Coordinate Measuring Machine thread position measurement analysis

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Abstract. Measuring the true position of a cylinder with a Coordinate Measuring Machine became a simple fact for programmer developer, for this they have to choose between different strategies available on the CMM software to improve measurement accuracy. Everything is changing when we try to measure a true position threaded hole, during serial production this position will pass between some changes that will affect the profile of the thread and the beginning of the threaded hole. Although CMM cylinder strategies methods exist they are not efficiently developed for precise measurement of a thread position. This article will analyse the difference between current methods that are available on the market and will compare the results with an experimental new method, this new method is developed from the method available plus other tools available in the CMM software. The importance of this method is to increase thread position measurement precision during all production cycle time.

1. Introduction

Due to the technological advancement, which accelerates the development of new systems and methods for final product, the design of the finished products has reached a point that increasingly demands for accuracy of the execution and assembly to be better controlled. The impact of these requirements have a direct influence on the development steps of final product that in the end lead to the development of more precise control methods.

Since the final products are made up of assembled parts, by default they will have threaded holes to can facilitate the assembly's processes. The control on the CMM's of these holes is a challenge that increases once with the drawing tolerances. In Automotive Industry we have a variety of parts where we can find more and more threaded holes due to the high machining precision accuracy. The engine blocks can have easily up to 100 threads, or more, that must be controlled during serial production so that the process can be validated and guaranteed.

The current state of the technology offers two different types of approach for this measurement strategy: measuring by using special centering pins and direct measurement on the threaded surface, both types of measurement have pro and cons.

In this article we will present the traditional methods of measurement and a new method developed for the efficiency and accuracy of these types of measurements.

2. Material and methods

For this article we'll use metric threaded holes, this type of thread being the most common thread used in aluminum machined parts that are used in Automotive Industry.

According to the actual level of knowledge, in the measurement process of a thread we always have to take some initial decisions before measuring the threads. Forming threads are cleaner but need to be formed complete and the wear of the tool creates incomplete threads, milling threads have a clear cut true the hole and can present porosity or to have a lot of chips. Threads must be cleaned.

The actual research has a single configuration of the CMM machine so that the results of the measurement to be evaluated only from measurement strategy point of view. The diameter of the probe is very important for thread measurement process. If we use a probe with a small ruby ball we can risk of having measurement errors by not have contact only with the active probe but also with the probe body, if we use a big ruby ball will not be relevant for this research because the focus is to go closest to the pitch diameter.

The tests were made on the same samples threaded holes with the same alignment system and with the same scanning parameters. Our goal is to increase the measurement precision with a combination of parameters that are already available on the software but didn't communicate as a single element.

The tests are divided in four categories, tree of them are traditional measurement methods and the fourth is a combination of all tree initial tests:

2.1. Method 1 (Method 2.1.1 and 2.1.2)

We measure thread True Position (TP) by measuring a cylinder formed by 2 circles.

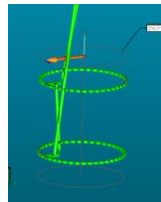*2.1.1. Normal circles.* The 2 circle are scanned at 4 mm between them (figure 1).

Figure 1. Cylinder created from two circles.

2.1.2. Pitch circles. The 2 circle are scanned at 4mm between them and the rotation will follow the thread rotation direction and pitch (figure 2).
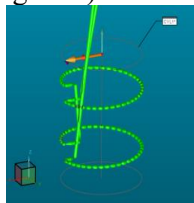

Figure 2. Cylinder created from two circles that are set to have an elliptical move with an increment that follow the pitch of the thread.

2.2. Method 2 (Method 2.2)

We measure thread TP by measuring a cylinder formed by an elliptical revolution. The ellipse will be created from 4 revolutions that will follow the thread rotation direction (figure 3).
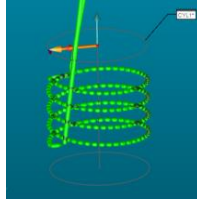
Figure 3. Cylinder created from an elliptical move with an increment that follows the pitch of the thread.

