angle, and there is a limit of

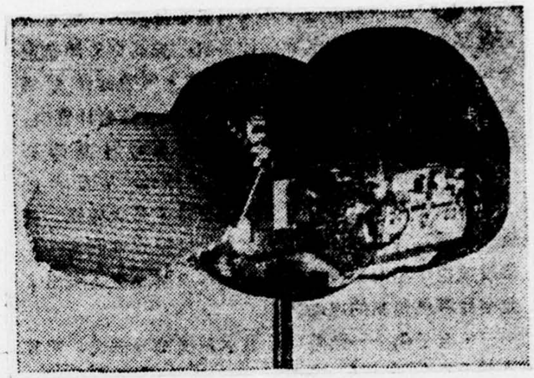

Fig. 5 The flame control radar of F-16

25°. At medium velocity, a responding instruction will gradually change into another form. The input signal of the pilot, through the side bar and quadri-redundancy stable control system and along four different cables reaches every compartment. The whole side bar is very soft (its hardness is no more than a piece of hard rubber) and it contains a sensor. The bar is basically not moving (forward and backward, left and right, there is a displacement of only 1.6mm). The pilot can actively control various actions of the craft by using his hand holding the bar. On the top of the bar there is a button, by which every attitude of the craft can be controlled. In addition, radar, flame control, front wheel control and refueling in the air are all comprehensively controlled by a button on the bar. So the operation of the pilot is rather simple and very convenient, and his working load is thereby greatly reduced. According to a statement made by General Dynamic , electric control system can reduce the weight of a control system by 181kg. According to the publications of the exhibition, the Concord supersonic passager aircraft, MRCA, YC-14, F-15, F-18 and B-1 all use electric control system, and Fantasy 2000, which is under manufacturing, is also desinged to use such a control system.

In Series. From the items displayed in this exhibition, it can be clearly seen that equipment designed for aviation in foreign countries all have their continuity and form into series that can be used for various types of aircrafts. For instance, the inertial navigation system displayed by US (Litten Company) ~~Riden*Company~~ and the inertial Doppler navigation system by a test equipment company of France are typical products in series. Riden Company has provided a series of inertial navigation system for 25 different plans, from LN-3 to LN-50 inertial navigation systems. This serial inertial navigation systems,which are made by using latest techniques include AN/ASN 130 of fighter F-18, and the series used for civil aircrafts include LTN-51, LTN-58, LTN-72, LTN-72R, LTN-76, LTN-104 and :TN-201. The AN/ASN-130 is a gyro-inertial navigation system . The navigation computer is made by Riden themselves and it contains 1,600 characters. The correction time on the ground of this inertial navigation system is 9 minutes and it weighs 9kg. This is a system which has small size, light weight and which is reliable and easy to maintain. The inertial Doppler system--CID76 of that French company uses 255 type double gyro-platform, and it is an improved one of the 250 type gyro-platform of America Panther inertial navigation system. Together with one set of Doppler radar and one computer, it can solve all problems in navigation and attacking mission.

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* A Chinese transliteration of the name of an American company

Micrification. As the property of aircrafts is continuously to be promoted, the airborne systems have become more and more complicated. So under the condition of not jeopardizing reliability, the reduction of their size and weight has become a very serious requirement. Except for using new principle to design new type of systems and to improve electronic system so as to elevate its performance and to reduce its size and weight, in making new component parts (such as gyro and accelerator), micrification is also the first requirement. In this exhibition, the MGL-80 micro-flexible gyro of US Sperry Auto Gyro. ~~Szupiailot~~ Company is a good example. It is a small, solid and light gyro. It weighs only 14g, its starting time is only three second, which is really short and its rotator rotates 24,000 turns per minutes. Because of such characteristics, it commands wide attention. It can be used in aircrafts which have either fixed wings or revolving wings, in a drone aircraft, space vehicle , submarine and air/ground launched missiles. Also because of its double axle stability, it can be use in the stabilization of weapon aiming.

At this exhibition, there are only a few fighter airborne electronic equipment (such as radar, computer and electronic fighting equipment), and most of them are pictures or models. Only Thompson-CSF Company exhibits CYRANON multimode radar (used in Fantasy F1). The **Eclikson*** Company of Sweden displays a pulse Doppler flame control radar which is used in JA-37. From their system, those radars are general pulse radar systems and there is nothing newly created. The flame control radar in F-16 is a interfering

* A Chinese transliteration of the name of a company in Sweden

multifunction and digital flame control radar and its size, weight and cost is only one half of the radar used in other types of fighters. It has the ability of all-weather air-to-air and air-to-ground fighting and weapon dropping, and can search and track target in all directions and all attitudes without having impact of the return wave from the ground, so it can guarantee to complete its mission. Its action can cover a distance of 148km, and the average failure time interval is 90 hours. The whole set weighs 118kg, and its volume is 0.08 cubic meter.

Airborne computers are the specially used ones in various airborne systems. They include that which is used in automatic flight control system; that which is used in horizontal viewing device/weapon aiming system; navigation computer, flame control computer and engine speed and temperature adjusting computer. And there are computers used in air traffic control system and data processing system. For instance, the GCSLC-4516 processor series made by Riden Company, of which the size is small, the power consuming rate is low and its cost is low, has been approved by the US airforce, army, navy and other more than 20 planning organizations. This series can be used in aircrafts, missiles, ships amd space vehicles. Its functions include navigation, guidance, electronic warfare, display, control, communication data processing and weapon dropping, and it adopts Karlman* filter technique. At the present time, in many countries, computers are used in the automatic adjustment of engine speed and temperature. For instance, the SNL100 engine control computer exhibited by a machinery and

* A Chinese transliteration

electricity company in France is used for speed control and calculation display of LP compressor of CF6-50 engine in aircraft A-300B. The functions it completed include calculating and dispaying total temperature, calculating first rotating speed basic value and error signal in rotating speed of the engine and calculating and displaying the approximate temperature of the computer failure time.

On the other hand, From the items exhibited at this exhibition, it can be seen that new materials and the application of new technology have equally rapid development, such as the application of photo-conducting cable to electric control system and horizontal viewing device. The photo-conducting cable used in the electric control system of NRCA is made of hundreds of fine glass fibre, of the which the diameter is approximately 70 micron. The standard and usable cable can give signal decay of 0.04-0.4 decibel/m, and it can guarantee the channel electric insulation and eliminate electro-magnetic interference in the insert circuit when data are being transmitted through the channel. The "around welding" technology of the new multi-core logic insert conducting wire is carried out by using computer to control the semi-automic equipment and it does not use welding tin but solder the conducting wire to a bar. This not only promotes working efficiency (one person can finish more than one hundred wires in an hour) and also increases the reliability of the inserts. This equipment is made by SERCEL Company of France. Now in France, the Thompson-CSF Company and the French Machinery and Elecrticity Company use this equipment. The Smith Company of England also uses this equipment and some other equipment associated with this one--digital logic insert automatic test platform has also begun to be used. By this, the speed of insert quality checking can be improved and the failure source finding can be more accurate. Thus the manufacturing of special equipment for aviation and electronic equipment can greatly speed up.

What has been reported above is the general situation of some special items and electronic equipment at the 32nd aero-exhibition in Paris. We should critically learn and accept everything which is useful to us so as to speed up aero-industrial construction and rapidly change our backwardness.

ALUMINUM POWDER PAINT
NOT TO BE OVERLOOKED

Bao-Kuang Chao

Flying in the blue sky and under the bright sunshine, the airplane radiates sparkling light as a result of reflection from its aluminum alloy "topcoat". Until now, the aluminum alloy is still the major material in the manufacture of airplane.

The aluminum alloy material commonly used is available in various sizes and shapes in the form of plate, sheet, tube, bar and the like, however, there is one more product, the "aluminum powder", which can not be overlooked. The aluminum powder makes great contributions in the process of manufacturing aircrafts, it remains unpopular or even unknown to many people simply because it is contented with the role of "unsung hero".

The fabrication of aluminum powder involves the atomization of molten aluminum followed by ball milling, or the utilization of ball milling for the process of pressing and crushing the aluminum foil into extra fine scales with thickness ranging from 0.3 to 1 micrometer (1 micrometer = 10^{-6} meter). Because of this extremely small size, even with the use of most modern equipment it could not be fabricated in any form of components with a fixed geometry. In what way the aluminum powder makes its contributions ?

By looking through a pierced hole on the "window paper", one would see inside the room heating pipes from which the secrets of aluminum powder could be uncovered. By close observation and analysis, the layer of silver white coating was identified to be the material containing aluminum powder. The aluminum powder paint, ~~was~~ made by adding aluminum powder to various kinds of paints, ~~which~~ was found to be coated on the iron gate of a building, on the flag pole erected on the ground, on the truck with refrigerator for transporting food, on the electric furnace and stove, on the container ~~carring~~ carrying petrolum products, and so on. By mixing itself with the paints, the aluminum powder makes contributions to the aircrafts industry.

Novel Techniques To Increase Service Life

Airplane in parking or on landing, on tak~~ing~~e-off or during flight encounters many hazards: the erosive air stream, the broiling sun beam, the sudden change of temperature, the contamination due to smoke and salty fog, the exposure to rain, snow, hail, baking as well as freezing. Without sprayed coating the aircraft would "fight the battle as if naked". The hazards, as described, would cause corrosion to the metallic components and damaged to the non-matallic ones. The majority of the parts inside or outside the plane has to be protected by coating.

