Temporal change in flatness of flat surface due to optical mounting and gravity

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Abstract

In the process of measuring flatness, there are many effects that affect accuracy of the measurement. This paper investigated temporal change in flatness of flat surface due to optical mounting and gravity. Flatness and topography of flat surface, diameter range from 60 mm to 300 mm, were investigated and were measured by using Fizeau interferometer. Differences in mounting and geometry of the specimen lead to difference in equilibrium time. The experimental result were recorded from when the optical flat was mounted vertically since the beginning. The temporal study was evaluated from 8 positions along X-axis and Y-axis. The experimental results show that with three-points mounting, stabilization time required is longer than the sling type mounting. Moreover, large (heavy) optical flat demonstrated larger temporal change which is not only come from weight but also environmental condition.

Keywords : mounting: optical flat: Fizeau interferometer

Introduction

The challenge of modern machining industries involves the achievement of high quality and high geometric and dimensional accuracy of work piece. [1] For better part functioning and assembly, part will be made up with good dimensional tolerance as well as with good geometric tolerance. Flatness is commonly used on planar surface capable of resting on matting planar surface without any significant rocking. Another important application of flat surface can be found optics. The mechanism behind the formation of flatness as geometric tolerance is very dynamic, complicated, and process dependent. Several factors will influence the flatness in a CNC milling operations such as spindle speed, feed rate, depth of cut and insert type.

Flatness is a surface form control. [2] A perfectly flat surface is defined as having all its elements in the same plane. The flatness tolerance zone consists of the distance between two parallel planes. In order to obtain a reliable assessment of flatness form, an appropriate extraction strategy for obtaining a representative set of points on the work piece is required. Flatness can be measured by various techniques which can be divided into 2 groups, contact and non-contact type. The contact method can be conducted using dial indicator, height gauge, coordinate measuring machine (CMM) and other instruments. However neither of these methods can measure flatness more accurately than about 2.5 μm. [3, 4, 5, 6 and 7]

Another method which is commonly used with lapped parts is the reflection and interference of monochromatic light. [8] A monochromatic light source and an optical flat are needed for this measuring method. The optical flat, a piece of transparent glass that has itself been lapped and polished on one or both sides, is placed on the lapped surface. The monochromatic light is then shone down through the glass. The light will pass through the glass and reflect off the workpiece. As the light reflects in the gap between the workpiece and the polished surface of the glass, the light will interfere with itself creating light and dark fringes. Each fringe represents a change of one half wavelength in the width of the gap between the glass and the workpiece. The light bands display a contour map of the surface of the workpiece and can be readily interpreted for flatness. [9] The more advanced flatness measuring instrument with the highest accuracy is by using flatness interferometer. Fizeau interferometer is equipped with the He-Ne laser generating a single wavelength illumination and phase shifter. Phases of the interference pattern were determined from phase shifting algorithm and converted to distance between reference flat and the workpiece. The difference between the maximum point and the minimum point is referred to as flatness. [10]

In this paper, the optical flats diameter range from 60 mm up to 300 mm were mounted on two types of mounting vertically. Flatness of the optical flats were measured by using Fizeau interferometer for over period of time. Temporal changes in flatness due to geometry and mounting mechanism were investigated.

Experimental Setup

The quartz optical flats with various dimensions were used in this study. Size and weight of all specimens are detailed in Table 1. Temporal change in flatness of the surface was investigated by measuring flatness of the optical flat at the time interval of 5 minutes for 400 minutes.

Table 1 Specifications of all specimens

Specimens	ϕ /mm	Thickness/mm	Weight/g
A	60	20	140.63
B	100	20	397.97
C	150	30	1341.67
D	300	50.8	9087.58

The flatness interferometer used, manufactured by 4D technology, can measured flatness of the specimen diameter up to 300 mm. The flatness interferometer system equipped with the 633 nm stabilized He-Ne laser, phase shifter and a reference flat with flatness quality better than λ/20 (31.65 nm) Figure 1 illustrates configuration of the flatness interferometer system.

