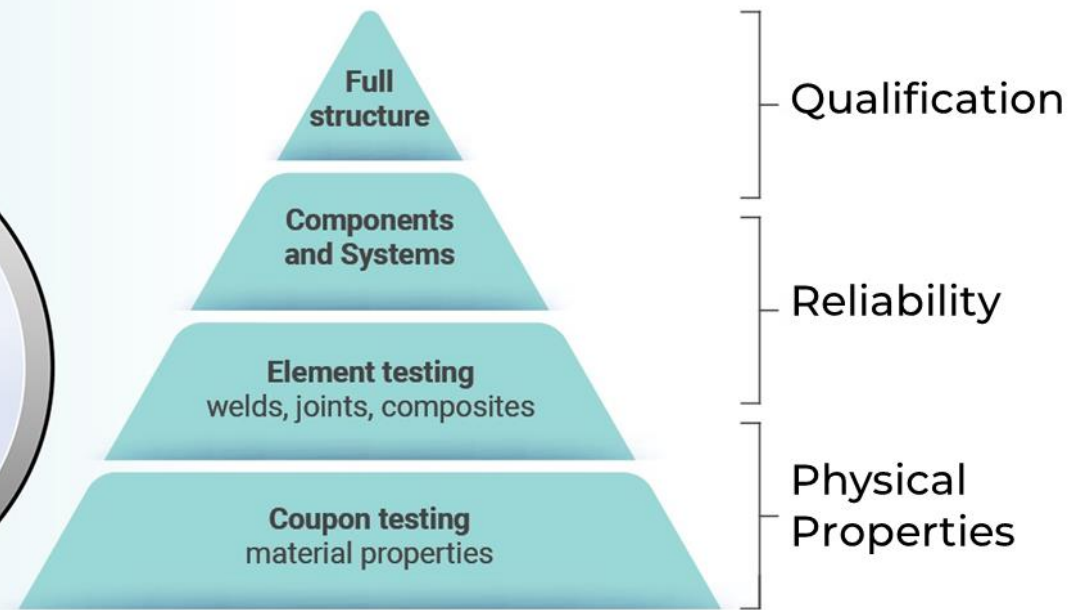
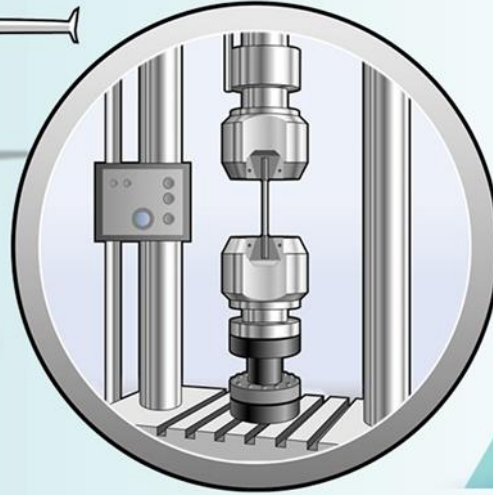
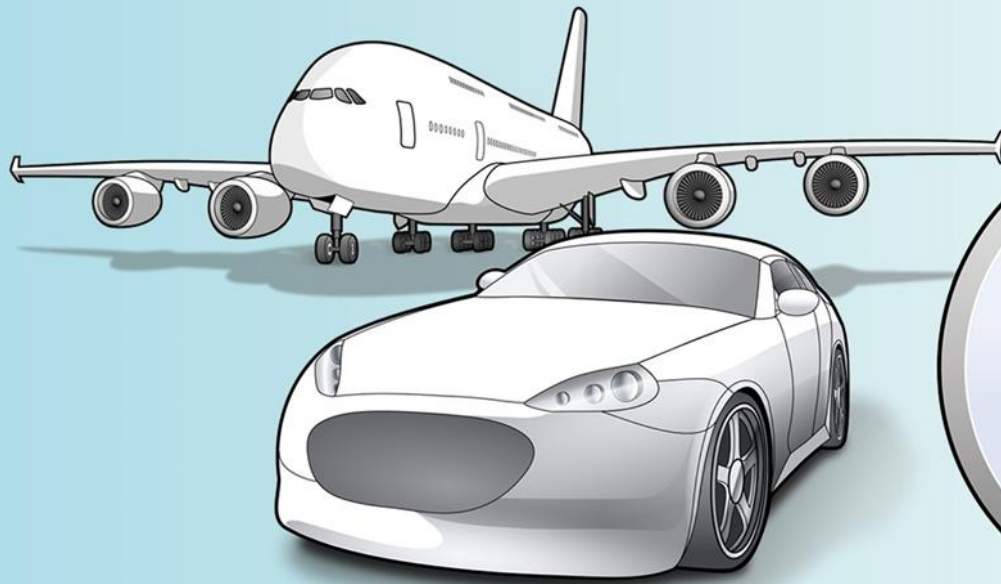




