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Some considerations about the use of different sensors, in coordinate measuring of the small parts

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Abstract. The paper presents some particular aspects associated with measuring of the small-size parts with high precision, manufactured by injection procedures. The coordinate measuring machine (CMM) are very used in process of measuring parts with different shapes, dimensions and materials of the most varied. It is studied by experiments, the influence of hygroscopicity on the geometrical properties of polyamide parts, using different types of measuring sensors. We selected a few pieces- cover type, with precision features dimensions and shape tolerances. To measure them was used some sensors which is equipped CMM ScopeCheck S 400 and equipment for dehumidifying. Starting from the need for high precision measurement of geometric characteristics of the parts obtained by injection of plastic, it has been found that the hygroscopicity has a significant influence. To achieve the purpose were used three types of measuring sensors under different conditions of keeping after manufacture. It was observed that the influence of humidity is significantly reduced if the parts are kept in exikator or vacuum dryer.

1. Introduction

The CMM are used to solve of control issues and expertise of industrial products. They operate with numerical data in rectangular or polar coordinates, with tactile or optical probing systems, capable to access all geometrical elements of controlled part. They are used for measuring geometrical characteristics of parts: deviations of form, position and orientation, diameters, angles etc. Measurement results can be displayed both graphically and numerically. Resolution coordinate measuring machines range from 1μm (on the manual control) to 10 nm (on the automatic).

The types of sensors that coordinate measuring machines are using today are:

- optical image: which are based on a high-resolution CCD camera;
- tactile: in which measurement points are recorded by physical palpation of the piece;
- laser: it is recorded and transmitted to individual sets of data captured by the laser fascicle;
- X-rays: when making a 3D scan of the piece, inside and outside, to be completed in measuring program model.

2. The equipment used for experimental verification

For the experiments was used Scope Check S 400, a coordinate measuring machine with dimensions measuring table 400 x 200 x 200 mm and the maximum permissible weight of parts that can be measured 8 kg. The machine has a measurement resolution of 0.1 micrometers, and the uncertainty of measurement up to 2 micrometers. The supply voltage of the machine is 115-230 V (50-60 Hz), maximum power consumption 1.5 kVA and 10A maximum amperage. For the normal functioning of the machine, humidity should be between 40-70% and ambient temperature of 20-21°C.

Scope Check S 400 is equipped with a number of sensors in modular construction for measuring interactive, integrated PLC-controlled production process. To obtain maximum of precision, the main axes of measurement (OX and OY) are separated constructive. On all three axes are set precision guides from steel. Involvement of axes is made with continuous current servomotors and ball screws.

The measuring points are recorded in the machine coordinate system, in conjunction with the data read from the integrated measuring length. The data is processed using a mathematical evaluation software, which determines the geometrical characteristics of measured values and displays them.

WinWerth 8 is a measurement program that has an interface very easy to use with a lot of functions and a variety of measurement modes. The machine is controlled and coordinated the program manually, automatically or interactively. In manual mode, can be inserted values of coordinates and parameters functioning machine that is given; interactive mode, measurements can be made with joystick control, and automatically by using the CAD model or program with interface measurement DMIS (Dimensional Measuring Interface Specification). Scope Check S 400 disposes of 3 sensors: optical (with additional functions such as Autofocus, BestFit, 3D Patch), touch (with interchangeable sensors 3 mm, 1 mm and 0.5 mm) and laser (with the "high speed scanning"). So, the interface of WinWerth 8 program are six modes: screenshot, optical or laser shooting mode, autofocus, stylus, laser mode manually.

2.1. Dimensional measurements technique with multiple sensors

2.1.1. Optical sensor the image processing. The electronic part of matrix camera of the sensor (Figure 1) converts the optical signal into a digital image, which is the used to calculate and measure different points, with appropriate software for processing and measurement images.

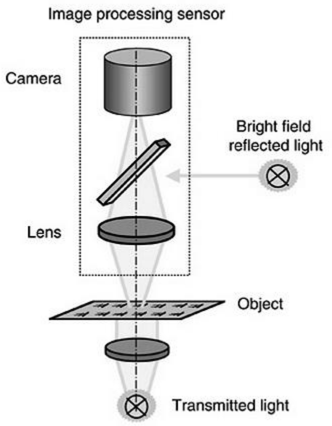


Figure 1. The image processing sensor with transmitted and reflected light

To get the lowest measurement uncertainty the telecentric lens are used. The advantage of this lens is that they do not distort images so even at maximum zoom, they remain unchanged. When are not used this lens, the images of the metered are altered at minimum zoom and appears distortion of image while the measurement uncertainties are high. For a better flexibility is used a multi-lens zoom system (Figure 2a). To increase the accuracy, the measuring machine has a optical system Werth Zoom, which ensures high repeatability (Figure 2b) in repositioning in the same coordinate system and at same values.