After coating, the components are sheathed with a layer of paints against which the above mentioned hazards, if present, would have to attack first. It is with this spirit of self-sacrifice the paint always fights on the front line. To improve its fighting power, people have investigated, and produced as well, many variety of paints but have yet to come up with one which could sustain all the severe damaging effects the airplane encounters, the worst being the direct sun light.

After a rain fall it occasionally appears in the cleared blue sky a beautiful rainbow which is composed of seven colors: red, orange, yellow, green, blue, and purple. These seven colors constitute one part of the sunlight which is visible to the naked eye. Besides, there are invisible radiations as well, such as infra-red and ultra-violet, which are not unfamiliar to us; the infra-red is known to be "heat ray" due to its large thermal energy, while the ultra-violet ray could cause the skin tanned or even peeling off because of its strong chemical activity.

Constantly submerged in "sun bathe" all year round the airplane, especially flying in high altitude, is under attack by the strong sun beam. The infra-red radiation will cause thermal damages to the paint layer due to excessive heat, while the ultra-violet radiation, on the other hand, will creat disturbance due to its active photo-chemical effects by penetrating into the layer and cause even more damages. Their combined action will destroy the structure of the paint, change the color and fragility, reduce strength and resiliency, increase strain with the resultant effects of breakage, peeled-off, and the loss of its protective ability. After being added to the paint the aluminum powder will appear as suspension in the mixture forming continuous membranes which, like a mirror, reflect off 75 percent of the visible light, 65 percent of the ultra-viiolet and most part of the infra-red, and consequently, the damaging effects of the sunlight will be reduced. The aluminum powder, served as additive, is able to increase the service life of the paint and to help the aircraft achieving "long life".

Water Proof Armour

Water and moisture are considered to be another big enemies to the paint. The infiltration of water and moisture is responsible for the following effects related to paint: softening and expanding, rising bubbles, aging and reducing adhesion power. The metallic parts, after making contact with water or moisture by way of penetration, will become corroded, and non-metallic parts will be damaged due to expansion and deformation. The addition of aluminum powder to the paint amounts to the formation of layers of scale-like "armour"; infiltration can only be accomplished in this substances by travelling around many densely distributed powder particles along winding routes with increased distances, and, as a result, the paint becomes less permeable. In amounts of 5 percent, the addition of aluminum powder decreases the permeability by a factor of 2. Encounted by this aluminum "armour", water and moisture will have as much difficulties to infiltrate the paint layer as ~~clibing~~ climbing the blue sky.

Indispensible Fighting Warrior

As far as the manufacturing of plane is concerned, the magnesum alloy is most "attractive". It has a small specific gravity in the order of 1.7, high-strenth-weight and stiffness-weight ratio, high degree of fatigue resistance and shock resistance capable of large load, it offers excellent machinability. All these advantages certainly make it an indispensible material in the manufacturing of aircrafts, with each plane having hundreds or even thousands of parts made of magnes~~um~~ium alloys.

The magnesum alloy, however, is very "delicate", has a very low resistance to corrosion, especially in situations, such as in occean climate, where moisture and salty fog are abundant. On the polished surface of a magnesum alloy components a stain of dirt, metallic dust or even finger print could cause the corrosion quickly taking place. See how "delicate" it is!

Having such a weakness, why is it still being used in large quantity in airplanes?

The answer is that its advantages overcome its weakness. The key for accomplishing this is to prevent it by all means being contaminated. In addition to the oxidation treatment, the magnesum alloy parts usually receive the application of multiple sprayed coating for protection. To reduce the permeability, a certain amount of aluminum powder is added to the rust proof primer. To further prevent the corrosive factors due to electric potential arising from the contact between the aluminum powder and the magnesum alloy components, the aluminum powder should be applied to the second layer of the base coat.

Through the combined efforts made by the paint and aluminum powder, the magnesum alloy components establish their ground of existance.

Against Waste

Many electroplated components are used in aircraft. They are plated with metals like zinc, cadminum, tin, copper, nickel and chrominum, a process wasting many precious metals. Electroplating is a technology of complexity consisting of various procedures, it is time consuming and a waste of labor. The aluminum powder could play a role halping us to eleminate some of the unnecessary ~~unnessary~~ and wasteful processes.

Many airplane components of the fuel and lubrication system require electroplating with zinc, cadmium or tin for the protection to resist corrosion. It is not difficult for iron and steel parts to be plated with these metals, but the same process is proved to be much complicated for aluminum or magnesum alloy components. By spraying aluminum powder paint, however, will eliminate the need of plating. Besides, it is a comparatively simple operation ~~with~~ saving many valuable metals. In amounts of 3 percent, the addition of aluminum powder to aldehyde based paint will form a product which is petrolum chemical resistant, stable and heat-resistant up to temperature range of 300°C, an accomplishment could not have been done by the electroplated products mentioned above.

Engine components made of high-temperature steel alloy containing nickel, chromium, cobalt and other precious metals are mandatory because of their operations usually performed in a high temperature environment with extremely hot gases acting on, under such conditions low temperature steel alloy would soon be corroded. Improvements can be made on low temperature steel alloy by electro-depositing nickel and by combined treatment of some other processes, or alternatively, by coating with heat-resistant paint with an effective temperature range from 250°C to 300°C. This temperature range can be further raised to 500°C if 10 percent of aluminum powder is added to the epoxide polyamide heat-resistant paint. This is possible, because under high temperature the infiltrated aluminum powder will combine with the iron steel in the formulation of high temperature alloy. At least part of, if not all, the savings of the precious metals has been accomplished by the substitution of aluminum powder paint.

For the purpose of decoration, many interior components in airplane are electroplated with chromium, prior to which they are plated with copper and nickel. The surface must be polished many times before and during the electroplating process. It is a very complicated operation, must it be done this way? Could it be decorated by spraying a coat of non-suspension aluminum powder paint? Due to its characteristics, the paint membranes present a resemblance in appearance to a hammered impact design. It is very attractive in color and texture with finishing roughness. It has the advantages of endurance, free of dust and ease of clean. Reducing the work time and labor as well as the use of precious metals means a tremendes cost savings. Its usefulness is both decorative and protective.

Special Functions

In airplane there are situations where light colored paints are preferred to be applied to components on which primer has been coated. Due to the dark colored primer, several layers of paints need to be sprayed with the resultant increase in airplane weight. Because of its light color and strong coverage ability, one application of paint containing aluminum powder is sufficient ~~of~~ to cover up the primer, this means a total of two coatings as compared to several coatings of paint without aluminum powder. In another situation where some parts are coated twice by the same paint~~s~~ ~~twice~~ with the strong possibility of missing some spots during the second coating. By adding the aluminum powder will eliminate the occur~~ance~~rence of this event, thereby prevent the omission and improve the protective function of sprayed painting.

Progress has continuously been made in the usage of aluminum powder, it will become even more so if advancement can be made on the process of ionization spray plating using the agent of aluminum powder core covered by nickel outer shell. In summary, the aluminum powder has contributed a great deal to the aircraft industry, as small as it is, it can not be overlooked.

MODERATE SPEED FEED GRINDING

Chi-Kuang Yin

Moderate ~~Low~~ speed feed grinding is a precision machining process of high efficiency, a new technology developed on the basis of conventional grinding.

The Development

Any comrade familiar with machining process will realize that grinding is one of the most important technology in machine manufacture which involves lathing, milling, planing as well as grinding. Because of its achievements in producing workpieces of accurate geometry and fine surface roughness, grinding has always been employed in machine processing of metals. Due to its low efficiency, grinding has been credited only for a small amount of finish allowances. For machine processing of components from basic forms to finished products requiring a large amount of finish allowances, other types of machining operations --- milling, planing and etc. --- are usually called upon. Following the advancement of aeronautic industry, most recently extensive use of precision casting and forging base materials has been made, among which are high-temperature alloys of excellent hardness and toughness, however, a great deal of difficulties are often encountered when these materials are machin~~ing~~e processed by conventional milling, plan~~ing,~~ning and broaching operations. Even with the use of ordinary grinding process, it is not always possible to meet the standard of high precision and fine finish roughness required for the workpieces.

In aeronautical turbo-engine, heat-resistant alloy casting base materials are widely employed in the manufacturing of turbine blades which are large in quantity and difficult to machine.

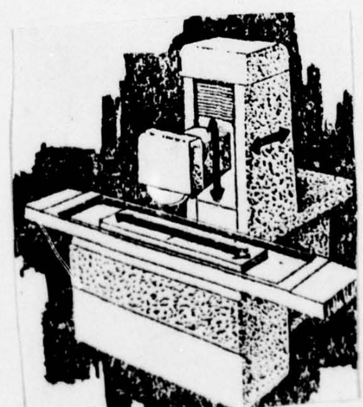
Tool wear is very serious when machine processing blades is performed by traditional milling. To maintain the acceptable precision, it often requires sharpening and repairing of the cutter after machining only one blade, it is indeed a process of low efficiency.

People have long been looking for a new technology with quaranteed precision quality and improved efficiency in order to fulfil the ever increasing demands in grinding. Moderate speed feed grinding is the new kind of technology in need, it performs deep cutting, the workpiece moves with the work stand along one direction and feeds slowly across the grain wheel. Its full name perhaps should be called "full depth moderate feed grinding", it is also known as "strength grinding", or, "creepy grinding".