2023 HBK Technology Days

14 November 2023



- Materials and surface coatings and processes

Dr. Michelle Hill,
Head of Materials Testing, HBK

Mr. Ben Griffiths,
Chief Engineer, Select Engineering Services

Materials and surface coatings and processes

Abstract

- Many structural components have surface treatments or coatings applied to the surface of the material to help protect against environmental or in service damage. Although these coatings are themselves not structural, it is important to understand the effect of these surface treatments on the fatigue life of a material, as significant knockdowns can be observed. The effects of historical surface treatments such as cadmium plating and chromic acid anodising have been well characterised. The introduction of REACH regulations in Europe for protection of human health and the environment from the use of chemicals has led to the development of new surface treatment systems, many of which are not well understood.
- In addition to development of new treatments and coatings, there is also an ongoing requirement to extend the life of legacy components in service, where parts may have been overhauled many times. An example of such an application is the landing gears on many legacy United States Air Force aircraft. This presentation will provide an overview of material and surface treatment fatigue test and characterization approach and discuss key considerations when planning a fatigue test program.

Materials and surface coatings and processes

▲ About the presenter, Dr. Michelle Hill, Head of Materials Testing, HBK

- Michelle holds a Master's degree in Aeronautical Engineering and a PhD studying the damage resistance and tolerance of composite sandwich structures, obtained from Loughborough University. She joined HBK in May 2017, having previously held the position of Chief of Materials at the Rolls-Royce CTAL facility on the Isle of Wight. Her speciality is in composite materials characterisation and testing, with hands-on experience in defining and executing large material qualification programmes.
- Having spent 10 years on the Rolls-Royce composite fan system programme, leading the Materials team, Michelle has experience of how to relate materials testing to real applications and how to characterize difficult structures such as hybrid joints. At HBK she is responsible for the AMCT facility and the management of the commercial testing activities along with research into the fatigue behaviour of additively manufactured materials and composites.

▲ About the presenter, Mr. Ben Griffiths, Chief Engineer, Select Engineering Services

- Ben Griffiths has a Master's degree in Mechanical Engineering from Utah State University and is a licensed Professional Engineer in the state of Utah. He has 10 years of experience conducting research and development with an emphasis on materials testing and analysis. Some of the research projects he has worked on include:
 - Fatigue testing/analysis of landing gear materials with various surface treatments
 - Full-scale crash testing of composite towers using surrogate aircraft wing sections
 - Electrically conductive coating qualification testing
 - Welding of thick section Grade 91 steel to study Type IV creep rupture
- Mr. Griffiths is representing Select Engineering Services (SES) which is an employee-owned small business operating out of the state of Utah. SES primarily focuses on engineering and analytical services for the United States Air Force (USAF) and other DoD agencies.

Materials and Surface Coatings and Processes

2023 HBK TECHNOLOGY DAYS



Presenters:

Dr Michelle Hill, Head of Materials testing, HBK

Mr Ben Griffiths, Chief Engineer, Select Engineering Services

Dr Andrew Halfpenny, Director of Technology – nCode products, HBK



Agenda

1. Materials and surface coatings and processes

- Introduction
- USAF Project Background and Significance

2. Fatigue methodology for combining surface treatment factors in strain-life fatigue

- Strain-Life Testing
- Theory and Calculations

3. Application of the Material Assessment and Predictive Analysis (MAPA) Tool for Fatigue Data Management

- Tested Results
- MAPA Data Manager
- Ongoing Efforts

Introduction

What do we mean by surface treatments and processes?



Something added to the surface – e.g. plating

Something done to the surface – e.g. shot peening

Can be a combination – e.g. shot peening and chrome plating

Must account for all processes conducted – e.g. pre-treatments, primers

Hasn't this already been studied?

REACH regulations have forced the development of new coatings

Historical designs may not have had detailed fatigue data

To extend useable lives components may be repaired or stripped and recoated many times

Surface treatments may be applied to new materials with different surface textures



Why are surface coatings important for fatigue?