2.3. Method 3 (Method 2.3.1 and 2.3.2)

We measure thread TP by measuring lines.

2.3.1. Cylinder created from 3 lines. The lines will be scanned symmetrical and the length will be the same as in method 2 (figure 4).
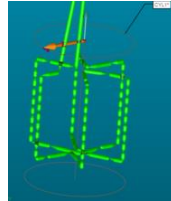

Figure 4. Cylinder created from three symmetric lines.

2.3.2. Cylinder created from 6 lines. The lines will be scanned symmetrical and the length will be the same as in method 2 (figure 5).

Figure 5. Cylinder created from three symmetric lines.

2.4. Method 4 (Method 2.4)

We measure thread TP by combining the methods described above and by applying a combination of data available in the measuring software. The thinking is to create a cylinder (figure 9) that use pitch elliptical revolution steps as in 2.2, the start point of this cylinder is established in 3 steps: (1) we measure a circle like in Method 1 (figure 6) to determinate the center of the thread, next we will create an evaluation line (figure 7) on the length of the cylinder like in Method 3, the linearity evaluation (figure 8) of the line will indicate the pitch start point (4), the last point is established as the start point for evaluated cylinder (figure 9).
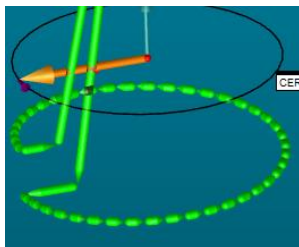

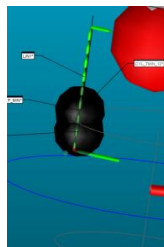**Figure 6.** Step 1 represent the initial circle used to centre the measurement.

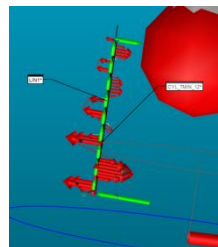**Figure 7.** Steps 2 represent a directrix line of the cylinder.

Figure 8. Steps 3 represent the identification of the pitch diameter.
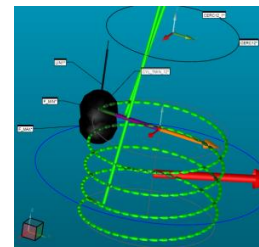
Figure 9. Steps 4 represent the elliptical revolution on the pitch diameter.

3. Results and discussions

The methods described above where evaluated by measuring a device represented in figure 10 that had five M6x1 threads where we measured for tree times same locations.
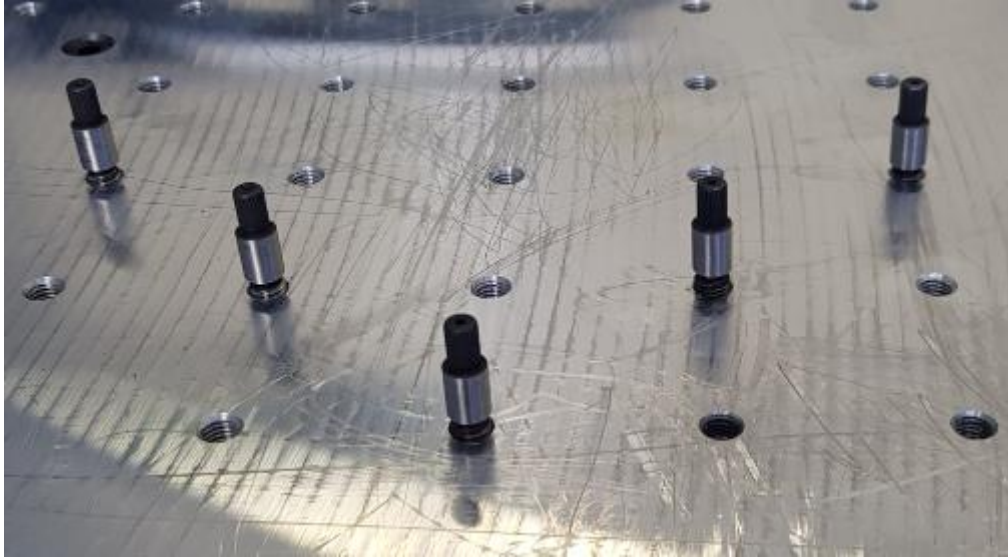

Figure 10. Device used for evaluate measurement strategy.