There movements of lens are motorized, thus ensuring exactly the same values of zoom and the same accuracy every time. This design is valid for zooms between 1× and 10× at focal length to measured parts between 20 mm and 250 mm. To realize measurements with optical sensor, illumination and contrast have an important role, they must be appropriate.

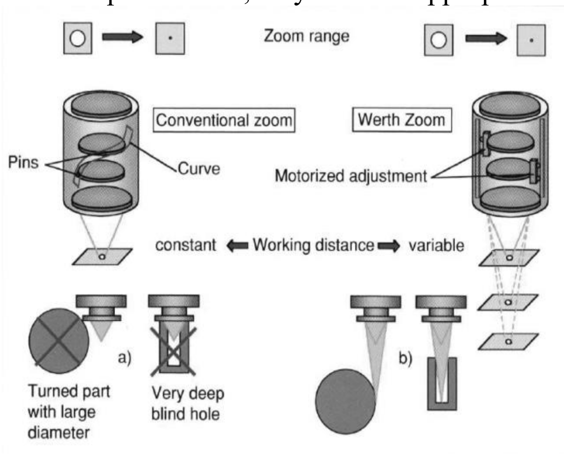


Figure 2. Optical lens system [1]
a) conventional zoom
b) adjustable Werth Zoom and adjustable focus distance

To have an adequate contrast and accentuated of margins, the metered with flat surfaces, measurements can be made with light contour (Figure 3).

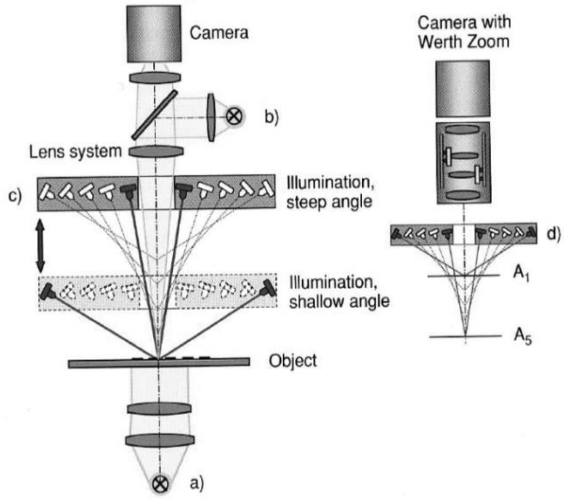


Figure 3. Types of illumination [1]:

a) lower lighting (contour)

b) top illumination (integrated into lens system)

c) d) light side (MultiRing) - adjustable to different heights

d) the light side (MultiRing)

The same hardware is used for autofocus sensor as processing of images. Autofocus is used to measure flat surfaces (parameters, values, tolerances of form). The main disadvantage of autofocus is increased attention that should work for better results and that is very slow.

2.1.2. Point laser sensor. Measuring principle of laser (Figure 4) is based on design of the light ray (red) produced by laser diode, on the object. The reflected ray is absorbed by an optoelectronic sensor. The point is then determined using triangulation technique. The advantage of laser sensor compared to the optical sensor is measuring speed is much higher. In this way can be measured up to thousands of points per second, so this sensor is ideal for scanning surfaces.

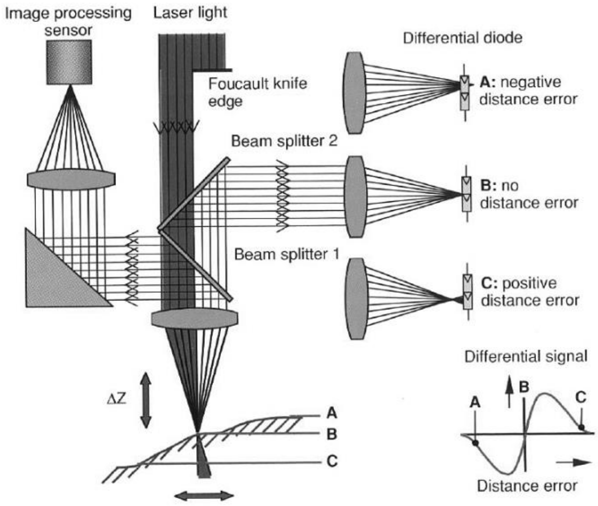
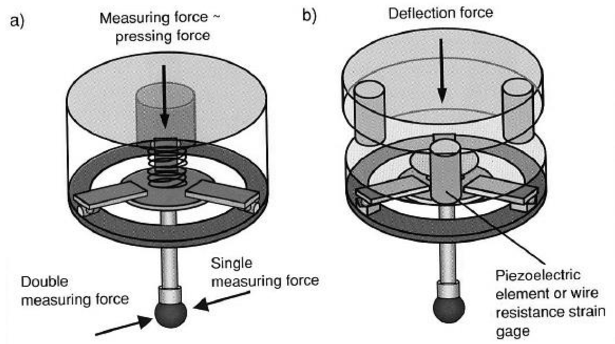


