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Overview of recent dissertations in the field in Finland

Steel research for improved wear resistance in demanding applications

The primary aim of the thesis has been to provide new information regarding the wear of ultra-high strength steels in demanding wear conditions. The emphasis has been on understanding which features affect the abrasive and impact wear resistance of steels.

The efficiency of machinery has improved dramatically in many industrial sectors during the past few decades. Some examples are the applications used in mining and mineral handling as well as agricultural machinery. While the processes become faster and the machinery more powerful, the materials used in the applications face increasing requirements, especially regarding wear resistance. In addition, more advanced materials are required in mobile machinery for stronger, but lightweight structures to reduce emissions.

Ultra-high strength steels are important for various applications which are used in harsh conditions facing heavy wear. Several martensitic grade steels were tested in the study to gain more knowledge on their wear behavior. Moreover, novel carbide-free bainitic (CFB) concept steels were tested for wear performance. The wear tests were done at Tampere Wear Center (Tampere University) with application-oriented testing devices. Mechanical testing and material characterization were also included in the research work.

The results revealed that the initial hardness on the steels is a major factor in terms of wear resistance, but the work-hardening capability of steels was also found crucial. Retained austenite, tempering and prior austenite grain size were found to influence the wear of martensitic steels. New bainitic steels showed extremely promising wear test results, which was mainly attributed to the high work-hardening capability.

The research work provides new information, which can be utilized to develop even stronger and more durable wear-resistant steels. The results may also be used for improving other ultra-high strength steels, such as protection steels and automotive steels for increased safety. Furthermore, the research work on the novel bainitic steels should be continued to enable the use of CFB steels as wear-resistant materials.

The doctoral dissertation of MSc (Tech) **Oskari Haiko** in the field of Materials Engineering "Effect of microstructural characteristics and mechanical properties on the impact-abrasive and abrasive wear resistance of ultra-high strength steels" was publicly examined in the Faculty of Technology at the University of Oulu on 10.9.2021. The Opponents were Associate Professor Jens Hardell, Luleå University of Technology and Doctor Marke Kallio, Metso Outotec. The Custos was be Professor Jukka Kömi, University of Oulu.

Link to the thesis in University of Oulu repository: http://jultika.oulu.fi/Record/isbn978-952-62-3012-2

Low friction ceramic composites

Friction and wear represent a chronic problem in the form of economical cost and technological setback. Tribological research aims at understanding and solving the problems that emerge from the interaction between surfaces that are in contact with relative motion, causing energy losses and material degradation due to friction and wear.

Objectives of the dissertation were (i) studying the effectiveness of ceramic composites with different solid lubricants against friction and wear, and (ii) developing a novel self-lubricating material. Composite materials with different solid lubricants were reviewed. The materials were synthesized by pulsed electric current sintering. Significant improvements were achieved in the friction behaviour of the studied ceramic materials, with improved wear resistance.

Formation of Mo_4O_{11} under sliding motion was reported for the first time. It was responsible of reducing the friction coefficient of alumina hardened zirconia by 65 % at 400 °C. A new ceramic composite was developed, with zirconia matrix and a reduced tungsten oxide ($WO_{2.9}$). Utilization of this easy shear oxide was reported for the first time. The novel self-lubricating composite had very low friction coefficient when tested at 25 °C (as low as 0.08 in bulk form).

Although friction and wear are surface related phenomena and certain thin film applications have proven to be very effective for protection against wear, there are still uncharted areas when it comes to new materials, bulk or film. Oxygen deficiency and its utilization in low shear structures has a potential for future growth in the field as it has been demonstrated in this thesis work.

The doctoral dissertation of M.Sc. **M. Erkin Cura** in the field of Materials Science "Ceramic Composites with Solid Lubricants Processed by Pulsed Electric Current Sintering" was publicly examined on 20th of August 2021. The Opponent was Professor Allan Matthews, University of Manchester, UK. The Custos was Professor Jari Koskinen Aalto University School of Chemical Engineering.

Link to the thesis https://aaltodoc.aalto.fi/handle/123456789/109014