Advanced laser profile scanner application for micro part detection

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Abstract

Production processes for macro parts are often not applicable to micro production, due to the occurrence of size effects. Especially the handling is very challenging. To overcome the micro specific problems the production in linked parts is examined. A substrate, ideally the base material, is used to keep the micro parts interconnected and thereby a rescaling to macro dimensions is realised. On the one hand an exact equidistant arrangement of the parts cannot be assured by the production processes. On the other hand small tolerances for micro parts demand a high precision positioning for subsequent processing stages. A detection of the micro parts within the linked parts and a separate referencing with respect to the feed system becomes necessary. In this context the application of a laser profile scanner is investigated. Especially the optimisation of the measuring by inclining the sensor around its vertical axis is studied. A real-time capable recognition algorithm for typical geometrical features with sufficient robustness against noise and measuring errors is developed. To analyse the influence of the inclination a test series is performed and compared to reference measurements done by microscopy.

1 Introduction

The handling of fragile micro parts during the production process is a core topic. Due to the micro dimensions complicating size effects [1] occur like dominating adhesion forces [2] caused by the small mass to surface ratio. As solution for these problems the production and handling in linked parts [3] is investigated. Between the different production stages the parts are not separated, but kept linked by the base material. Thereby a rescaling to macro dimensions is realised. A better handling and continuous feeding becomes possible [4].

The production processes do not secure an accurate equidistant arrangement of the parts in the linked structure. So the individual parts must be referenced separately to the feed system. Further the small tolerances for these parts lead to the demand of a high precision positioning for subsequent processing steps, hence a high precision measuring. This is done by a laser profile scanner. To evaluate the data and recognise typical geometrical features a real-time capable algorithm with sufficient robustness against noise and measuring errors is developed. Due to the limited sample rate of laser profile scanners, which in practice often depends on the necessary exposure time, the accuracy of the measuring decreases with increasing feed rates. To overcome these problems the strategy of inclining the sensor around its vertical axis is investigated.

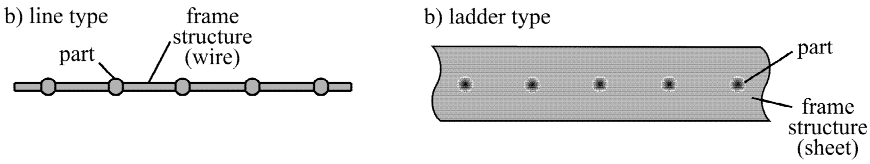

Figure 1: Basic types of linked parts

2 Principle of function and continuous measuring

A function scheme of the laser profile scanner is shown in Figure 2. The scanner works according to the principle of triangulation. It projects a laser line on the measuring object and records the image with a CMOS. To focus the image on the CMOS reception optics are used. The position of the CMOS differs from the position of the laser and the image is recorded under an angle. Like this the sensor electronics can calculate a 2-D height profile of the scanned object on the projected line. The resolution on the line depends on the CMOS resolution and

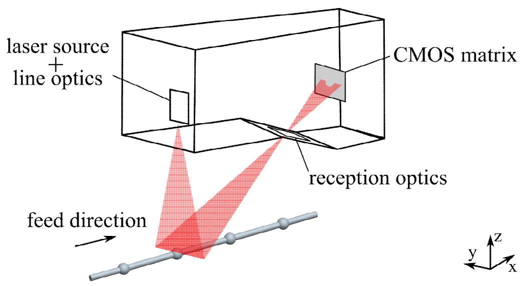

Figure 2: Laser profile scanner

the magnification of the reception optics. For the used system it is about 10 µm. To realise a continuous measuring of the surface of the linked parts the concept of light section is applied. The laser scanner is fixed in place while the linked parts are moved through the measuring field. A single data set consists of a height profile on the measured line at a certain time. By merging the single sections with the position information a 3-D scatter diagram is generated. The distance between the measurements depends on the feed rate and the sample rate. It can be kept constant by using a trigger signal. In the following it will be named the axial resolution. To realise both, a high positioning accuracy and a high feed rate at the same time, the sensor needs to be operated with an adequate sample rate f_s. The CMOS is adjustable up to a maximum resolution. Due to the limited processing power of the sensor electronics at a certain level the CMOS resolution cannot be raised without reducing the sample rate and vice versa. Further the exposure time is often another limiting factor.