Grinding Characteristics

Moderate speed feed grinding is a new technology developed on the basis of conventional grinding, its major characteristics consist of deep cut, moderate speed feed and strong cooling.

Deep Cut   Grain wheel performs cutting at considerable depth. It is known that the depth of cut for the ordinary grinding is in the range of several thousnadth of mm (1 mm = 10^{-3} meter) to several hundredth of mm with a maximum not more than a few tenth of mm, in the case of moderate speed feed grinding, it ranges from several mm to a few cm.



Moderate speed feed   Work stand moves slowly to feed at speed ranging from 10 mm to 300 mm per minute as compared to the back-and-forth speed of 3 to 30 meter per minute for ordinary grinding. The direction of motion can be seen in the illustrated diagram.

Strong Cooling   To achieve effective cooling and clearance, large volume of coolants under high pressure must be supplied to workpiece and grain wheel. The grinding fluids needed are in the amounts of tens to several hundreds of liters under the pressure ranging from 3 kg to 20 kg per cm^2, in comparison, ordinary grinding only needs a relatively small quantity of fluids under a pressure not more than 1 kg/cm^2.

Advantages

Workpiece normally requiring a series of processes in milling, planing and grinding to finish can now be accomplished by one or two operations of moderate speed feed grinding with no need for preparation before machining. Combining multiple procedures into one system in moderate speed feed grinding simplifies machining process, with further advantages of reduced work turn around time, less tool wear, lower production expenses and improved performing efficiency. Since the moderate speed feed grinding has been in operation, machine processing of turbine engine blade teeth, for example, can be done at one stroke instead of several procedures previously required of milling, grinding and other forms of machining.

Moderate speed feed grinding is differentiated from ordinary grinding in that it will not be influenced by surface effects (oxidation film, casting thermal shock, quench hardening, surface breakage etc.), and is capable of machining heat-resistant alloys, a process difficult to perform by ordinary grinding. Completing the whole machining process direct from base forms to finished products at one stroke by grinding makes possible to decrease the finish allowances, to minimize the base form dimensions and to reduce the consumption of metals.

During one grinding cycle only one or two contacts are made between grain wheel and workpiece, while in the case of ordinary grinding process the occur~~ance~~rence of multiple contacts leads to acceleration of wheel wear. Moderate speed feed grinding enables the wheel to increase its service life and to maintain its accurate forms, as a result, higher degree of dimensional precision and surface smoothness can be obtained. Its superio~~rty~~rity is characterized by its performance on contour surface as well as any surface with grooves. Its surface precision can reach the value of 4 to 5 μ ($1\mu = 10^{-3}$ mm = 10^{-6} m), and its surface roughness ranges from $\nabla 8$ to $\nabla 9$.

Due to the collective efforts of the participated grains, moderate speed feed grinding performs its operation as if it were composed of multiple cutting edges

1. grains
2. bonding agent

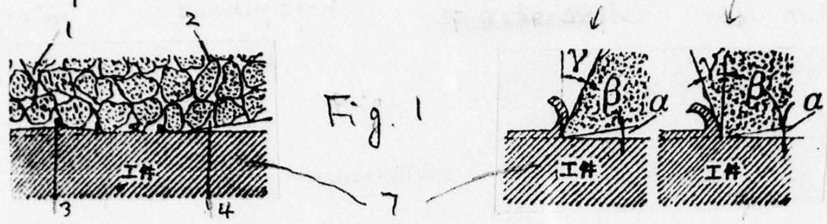


Fig. 1

5. positive rake angle
6 negative rake angle
7 workpieces

3. Chips
4. chips storage cavity

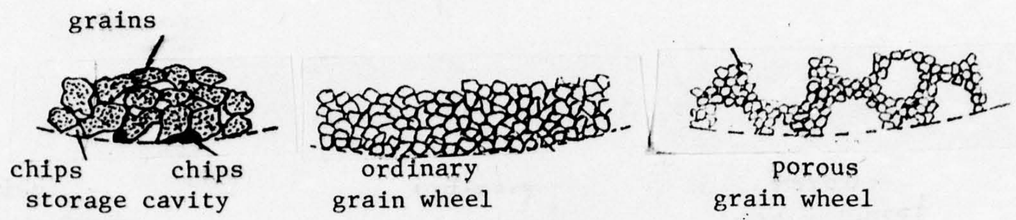
and blades. (see fig. 1) Consequently, it can remove in unit time a large amount of metals with a rate reaching as high as 340 kg / hr., with respect to machining efficiency it surpasses both the milling and planing processes, and in terms of productivity it is 4 to 5 times large than that of the ordinary grinding operation.

Suited for process control and automation, moderate speed feed grinding has attracted large attentions from many nations. In the advancement of technology, its range of application has become ever increasing with bright future especially in the field of aeronautical industry. It can be effectively employed, for instance, in machining blades, camber , and oil pump runners.

Basic Priciples

As mentioned above, there are differences between moderate speed feed grinding and ordinary grinding, consider the case to machine a workpiece requiring finish allowances of 2 mm, it takes a total of 200 back-and-forth movements for grinding operated at a depth of cut of 0.01 mm, in comparison, moderate speed feed grinding performed at full depth of cut requires only one feed operation.

Improvement of grinding efficiency can be realized by operating the grain wheel at increased depth of cut, but why is it necessary to lower the feed speed of the work stand ? This is because grinding involves contacts made on workpiece by grain wheel through abrasive grains. Each grain having sharp edges is like a cutting blade. In its participation of metal machining process, each grain performs like a cutting blade having both positive and negative rake angles (see fig. 1). Positioned on the rim of the wheel and rotating with it, the grains participate in the abrasive actions against the workpiece which constitutes the process of grinding. It is obvious that all the metal chips removed in the process must be cleared out of the cutting area, otherwise it will obstruct the grinding process.

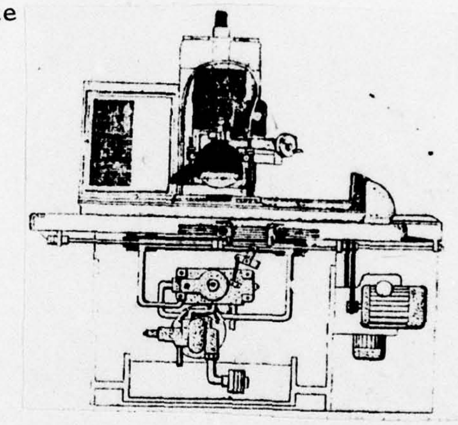


There are spaces existing among the grains on the wheel as indicated in fig. 2, the relative spacing is subject to the variation of grain size, for example, among the sized 36 grains, the typical spacing is of the order of 1 mm^3. In the process of grinding, the removed metal chips are piled up temporarity in these spaces which are usually called "chips storage cavity". After these spaces are filled, the grinding efficiency will be reduced, furthermore, the large amount of heat generated due to the friction between chips and workpiece will cause thermal damages. In the grinding process, therefore, there is one important principle which must be observed, ~~namly~~ namely, the total volume of the removed chips should not be greater than the volume of the storage spaces. Such requirement is always satisfied in ordinary grinding under the conditions of low cut, small quantity of chips removed and short arc area of contact between wheel and workpiece. Moderate speed feed grinding is operated, on the other hand, at deep cut with enlarged arc area of contact. As a result, each participated grain proceeds practically a farther distance and large amounts of chips are ~~accumalated~~ accumulated. Consequently, in connection with deep cut, the work stand feed speed must be reduced at a rate based on the considerations of elements such as grain size and structure in order that "storage spaces" would not be over-stocked with chips. This is also the basic principle as why in moderate speed feed grinding the work stand feed speed must be decreased.

Brief Introduction To Moderate Speed Feed Grinder

Like other machining equipments, moderate speed feed grinder consists of two basic types : the specialty grinder, equipped with process control and automation for the purpose of improving production efficiency, which is designed for a special kind of components or to perform a series of procedures on a specific part; and a general purpose grinder which can be employed, because of its distinguished generality, either as an ordinary grinder or as a moderate speed feed grinder.

Fig. 3 is a schematic diagram of moderate speed feed grinder. In accordance with its characteristics of deep cut and large quantity of chips removed, moderate speed feed grinder should have a strong structure strength and be equipped with high-power device. Generally speaking, the power should be proportional to stock removed rate and is in the range of 10 to 100 watts, furthermore, the rigidity and the dynamic equilibrium of the wheel major axis must be strengthened.



Schematic diagram of moderate speed feed grinder

Its work stand feed speed, ~~varing~~ varying from ten's of mm to hundred's of mm per minute , must be stable and adjustable stepwise.

Moderate speed feed grinder is customarily supplied with a cooling and clearing system in which large volume and high-pressured streams of fluids are forced through between the wheel and workpiece, in addition to providing a thorough cooling action it also flushes effectively chips out of ~~hte~~ the cutting area. Methods of swirl separation is widely used with satisfaction in purification and filtration of coolants.

Other concerns related to moderate speed feed grinder are reliable protection and ~~safty~~ safety devices, such as protective covers, which can be utilized in events of coolants splashing and wheel breakage to prevent damage to equipment and injury to surrounding personnel. Absolute production safty ought to be assured.

Soft-grade porous grain wheel is preferred. Wheel truing and dressing are important links in the grinding process, affecting both productivity and machining quality. To determine the best method in truing and dressing, elements must be considered are: workpiece and its quantity, machining requirement, the selection ~~of~~ of adquate devices using hard bronze alloys or diamond rolls.