Figure 4. Laser sensor with integrated image processor [2]

2.1.3. Tactile sensor. In principle, all tactile sensors (Figure 5-6) function by mechanical contact with the measured part. The resulting signal is then forwarded for processing. A distinction must be made here between Touch Trigger (connected sensor) and tactile probe (measuring sensor). With tactile sensor geometry (shape and size) of a probe element (scope probes) as the spatial position and geometrical shape of surface of measured object, are contained in the measurements results. To obtain smaller measurements uncertainty, tactile sensor must be calibrated to correct probing errors and contact with surfaces. This is done using the program WinWerth.



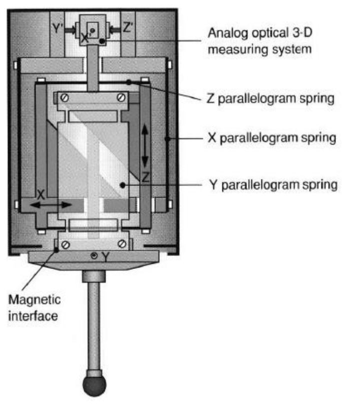


Figure 5. Probes with electromechanical converter (measuring force of pressure/deflection)

Figure 6. 3D probe with elastic parallelogram mechanisms

The main disadvantage of this tactile sensors is that they are first brought into contact with measured part, all data is saved, then automatically retire and after can be measured the point in the measuring program.

2.2. Comparative study on measurements with different measuring sensors on parts injected from polyamide

2.2.1. Flatness measurement and tolerated dimensions. We selected a few pieces, cover type, made from polyamide, with precision features dimensions and form deviations tolerated. To measure them was used some sensors which is equipped Coordinate Measuring Machine Scope Check S 400 and equipment for dehumidifying parts.

For the beginning, it was measured the part from Figure 7, having deviations from flatness, with tolerances of 0.20 mm on the plain surface. There were used, by turn, autofocus, laser and tactile probe. Then was measured the tolerated dimensions of part from Figure 7b. The dimensions were measured with Scope Check in optical module (autofocus) and with the digital micrometer (thickness).