3 Detection algorithm

The detection algorithm is illustrated in Figure 3. It works in two steps. First the measuring data from the scanner is merged with the position information from the feed drive. Then it is sorted and aligned to the axes of the coordinate system. The rough localisation is realised by cutting off all the data within a border radius around the wire centre axis, so that only the data from the sphere surfaces remains. Then in the second step the accurate localisation follows. An ideal sphere is shifted along the centre axis in 1 µm steps and compared to the data. The points of the minimum error are identified as the sphere centre points. For the tests the data evaluation is done in a post-processing, but the algorithm is prepared for a real time implementation, which will be done in future work.

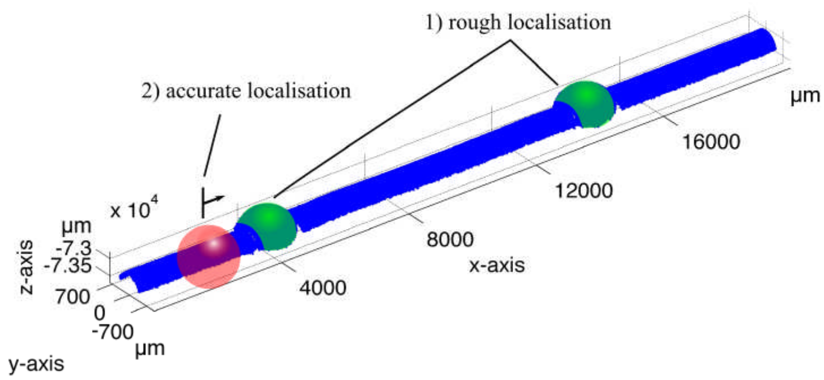

Figure 3: Detection algorithm of sphere (specimen)

4 Optimisation idea

In the standard configuration Figure 4 a) the sensor's measuring field is oriented perpendicular to the feed direction. In this case the resolution perpendicular to the feed direction, which in the following will be named lateral resolution, is exactly the same as the sensor resolution. Evaluating the different parameters of influence on the measuring results for the standard configuration a) it was shown that higher resolutions both lateral as well as axial improve the recognition robustness of the system as well as the accuracy [5]. A special problem is that the axial resolution $b = v/f_s$ increases with increasing feed rates v.

The resolution of optical systems apart from the sensor resolution can only be increased by the optics. A higher magnification increases the resolution, where the measuring field is reduced at the same time. An adaption of the magnification especially for laser profile scanners is not implemented as standard and expensive to realise. As the sensor is used for the detection of micro parts only a little part of the measuring field is utilised. The presented investigation analyses the idea of increasing the effective resolution by adapting the measuring field of the sensor to the measuring object by rotating the sensor around its vertical axis, Figure 4 b).

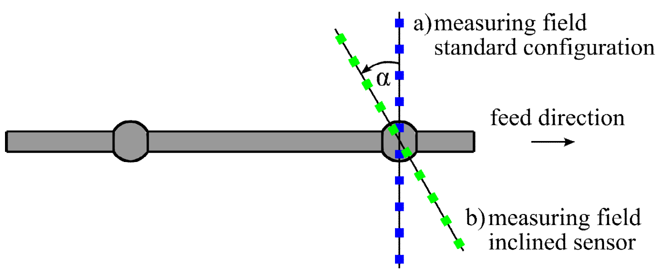

Figure 4: Sensor inclination

Figure 5 shows the influence of the inclination on the effective resolution. For the illustration the sensor resolution is reduced, but the proportions of the sample component in relation to the measuring field correspond to the presented tests. In Figure 5 a) the standard case is shown, where the lateral resolution corresponds one by one to the sensor resolution and the axial resolution results directly of the sample rate and the feed velocity. Figure 5 b) shows the case of the inclined sensor. The axial resolution $b' = \sin(\alpha) \cdot a$ improves with the inclination. Regarding a single measurement it is better at smaller angles α. This is only true if the sample rate is high enough to guarantee at least a little overlapping of the measurements in the axial direction, so that no gaps occur. The effective axial resolution improves even more with the degree of overlapping respectively at higher inclination angles α. The lateral resolution $a' = \cos(\alpha) \cdot a$ improves with higher inclination. There are more measuring data on the scanned object.