Moderate speed feed grinding, after being tried ~~seelctively,~~ selectively, is expected to meet the combined requirements, technical as well as economical, of high quality, high efficiency and low cost.

It has certainly achieved the liberation of thinking and a great victory in production after the smashing of "gang of four". Under the leadship of Chairman Hwa and the Party, our fellow countrymen are striving for the four great goals of modernization. As a new technology, moderate speed feed grinding will definitely play a major role in the construction of a socialist society.

AIR DEFENSE RADAR AND ANTI-RADAR IN THE MIDEAST WAR

Wong-Ping Tao

As far as weapons are concerned, the fourth Mideast war engaged in October of 1973 can be regarded as the confrontation between the two superpowers, the Soviet Union and the United States of America, in armaments of various kinds with the exception of nuclear weapons, it is also considered to be the test ground of weapons from tanks to aircrafts, and from ballistic missiles to radars as well as various electronic equipments.

Althrough the war itself lasted only about twenty days, but it was engaged on a large scale, involving some four thousands tanks and two thousands aircrafts from both sides, there were approximately five hundreds airplances shot down and two thousands tanks damaged or captured. Most of the missing planes of Egypt and Syria were lost in air battles while the lost Israeli ~~Isreali~~ planes were shot down by surface-to-air missiles and by anti-aircraft artillery. In order to break through the Egyptian air defense ballistic missiles system, the Israel ~~Isreal~~ was forced in the last ten days of war to employ the electronic intelligence countermeasures and anti-radar ballistic missiles. This article is to report and analyse the radars employed in Egyptian anti-aircraft weapon system and the anti-radar measures used by Isreal in this Mideast war.

The Radar And Electronic System Of SA-6 Ballistic Missiles

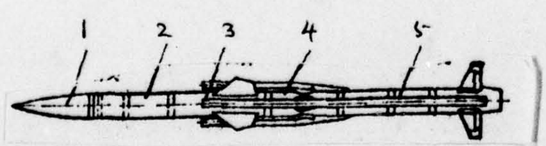
During this Mideast war, the Egypt and Syria employed in their air defense system mostly the SA-2, SA-3, SA-6 and SA-7 ballistic missiles made by the Soviet Union, they also made use of radar control quadruple-barrelled 23 mm anti-aircraft artillery. SA-2 is a high altitude surface-to-air ballistic missile, SA-3 is a counterpart at medium altitude, Sa-6 is intended ~~intnded~~ primarily for intercepting airplanes at medium or low altitude, SA-7 and quadruple-barrelled 23 mm anti-aircraft artillery are employed for close-in defense against dive bombers or low level planes.

Egypt has built a surface-to-air ballistic missile launching ground on the west coast along Suez Canal, establishing a tight air-defense zone extended to 33 Km wide and to a height of 15 Km above the ground, with the missiles mainly consisting of SA-2, SA-3 and SA-6. It was reported that, during the first week of the war, Isreal has lost seventy eight planes (mostly U.S. made F-4 and A-4), almost all of which were shot down by SA-6, SA-7 and quadruple-barrelled 23 mm anti-aircraft artillery.

Isreal was more experienced with regard to SA-2 and SA-3 ballistic missiles, relying on the use of electronic countermeasures and anti-radar ballistic missisles. Reports indicated that very few Isreali planes were shot down by SA-2 or SA-3.

Brief description of SA-6 ballistic missiles will be introduced here, with emphasis on radar and electronic control system.

The sectional diagram of SA-6 is shown in Fig. 1, this missile is 6.2 m long with a length-diameter ratio approching the value of 19. Its cone shaped head has the effect of reducing resistance. Two sets of cross shaped fins, situated in the middle and tail section, provide the necessary lift and act as devices for direction control and balance adjustment. In this ~~head~~ nose section, first is the semi-active guidance radar and fuse device, next is a container housing 40 ~~Kg~~ kg of explosive charge. The major components in the midsection are control and guidance electronic system, electric source, fuel tank and ramjet engine. In the tail section, the upper fin carries a streamlined antenna and on the tip of the lower fin there is another antenna served as the communication receiver. The missile weighs 550 ~~Kg~~ kg with an average speed of M = 2.5.



1. fuse and semi-active guidance radar system
2. explosive charge
3. midsection control and guidance electronic package
4. fuel tank
5. ramjet engine

The good mobility is a characteristic of SA-6 ballistic missile with respect to its launch and control guidance system, which consists of eight transport launch vehicles (on each vehicle mounted three missiles) and one command vehicle, as pictured in Fig. 2. Installed on the command vehicle there is target detection and identification radar which is equipped with a reflector surface antenna of the dimension 3.6 m long and 1.4 m high. In the same vehicle there is second radar whose function is for target tracing and illumination, with its paraboloidal Cassegrain antenna supported by a cylindrical structure on the top of the vehicle, as it can be seen in Fig. 2. The command vehicle and the launch vehicles are mounted separately on a tracked armor carriers. The carrier has a dimension of 6.8 m by 3.2 m and travels 45 ~~Km~~ km in one hour.

The antenna of the target detection and identification radar can rotate around a vertical axis and operates on two frequency bands in the search of targets. Operating at a frequency of 4900-5000 MHz in the search of target at a low altitude around 100 m, the search range is about 24 ~~Km~~ km. As the frequency of operation raised to 6450-6750 MHz, the search range will increase to 40 ~~Km~~ km for low altitude target and to a maximum of 80 ~~Km~~ km for target in high altitude from 15 to 18 ~~Km~~ km. The radar is equipped with an identification device which sends coded pulse signals after the detection of a target, if the target is a " friendly " one and is presumably equipped with a counterpart device that detects the initial radar signals and responds by transmitting pulse signals also security coded back to the search radar, ~~thereby~~ the identification can be established as whether the target is friend or foe.

Figure 2.

Figure 3.

Operated together with the SA-6 system there is usually another vehicle on which mounted a warning and tracking radar, as shown in Fig. 3, operating at two frequencies : 810-850 and 850-900 MHz. It has two elliptical reflector antennas with a surface area of 11 x 5.5 m^2. The search range is approximately 250 ~~Km;~~ km with a range accuracy of 90 m and altitude accuracy of 0.5 degrees.

On the basis of foreign reports, the operating procedures of SA-6 system can be summarized as follows : after the target is located by the warning and tracking radar, preliminary data concerning its position, altitude and distance are trasmitted to the detection and identification (D & I) radar. By measuring these data more accurately and with the help of the identification device which establishes the identity of the target as friend or foe, the D & I radar will relay this information to the target tracing and illumination (T & I) radar on the top of the command vehicle. The T & I radar and its antenna will perform their function by tracing and illuminating the target with pulsed or continuous waves, the frequency of operation being 8 - 9 GHz. The process of tracing and illuminating makes possible for the semi-active guidance device in the SA-6 missile to make use of the electromagnetic radiation reflected back from the target.

As the target approaches within a certain range and direction, missile is immediately launched by the SA-6 system, and at the mean time, based on the signals sent by the transmitter in the missile tail section, the D & I radar on the command vehicle starts to track the missile and to issue instructions for correcting the missile path if a difference is discovered that the missile and the target are not aligned, it is necessary for both the D & I radar and T & I radar to supply synchronizing information to the missile until the missile comes very close to the target. The missile is continuously being monitored along most part of its path, its semi-active homing guidance will become operational within the close range of the target. Equipped with infra-red sensing device, the missile is able to home on the target by tracing the infra-red radiated from the target when the radar is ineffective due to jamming.

According to published information, SA-6 has the ability to counter jamming and to trace the source of interference. It is accomplished by the interference prevention device in the missile, capable of receiving signals in the broad frequency range 100 MHz - 18 GHz.

In addistion, SA-6 has a optical control system, manually operated or remote controled through binoculars by a ground personnel, which can perform optical guidance in the case of serious electronic interference.

SA-7 And Quadruple-barrelled Anti-aircraft Artillery

The SA-7 surface-to-air ballistic missile used by Egypt and Syria in the last Mideast war is of two types : the carry-on-shoulder type and its modified model. The modified version is mounted on a self-propelled tracked vehicle, with each vehicle carring eight missiles. These eight missiles can be launched simultaneously or in two groups, with four in each group, thereby increasing the accuracy of hitting the target. Each vehicle is equipped with guidance radar whcih also provides target tracing for the missile. The SA-7 homing device can operate in the infra-red frequency range. By changing the wave length effectively, it can prevent the missile from hitting a decoy. Installed in the homing guidance system there is an infra-red filter which can modulate the thermal radiation from the target, enabling the missile to home on a target instead of a decoy.

Fig. 4 shows the configuration of the 23 mm quadruple-barrelled anti-aircraft artillery and a guidance radar, both mounted on a self-propelled tracked vehicle. The frequency of operation for this radar is 15.56 GHz, the antenna is of circular form with a dimeter of 0.5 m and thickness of 0.46 m. It has a very accurat target tracing ability because of the narrow frequency range. The artillery has a firing rnage of 1220 m, a angle variation 0-85 degrees, and a capacity of firing 1000 rounds of ammunition per minute. The maximum search range is 15 Km, while the maximum tracing range is 10 Km. Usually working together with another search radar with larger search range, and before the active tracing is in operation it is under the control of the other search radar.