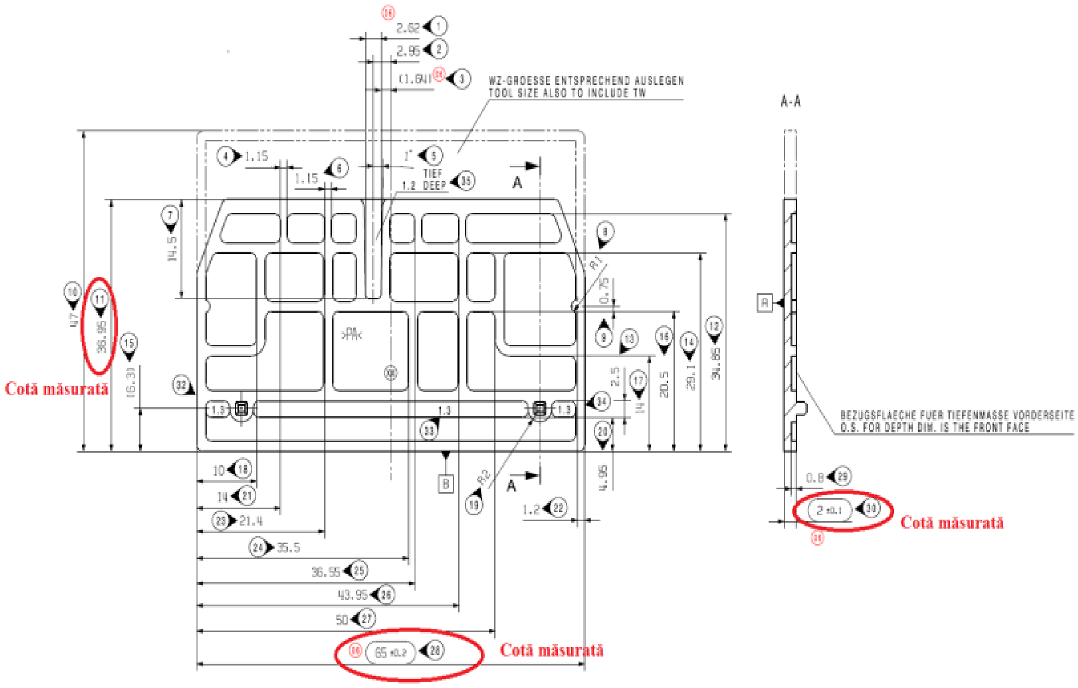


Figure 7. Measured part

For more precise results to measure the flatness with optical sensor autofocus (Figure 8) always is chosen maximum zoom [3], in order to highlight roughness of parts measured.

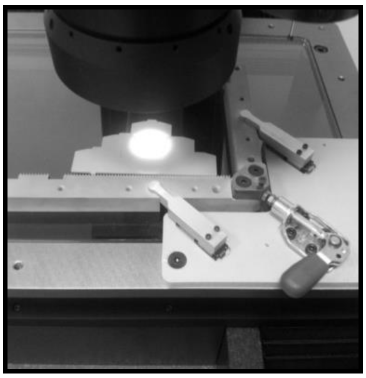


Figure 8. Measurement with Autofocus

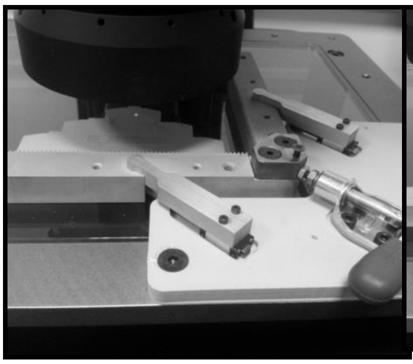


Figure 9. Measurement with Laser

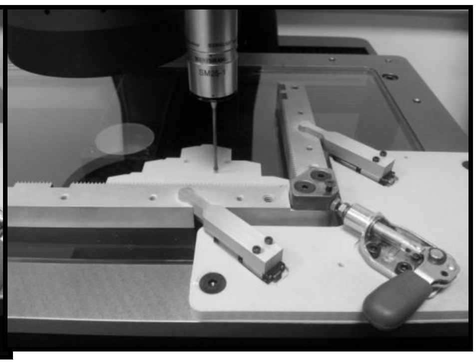


Figure 10. Measurement with Probe

Measurements with laser sensor (Figure 9) are most used because the results are almost as accurate like autofocus sensor and the highest speed of analysis of surfaces. Measurements with tactile sensor (Figure 10) give the most accurate results. Yet if probe is not calibrated, the results will be inaccurate.

2.2.2. Influence of humidity on the dimensions of a part injected from Polyamide. At injection, plastics have some nominal size, but after 2-3 hours they absorb humidity and increase (according to ISO 62 under normal conditions: 23 ° C at normal relative humidity 50%) between 2.6% and 3.2% of their normal that they had at injection. Humidity saturation of the piece injected will be between 8-9%, in other words even if we leave it in the rain will not increase more than 8-9% of the size it had the injection [4], [5].

The big problem is that the parts what are inject [6-8], sometimes come after many hours or even days at specialists in metrology, during which change their some geometrical characteristics because of humidity. For remove the humidity of the pieces, they are placed in exikator for up to 48 hours where the silica gel absorbs humidity. To expedite the process, the pieces can be inserted in vacuum the time preceding measurements with 24 hours. For highlight the influence of humidity on the plastic parts (Polyamide), we conducted a series of measurements on the same piece, kept in different environments.

3. Experimental results

After measuring flatness on the three types of sensors, measuring result were centralized in a diagram (Figure 11).

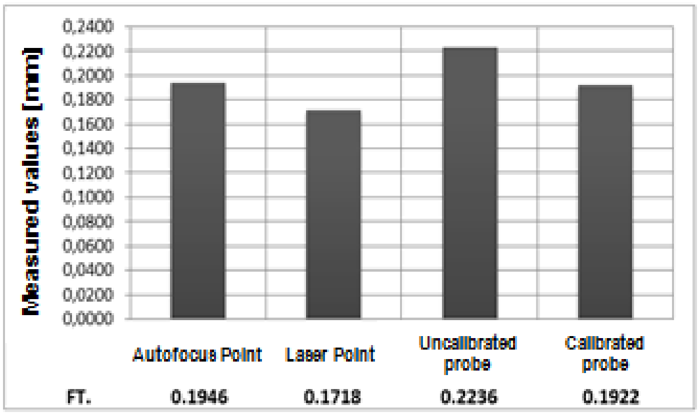


Figure 11. Results of flatness measurements with different sensors

Next, the effect on humidity of injected piece is studied, in different keeping conditions: outdoor (Figure 12), in the exikator (Figure 13-14), in the vacuum dryer (Figure 15-16) and graphs for these situations have been drawn up.

