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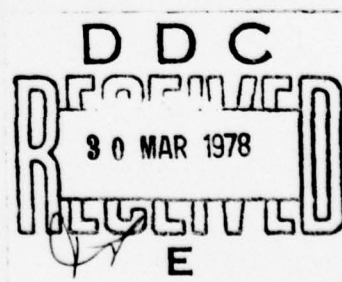
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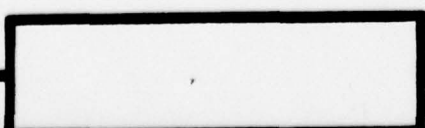
PROTECTIVE COATING FOR AIRCRAFT ENGINES

by

Wang Hsing-yeh



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PROTECTIVE COATING FOR AIRCRAFT ENGINES

Thin in thickness and light in weight, coating could be used as a way of improving certain properties of materials. It is easier and more effective than improving the materials themselves and has broad applications.

Coating has a broad spectrum of applications. Porcelain enamel is applied to washing bowls, ^{earthenware jars} rice bowls and dishes. Oil paint is applied to desks, dressers, doors and windows. Stoves and ^{Chimneys} ~~chimneys~~ use ceramic enamel. Cars and agricultural machinaries use many plated and painted parts. Airplanes use different kinds of camouflage coating. In the following, we introduce the coating for jet engines.

USAGE

In daily life, we often see that equipments made of iron become rusty, wood become corroded. Surfaces of aluminum develop pimples due to contact with salts. Similar corrosion phenomena would occur to the parts of a jet engine if these parts do not receive special treatment. This is easily understood if we observe the materials which constitute the jet engine and the conditions under which the engine has to operate. In flight, a large amount of air enters the engine. After passing through a compressor, it mixes with fuel and combustion occurs. The gaseous mixture reaches a temperature above a thousand degrees Celsius and eventually exits from the exhaust nozzle at high speed. All the parts of the engine which come into contact with this gas at various stages are threatened with different corrosions.

The front part of the engine is at a lower temperature. These parts are made of light weight, hard magnesium and aluminum alloys. As air enters the engine, it carries along dirt, grease and salty mist which, coupled with temperature effect, adhere to the surface of parts and serious corrossions result. These pimples reduce the surface smoothness and the strength of materials. Consequently the life span of these parts is reduced. Corrosion will be greatly reduced if corrosion-resistant coating is applied to them to keep them from being exposed to salty air and moisture thus resulting in longer life for these parts.

When water mills and the axes of grinding stones squeak, application of lubricant oil will reduce the friction. Inside the engine, however, there are some parts requiring long life come into contact with each other and generate friction but which can not be lubricated. For an example, the vibration reducing mid-span shrouds on the turbine blades (Figure 1) require that they be overhauled after thousands hours of service. These shrouds undergo temperature changes, impulse, and vibrations during the start and stop of the engine. This results in wear of the contacting surfaces and increase of gaps thus requiring parts to be repaired or replaced. If a hard material is coated on the surface, just like adding metal part on the shoe sole, resistance to wear will be increased and the life of the parts prolonged. Similarly, one can also apply a wear-resistant coating to the parts to restore them to conform with original specifications, and continue their services. This is very cost-effective and is widely used in repair work.

Due to design requirement, there are certain gaps between the compressor blades and the housing; turbine blades and outer ring. Compressed air tends to leak through these gaps and causes loss of efficiency. With proper coating applied to the inner part of the housing or outer ring, normal rotation of blades will not be hindered yet the gaps between the blades and the housing will be reduced to a minimum to improve the engine efficiency. It will increase the thrust power with fuel consumption unchanged. Presently organic coating, organic silicon coating or soft metal plating is used in compressor housings. High temperature metallic honeycomb or graphite is used as filler. They are known as sealing coating or gap-reducing coating.

Combustion chamber burner, turbine blades and exhaust nozzle all come into direct contact with high temperature gas which is hot enough to melt aluminum. Not even carbon steel could withstand the heat. These parts must be made of nickel, cobalt, chromium alloys which can withstand high temperature and erosion due to moisture. However heat corrosion will still occur if no protective coating is applied. This is due to the fact that through high temperature oxidation, the sulfur in the fuel reacts with the salt in the air ~~to~~ ^{to} form sodium sulphate. This affects the oxidation-resistance and structure of the alloy surface, weakening the oxidation-resistance and strength of material at high temperature. Under the constant bombardment of high temperature, high pressure, high speed air flow, coupled with mechanical stress, vibration, and hot-cold cycle, the engine parts will break, deform, crack and burn through. It constitutes a serious threat to operation

safety. To reduce corrosion phenomena, heat-resistant, corrosion-resistant materials should be applied to the surface of the parts in order to avoid contact with the burning gas. Diffused aluminum is used on the surface of the turbine blade to increase its life to five to six fold. Porcelain coating is applied to the surface of burners to increase its life to two and half fold.

