Application of laser optical displacement sensor to foundry processes control and research

J. Mutwil*, R. Janowski
*Department of Mechanical Engineering, University of Zielona Góra, Podgórna 50, 65-246 Zielona Góra
*Corresponding author. E-mail address: j.mutwil@iizp.uz.zgora.pl

Received 20.04.2009; accepted in revised form 24.04.2009

Abstract
An experimental set-up elaborated for distance measurement with a use of a laser optical displacement sensor has been described. The features of the elaborated device allow to measure a surface roughness and dimensions of small details. Elaborated computer software allows automatically to estimate the classical surface roughness indices. The surface roughness indices can be estimated also for sloping planes. A solidification surface profile in macro and micro scale can also be measured. The mentioned solidification surface profile is measured on solidified shells obtained by using of so-called remove remainder test. Exemplary measurements of mould and casting surface roughness have been presented.

Keywords: Laser technique, Experimental set-up, Dimension control, Surface roughness, Solidification surface profile

1. Introduction
Optical distance measurement techniques gain still on importance. An interlaboratory comparison on mechanical and optical coordinate measuring machines shows that optical devices can be as good as mechanical ones [1].

The same tendency refers to the surface roughness measurements. Not long ago the most common method used here was by using a surface profilometer with a contact stylus [2]. This method is accurate but has also some disadvantages (surface scratches, wear of stylus tip, long measuring time, difficulty of on-line measurement [2, 3]. For in-process measurement various optical techniques have been analysed and investigated. It was judged that the light scattering method is most suitable for the in-process measurement of surface roughness [2, 3, 4].

In paper [5] authors have presented an experimental set-up elaborated for measurement of solidification surface profile of shells obtained by using of so-called remove remainder test [6, 7].

In elaborated set-up a laser optical displacement sensor has been used. Initial investigations have confirmed usefulness of this solution (device+software) to analysis of solidification surface profile in macro and micro scale. The obtained results were so encouraged (measurement accuracy and short time of measurement and analysis) that it has been decided to estimate his usefulness (after some design changes) for dimensions and surface quality monitoring of casting and mould cavities.

2. Description of experimental setup design
A design of elaborated set-up to measuring a surface roughness and dimensions of small details is shown in Fig. 1.
An important element of the setup is a fixed laser optical displacement sensor (7). A measured object (1) is below the laser sensor placed on a movable base (2). In this way the object can move slowly (the velocity can be in large range selected) along the sensor. Two sample holder (3) assure a stability of the sample by moving. A drive mechanism have been adopted from computer scanner containing a drive engine (5), a guide rail (4) and a drive line (6). A sample displacement is measured by conductive plastic linear-position transducer (8). The resolution of the sensor (8) is by producer defined as <0.01mm. Measured signals are registered by microprocessor recorder PDOC-16 (9). The used laser sensor Micro-Epsilon optoNCDT 1700-100 has following measurement features: 1) measuring range: 100mm, 2) start of measuring range: 70mm, 3) end of measuring range: 170mm, 4) reference distance:120mm (MMR-midrange), 5) resolution: 0.006mm, 6) spot diameter (by MMR): 0.06mm, 7) measurement frequency: 2.5 kHz-312 Hz. Presented measurement parameters of laser sensor (resolution and spot diameter by midrange) allowed to assume, that by using of elaborated measurement setup a surface roughness can be also analysed.

3. Exemplary measurement

In order to check an ability of the elaborated measurement set-up to foundry processes monitoring and research some test objects have been chosen (Fig. 2). Such chosen measurement objects allowed to measure: 1) mould surface roughness (Fig. 2a,b: two standard cylindrical samples rammed with two different moulding sands (different sand grains fineness: I) 020/016/010; II) 032/020/016); 2) dimensions and surface roughness of a casting (Fig. 2c: stepped shaped casting with machined and no machined surfaces), 3) solidification profile of solidified shells obtained by using the remove remainder technique [6, 7].

For measurement analysis a computer software have been by Mutwil elaborated, which among other things allow to estimate the classical roughness indices (Ra, Rz), also for sloping planes surfaces.

Because the accuracy of all such measurements is strongly depended on frequency of data collecting (measuring step) this factor has been in presented bellow investigations considered.
Fig. 3. Casting measurement: a) time dependency of measured signals (L= horizontal coordinate measured along the casting radius; h=casting height as vertical coordinate; v=sample horizontal velocity), b) casting height distribution as h=f(L) function (measured up to casting symmetry axis; measuring step=0.33 mm), c) casting height distribution as h=f(L) function (measurements of two bottom planes: machined and no machined surface – see Fig. 2c; measuring step=0.055 mm)
Fig. 4. Roughness measurements: a) machined surface of casting from Fig. 2c (measuring step=0.02mm), b) no machined surface of casting from Fig. 2c (measuring step=0.02mm), c) head surface of facing sand sample (Fig. 2a; measuring step=0.055mm), d) head surface of backing sand sample (Fig. 2b; measuring step=0.055mm)
Fig. 5. Lines of solidification profile obtained for solidified shell (Fig. 2d) by different measuring step:
  a) 0.11 mm, b) 0.22 mm, c) 0.33 mm
In Fig. 3a a time dependency of the casting height \( h \) and the distance \( L \) from the measuring start point (reference point for vertical dimensions) as well as the velocity of device movable base are presented. In b, c sections the casting height \( h \) as function of \( L \)-distance \( (h=f(L)) \) is presented. In a, b sections some specific points have been marked by letter. At the left side of all these pictures some values for marked points have been written in successive lines. An quantitative interpretation of the showed measurement results make easier the values written in pictures area.

In Fig. 4 the results of surface roughness measurements have been presented. In upper right pictures region the values of estimated \( Ra \) and \( Rz \) indices as well as the \( a, b \) parameters of linear function (basic line for \( Ra \) estimation) have been showed. The estimation of \( a, b \) parameters is made by least squares method automatically after choosing the analysis range. The curve of the fitted linear function is automatically plotted in analysed surface region (see Fig. 4). Analysis of the a-parameter values (slope) shows that all of analysed surfaces were low-sloping.

In Fig. 5 measurement results of the solidification surface profile for sample showed in Fig. 2d are presented. The three demonstrated curves obtained by three different measuring steps let show the influence of this parameter on measuring accuracy. It should be here explained some notation being used, for example: 1) \( g\text{-}AK \) - average shell thickness \( (g) \) in sample range between A-K points, 2) \( Wn\text{-}AK \) - average value of \( Wn \)-parameter in sample range between A-K points, where: \( Wn \)- a quotient of profile line length to the \( h \)-distance in the analysed range, 3) in all notations the 14 number is a number of register channel in which the laser sensor signal was measured.

4. Conclusion

The elaborated measurement setup allows to determine:

- line dimensions of small castings (details)(max. horizontal coordinate: \( L=150mm \), max. vertical coordinate: \( h=100 \)),
- static measuring accuracy is respectively no worse than: 0.006mm by vertical- and 0.01 by horizontal dimensions measurements,
- dynamic measurement accuracy is strongly depended on data collecting frequency (measuring step),
- values of \( Ra \) and \( Rz \) surface roughness indices also for sloping planes surfaces,
- the thickness distribution along the metals and alloys solidified shells (profile line of the solidified shells),
- the roughness of the solidification surface.

The presented investigations allow to assume that after some design changes the presented solution will be able to foundry in-process control.

Acknowledgements

The work financially supported by the State Committee for Scientific Research as a research grant No. 7 T08B 032 16 for years 1999-2001.

References