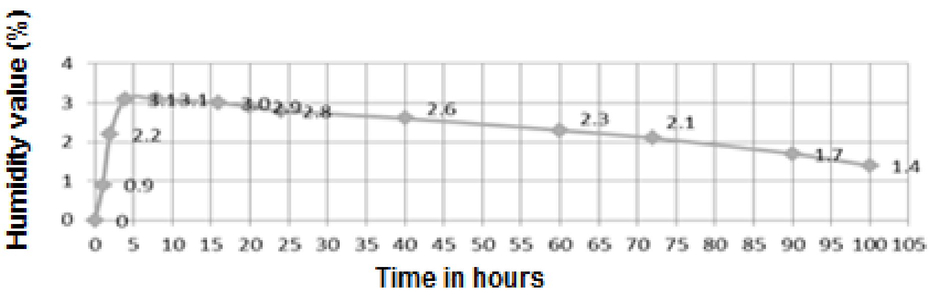


Figure 12. The results of humidity at measured parts, left to outdoor 100 hours

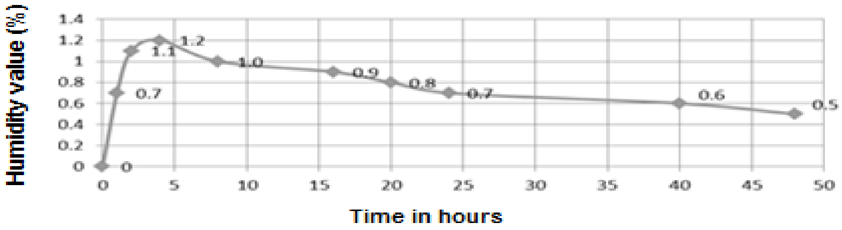


Figure 13. The results obtained for parts placed in exikator immediately after injection

Figure 14. The exikator

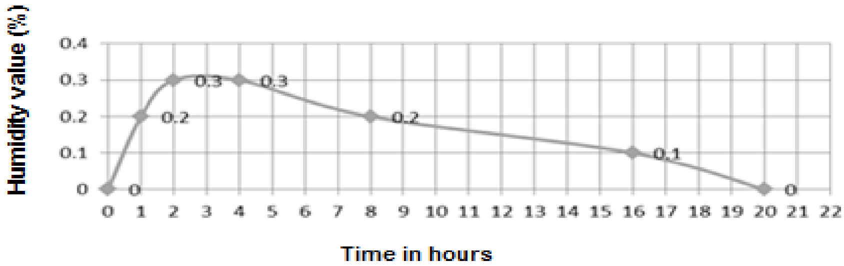


Figure 15. The results obtained for parts kept in the vacuum dryer for 20 hours

Figure 16. The dryer

As to the effect of humidity on the three tolerated dimensions of a piece measured with Scope Check S 400 and a digital micrometer, kept in different storage conditions, the results can be seen in Table 1.

Table 1. The influence of humidity on tolerated dimensions

	Nominal value +Tolerance (*mm*)	Sample 1 (*mm*)	Sample 2 (*mm*)
AI	36.95±0.28	36.80	36.82
AI	65.00±0.20	64.75	64.80
AI	2.00±0.10	1.97	1.97
AC	36.95±0.28	36.99	36.99
AC	65.00±0.20	65.09	65.10
AC	2.00±0.10	2.08	2.09
EX2.5	36.95±0.28	36.94	36.96
EX2.5	65.00±0.20	65.03	65.05
EX2.5	2.00±0.10	2.04	2.06
EX24	36.95±0.28	36.90	36.92
EX24	65.00±0.20	64.98	65.00
EX24	2.00±0.10	0.02	2.03

AI -The value of dimensions measured immediately after injection.
AC -The value of dimensions measured at 2.5 hours after injection (ambient conditions).
EX2.5 -The value of dimensions measured at 2.5 hours after injection (exikator).
EX24 -The value of dimensions measured at 24 hours after injection (exikator).

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4. Conclusion

Starting from the need for high precision measurement of geometric characteristics of the piece obtained by injection of plastic, it has been found that the hygroscopicity has a significant influence. To achieve the purpose were used three types of coordinate measuring sensors under different conditions of keeping of parts after manufacture. It was also observed that the influence of humidity is significantly reduced if the parts are kept in exikator or vacuum dryer.

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