

A SPACE TRIBOLOGY HANDBOOK

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ABSTRACT

The need for a reference handbook on space tribology has been recognised for some time. ESTL has now produced such a handbook which is based principally (though not exclusively) on ESTL's experience in this field over the last 25 years. The Handbook has been written with the aims of assisting designers and engineers in the implementation of sound tribological practices and to help them determine how best to treat and lubricate components for their given application. Additionally, the Handbook offer guidance on the ground testing of tribo-components either in isolation or as part of their parent mechanisms. This paper outlines the structure and contents of the Handbook, and in so doing provides an introduction to the Handbook to its potential users.

1. INTRODUCTION

The specific aims of the Handbook are:

- to provide a definitive reference manual on space tribology.
- to provide useful data on typical systems where tribology is important either to performance or reliability.
- to specify guidelines for the selection, use and limitations of tribo-materials (encompassing lubricants, surface treatments and substrate materials)
- to aid the designer in the selection of tribo-components.
- to provide guidance on the ground testing of tribo-components and mechanisms

2. STRUCTURE OF HANDBOOK

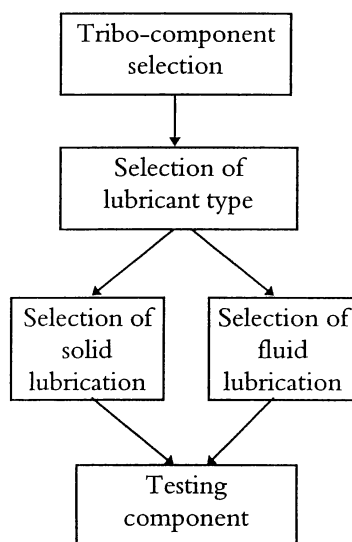
The Handbook comprises seven chapters, the titles of which are listed in Table 1 below.

The purpose of Chapter 1 is to familiarise the reader with relevant fundamental concepts. The remaining six

Table 1 Chapter Headings

1. Basic Tribology
2. Tribo-component Selection, Design and Performance
3. Selection of Lubricant Type
4. Solid Lubricants
5. Fluid Lubricants
6. Materials for Tribological Components and Surfaces
7. Component and Mechanism Testing

chapters form the Handbook's guidelines which span the progression from initial selection of tribo-component, its lubrication, to finally its testing at component and mechanism level. The logistics of using the Handbook are as shown in the flow chart below.



Chapter 6, which details the properties of tribo-materials, is to be consulted when making selections on substrate materials or surface coatings and treatments (other than lubricants) which may enhance performance.

3. CONTENTS OF HANDBOOK

Below we outline the contents of each chapter.

Contents of Chapter 1. Basic tribology

- 1.1 Surfaces and interfaces
- 1.2 Surfaces in contact
- 1.3 Friction
- 1.4 Adhesion and fretting
- 1.5 Wear
- 1.6 Measurement of friction and wear
- 1.7 Lubrication
- 1.8 Space and spacecraft environment
- 1.9 Further reading

This first chapter (Basic Tribology) provides an introduction to tribology and is concerned with the nature of surfaces, contacts and lubrication. Topics covered include:

- the roughness of engineering surfaces and its measurement.
- the behaviour of surfaces in contact viz., Hertzian contacts; calculation of contact area and pressure; yield criteria; stress distributions; how surface roughness affects Hertzian analysis.
- friction and wear: sources of friction; wear mechanisms; wear theory; use of tribometry for the measurement of friction and wear.
- principles underlying fluid and dry (solid) lubrication.
- space and spacecraft environments: launch environment; spacecraft environment in terms of vacuum pressure, radiation and temperature; guide to environmental sources of mechanism degradation.

Contents of Chapter 2. Tribo-component selection, design and performance

- 2.1 Rotary, rolling-element bearings
- 2.2 Plain, spherical and rod-end bearings
- 2.3 Ball, roller and plain screws
- 2.4 Slide, ball and roller linear bearings
- 2.5 Gears
- 2.6 Sliding electrical contacts
- 2.7 Other tribo-components

Chapter 2 is intended to assist the designer in the selection of tribological components - that is, on how to choose the most suitable component for a given application. All standard components are covered as listed above. The section on 'Other tribo-components' covers items such as brakes, cams, levers and fasteners. For each generic component (e.g. rotary rolling-element bearing) the following topics are featured:

- selection of component type (e.g. for rotary rolling element bearings the choice is between: single row,

deep groove; angular contact; four point contact; wire race; thrust; roller or needle).

- description of each component type, with guidelines regarding the applications to which they are best suited.
- listings of materials from which the component is manufactured and their physical properties.
- precision data.
- preload and load capacity.
- application notes.
- how components misbehave.
- descriptions of available software for predicting component behaviour.
- examples of spacecraft applications where different component types have been used.

