

Surface quality control device for on-line applications

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Abstract

This paper details the development of a novel device for monitoring the quality of the metal surfaces sculptured by modern machine tools. The developed system, that can be proposed as a machine tool accessory, integrates the three functions of dimensional, roughness and waviness measurement. The measure is achieved, without contact, scanning the surface with an optical measuring probe handled like an ordinary tool, which is loaded from the tool magazine and then employed to perform the on-line measurement; a simple fibre connection to the control unit guarantees high immunity to disturbances. The experimental validation proved the capability of the developed solution to meet the severe requirements of the modern production systems showing the particular suitability of the inspection tool to the cases of Flexible Manufacturing Systems and Agile Production.

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1. Introduction

In modern manufacturing plants, on-line measurements are more effective and beneficial than traditional off-line methods: the compliance verification on workpieces still clamped on the machine tool does allow immediate corrective actions, avoiding, for instance, the re-setting dead time and refraining from further processing the non-compliant semi-finished products. To get the best results both surface finishing prediction techniques based on sophisticated modelling of the working process and surface quality monitoring must be applied [1–4].

The present work deals with an innovative surface quality measuring device that can be successfully used for both surface compliance verification and the data gathering needed for process modelling.

Traditionally both roughness and dimensions are measured by means of contact measuring devices. They present, though, considerable limitations: the measurement is slow, the contact between the measuring probe and the surface can result in local scratches and probes are normally cumbersome and unsuitable to the workspace of a machine tool for robustness and reliability reasons due to the presence of moving parts in the measuring heads. On the other hand, contact-less techniques [5–13], particularly those capable of recording the surface profiles, can be successfully employed for the development of innovative devices. Table 1 sums up the

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Table 1
Comparison of optical non-contact measuring techniques

Principle of measurement	Roughness (μm)	Profile acquisition	Waviness measure	Dimensional measure	Sensitivity to material and texture
Triangulation	>0.8	Yes	Yes	Yes	Medium-high
Speckle pattern	<0.3; 1–30	No	No	No	High
Scattering	0.006–2.0	No	No	No	High
Conoscopic microscopy	>0.6	Yes	Yes	Yes	n.a.
Confocal/autofocus	>0.1	Yes	Yes	Yes	Small
Extended range confocal	>0.1	Yes	Yes	Yes	Small

features of the main optical techniques so far proposed for surface measurements. All the optical techniques suffer from a certain sensitivity to the specific material and surface finish. Some intrinsic limits derive from macroscopic factors, such as those concerning the local slope compared to the direction of observation, others have a microscopic nature and show themselves through diffraction phenomena. In general, optical probes have difficulties in gauging rapid profile variations and are usually disturbed by local curvatures comparable to the probe's optical wavelength. Still the roughness measurable range is acceptable for most industrial applications and in particular for those of the machine tool sector.

A typical optical technique for profile measurements is triangulation. Yet, its application to surface characterization is strongly limited at low-roughness surfaces [7]. Scattering-based measuring techniques, instead, established themselves for in-line roughness measurement [8]. Scatterometers are applied in production lines where it is important to employ robust measuring systems, capable of performing well-reproducible measures for a defined kind of surfaces (i.e. rolling mills plants with continuous production). Scatterometers cannot provide a dimensional measure, performing an indirect measure of the roughness, without any relief of the surface profile.

Conoscopic holography is an interferometric technique which offers good immunity to disturbances due to the vibrations of the measuring probe [9]. Another beneficial feature is the intrinsic collinearity of the measuring apparatus, which is thus able to perform the measure also in case of high slopes in the surface profile. On the other hand, the commercially available devices do not seem to have reached a satisfying degree of maturity yet and cannot guarantee the typical industrial requirements of reliability, usability and robustness.

Confocal and autofocus techniques find application in surface metrology [10]. There is a wide offer

of commercial 3D profilometers based on a confocal sensor and a mechanical scanning system with high-precision tables; yet, these instruments can be used only in controlled environments, like metrological laboratories. The main issue is the presence, inside the probe, of high-precision mechanical parts in motion, which are out of their place in harsh industrial conditions.

The extended-field confocal techniques [11–13] solve the problem of the autofocus systems, eliminating every moving part; these techniques were applied in the innovative application described in this paper.

2. System description

The developed system has been designed for applications on machine tools primarily addressed to the automotive and high-precision mechanics market. The reference machine tools family – the specimen used for the experiments is shown in Fig. 1 – consists of flexible modules equipped with linear motors for high-speed chip-forming semi-dry machining. The modularity and flexibility features make it possible to use the modules both in large scale production plants as transfer lines and in small scale production workshops as stand-alone isles.



Fig. 1. The machining centre IBR-1.8g.

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