3.1. Graphic description for each Zone and each Method

The results are presented by centering all the deviations and by marking each method with a unique color presented in figures: 11, 12 and 13.
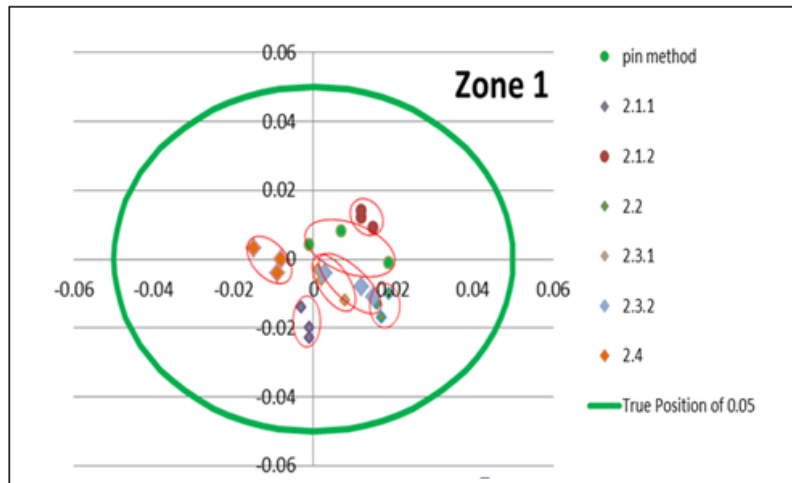

Figure 11. Zone 1 indicate all the measured points deviated from the nominals.
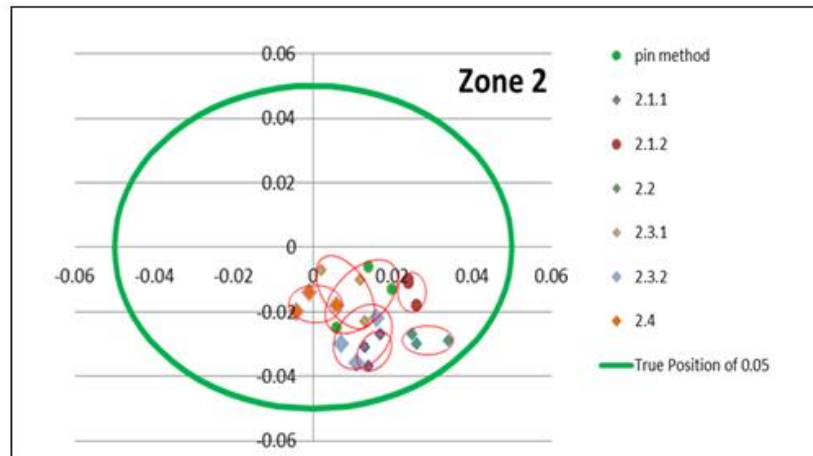
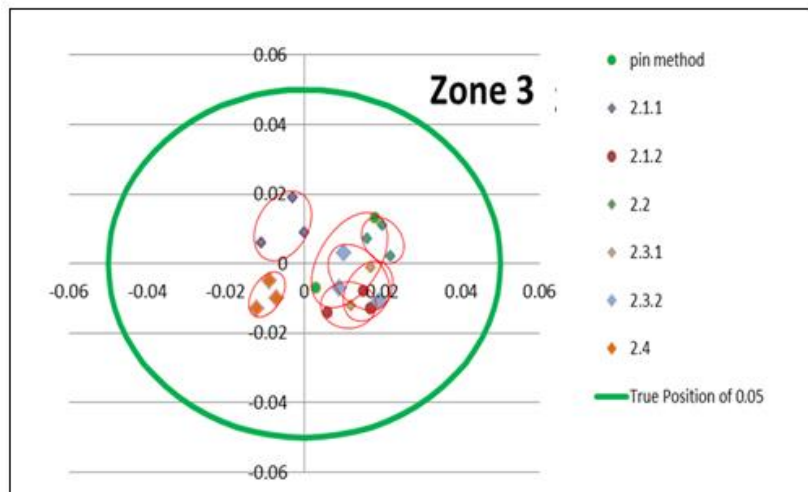**Figure 12.** Zone 2 indicate all the measured points deviated from the nominals.

