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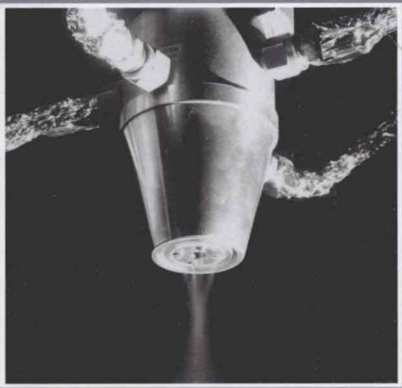

Surface engineering of light alloys

Aluminium, magnesium and titanium alloys

Edited by Hanshan Dong

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Preface

Light alloys, which encompass magnesium-, aluminium- and titanium-based materials, are the materials of choice for transport applications (such as aerospace, automotive and light rail) because of their low-density and high strength-to-weight ratio. Weight reduction in transport translates directly to fuel saving and emissions deduction, thus greatly contributing to ecologically and economically sustainable development. In addition, light alloys are attractive for some specific applications due to their unique properties. For example, outstanding biocompatibility makes titanium alloys the material of choice for body implants.

On the other hand, the relatively poor surface properties of light alloys represent a serious barrier to their wider application. For example, magnesium alloys have a reputation for extremely poor corrosion resistance in most environments; therefore, corrosion protection is essential for magnesium alloys in many applications (see Chapter 1). Further, light alloys are characterised, especially in sliding situations, by poor tribological properties manifested as: low load-bearing capacity and low resistance to abrasion mainly due to low hardness; and high adhesion tendency due to relatively high ductility and reactivity (Chapters 2 and 3). Therefore, light alloys are normally restricted to applications in which tribological performance is not critical.

Currently, however, there is a growing requirement to expand the use of titanium alloys to non-aerospace tribological applications. For example, it has long been the dream of designers to substitute titanium for steel components in racing-car engines to reduce the mass of valve trains, increase top speed and increase fuel efficiency. However, titanium alloys are characterised by poor wear behaviour (Chapter 3) and therefore it is impossible to use titanium components in valve train systems without proper surface engineering. More challenging examples include: water droplet erosion in longer titanium blades for high-efficiency low-pressure turbines, and adhesive wear of telescopic-action titanium tubes for aerial refuelling systems.

Equally, while aluminium alloys and magnesium alloys have found increasing application, particularly in aerospace and automotive industries, these alloys are susceptible to surface degradation. For instance, aluminium alloys are used in the space industry in launchers, space stations and satellites because of their lightness, adequate corrosion resistance and good cryogenic properties. However, UV degradation and cold welding (or adhesion) in vacuum are concerns for successful long-term application of aluminium alloys and their finishes in space (Chapter 18). Similarly, the poor corrosion resistance of magnesium alloys in some service environments has limited further expansion of applications (Chapter 6).

Therefore, the clear and major challenge to surface engineering researchers and engineers, from both the scientific and technological viewpoints, is how to improve the surface properties of light alloys. During the past two decades, many surface engineering technologies have been developed to combat surface related failures such as corrosion, wear and fatigue of steels. The central problem is that surface engineering of light alloys is more difficult than it is for steels.

Firstly, there is no martensitic transformation hardening in light alloys: either there is no martensitic transformation – in magnesium alloys and aluminium alloys – or martensite in titanium alloys is not hard. Consequently, light alloys cannot be effectively hardened by induction hardening and, in most cases, it is difficult to provide a hardened subsurface for thin hard coatings. For this reason, although thin hard coatings *could* provide light alloys with improved tribological properties in terms of low-friction and wear, provided the applied load is low, the plastic deformation of the substrate, resulting from high contact stresses, gives rise to collapse of the coatings – the so-called 'thin ice effect'.

Secondly, there is always an oxide film, thin or thick, on the surface of light alloys. These oxide films confer good corrosion resistance to aluminium alloys (Al_2O_3 film) and titanium alloys (TiO_2 film). However, such oxide films may cause difficult problems for surface engineering. They can reduce the bonding strength of surface coatings (for example, varying success of Ni plating) or retard diffusion of interstitial alloying elements during thermochemical treatment.

Thirdly, light alloys are very active and have strong affinity with oxygen, and therefore high purity gases must be used to prevent surface oxidation during thermochemical treatment (e.g. plasma nitriding of aluminium alloys).

Extensive research has been conducted to develop advanced surface engineering technologies for light alloys. However, surface engineering of light alloys has not yet been covered in a single book. Therefore, the objective of this book is to present a comprehensive review of the current status of surface engineering of light alloys. It can be divided into three sections, starting with a discussion on the surface degradation of light alloys (Chapters 1 to 3), followed by a portfolio of advanced surface engineering technologies applicable to light alloys (Chapters 4 to 15) and finishing with some application case studies (Chapters 16 to 18). Among these advanced surface engineering technologies, plasma electrolytic oxidation treatment (Chapters 5 and 6) and ceramic conversion treatment (Chapter 14) are designed for light alloys.

The editor would like to take this opportunity to thank all the contributors, who are world-leading experts in their own research areas, for their willingness to share their time and knowledge. The contributions of Woodhead Publishing Limited, Rob Sitton, Lucy Cornwell and Francis Dodds are gratefully acknowledged. Finally, I must express my special gratitude to my family for their love, encouragement and support.

H. Dong

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