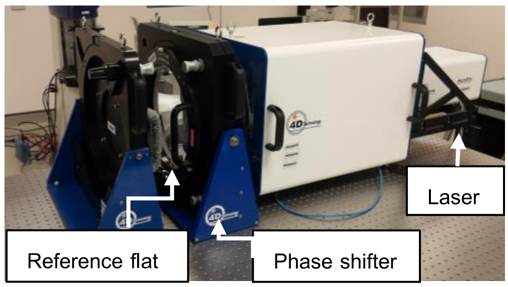
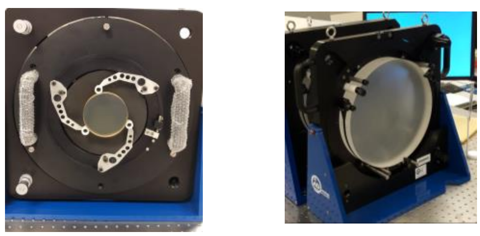


Figure 1 Flatness interferometer

Two types of optical mount were used in this study, sling type and three-point type. Configuration of the optical mounts are show in Figure 2



(a) (b)

Figure 2 Optical mount; (a) Three-point type (b) Sling type

Sling type mounting was employed in order to investigate the accuracy of the flatness measurement and influence of the environmental effect. Whereas, the three-point type mounting was employed for this study. The study can be divided into 2 parts, study of the influence from specimen's geometry and that from mounting.

I. Study of specimen geometry effect

The optical flats as listed in Table 1 were mounted using three-point type mounting and were measured using flatness interferometer. All optical flats were mounted using the same mounting with the exactly same force. The measurement were carried out for 400 minutes and the equilibrium time of all optical flat were determined.

II. Study of mounting effect

The optical flats were mounted on the three-point type mounting. It should be noted that the mounting can be adjusted the clamping force by the screw, pitch distance of 0.7 mm, as shown in Figure 3.

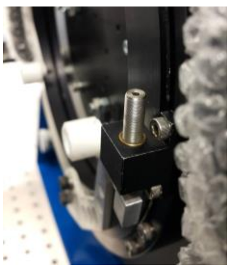


Figure 3 Thread for adjusting the clamping force

Results and Discussion

Figure 4 shows measured contour map of the optical flat D.

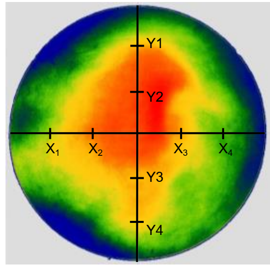


Figure 4 Flatness of the optical flat D

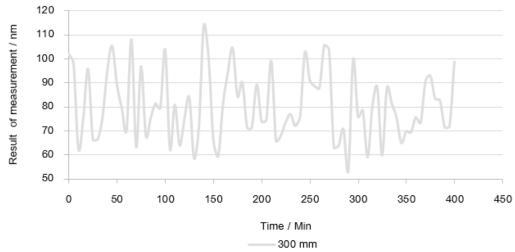


Figure 5 Flatness value of the optical flat D

Figure 5 presents the measured flatness value of the optical flat D recorded for 400 minutes. The variation during such period of time is observed to be within ± 30 nm. Not only flatness value has variation by time but contour map of the optical flat also change. Show in Figure 6 and Figure 7

Figure 6 and Figure 7 illustrate variation of the profile along X-axis and Y-axis over time, respectively.

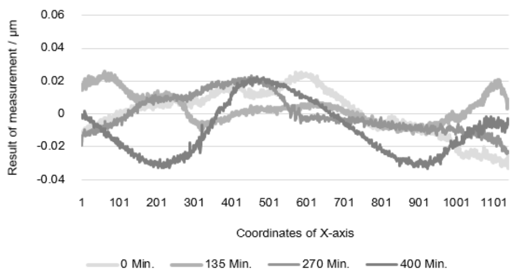


Figure 6 Profile along X-axis of optical flat D

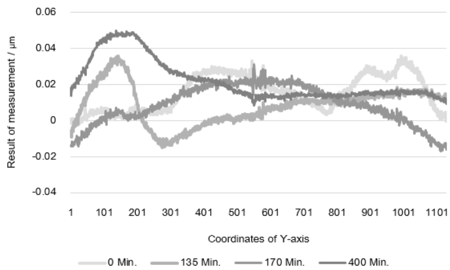


Figure 7 Profile along Y-axis of optical flat D

It was clearly shown that although a sling mounting theoretically should provide the best condition of the optical flat, the variation of the profile over time was observed. This is anticipated to be due to environmental effect.