Surface treatments can introduce material changes and cause local surface stress concentrations, which in many cases can have a negative effect on component fatigue life.



The extent of these effects depends on the type of treatment applied, as each can cause a difference in the nature and depth of material changes introduced during the treatment process.



Surface treatments often have no discernable effect on the tensile properties of the material, however, there can be a significant degradation in fatigue life.



Strain-life (EN) and Stress-life (SN) fatigue tests on axially loaded specimens will detect any change in performance due to the surface coating as fatigue cracks should initiate from the surface.



Alternative tests such as 4-point bending fatigue can also be used, however, these tests are only useful for determining any knockdown compared to a baseline curve and the SN curve cannot be used directly in a CAE fatigue analysis unless the component is only loaded in pure bending.

CONTRIBUTING ORGANIZATIONS



- **United States Air Force**

- *Supply Chain Management*
- *Landing Gear Systems*
- *Requirements / End Customer / End User*



- **HOTTINGER BRÜEL & KJÆR**

- *Sensors and measurement systems*
- *Software for durability and reliability*
- *Methods development and mechanical testing for fatigue performance characterization*



- **Select Engineering Services**

- *US DoD contractor providing engineering, technical services, and products*
- *Test program management and fatigue analysis integration tools development*



- **General Atomics - Systems Integration**

- *Landing gear fatigue analysis*





PROJECT BACKGROUND AND SIGNIFICANCE



■ ***Aging USAF Aircraft Fleet***

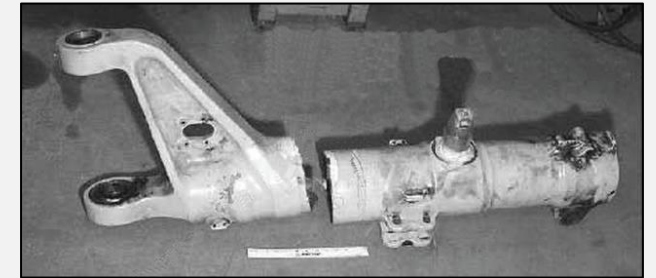
- Average aircraft age is ≈ 29 years (over 60 years for B-52)¹
- Continue to extend beyond original design life
- Thousands of landings during aircraft lifetime
- Significant ground handling loads on landing gears
- Critical decisions for timely removal of components from service

■ ***Safe-Life Design for Landing Gear (high strength materials)***

- Finite operational life
- Crack initiation undetectable (*micro-scale*)
- Rapid progression from crack initiation to catastrophic failure



USAF B-52 Average Age is over 60 Years^{1,3}



Commercial Aircraft Landing Gear Fatigue Failure²



C-5 Main Landing Gear⁴

¹<https://www.heritage.org/military-strength/assessment-us-military-power/us-air-force>

²<https://www.lamdatechs.com/wp-content/uploads/LandingGear-v2.pdf>

³<https://www.military.com/daily-news/2019/05/07/us-sends-b-52-bombers-mideast-after-reported-threats-iran.html>

⁴<http://www.fortogden.com/hill-261.html>



PROJECT BACKGROUND AND SIGNIFICANCE



■ *Landing Gear Surface Treatments*

■ *Affected Surface Material Properties*

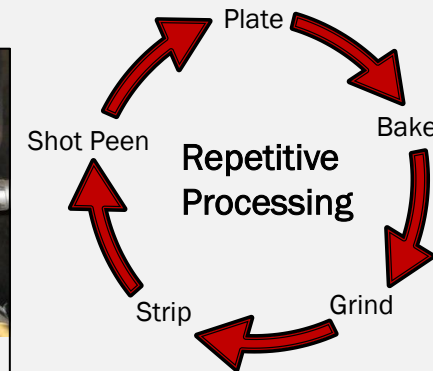
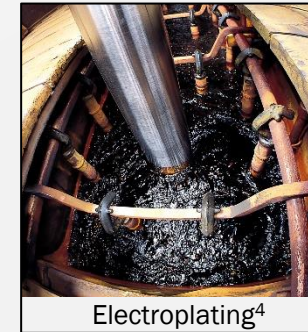
- Microstructure
- Roughness
- Residual Stresses

■ *Coatings Stripped/Re-Applied*

- May be repeated several times
- Indeterminate number of overhauls
- Multiple coating options and specs