As aviation advanced, the air temperature inside the turbine engine increased. For an example, it is 950°C in the 50's, 1100°C in the 60's. Presently it reaches 1270°C . But the melting point of the turbine blades which are made of nickel base alloy and cobalt base alloy is about 1315°C . The manufacture technology lags behind the requirement of production development. Therefore, in general the emphasis is placed on design to provide it with air cooling. Concurrently heat-resistant thermally insulated ceramic coating and techniques of strengthening the surface are used to prolong the life and improve the performance of the engine.

Aside from the corrosion resistant, wear-resistant coating, other special purpose coatings are under development. For an example, color changing coating for testing, de-icing coating for air flow deflector cover, coating to reduce heat loss for high temperature parts, coating on engine to resist hydraulic liquid, etc.

TYPES

Figure 2 is a schematic diagram showing the categories and applications of various coatings on a ^{Turbo}jet engine.

Various parts in the engine operate under different conditions and have different functions. Therefore the requirements for coatings are different. Generally the coatings should be such that: the binding between the coating and the part is strong, the coefficients of expansion for both are close; the coating will resist high temperature, corrosion, kerosine fuel, lubricants, and hydraulic liquid; it will not mix with oil or water and it will be air-tight; it will not corrode the surface it tries to protect; it has sufficient hardness and strength.

We have described different coatings according to their functions. Now they are classified according to the materials.

Metallic: Using corrosion-resistant metal or alloy to coat the parts surface such as electroplating of chromium, silver, cadmium, and nickel or diffused metallic layer such as diffused aluminum, diffused chromium, and aluminum-chromium. High temperature flame sprayed coating of nickel, chromium, or aluminum powders, is another form of coating.

Chromium Plating: Mainly used to reduce wear. Applied to the surface of rotating parts with an operating temperature below 290°C such as an auxiliary gear of the engine.

Silver Plating: Used as lubricant for bearing and gear to reduce the instantaneous friction when the engine just starts and lubricating oil is insufficient. It could also prevent bolts and nuts from fusing together at high temperature.

Cadmium Plating: In a salty environment, cadmium plating will protect parts from corrosion. Since cadmium coating tends to make the coated material brittle when temperature is above 230°C , cadmium plated steel used for lower temperature is processed further by chromium compounds. The rotor in compressor is generally treated by cadmium plating.

Diffused aluminum, diffused chromium or diffused aluminum-chromium: Mainly used in turbine deflected and rotating blades. Diffused aluminum can withstand temperature up to 1200°C . To fulfill the requirement above 1200°C , study is underway to add small amount of rare earth and noble metal elements to the aluminum or chromium base.

non-metallic: There are paint coating, ceramic coating, etc.

Paint Coating: Mainly synthetic and silicon organic resins which are oil-resistant and heat-resistant. They could be applied to aluminum alloy, magnesium alloy and are widely used to coat the compressor blades.

Ceramic Coating: The burner and exhaust nozzle which are directly in contact with high temperature flame could be protected by ceramic coating. This is a form of porcelain which provides thermal insulation and prevent gas from coming into contact with the metallic surface. The coating requires 1025°C and 25 minutes to cure and has a thickness of 0.02 to 0.06 mm. The disadvantage of this kind of coating is that it tends to be brittle at room temperature and will deform at high temperature.

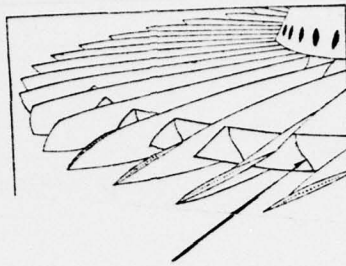
As the performance of the engine constantly advances, the operating temperature increases. Gradually corrosion resistant materials such as stainless steel, titanium alloy are used for parts in compressors. However some steel has high-temperature oxidation problem and require coating for protection. Presently, organic silicon aluminum powder is under study as high-temperature coating.

To improve high-temperature property for turbine blades, development of diffused aluminum alloy is underway. It would be used to improve the oxidation and deformation resistance of high temperature alloy. Diffused aluminum alloy is a double-layered coating. Compared to ordinary diffused aluminum coating, it could improve the structure and composition of the coating. When the outer layer aluminum compound decays, the inner oxidation-resistant layer continues to function. Even when aluminum compound cracks, the cohesion of the lower layer will prevent this from spreading.