During the Mideast War, in the battle against surface-to-air ballistic missile launching stations, ~~Isreal~~ Israel was very much dependent on the use of electronic countermeasures for delivery of metal foil, which were installed on both fighters and helicopters. Flying over the battle fields on mission of warning and guard, the helicopter could also provide attack fighters with information concerning enemy missile launching operation.

Isreal also employed in the war the "shrike", a radar-homing anti-radar ballistic missile. It was a passive-homing ballistic missile, when illuminated by enemy radar radiation, the aircraft would launch "shrike" which, guided by enemy radar wave, started and continued its flight homing at radar antenna.

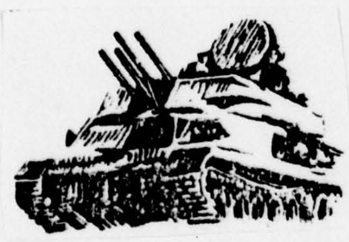


Fig. 4

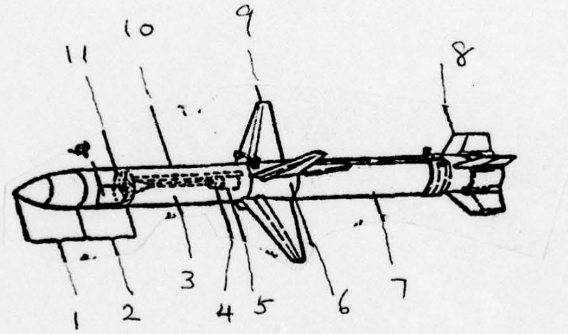


Fig. 5

1. electromagnetic wave receiver
2. control and guidance computer
3. explosive charges
4. fuse charge
5. fuse
6. flight control compartment
7. rocket engine
8. stability tail fin
9. main fin
10. shell head
11. antenna

The schemetical diagrams of "shrike" is illustrated in Fig. 5. The electromagnetic wave receiver, as shown in the diagram, is the homing device of the missile. In order to differentiate among various electromagnetic waves transmitted by the enemy radar, it has been equipped with varied type of homing sense devices which amounts to 14 different kinds, as revealed by electronic surveillance report, one of these devices best suited for certain enemy radar frequency is usually selected before launching.

For "shrike", there are eight different explosive charges, six different control components, and ten different engines. Therefore, it is of a "modular" structure, the only common components among its different models are the tail and control fins.

It has a overall length of 305 cm, a diameter of 20 cm, a fin span of 92 cm and a tail fin of 46 cm. Its weight varies among different models, being approximately 180 ~~Kg.~~ kg including 20 ~~Kg~~ kg plus of explosive charges. Its structure consists of four components: the guidance component with its pointed head, the explosive charge compartment, fin control component and rocket engine component. Its maximum firing range is around 40 ~~Km.~~ km

The homing device is devided into two parts: the receiver and the computer, with its antenna cover made by fiberglass. Inside the antenna cover lies the radar radiation receiver containing a signal detection device which, after detecting the target electromagnetic radiation, can perform measurements on the position and direction of the target. The receiver is able to detect the enemy radar radiation within a conic section with its surface line making a 30° angle with respect to the missile flight path. The detectable wave frequency rang~~ing~~es from 1560 to 5200 MHz.

The receiver consists of four detectors. The first one receives waves from the top, the second one from the right, the third and the fourth one detect radiations from below and from left respectively. Measurements on wave strength are made, data obtained are sent to the computer. After the completion of data processing, command will be sent to the control instrument to direct the course of the missile.

There is a rectangular antenna on each side, right and left, of the computer, performing the adjustment to the timing of detonation. The electronic wiring boards for the control of detonation are fixed in the far back part of the control and guidance compartment.

Behind the control compartment is the space for the storage of explosive charges and ignition mechanism, an arrangement similar to ordinary bombs. For the creation of directional force in explosion, usually required for ballistic missile, the compartment containing explosives is cone-shaped to increase its penetration ability. The compartment is 67 cm long and has a capacity load of 66 kg, instead of explosive substances, it is sometimes filled with "white phosphorus" or "red phosphorus". In situation such that a few "shrike" are not sufficient for destroying a large radar site, missiles filled with "phosphorus" are used for producing flame and smoke after hitting the radar, making a visible target for other planes to attack.

Next to the charge compartment is the control section which includes four operational fins, connected perpendicular to each other, operating under the command of the computer to control and maintain the correct flight path of the missile.

Reports indicated that Israeli ~~Isreali~~ armament supplied by the United States includes new homing devices which are adequate for attacking Sa-2 and SA-3 missiles and their radar system. The "shrike" anti-radar missiles, however, are not very effective to cope with the SA-6 and SA-7 radar systems. This is because the Israel ~~Isreal~~ and American military authorities failed to detect the operational procedures with higher operting frequencies adopted by SA-6 and SA-7 radar systems.

Electronic Countermeasures In Mideast War

Israel ~~Isreal~~ air force suffered heavy loss in the first week of the Mideast War, within the first two days as many as thirty Israeli ~~Isreali~~ airplanes have been shot down by Egyptian and Syrian surface-to-air ballistic missiles. Soon after the war broke out, Israel ~~Isreal~~ discovered the following facts:

(1) It was a difficult task in dealing with SA-6 ballistic missiles. The SA-6 radar system, which had the capability of transmitting five different sets of signals, proved to be more complicated than those formerly detected by electronic surveillance system. Israel ~~Isreal~~ also found that this was a system for which measurements and analyses had yet to be made and with which they had no electronic countermeasures and tactics to cope.

(2) The technique for jamming SA-7 infra-red sensing device was not effective.

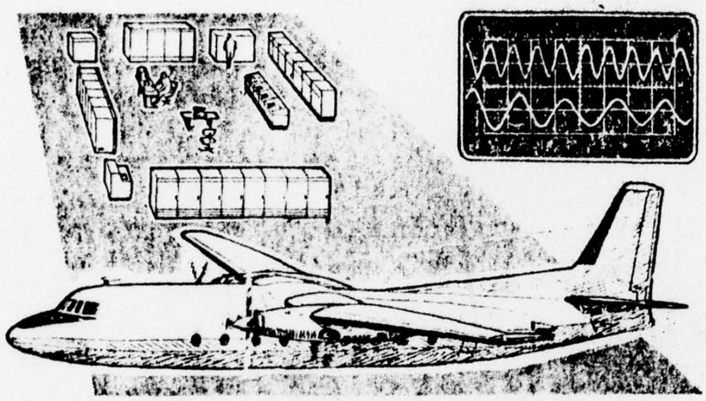
(3) SA-7 radar operated at a very high frequency of 15.56 GHz, which the aggressor Israel ~~Isreal~~ and her American supporter had no means to work against. The ALR-45 broad range non-search reconnaissance receiver, also supplied by the United States, operated in a frequency range covering only 2 - 14.5 GHz and, therefore, was unable to detect the SA-7 radar signals. No facility was available ~~avaliable~~ to perform brute force jamming.

In the first week of the war, Israeli ~~Isreali~~ aircraft relied chiefly upon dropping pieces of metal foil for protection against radar-controlled missile attack. With no special device for dropping metal foil, the Israeli ~~Isreali~~ F-4 planes had to store metal foil insisde aileron panel which could be opened when releasing metal foil.

In the last two weeks of the war, Israel ~~Isreal~~ made use of American supply pylon pods, attached under the wings, which had the capacity for delivery of 125 Kg aluminum foil or glass foil coated with metal. To cope with SA-7 ballistic missile, Isreal also employed flare bombs launched from pylon pods.

VIBRATION AND COMPUTER

N. H. Hon P. G. Fu



What is vibration? It is simply one type of high frequency oscillation, failure to eliminate vibration will cause damage or even disintegration to the airplane structure. Therefore, the appearance of this phenomenon immediately attracted the attention of many people. Especially today, due to many possible applications of air vehicles, the requirements for better function become more demanding; it perhaps can be said that how to solve the vibration problem in a reasonable and effective manner is a key factor in the design of air vehicles.

There are many kinds of vibrations in air vehicles which include: wing bending -- torsion vibration, wing bending (or deformation) -- control surface rotation vibration, fuselage bending (or torsion) -- tail vibration, fuselage -- tail -- control surface vibration etc. In the earlier period, due to the limitation in technology and scientific knwoledge, people could only estimate the vibration critical velocity based on simple semi-empirical formula, or describe conservatively the requirements concerning rigidity and hardness for some important components (for instance, the static deformation of wings or wing tips, static twist angle of control surface and vibration frequency ratio) in order to prevent the occur~~ance~~rence of vibration in flight. Now these methods apparently can no longer satisfy the requirements in the development of modern air vehicles. In the advancement of theoretical aerodynamics, structure vibration theory and related mathematics, the mathematical model of vibration has been continously modified, formulating a complete system of vibration theory. Due to its complexity, if the computations were performed manually (e.g., by desk calculator), it would not only take many man-hours of labor but also give inaccurate answer which could not meet the requirements suitab~~el~~le for the ~~devlop-~~ develop-ment of modern air vehicles. Recently, the appearance of high-speed and large memory computer makes possible the computations of vibration theoretical problems, it further provides a powerful new tool proved to be extremely useful in the investigation of vibration problems and in the rapid advancement of air vehicles.