■ *Known Detrimental Effects*

- Not considered in legacy USAF design



¹<http://www.nationalbronze.com/News/nickel-aluminum-bronze-for-landing-gear-bushings/>

²<https://www.danobatgrinding.com/en/aerospace-landing-gear-struts-machining>

³<https://www.wheelabratorgroup.com/aerospace>

⁴<https://www.hydro-platers.com/>

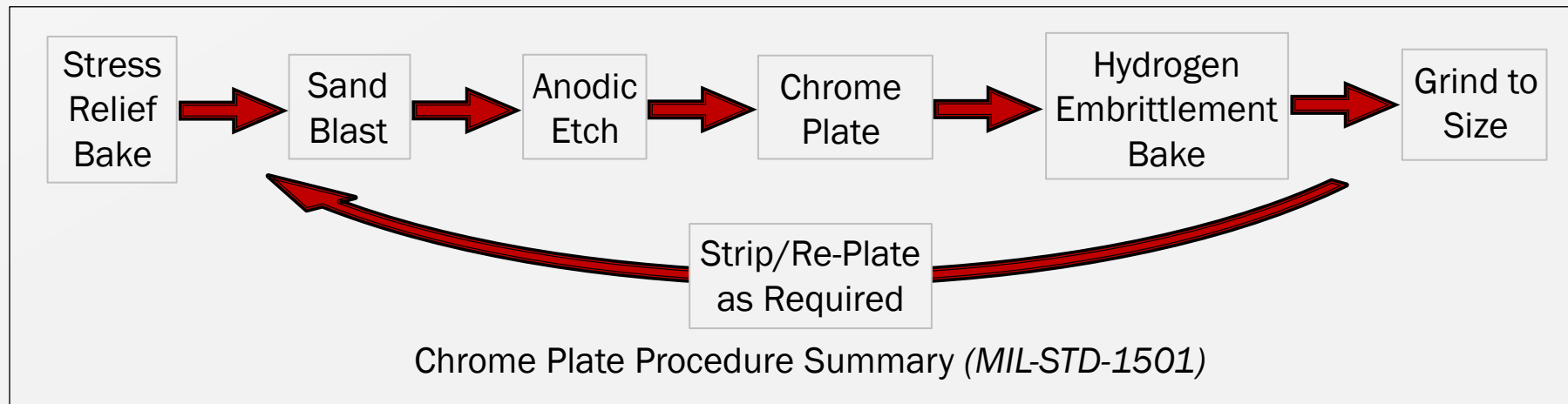


PROJECT BACKGROUND AND SIGNIFICANCE



■ *Surface Treatment Procedures*

- *Based on Military Standards*
- *USAF dictates specific landing gear overhaul parameters*
- *Substantial number of variables to control/consider*





