The current generation of aircraft coatings had its basis in the polymer technologies of the 1970s and the use of chromate-based metal pretreatments and primers. There have been some incremental improvements in the epoxy and polyamide oligomers used in the primers as well as the isocyanates and flexible polyols used in topcoats, plus increases in the volume solids of the coatings to continue minimally meeting environmental requirements, but no truly new technologies have been developed and applied to aircraft coatings since that time. However, because of increasing economic and environmental pressures, this situation will soon change. Also, the U.S. Air Force is seeking a coating system that will have an ultimate lifetime of 30 years for maintenance cost control and fleet sustainability. The first change in the present coatings system will be in the pretreatments plus primers that currently constitute the metal protection system for the high strength Al alloys used for aircraft. For military aircraft, these alloys will continue to be Al 2024 T-3 and Al 7075-T6, heat-treated metals that have phase-separated regions rich in reactive metals such as Cu, Mg, and Zn.

There are several new technologies now under consideration for such metal protection including conductive polymeric as primers without Cr-based metal pretreatments, sol-gel based pretreatments and primers, plasma polymer metal pretreatments, and organo-modified aluminum oxide particles. Each of these technologies has shown some promise for Cr replacement, but each presently has a weakness that needs to be corrected for immediate usage. For the topcoat system, fluorinated polyols and improved use of UV-absorbers and light stabilizers will probably be the first changes implemented, with ceramer and other new crosslinking systems the most likely next polymer matrix candidates. The target for the entire coatings system is to have drastically improved wet-adhesion due to a covalently bonded system that has a gradient in composition that goes continuously from metal to metal oxide to mixed metal oxide/organic polymer to high-performance UV-stable organic polymer. The materials cost for such a system may be quite high, but the maintenance cost savings will much more than offset these costs.

INTRODUCTION

The three primary reasons for painting military aircraft are survivability (visual appearance, infrared signature), corrosion protection, and appearance (including weatherability as well as abrasion and chemical resistance), while civilian and commercial aircraft use coatings for corrosion protection, airline identification, and appearance. The coating film on aircraft protects the metal and composite components of aircraft from their environment, since many components are designed and fabricated for structural reasons from materials that are not very resistant to atmospheric exposure. As aircraft coatings systems evolved, by the 1960s and 1970s, the predominant requirements were chemical and fluid resistance, corrosion resistance, exterior durability, and ambient cure. There are also coatings used over the plastics and metal substrates on the interior of aircraft, but this paper addresses only the high performance exterior coatings used on aircraft.

CURRENT COATINGS SYSTEMS

The current aircraft coatings systems are based mainly on a chromate pretreatment to an aerospace Al alloy surface, a chromated epoxy-polyamide primer, and a urethane topcoat based on a two-component isocyanate-flexible polyol system. A schematic of such a coating system, which is used by the military, is given in Figure 1. Sometimes a teat is used between the primer and the topcoat. The corrosion protection of this system depends on both the chromated pretreatment and the chromate pigment used in the primer. The relatively current specifications for common military and commercial aircraft coatings are discussed in several references. The Department of Defense (DoD) specification number for its common gray topcoat is MIL-C-85285; and the specification number for the solvent primer is MIL-P-23377. The coatings are usually applied by electrostatic assisted spray coating methods. The OEM business for commercial aircraft is dominated world-wide by Boeing and Airbus, and both seem to have fairly similar specifications for OEM usage. References in this paper will be predominantly from Boeing. Military usages and specifications are more diverse, and this paper will utilize U.S. DoD information pertaining to U.S. Air Force and Navy aircraft.
The specifications for the military and commercial coatings are quite similar, but the flight usage and refinish practices of commercial and military aircraft are very different. Military aircraft spend up to 95% of their time on the ground, where a primary threat to performance is corrosion, while commercial aircraft spend up to 30% of their time in flight; the primary threat to performance is probably structural fatigue. A discussion of corrosion threats in commercial aircraft was given in a recent article. The primary aircraft for which these needs in next generation military finishes are increased service life protection against corrosion and increased durability in the topcoat. For the next generation of USAF coatings, all materials must be environmentally benign (i.e., chromate-free pretreatment and primer), with a 40-year corrosion protective (pretreatment + primer) system, and a minimum of eight years of topcoat durability with mission strippability as needed. Maintenance costs for the USAF fleet in 1997 were $800 million. The annual cost of corrosion maintenance per aircraft is escalating at a rate of 36%. The primary aircraft for which these new coatings will be used are the aging KC-135, KC-141, and C-5 tanker and transport aircraft of the USAF fleet.

Enhanced Durability—Minimum Maintenance

These requirements given represent an extraordinary increase in performance requirements from those presently in use and are even more demanding in that there must be chromate-free corrosion protection.

There will be a need for the extraordinary lifetime of pretreatment + primer structure, and for the topcoat, a cleanable durable system is demanded. The goals of these requirements are increased fleet readiness, risk reduction, and drastically reduced maintenance costs. This will mean that the coating must have drastically improved exterior durability, as well as cleanability in field use. It should not be soiled easily by lubrication fluids or other hazards of normal use. The optical properties should be tailorable to mission requirements—this most often will require a matte, camouflage appearance. This last requirement has been difficult to achieve simultaneously with true cleanability.

Strippability

The topcoat system should be strippable in existing Air Logistic Centers (ALCs) using environmentally acceptable materials and methods. The primer-pretreatment system should not be affected by topcoat removal and should be recoatable in the field or at ALCs as needed.

Compliance with Volatile Organic Compound Emission Regulations

In new military and commercial coatings, VOC compliance will be an important issue, but definitely not a new issue. There has been ongoing work to reduce VOC emissions in all classes of coatings, including those for aircraft, since the 1960s, and a drastic improvement in VOC reductions has occurred in this period. In aircraft coatings, most of the VOC reduction has occurred through the use of high-solids, two-component systems for primers and topcoats as well as some use of waterborne (W/B) systems for primers. These developments will continue. The most difficult improvements to achieve will be in obtaining the proper rheological properties of new topcoats that provide enhanced exterior durability and fluid resistance. The very systems that can provide these properties, such as fluorocarbon containing oligomers/polymers, require very strong solvents and have not been amenable for use in W/B systems. The restrictions of ambient cure at high crosslinking levels for fluid resistance also provide a considerable challenge for VOC reduction.