Theoretical Calculations On Vibration

The entire process from proposal of the ~~programme~~ program to completion of design requires verification in all respects, including feasibility studies of the plan. Generally speaking, there are three alternatives to the solutions of the vibration problem: 1. theoretical calculations on vibration, 2. wind tunnel test of vibration models, 3. free flight test of air vehicles. In the initial design stage, it is impossible to perform free flight test and is very difficult to conduct wind tunnel test of vibration models, as a result of numerous type of vibrations it would be practically impossible to make various vibrations models within a short period of time in order to test each and every one of them, the only alternative is the theoretical calculations on vibration which can approximately and timly provide air vehicle with its characteristics. It can be seen that the theoretical calsulations on vibration can make definite contributions in shortening the time span of vehicle design.

After the air vehicle preliminary plan is drafted, determinations can be made concerning external configurations, stress structure arrangements and combination of components, and calculations can be proceeded in the area of rigidity and vibration. When requirements in these two respects are met, indicating the plan is feasible and no major modification is needed, it can now proceed to the design of parts and components. After the combination of components and mass distribution are decided, more accurate value of flexibility influence coefficients and system vibration characteristics can be obtained, improving the overall precision of the calculations. If the vibration critical velocity under certain circumstances is discovered to be close or smaller than the expected value, correction can be achieved through modification (for example, changing the system mass distribution or rigidity distribution etc.) in order to raise its value to the required standard. In the case of unsatisfied design, the theoretical calculations of vibration can serve as a guidance in the modification of plan, it can assist the design reaching its expected functional capabilities and can provide saveguard to the air vehicles for the prevention of vibration.

Flow Chart of Vibration Calculations

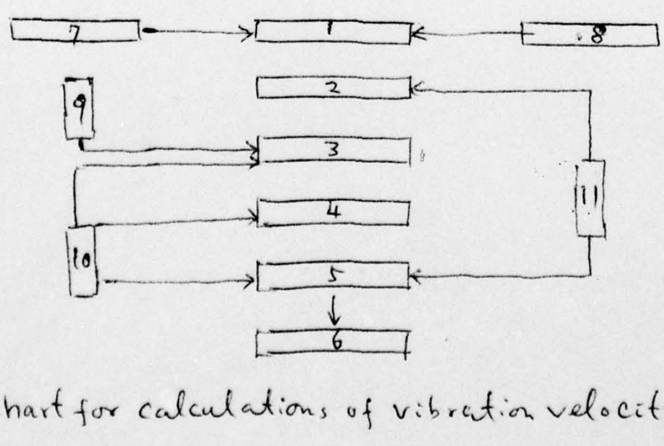
For the present time, there are many methods in the vibration calculations using the computers. They can compute the vibration critical velocity for a single component as well as provide solutions to the vibration problems for the combined system.

In the calculations of vibration velocity and frequency, it is usually carried out by first writing programs based on flow charts, with computations performed on computers.

The computation procedures consist of: 1. after the preliminary plan was determined, the flexibility influence coefficients will be calculated based on stress structure arrangements and combination of components, 2. to input the preliminary estimates of mass distribution and to obtain system vibration characteristics (system harmonic vibration frequencies and vibration modes), 3. to design the control coordinates of reference on wings surface, 4. to obtain vibration aerodynamics based on wings geometric parameters, Mach number and damping frequencies, and 5. to calculate vibration critical velocity and frequency by solving the vibration equations based on input parameters and the results obtained from previous procedures.

Because of its overall considerations under different combination conditions and its ability to obtain solutions with less time, theoretical calculations on vibration has occupied a very important position with wide application in the design of air vehicles. It has shortcomings and limitations, however. It is valid only under certain conditions beyond which its results would become less dependable, in the determination of its mathematical models, considerations are focused on the major factors infleuencing the vibration characteristics, without taking properly other accidental elements into account. The correctness of the theory must consequently rely on practice. In order to quarantee the flight safty, model wind tunnel test of key components and their combinations must be carried out and, when conditions permit, free flight test is necessarily needed.

1. to obtain the flexibility influence coefficients
2. to obtain the vibration characteristic of the system
3. to design control coordinates of reference
4. to obtain aerodynamic factors of vibration
5. to solve vibration equations
6. to obtain vibration critical velocity and frequency
7. stress structure arrangement
8. combination of components
9. control coordiantes of reference
10. geometric parameters
11. mass distribution



Flow chart for calculations of vibration velocity and frequency

A WITNESS OF THE CRASH OF A-10

H. B. Wang

This article describes the crash of US A-10 close-support attack aircraft at the 32nd Paris air show on June 3, 1977.

June 3 of last year was the opening day of thd 32nd Paris air show. On the day, a large crowd gathered at Le Bourget airport near Paris. Commercial leaflets and pamphlets were distributed among the crowd, there were various kinds of aircrafts parked on the exhibition ground, mixed with the noisy background, all of a sudden a sound of explosion was heard.

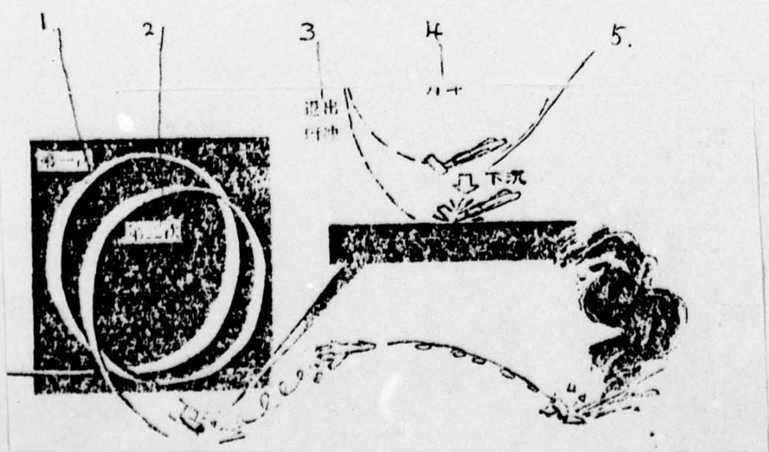
On the side of the airport, the fleight demonstration has been performed since 9 a m., the next scheduled one will be the flight demonstration of the single seat transonic close-support attack aircraft A-10, newly designed and developed by the Fairchild Republic of the United States.

A-10 was test piloted by Nelson, Fairchild director of flight oprations. He has accumulated more than ten thousands hours of flight time since the second World War, including two thousands ~~and~~ five hundreds hours of test piloting P-51, F-80, F-100, F-102 and F-106. He piloted the test flight of A-10 for the first time in May, 1972 and completed the whole operation after spending more than five hundreds hours in actual flight. Therefore, he was considered to be well familiar with the A-10.

According to the schedule, the flying demonstration of A-10 started at 3:08 pm. The weather was bad with low level of clouds. Nelson flew along the No. 3 runway after take-off and, at an altitude of 50 m, completed the first loop operation. Immediately the plane entered the next loop, diving with a high sink rate toward the ground. The audience were all surprised to see the plane did not reverse its direction until it almost hit the ground, by then the plane has already been very close to the ground with large velocity, reaching a position too low for recovery. Consequently, it struck the ground near the runway tail first in a nose-high a~~l~~titude. The tail broke apart immediately aft of the cock~~it~~pit, the aircraft had sufficient forward speed to fly on for more than 100 m before again hitting the ground. After the cock~~it~~pit separated from the rest of the fuselage, it rolled inverted and skidded, partially disintegrating. The wings and fuselage cartwheeled and burned, but except for one engine narcelle, remained intact. Fire brode out on initial impact, apparently from a ruptured fuel line under the fuselage just aft of the wing. There was a secondary explosion, apparently fuel from the wing tanks, after the second impact of the airplane.

Shocked by this event, the audience were running toward the scene, fire and engineering trucks, ambulances, and command vehicles all arried at the scene shortly after the crash. Although rescu~~r~~ed from the wreckage, Nelson died on his way in a helicopter to the hospital as a result of injuries sustained in the crash.

1. first loop
2. second loop
3. recovery from diving
4. cartwheel
5. sink



The crash of A-10 was a great astonishment to all the nations participated in the air show, for which flags were lowered half for the remaining show, and was broadcasted in the evening news by French TV stations.

The crash was the first for the A-10. Since it happened in a public air show, it had a great impact to USAF and, in particular, to Fairchild which did the research and development work. The US Transportation Secretary Adams was quoted as saying " the crash of A-10 griefed me deeply ", and instructed that US pilots should pay special attention to safety ~~safty~~ requirements and should not fly too low in order to prevent from repeating any similar event. Scheduled flying demonstration for a second A-10 was cancelled, the plane has been parked on the exhibition ground throughout the remaining show.

On the next day after the crash, a special team was sent by the USAF to investigate. It was reported by this team that the flight profile being performed by the aircraft did not differ significantly from that filed with the approved by the French, although it had been modified from the demonstration performed earlier during pre-show demonstrations. No mention was made regarding possible mechanical ~~mechnical~~ failure. It was concluded in the report : after completed one loop and entered a second loop, the plane was only in nose-high with a large sink rate due to the action of inertia, causing the tail making contacts with the ground. In addition, the report indicated that there was a period immediately prior to first impact when the aircraft's sink rate and altitude were such that sucessful ejection would have been impossible, a successful one would have been possible, however, for several seconds immediately after the initial impact had the pilot been capable of activating the escape ~~escapac~~ seat, unfortunately, Nelson failed in doing so.

The report, after investigation was made, seemed to establish that the crash was basically due to the failure of the pilot in following the strict regulations, which made the US calmed down considerably. Investigation team further notified USAF that there was no apparent reason to pull the aircraft out of the show and the Defense Department offered to supply pilots if Fairchild would continue flight demonstrations at the show, but the company declined.

