HIGHER TECHNICAL INSTITUTE

MECHANICAL ENGINEERING DEPARTMENT

DIPLOMA PROJECT

DESIGN AND CONSTRUCTION OF LARGE AREA DEPOSITION OF COATINGS BY THERMAL SPRAY TECHNIQUES

M/913

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JUNE 2001

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Project Report
Submitted to

the Department of Mechanical Engineering

of the Higher Technical Institute

Nicosia Cyprus

in partial fulfillment of the requirements
for the diploma of

TECHNICIAN ENGINEER

in

MECHANICAL ENGINEERING

June 2001

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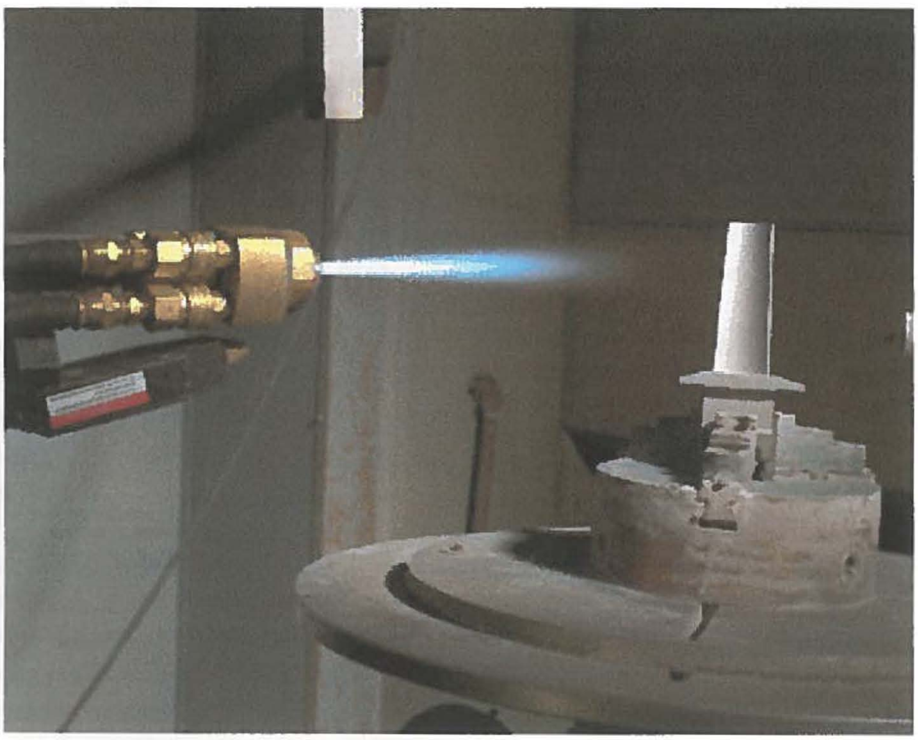

ABSTRACT

The primary objective of this project is to fabricate nanostructured coatings from amorphous powders by a thermal spray process, to prolong tool life and to explore other potential applications of such coatings in solar thermal and photovoltaic collectors and fuel cells.

Nanocoatings will enable increased thermal absorption, wear, heat transfer and corrosion resistance, fatigue strength and fracture toughness compared with conventionally manufactured coatings. High performance nanostructured coatings are projected to have a large economic impact in the energy, transportation and aerospace industries in the 21st century.

Advances in high performance materials for structural and thermal applications and the associated deposition methodologies will increasingly depend on our ability to control the size, distribution and morphology of their constituent phases at the sub-micrometer or nanometer level. Since capabilities for synthesising such nanostructured materials in bulk are becoming available, it is now possible to produce quantities of materials needed for prototype development and testing.

Nanostructured materials are a new class of synthetic materials with ultrafine microstructures, somewhat arbitrarily defined as structures smaller than 100 nm. These materials may be composed of metals, ceramics, polymers, and their composites. The materials can be in the form of powders, thin films, porous media, or dense structures.

The initiation of this project falls within the activities of the Nanomaterials Research Center (NRC), a newly established center at HTI, which serves as a bridge for technology transfer between HTI and the technology users (industry at large). The primary mission of NRC is to develop new methods for the economical production of nanostructured metals, ceramics, and their composites.

Current research is focused on methods for the production of nanostructured powders, nanophase coatings (wear resistant surfaces, thermal barriers, solar cell fabrications, selective surfaces) and nanophase composites (gas turbine engines, bulletproof vests).