PROJECT BACKGROUND AND SIGNIFICANCE



■ *Completed Work*

■ *Testing*

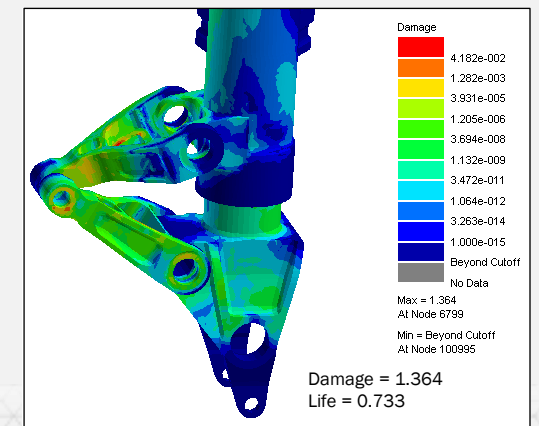
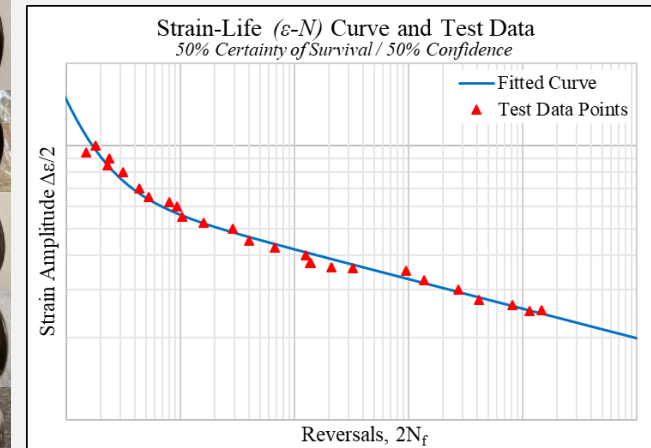
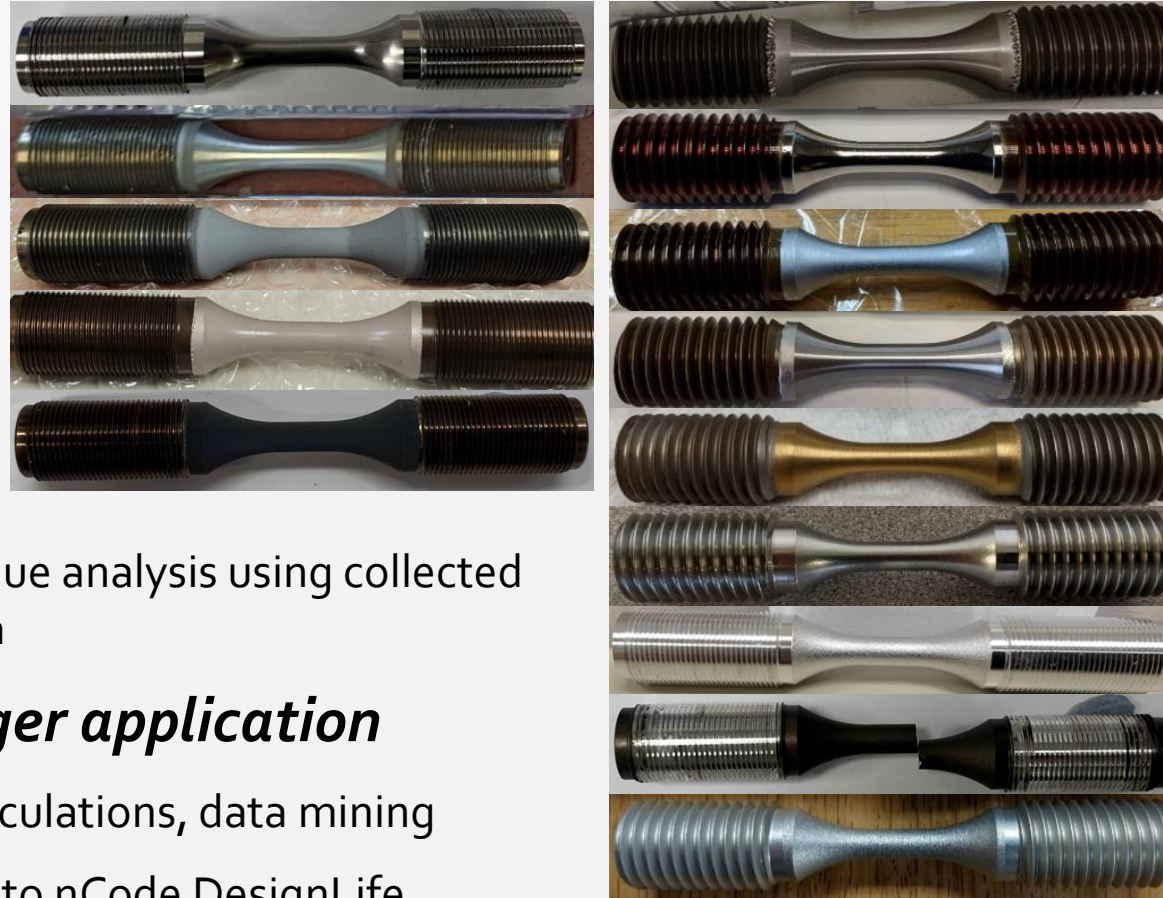
- ≈500 fatigue tests
- 26 surface treatments
- 3 different materials

■ *Fatigue Analysis*

- nCode DesignLife fatigue analysis using collected surface treatment data

■ *MAPA Data Manager application*

- Strain-life test data calculations, data mining
- Export data for import to nCode DesignLife