For in depth investigation of flatness fluctuation, height value from 8 selected were collected. In Figure 4, 8 points marked as X_1, X_2, X_3, X_4, Y_1, Y_2, Y_3 and Y_4. X_1, X_2, X_3 and X_4 are located approximately at $\frac{1}{6D},\frac{2}{6D},\frac{4}{6D} and \frac{5}{6D}$, respectively from the left edge of the specimen. Y_1, Y_2, Y_3 and Y_4 are located at $\frac{1}{6D},\frac{2}{6D},\frac{4}{6D} and \frac{5}{6D}$, respectively, from the top edge of the specimen D is referred to diameter of the specimen.

Figure 8 shows temporal change in height at point X_1, X_2 ,Y_1 and Y_2. The variation is well within ± 30 nm. It should be noted that the measurement uncertainty of the flatness interferometer is ± 31.65 nm Thus, are can conclude that the variation of ± 30 nm can be due to environment and it is well within the measurement uncertainty.

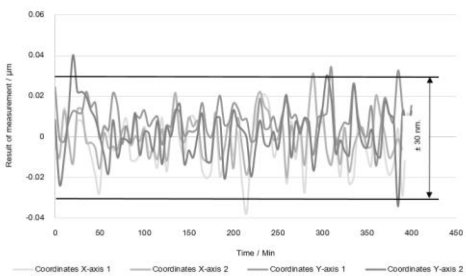


Figure 8 Variation in height at point X_1, X_2, Y_1, and Y_2 of optical flat D

The same experiment was carried out for the optical flat C mounted on three-point type mounting measured flatness value obtained during 70 minutes measurement is show in Figure 9. The variation is observed to be ± 50 nm which is larger than the measurement uncertainty. Thus, it can be concluded that the three-point mounting has some effect to the shape of the specimen.

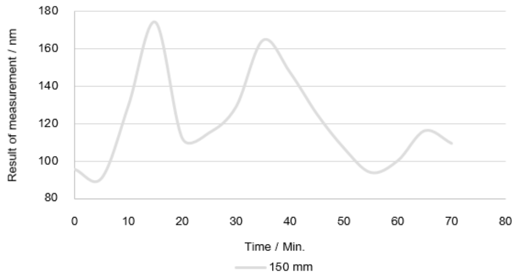


Figure 9 Flatness measure value of 150 mm

The equilibrium time or the resting time required for the optical to stabilize with the clamping force for the optical flat C is approximately 60 minutes (1 hour). For smaller optical flat A and B, the resting time is shorter as show in Figure 10. Figure 10 present the temporal change in height value of point Y_1 of optical flat A, B and C. Optical flat A has the smallest variation an also appeared to reach equilibrium fastest.

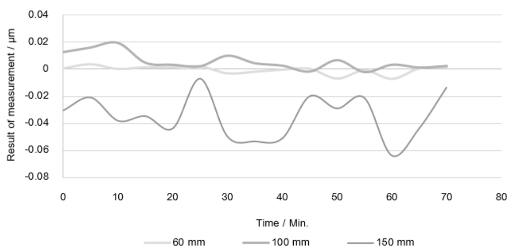


Figure 10 Variation in height at point Y_1 of optical flat A, B and C

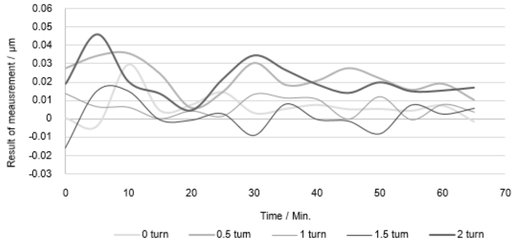


Figure 11 Variation in height at point Y_1 of optical flat at various clamping force

Since the three-point type mounting can adjusted the clamping force by rotating the thread. Each rotation equal to 0.7 mm transition. Figure 11 show the result when the optical flat C mounted on the three-point type mounting with increasing clamping force. The harder clamping force is, the large variation in flatness observed. The clamping force may result to deformation of the optical flat.

Conclusions

Mounting is the key factor that effect flatness quality of the optical flat. Mounting optical flat on the sling type mount shows no requirement of the resting time in order to achieve measurement accuracy of 32 nm. The three-point mounting type requires at least 60 minutes for optical flat to reach equilibrium. The bigger C heavier, specimen, the longer resting time required and the larger variation in measured flatness value.

Acknowledgments

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