In addition to the participation of Paris air show, as revealed by report, the A-10 would be visiting USAF, U. S. Army, West German Luftwaffe, Dutch Air Force and British Royal Air Force bases in Europe in the first concerted sales effort for the aircraft. The tour was modified slightly, because the original plan called for two aircraft to work together in demonstrations to show tactics devised for two aircraft in anti-tank work. in order to maintain the good name of the plane and to minimize the impact due to the crash. The financial loss for the company was recoverable, however, in an effort for expanding the world market, the life of an experienced pilot has been sacrificed in the ~~paymant~~ payment of high priced of blood.

CLOSE—SUPPORT AIRCRAFT --- A-10

K. S. Liu

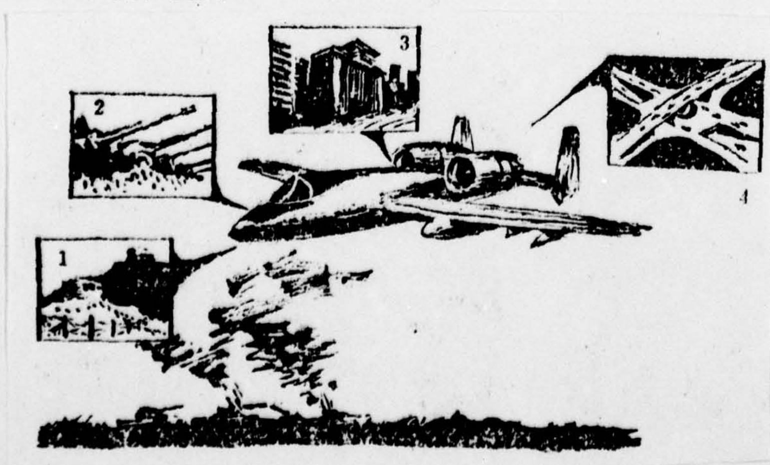
Appearance

Since the demolition of the fairy tale of American "air superiority" in the Vietnam war, the design concept of multifunction aircrafts has gradually been abandoned, emphasis is begining to be focused on the development of aircrafts suitable for one unique task. Since 1966 the United States Air Force has initiated an A-X programme, proposing to develop close-support aircraft capable of peneprating enemy defense and attacking directly small moving targets. In April of 1967, the USAF anounced the bidding for contracts, and in March of 1970 Northrop and Fairchild were selected as the two companies that were each to build two prototype for development test and evaluation in competition. Northrop's prototype was designated as A-9 and Fairchild's as A-10. The ~~comptition~~ competition took place in 1972, from October to December, including a total of 284 hours of flight time. It was anounced in January, 1973 by the USAF that the A-10 had been selected as the winner, which concluded the ~~comptition~~ Competition between the two companies. Northrop has failed and was ordered to discontinue the development of A-9, Fairchild has won the contract for the development test and evaluation of A-10 which took a total of eight to nine years to complete. The production of A-10 began in 1975 and in March of 1977 a total of 20 production A-10s has been delivered for operation. It is believed that in 1980's the A-10s will become the major air-to-ground attack force in the USAF.

Function

A-10 is a single-seat transonic close-support aircraft, primarily for attacking moving targets on the ground, such as tanks, and for this reason it was named "tank bomb". It s appearance is a product of armament expansion and the confrontation between the two superpowers of Soviet Union and USA. It was reported by foreign publication that, as far as design concept and operational test are concerned, the major objective in the design of A-10 was focused on Soviet European armor troops which were well protected by strong anti-aircraft capabilities. Equipped with

GAU-8/A gun system, which has a high degree of accuracy and low rate of failure (failure occur~~ed~~red only once for an average of 17,000 rounds of ammunition fired), the A-10 was found during flight test to be very effective in attacking tanks or any armored vehicles, for example, one report indicated that if took only 2 seconds to destroy a Soviet made T-62 tank. In order to increase its firing power, A-10 has employed bombs or missiles using uranium by product as their explosives, which have the capabilities for penetrating any Soviet made tanks. After learning some lessons in the Mideast October war, A-10 has equipped with new electronic countermeasure devices which are better qualified against several standard air defense weapons usually employed by the Soviet armored troops such as : SA-6, SA-7 surface-to-air ballistic missiles and the radar control quadruple-barrel 23 mm anti-aircraft artillery mounted on a tank. In one combat mission, A-10 could have the capability of destroying 11 tanks. In the confrontation between the Soviet Union and the USA, Europe is still considered to be the center area in which, as reported by a French newspaper, the Warsaw Treaty group has a military force involving 2,300 tanks, and the NATO has only 1,100 tanks. To improve this situation, the United States has been trying to supply Western Europe with A-10 units for strengthening the anti-tank tactical air forces. It is , therefore, natural to assume that A-10 is favored by the American military authority. Chief-of-Staff General Brown has said : " As far as United ~~Stated~~ States Air Force is concerned, the A-10s, F-15s and E-3As will be the major components of the tactical air force in 1980's ". What we have seen here is a profile of detente in appearance but armament expansion in reality between the Soviet Union and the USA.



Major functions of A-10

As a close-support aircraft, A-10 is not limited in its ability to attack tanks, it can be used for supporting ground troops, for attacking artillery and other defenseive equipments, it also has the capability for destroying ground commanding structure and communication or transportation center. (see Fig. 1)

Based on the above-mentioned functions, the USAF has listed the following design requirements for A-10 aircraft : short distance for take-off, quick response, ease maintenance, strong firing power, high rate of survival and suitable for use in forward airstrip.

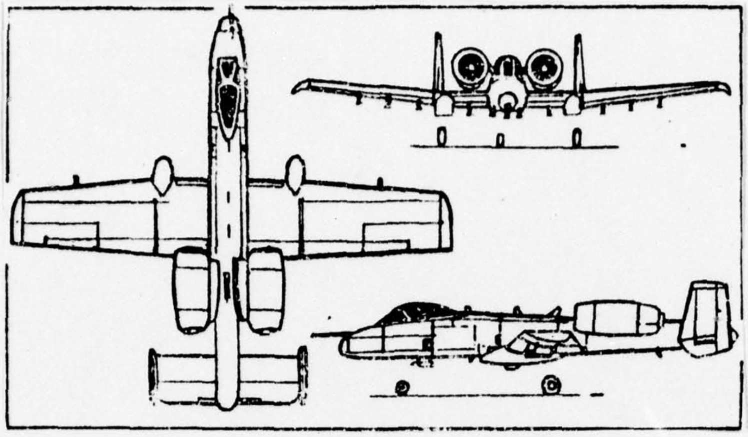
Characteristics

The comment " A-10 is an unconventionally built aircraft ", made in September of last year by the West Germany journal (Federal Republic National Defense), is indeed a correct statement. It has a very strange outer configuration. A pair of trapezoidal wings are installed right in the middle of the plane, with the outer panel slightly curved upward. Two TF34-GE-100 turbofan engines, enclosed in separate pods, each pylon-mounted to the upper rear fuselage at a point approximately midway between the wing ~~traling~~ trailing edges and the tailplane leading-edges, form a unique eye-catching appearance. Each engine can provide a thrust of 4,175 Kg. This configuration allows able space under the fuselage and wings for the storage of landing gear and various weapons, and prevents unwanted substances from entering the engine.

The tail unit consists of twin fins and interchangeable rudders mounted at the tips of constant-chord tailplane. Again it is an " unconventional " symbol.

Another point of interest about A-10 is that it has many stores pylons, a total of 11 them. They allow carriage of a wide range of stores, including general-purpose bombs, rockets, retarded bombs, air-to-ground ballistic missiles and self-defense air-to-air ballistic missiles. The maximum external losd can reach 7,200 Kg.

Besides the above-mentioned characteristics, there are no more features worth mentioning except perhaps the following : a single-seat enclosed cockpit, a GAU-8/A 30 mm seven-barrel cannon (capable for firing 2000 - 4000 rounds of ammunitions per min.), and a retractable tricycle landing gear.



Data

Wing span	16.76 m
Length overall	16.25 m
Height overall	4.47 m
Wings area	45.34 m^2
Maximum T - 0 (take off) weight	20206 Kg
Empty weight	8520 Kg
Max. fuel capacity	4830 Kg
External loading (weapons)	7250 Kg
Max. horizontal speed	740 Km/hr
Cruising speed (at sea level)	555 Km/hr
Max. climb	9144-11000 m
Close-support combat radius (2 hrs in target area)	460 Km
REconnaissance radius	750 Km
Close air support and escort (12 hrs idle)	484 Km
T-0 distance at max T-0 weight (sea level 32°C)	1160 m
T-0 distance at forward airstrip weight (13.6 ton)	339 m
Landing distance at max T-0 weight (32°C)	640 m
Landing distance at forward airstrip weight	325 m

Basic Knowledge Lecture

AIRCRAFT INTAKE DUCT (I)

H. S. Chao

Intake duct is one of the important components in jet planes. It has a decisive influence on the performance of aircraft, especially on modern high-velocity planes its effect is quite evident. Thus, the design of intake duct has become an important branch in the overall design of aircrafts. In this journal, introduction to the basic knowledge of intake duct will be presented in this and the subsequent publications. We will discuss here its function and the problem concerning the recoverage of the total pressure...