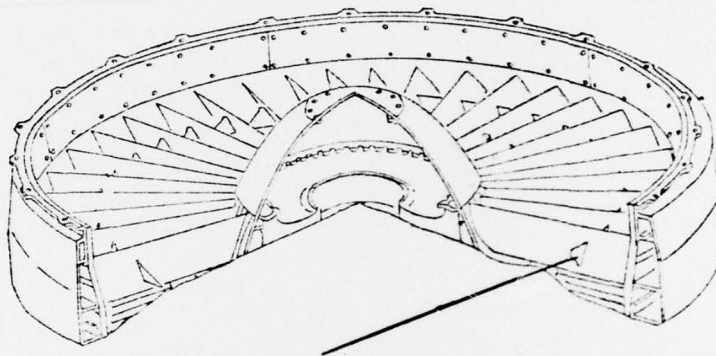
As to the ceramic coating applied to the burner in the combustion chamber and exhaust nozzle, further increase of the melting temperature would result in changing the basic properties of the material and cause deformation. Also ceramic is brittle at low temperature and mobile at high temperature thus could be blown away. Consequently it has limited usefulness. Nevertheless, within a certain limit, it could be used as coating to iron base alloy in place of high temperature alloys with high content of nickel, cobalt and chromium to conserve large amount of expensive metals. It has significant strategic as well as economic implications.

The quality and quantity of coating, to a large extent, depend on processing. To develop and formulate reasonable processing method is an important topic which is still in development. A problem which needs to be solved is how to develop excellent workmanship necessary for the coating to be thin and even.

During the last two decades, the life of an engine has been increased almost ten times. Aside from advance in design which utilize new materials and new technology, the progress in coating also contribute to this increase of life. Further advance in coating technology will go a long way toward improving the performance and life cycle of an engine.



Vibration-reducing mid-span shrouds.



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Figure 1. Vibration-reducing mid-span shrouds of an engine.

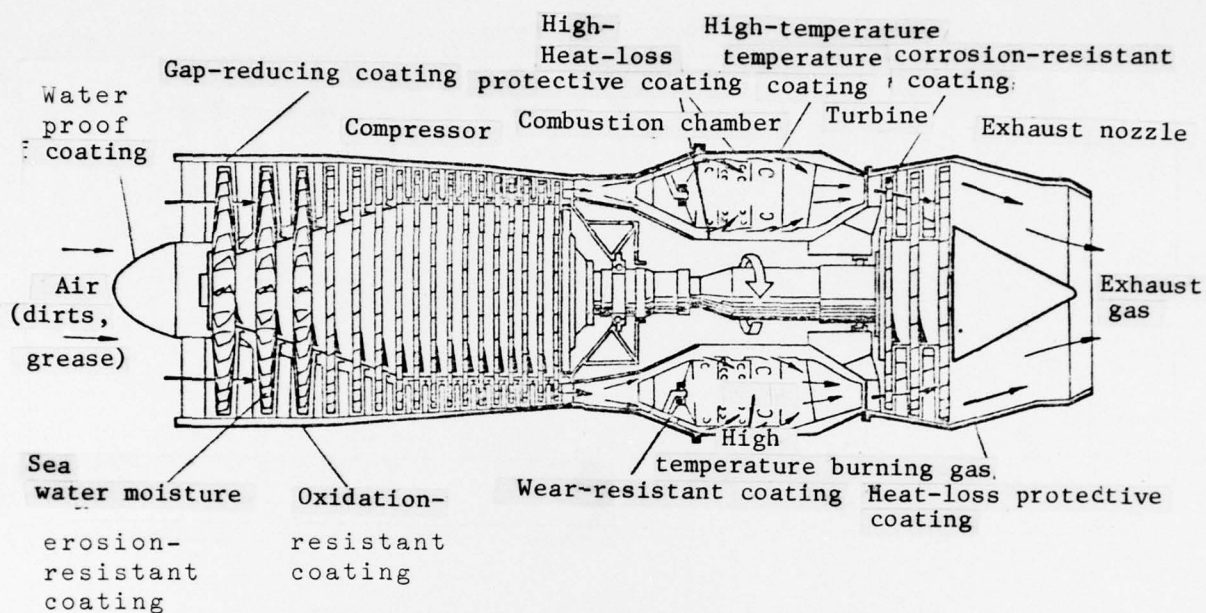


Figure 2. Types and positions of coating of a turbojet engine.