Figure 13. Zone 3 indicate all the measured points deviated from the nominals.

The results are presented by centering all the deviations and by marking each zone with a unique color and are presented in figures: 14 till 19, figure 20 describe each zone marking color. We used 5 zones to can have a better understanding of the distribution of each measurement.
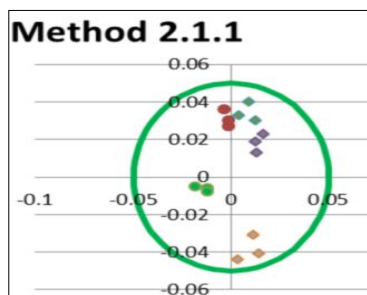

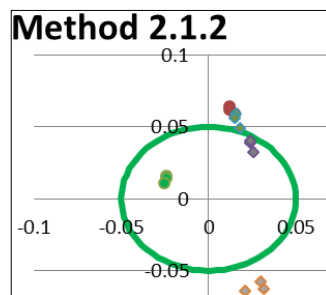**Figure 14.** Measurement dispersion for normal circles.

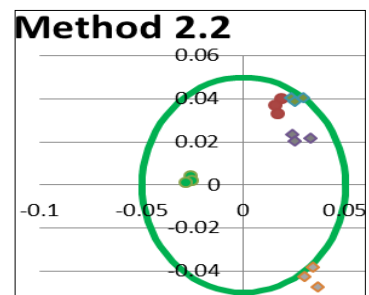**Figure 15.** Measurement dispersion for helicoidally circles.

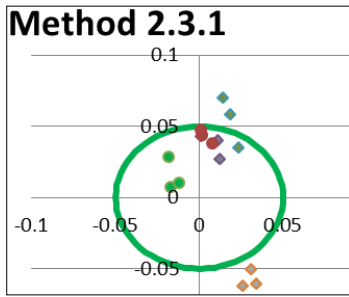**Figure 16.** Measurement dispersion for elliptical cylinder.

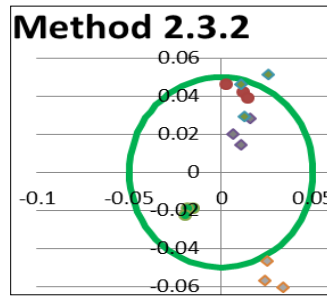**Figure 17.** Measurement dispersion for 3 lines cylinder.

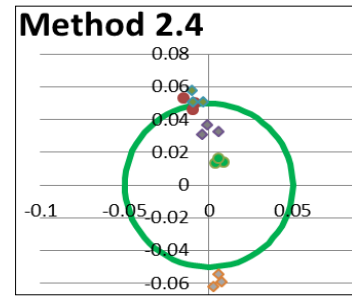**Figure 18.** Measurement dispersion for 6 lines cylinder.