The Function of Intake Duct

In jet airplane there is always an intake duct. Which part of the plane may be considered as intake duct? Let's take a look at Fig. 1, which is "MIG - 25". That was the same type of plane one of which was piloted by Soviet Far East Air Force lieutenant who escaped from his country on September 6, 1976 under the protest to the ruling of Soviet revisionist reactionary group. Its maximum ~~flight~~

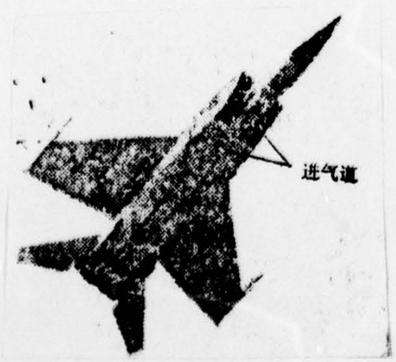
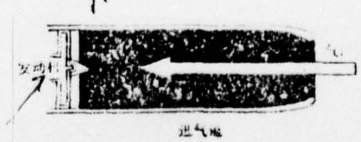


Fig. 1 MIG-25

Intake duct

Fig. 2 subsonic duct



turbine

Fig 3 supersonic duct

flight velocity is approximately 2.8 times the velocity of sound. Those two rectangular area on both sides of the plane are intake ducts, as can be seen in Fig. 1, they occupy a considerable space. In Fig. 2, it illustrates the duct form installed in subsonic or transonic aircrafts. It has a simple form, shaped as a tube, through

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which air stream passes into the engine. Fig. 3 is a supersonic plane intake duct. It contains a conic section, also known as compress surface or central part, extended beyond the entrance openning. The supersonic air stream, after making contacts with the central part, will be induced into the creation of shock waves. Subsequently, the velocity of the slip-stream will be decreased from supersonic to subsonic, and at the same time, the static pressure will be gradually increased. Since it is connected to the engine, the passage from the entrance of the duct (or the tip of the central part) to the entrance of the engine is called intake duct.

Why must there be an intake duct in jet plane? It is related to the principle of producing thrust in the jet turbine. To state it simply, the thrust is produced when air stream entering the turbine is first accelerated then followed by discharge at high velocities with a resultant reactive forces acting on the turbine. The basic function of the intake duct, therefore, is to supply the turbine with sufficient air. This is just like people need food, people tend to be more vigorous after eating. To the turbine air is "food", duct is "mouth" and "throat". It requires air in the amount of 65 Kg per second (every kg thrust produced requiring 16.25 kg of air) for a jet turbine generating thrust of 4 kg operated on ground. For a piston engine of 1600 HP operated under similar conditions only less than 2 kg of air per second is needed (it amounts to 1.25 kg for every 1000 HP). Compare to piston engine, jet turbine certainly has a voracious appetite.

Since the function of intake duct is to supply the turbine with air, furthermore, the thrust produced is proportional to the quantity of air it provides, would it then be more advantageous to have a duct designed carelessly and be made as large as possible? The answer is no! The slip-stream velocity at the exit of the duct (or the entrance to the turbine) is dictated by the turbine and its operation, having a rather low value about 0.3 - 0.6 of sound velocity at the entrance to the turbine (much less than the flight velocity, especilly for supersonic plane). This means it is necessary for the duct to effectively (i.e. to maintain a large volume of air) decrease the velocity of the air, and to allow a large quantity of air flowing into the turbine. To this end, there is no other way but to raise the air density by compression to insure that sufficient supply of air can be provided to the turbine. More specifically, the function of intake duct is to effectively decrease the air stream velocity and to increase its compression. In brief it is referred to velocity reduction and pressure increase.

Associated with this velocity reduction and pressure increase, there is an interesting phenomenon: in a supersonic plane, most part of the thrust produced by the power installation (including intake duct, turbine and nozzle) is "generated" in the intake duct, with the smaller remaining part came from the turbine itself. This point is illustrated, as an example, in Fig. 4. When a supersonic plane with Mach number 3 is flying at maximum velocity, the production of thrust can be divided into three parts: 17.6 % is from the turbine, 28.4 % is from the nozzle and the remaining 54 % is derived from intake duct. Due to its thrust "production", the intake duct has occupied a significant place in high velocity aircraft. Of course, we should not be misled by this particular example to doubt the turbine function. Turbine is the heart of a plane, without which no thrust can be produced, and the intake duct, under such conditions, is more like a "dead end street" generating resistance instead of thrust. It is only through the turbine the intake duct can perform its function, they complement each other.

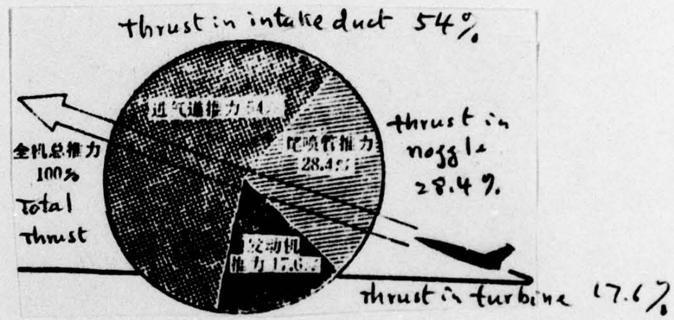

Fig. 4 the distribution of thrust in airplane

The Recovery Of Total Pressure In Intake Duct

As we known, at each point in air stream the pressure, velocity and temperature are generally varied. Imagine there were a friction-free duct (existing only in an ideal situation but not in reality) through which air stream is guided into a very large container without generating any shock waves, then the terminal velocity of the stream is decreased to zero and the air pressure inside the container is equivalent ot the total pressure at the starting point of the stream. The magnitude of this total pressure is manifested at the smae point as a total mechanical energy (the energy which can be converted into work) of the air stream. In the process of passing from the intake duct to the entrance of turbine, the supersonic air stream suffers from frictions existing between the stream and duct walls as well as among the stream itself, and in supersonic plane the stream is subjected to additional obstruction of shock waves with temperature increase as a result. All these factors will cause energy transformation, with part of the mechanical energy converted into thermal energy. Since heat is not usable as a direct source of work, only by means of heat engine can part of the thermal energy be converted into mechanical energy (i.e., useful work). The remaining larger part of the energy is wasted. As a consequence, the total mechanical energy of the air stream passing through the intake duct is definitely lower than its original value and the loss in total pressure is inevitable. To manifest the magnitude of this loss, it is usually expressed in terms of a ratio between two values of total pressure, one at the entrance of the turbine (or the exit of the duct) to the other one at the entrance of the duct. It is customarily referred to the recovery coefficient of total pressure, or briefly the total pressure recovery value.

The total pressure recovery value is a parameter characterizing the function of intake duct, a significant factor in the sesign of aircraft. A poorly-designed intake duct will result in large loss in total pressure, which means a small total pressure recovery value. This will not only increase its own resistance and reduce its thrust in the duct, but also will effect the production of thrust in the turbine and in nozzle. It amounts to a double efforts with only half accomplishment. Normally, 1 % loss in total pressure leads to at least 1.25 % reduction in thrust generated by the plane. According to this ratio, a 50 % loss in total pressure will have the effect that a plane can only generate 3,750 kg of thrust instead of 10,000 kg of thrust it is capable of producing.

Since the total pressure loss could have such a decisive influence on the thrust production, the question naturally arises as how to minimize this loss and increase the total pressure recovery value? One way to accomplish this is to reduce the friction between air stream and duct walls or ~~mong~~ among the stream itself by surface control or by making the duct as smooth as possible. On the other hand, as far as supersonic plane is concerned, the major cause for the loss in total pressure is due to the shock waves. The occurance of such waves is inevitable for a plane flying at supersonic speed. The only alternative seems to be the reduction of shock waves, which depends on the geo~~r~~metry of the physical object in addition to the velocities. As indicated in Fig. 2, the principal shock waves will be produced whenever the duct velocity exceeds the velocity of sound, and these principal waves usually cause large pressure loss. If a central part (or inclined board) is employed, as illustrated in Fig. 3, then two or more oblique shock waves will be generated, causing less pressure loss. This is why the intake duct is constructed differently in two different cases. This is also the primary arrangement for increasing the total pressure recovery value in a supersonic aircraft.

The Trend For Modern Ground-based Air Defense System

Since the Mideast War, the modern ground-based anti-aircraft weapons and radar system seemed to be developed following the trend:

(1) anti-aircraft weapons are composed mainly of surface-to-air ballistic missiles mounted on tracked vehicles with high mobility, anti-aircraft artillery being used for low altitude flying targets. Heavy artillery is no longer considered to be useful, for it can not reach any airplane at an altitude above ten thousands meters, nor is it effective against supersonic aircraft or low altitude target because of its low mobility. It is now popular to employ small sized, ranging from 20 to 40 mm, high speed firing anti-aircraft artillery, usually four or six barrelled. Operated in conjunction with control instrument and radar, this three-in-one set is generally mounted on a tracked vehicle.

(2) To prevent interference from objects on the ground, the radar system of surface-to-air ballistic missile or anti-aircraft artillery has widely employed pulse Doppler system. To prevent from jamming, it is operating at new frequency range with switching and anti-jamming ability. The capability of protection for interference from ground sbjects and prevention from enemy jamming is the major consideration in the development and installation of a modern air defense system. To ensure that the air defense system would not be in a state of collapse at any time because of interference or jamming, modern radar has made use of laser, infra-red, TV and optical devices.

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