Under this center, two operating divisions have been established, each with its own application goal(s) and commercialisation strategy: (1) nanopowder synthesis, which is commercialising high rate production of non-agglomerated nanoparticles and (2) large area deposition of coatings. Both of the divisions focus on the commercialisation of advanced materials processes for enhanced mechanical and thermal properties.

ACKNOWLEDGMENTS

I am grateful to my supervisor Dr. Nicos Angastiniotis for his guidance throughout the write-up of the project and for sharing his knowledge and ideas without which the project would have been incomplete. I would also like to thank my fellow Classmates, who have also been working under the guidance of Dr. Nicos Angastiniotis, for the useful information they have provided.

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1 INTRODUCTION

The primary objective of the proposed program is to fabricate nanocoatings from amorphous powders by a thermal spray process to prolong tool life. Nanocoatings will enable increased thermal absorption, wear, heat transfer and corrosion resistance, fatigue strength and fracture toughness compared with conventionally manufactured coatings.

In this respect, a novel thermochemical processing method for preparing amorphous powders, starting from homogeneous precursor compounds, has been developed by Nicos Angastiniotis et al. (European Patent # EPO 0800883). The invention relates to the formation of amorphous metal powders from amorphous metal oxide powders and, in addition, relates to a method of producing amorphous tungsten, molybdenum and molybdenum alloys and their alloys with chromium, iron, cobalt and nickel and, further, to the use of these powders to form refractory metal compounds of amorphous/nanocrystalline grain size. In addition to being useful for formation of silicides, carbides and nitrides and other refractory composition, the present invention is also useful in the elemental form to provide amorphous/nanostructured powder coatings and the like. They can also be blended with compositions for alloying and used in any application in which elemental metal is employed. The amorphous metal oxide can also be used in any reaction calling for such an oxide. The decreased particle size should facilitate mixing and improve reactivity. The particle size of the oxides makes these oxides useful as pigments and coatings and in ceramics.

The coatings fabricated out of these amorphous elements/alloys, if pore free, are anticipated to exhibit extraordinary thermal stability, hardness, toughness, ductility, wear resistance and adherence. We envision a wide use of these coatings on cutting tools, vehicles, and various naval, aerospace and industrial components to reduce the need for expensive maintenance.

Items fabricated from nanophase materials have superior characteristics. For example, nanophase copper has hardness and yield strength 500% greater than conventionally produced metal, and a nanophase ceramic material can be manufactured with much greater ductility than the conventionally manufactured counterpart. These same bulk-nanophase characteristics result in similar improvements in the characteristics of nanophase coatings, particularly in applications requiring enhanced wear resistant surfaces and increased thermal protection.

The foreseen partners in this initiative are companies which face problems during fabrication of components due to high wear rate or thermal instability. The intent is to resolve the aforementioned problems by developing the most suitable amorphous or nanophase powders of predetermined composition and subsequently apply them by a thermal spray technique or otherwise. Improving the wear and/or temperature resistance will be of utmost importance in increasing the life of the component. At the Higher Technical Institute we are willing to develop the most suitable powders and also participate in the resolution of the pertinent experimental parameters as they relate to the fabrication of wear resistant or thermal barrier nanocoatings.

The interest in nanocoatings for wear and abrasion resistance is justified due to the enhancement of both hardness and ductility found within materials with reduced grain size. Even though it has not been decided as of yet which will be the specific composition of the powder to be used, it is safe to say that the as deposited properties will be characterized by higher hardness and wear resistance than the conventional counterpart of the same composition. The possibility exists that the nano coatings will be characterized by a trade off between hardness and toughness at higher levels with a remarkable enhancement of both hardness and ductility. The potential benefits will be realized due to the reduced defect size and enhanced grain boundary relaxation. Diffusivity will be greatly enhanced due to the larger volume of grain boundaries. The critical control parameters during deposition will focus on the optimization of hardness and good adhesion.

Thermal barrier coatings are critical in engine technology, allowing operation at higher temperatures. They are fabricated by thermal spray techniques to combustion chambers, turbine airfoils and afterburners and play a critical role in increasing gas turbine engine efficiency and performance. The development of superior thermal barrier coatings is required to enhance thermal impedance, thermal shock resistance and cyclic fatigue properties by hindering the spalling in the ceramic splat boundaries near the ceramic to metal interface. It should be possible not only to strengthen the boundaries by refining the structure to the nanoscale but also to maintain the nanocrystallinity at elevated temperatures.