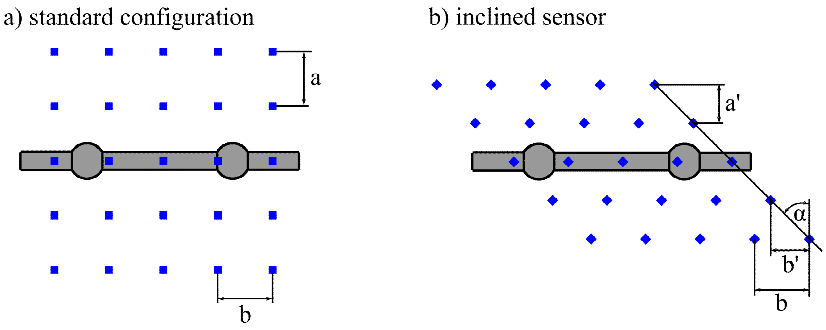

Figure 5: Inclination - resolution dependency

5 Experimental study

5.1 Testing procedure

To analyse the influence of the inclination angle α on the accuracy of the measuring respectively the robustness of the algorithm a study with varying angles as well as axial resolutions was performed. An ideal sample consisting of a wire (d=0.8mm) and two bearing balls (d=1.6mm) is used. The distance between the two balls is measured.
The testing parameters are listed in Table 1. The sensor resolution was kept constant during the test series. For each setting 10 repetition measurements were performed. As reference the mean value of the same numbers of microscopy measurements was used. For the data evaluation the error of the mean with reference to the microscope measurement and the standard deviation of the mean were determined.

Table 1: Testing parameters

inclination angle	α	0°	60°
sensor resolution	b	10µm	10µm
axial resolution	a	5µm	5µm
		20µm	20µm
		50µm	50µm
		100µm	100µm
		200µm	200µm
		…	…
		900µm	900µm

