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Topic Insights

The Rising Importance of Precision Engineering

Mark Hoffman [a], Liangchi Zhang [b]

[a] Dean of Engineering, The University of New South Wales, Sydney, NSW 2052, Australia

[b] Head of Laboratory for Precision and Nano Processing Technologies, The University of New South Wales, Sydney, NSW 2052, Australia

Precision engineering is the discipline that encompasses the design, development, fabrication, and measurement of parts of a mechanical, optical, or electronic system, in software or in fixtures and other structures. For example, a precision instrument or machine should be able to function or perform at a high accuracy that is many orders of magnitude smaller than the size of the instrument or machine itself. It is critical that such accuracy and accurate performance are repeatable and stable over a designated period. Precision engineering also involves the generation of new knowledge-bases and creation of new technologies which will advance the innovation of such machines, instruments, or systems.

Overall, precision engineering deals with anything that requires accuracy in its creation, from finding solutions to scientific and technological problems, developing new production methods to turning theory into reality. The field plays a crucial role in today's world, from aircraft engines, pharmaceuticals manufacture, agricultural machinery, food processing, silicon chips, mobile phones, cameras, supercomputers, robots, and unmanned vehicles to artificial intelligence—we are surrounded by the numerous products from precision engineering. The discipline is becoming more important in the development of future technologies, where accuracy and repeatability are increasingly needed to improve product performance by delivering better accuracy, reliability, and improved product life and enhancing safety; or to increase manufacturability by allowing for automation and, of course, by lowering costs.

A number of trends are evident in precision engineering: additive manufacturing, such as three-dimensional (3D) printing; micro- and nano-processing, which require precision, machine rigidity, physical machine control and accurate tooling; the processing of new engineered materials, such as composites, where traditional approaches to manufacturing and machining lead to many defects and surface integrity problems; and the growing demand for autonomous machine operation. We can also see "molecular manufacturing" on the horizon: industries making biomedical implants, prosthetics, and pharmaceuticals, which increasingly rely on nanotechnology—an area where precision engineering is paramount.

In this issue, a group of eight papers present some methods and processes related to two aspects of precision engineering: miniaturised surface texture generation and precision metrology.

The possible development of electrical equivalent molecular components—such as molecular transistors, capacitors, and diodes—is reviewed by Mathew and Fang, and provides newcomers to the field with an overview of some previous publications.

An investigation of surface microprocessing of the biomedical metallic materials, alloys Mg–6Gd–0.6Ca and decorated Ti6Al4V, using laser technology is presented by Hu et al. The reason for this study is that the impressive mechanical and functional properties, as well as the biocompatibility, of metallic biomaterials make them attractive for increasing use in medical applications. Poor surface topologies, however, hinder bio-integration and hence their full application. This study aims to understand the applicability of the microprocessed surfaces to cell adhesion and liquid biopsy.

A prospective alternative to single large expensive satellites is to utilize multiple satellites flying in formation with the advantage of increased redundancy and cheaper and simpler satellite designs. Formation flying, though, requires satellites to accurately measure and maintain desired distances from each other; dual-comb absolute distance ranging systems have been proposed and tested in laboratory conditions. Zhu and Wu provide a review of absolute distance measurement using dual-comb ranging and argue that, using two coherent frequency combs, dual-comb ranging can enable the fast measurement of time and phase response, and thus can overcome the existing difficulty in using conventional ranging tools.

Micro/nano-machining based on mechanical tooling is an important process in micro/nano-scale fabrication, in which the material removal mechanisms and the associated surface integrity achievable are fundamental to the quality fabrication of micro-components. However, it is not simple to scale down a mechanical machining process to micro/nano-scales due to tooling restrictions. Wang et al. discuss the advantage of a picosecond laser in the manufacture of Stavax steel surfaces with miniaturised micro/nano-scale features, and seek to demonstrate that the wettability of the textured surfaces can be tailored.

Freeform specular surfaces are encountering more and more applications in precision manufacturing and measurement systems, thanks to improved capabilities in the manufacture of optical components where high potential in accuracy and repeatability are required. Xu et al. discuss the effect of geometric parameters on the measurement accuracy in stereo deflectometry, and propose a measurement system based on the analysis to measure a stock concave mirror.

Lasers with ultrashort pulses are useful in materials processing, as they can significantly minimise the thermal effect on workpiece material, and also process transparent materials due to the mechanism of nonlinear multiphoton absorption. A review of micromachining using ultrashort pulse lasers is provided by Yu et al., describing the processes and providing some manufactured samples.

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