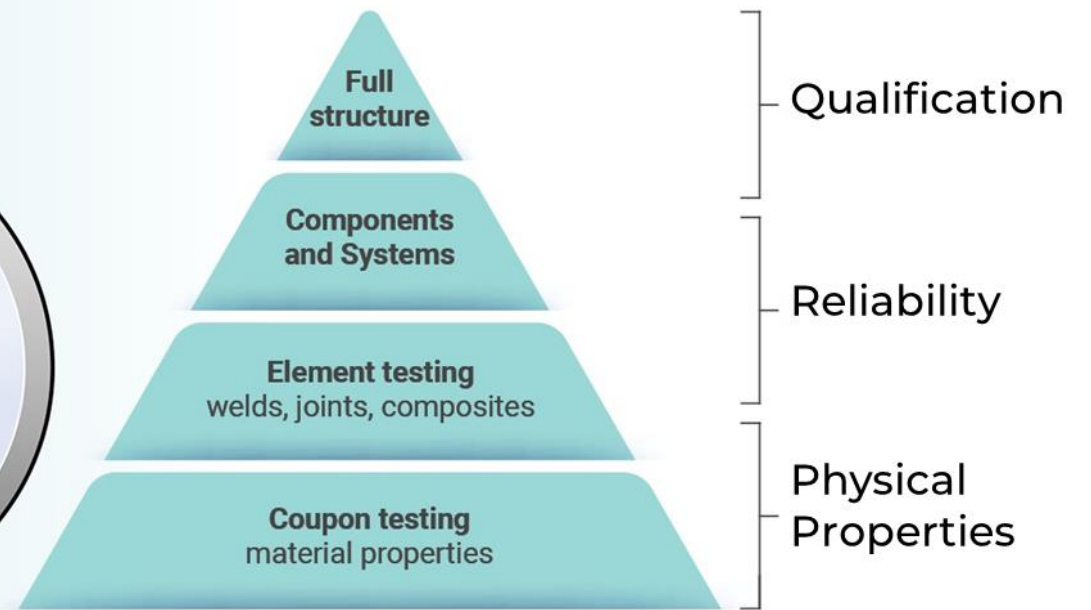
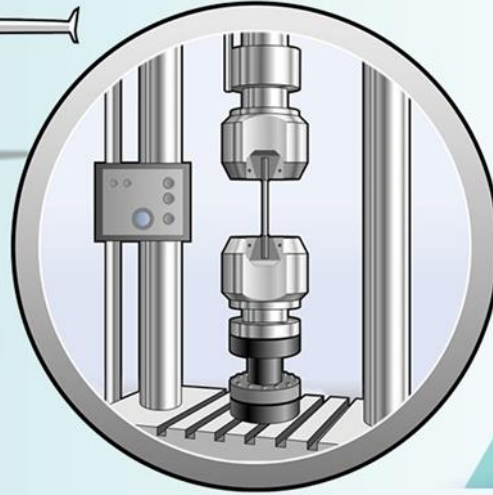
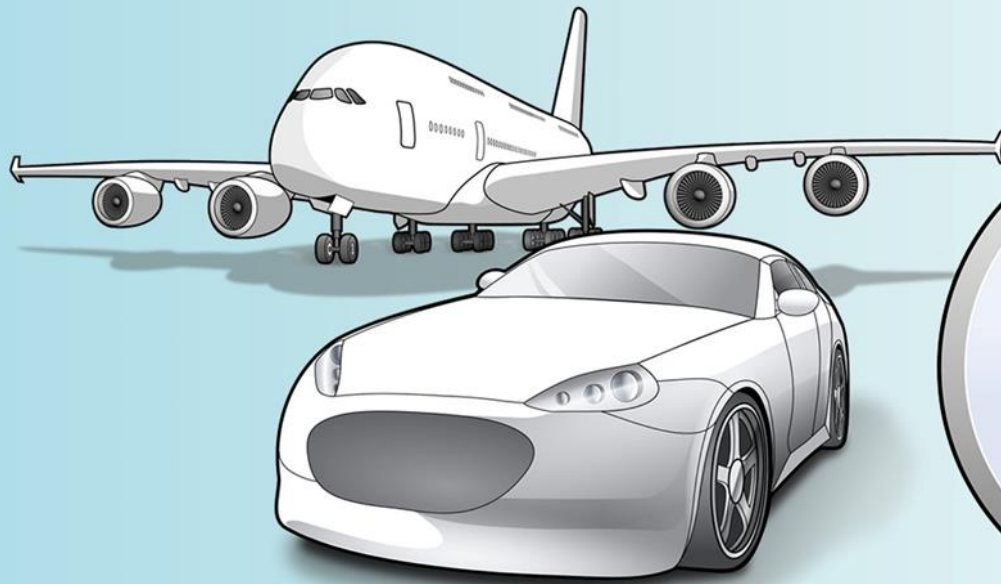


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