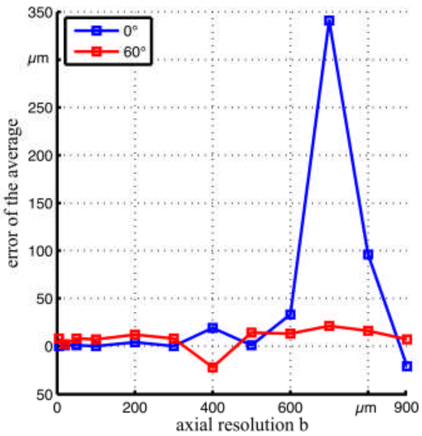

Figure 6: Error of the average

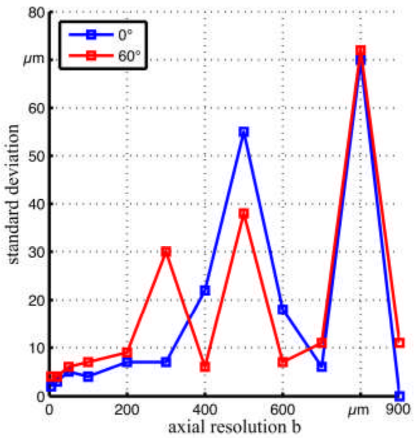

Figure 7: Standard deviation

5.2 Discussion of the results

Figure 6 shows the average error in dependency of the axial resolution a for the standard configuration and the inclination angle $\alpha = 60°$. Figure 7 shows the according standard deviation. For higher resolutions between 5µm and 300 µm the error of the mean for both cases is smaller than 17 µm and the standard deviation is smaller than 50 µm. Up to an axial resolution of 100 µm the standard deviation is smaller than 8 µm independently from the inclination. The standard configuration shows a slightly better accuracy. This can be explained by the processing of the data in the algorithm for the inclined configuration. The limited accuracy for the adjustment respectively measurement of the inclination on the test setup influences the accuracy of the position measurement. In addition to the resorting of the data because of the inclination angle α the misalignment of the angles around the other axes of the scanner coordinate system is compensated by the algorithm. Due to the measuring errors the calculated angle misalignment varies for different measuring. This is illustrated in Figure 8, where eight repeat measurements for the standard configuration $\alpha = 0°$ and the inclined case $\alpha = 60°$ at an axial resolution $b = 5\mu m$ were performed and the deviation from the mean of the angle misalignment for rotation around the x- and y-axis is calculated. The visible variation is a source of error. The diagram shows that the variation corrupts for the inclined sensor.

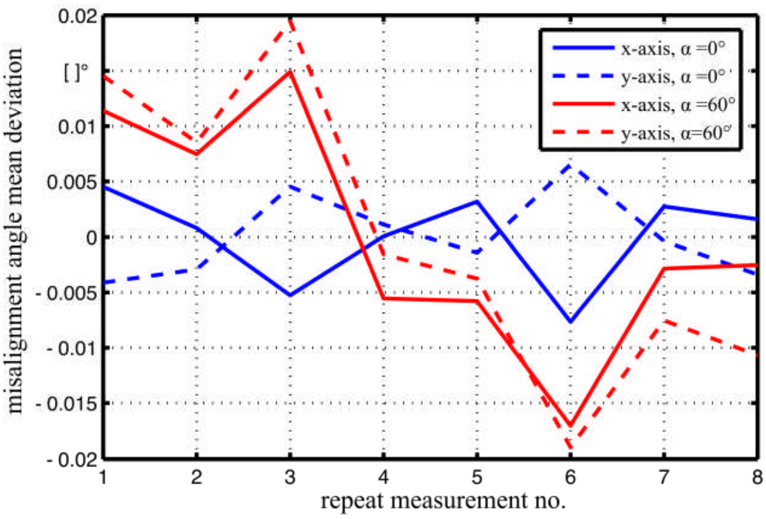

Figure 8: Calculated misalignments of the probe

Furthermore higher smaller resolutions of above 300 µm are regarded. The error of the average starts to show higher deviations at an axial resolution of 400 µm and higher. Opposite to the theory for the measuring a lower axial resolution does not necessarily cause a higher deviation. Namely in the standard deviation a regular scheme can be recognised, where peaks appear about each second step. An approach to explain this phenomenon is that the accuracy of the measurement especially for higher lower resolution depends strongly on the location of the measuring points on the wire respectively the balls. For the currently presented study each measuring was started at the same point, so that this fact has a remarkable influence on the measuring. The optimum starting point varies also with the inclination angle.
To approve this theory for the standard configuration $\alpha = 0°$ a study with five repeat measurements at three different starting points was performed. The results are shown in Table 2.

Table 2: Starting point variation

Starting point	resolution [µm]	offset [µm]	stadard deviation	deviation of the average with respect to measuring 1
1	50	0	6,14	0,00
2	50	10	7,92	11,26
3	50	20	9,85	11,72

A variation of the standard deviation and the average can clearly be shown. To eliminate the influence of the localisation of the measuring points a study with a

higher number of repeat measurements and varying starting points will be necessary.
Taking this variation into consideration for $\alpha = 60°$ a more stable tendency of the error of the average (Figure 6) for decreasing resolutions can be remarked compared to the standard configuration. The low standard deviation for some of the lower resolutions at the standard configuration can be explained by a high but constant error value.

6 Conclusion

The general suitability of a sensor inclination around its height axis to improve the utilisation and thereby the effective resolution and measuring accuracy could be shown. To completely prove this theory further investigations are necessary. Therefore further steps were shown up, like improving the test setup with regard to the alignment and adjustability as well as the testing procedure concerning a variation of the starting point.

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