Contents of Chapter 3. Selection of lubricant type

- 3.1 Guide to selection: dry versus fluid lubrication
- 3.2 Enhancing lubricant performance

Having identified the component type to be employed, the next question to address is whether to use fluid or dry lubrication. This chapter defines the criteria by which this decision can be made and also offers guidelines on selection for those applications where, in principle, both fluid and dry lubricants are applicable. Check lists are provided to help select a specific lubricant once the choice has been made between dry and fluid lubricant. Thereafter, guidelines on the selection of specific dry and fluid lubricants are given in Chapters 4 and 5 respectively.

Contents of Chapter 4. Solid lubricants

- 4.1 Selection of solid lubricant
- 4.2 Solid lubricant coatings
- 4.3 Bulk solid lubricants

Solid lubrication may be brought about in one of two ways. It can be transferred by rubbing from a solid made from, or containing, the dry lubricant - as for example with self-lubricating cages in ball bearings. Alternatively it can be applied to one counterface in the form of a film - as with techniques such as sputter deposition. Both the above forms of solid lubricant are discussed in Chapter 4.

The areas covered are:

Selection of solid lubricants:

- when to use solid lubricants.
- advantages and disadvantages of solid lubrication.
- types of solid lubricant.

Coatings:

- coating types and methods of application.
- guide to selection of solid lubricant coatings.
- tribological properties of thin vacuum-deposited films.

- performance of tribo-components lubricated with vacuum-deposited coatings.
- tribological properties of burnished films.
- tribological properties of bonded coatings.
- lubricant coatings for high temperature and cryogenic temperature.
- effect of environment on solid lubricant coatings.
- coatings to prevent static adhesion and fretting damage.
- stages and handling of coatings.

Bulk solid lubricants:

- polymers and polymer composites.
- non-polymeric composites.

Contents of Chapter 5. Fluid lubricants

- 5.1 Selection of fluid lubricant
- 5.2 Fluid lubricant database
- 5.3 Tribological properties of fluid lubricants
- 5.4 Fluid loss, retention and replenishment
- 5.5 Handling, cleaning and lubrication procedures

Chapter 5 deals with the selection of fluid lubricants, the areas covered being:

- when to use fluid lubricants.
- advantages and disadvantages of fluid lubrication.
- types of fluid lubricant.
- properties of selected fluid lubricants.
- degradation of PFPEs: delaying onset
- additives.
- fluid lubricant database (based on ESTL's DOLLS software and covering viscosity, temperature, molecular weight, surface tension, density, vapour pressure, VCM data, specific heat, thermal conductivity and alpha values).
- lubrication regimes.
- performance of fluid lubricated components.
- effect of environment.
- creep and migration.
- reservoirs.
- handling, storage and cleaning.
- lubrication procedure.

Contents of Chapter 6. Materials for tribological components and surfaces

- 6.1 Properties of materials
- 6.2 Engineering the surface
- 6.3 Materials selection for tribo-components

Chapter 6 surveys the properties of materials that have been used, or may be suitable for use, in tribological components in space satellites. As such it does not cover, and is not intended to cover, every available engineering material. The chapter should be used primarily as a source of basic material properties and as

a supplementary source of information to that provided in other chapters. Data are presented, principally in table form, on materials which have been used on spacecraft or on candidates for such usage. These data cover the properties of both bulk materials and surface treatments.

Specific topics covered include:

- material compatibility with vacuum environments.
- physical and mechanical properties of bulk tribo-component materials.
- comparative values of key properties.
- listings and descriptions of surface treatments; - suitability of surface treatments for use in tribo-components.
- a materials selection guide for bearings, gears, screws, fasteners and separating surfaces.

Contents of Chapter 7. Component and mechanism testing

- 7.1 Introduction
- 7.2 Test level hierarchy
- 7.3 Test environments
- 7.4 Test facilities
- 7.5 Guidance on component testing
- 7.6 Guidance on mechanism testing
- 7.7 Verification requirements

This chapter provides guidance on the testing of tribo-components and mechanisms for space satellite applications. It identifies and defines the various test environments and provides guidelines on how to achieve them. Examples are given of thermal-vacuum test set-ups for component and mechanism testing together with notes on the testing of specific tribo-components. The rationale for mechanism testing is explained and verification requirements, based on current ESA guidelines, are presented.

4. CONCLUDING REMARKS

It is the intention to update the Handbook on a periodic basis (every 2 years initially). These updates will involve inputting newly generated data and responding to any suggestions/feedback received from Handbook users.

5. ACKNOWLEDGEMENTS

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