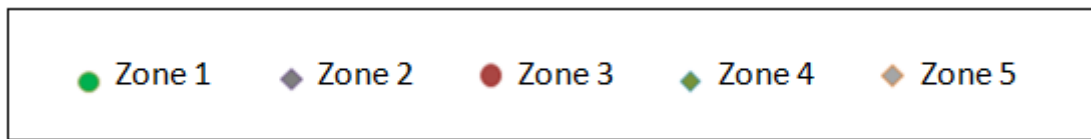**Figure 19.** Measurement dispersion for the new cylinder.

Figure 20. Color legend used to can identify in each Zone de deviations

3.2. Measurement accuracy

The results dispersion from the nominal values shows that each method is located in a different location. This creates a measurement error that influences the results depending on what measurement method was used. The method 2.4 is the most closest to the theoretical values and indicates this for all tree measurement sets.

3.3. Measurement repeatability

The results dispersion graphics made for each method separately identify that even if we use same measurement program the repeatability dispersion exist. The most repeatable methods are 2.1.2, 2.2 and 2.4. We know that all this methods use the spiral measurement strategy with the pitch movement.

4. Conclusions

We start this research with the thinking that the measurements where performed on a part where the machining tool is new, but in serial use, all the tolls will have a cycle time and the measurement must measure in good conditions during all cycle time of the tool.

From the results presented above we have identified that measurements where we use the elliptical revolution movement that follow the pitch step give us the best results. But from our experience we found out that this is not enough, because during the production other factors can influence our surfaces: tool wear, porosity, bad setup between drill ant thread tools, vibrations, etc. This was the start of creating method 2.4 where we are looking to measure always as near as possible the pitch diameter.

Measuring closer to the pitch diameter we'll have, no matter what is the cycle time or the type of the tool, a more accurate measurement then in the other methods. The start of the pitch will constantly be changed during a lifetime of a program, but the measurement program not.

Examples of good and bad surfaces that will have a major impact for each measurement method used are presented in figures 21, 22, 23 and 24.
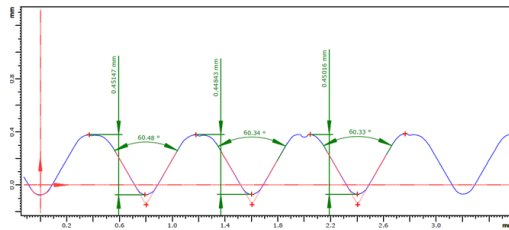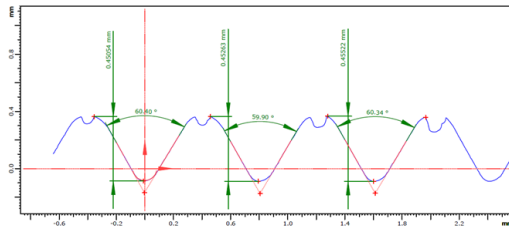
Figure 21. Thread section profile, new tool.

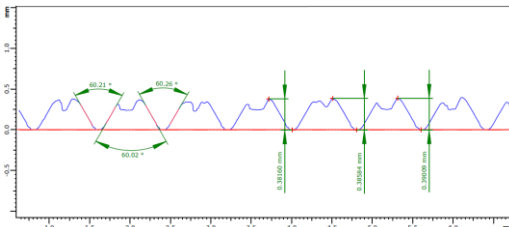
Figure 22. Thread section profile, slightly worn tool.

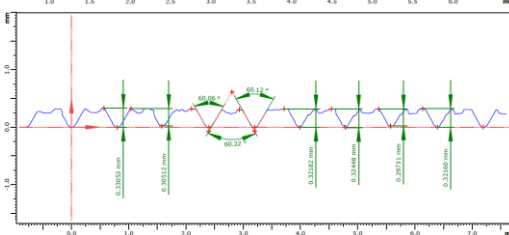**Figure 23.** Thread section profile, hard worn tool.

Figure 24. Thread section profile, damaged tool

References

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[4]   PC-Dmis 2019R1 Help Manual, data:03/2020

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