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MATHEMATICS CONNECTION BETWEEN CMM AND CNC PARAMETER SETUP

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Abstract

The purpose of this article is to establish a new approach for the use of CMM in production serial validation. Even the scope of CMM's is to give results based on drawing requirements, the capability of this measurement system, can ensure with an advanced program development the parameter setup of CNC's during setup or any changeover stages. The preparation and the scope of this development is to analyze the mathematic approach of coordinate systems which must be converted from a static coordinate system to a new system that is changed at every CNC clamping operation and rotation of any axis.

Key words: industry 4.0, CMM measurement strategy, CMM auto setup, interconnectivity

1. Introduction

This article will cover the theoretical basis of the construction and manufacturing technology of complex prismatic parts on computer numerical control machines (CNC) with the assistance during the process of coordinate measurement machine (CMM) [5]. The paper will also focus on exemplification of advanced computational techniques for determining the simulations that are necessary for correcting the machining process [6]. The practical part of this paper consists in the design of mathematic matrix for connecting the measurement report with the CNC part machining positioning so that for each null "0" positioning to be assigned a specific correction by the CMM measurement program [7]. To carry out these calculations, the main characteristics to be followed are defined, the machining process is defined and the types of tests to be carried out are determined [5]. The objective of the research project is to identify the optimal solution for combining the elements of the manufacturing process with the elements of the measurement process.

Thanks to technological advances, product design and development starts with 3D modelling in specialized software. The product model is defined by the customer from a functional point of view and then, depending on the selected manufacturing process, the technological model of the product is developed.

Technological modelling must consider two essential aspects: first, that the manufacturing processes can be feasible and at the same time efficient, and second, that the requirements imposed by the project such as the technical, physical, and mechanical characteristics of the finished part are kept within the agreed tolerances.

To get the product from a finished 3D model to a technical drawing, where we have the dimensions tolerated according to specific requirements, and then to a physical form that respects all these aspects take many hours of development, simulation, and testing. To optimize these testing processes, we have identified the need and opportunity to optimize machining process by introducing CMM into the manufacturing process [6], as an active element, not only to offer the measurement result, but also to adjust the process [11].

2. Material and method

The article is focused on the primary coordinate system "ABC" based on the drawing requirements as in Fig. 1, this alignment system is the main alignment for the CMM and the origin of CNC program. Drawing requirement is to measure the parts in a certain clamping condition as presented in Fig. 2, step that is required only for measurement evaluation of the part, for this the CMM device is constructed to respect drawing requirements and position of the part is aligned to ensure the possibilities to measure all required elements. CNC clamping devices, one for operation "OP10" presented in Fig. 3 and the other for the operation "OP20" presented in Fig. 4 are developed to ensure the fastest and easiest way of machining all required surfaces. Clamping the part on "OP10" is ensured from casting technological references and for "OP20" by the system reference "ABC" elements.

The article will show the transformation of alignment "ABC" that corresponds to CMM axis "XYZ" from the cartesian to homogeneous coordinates. The modification is important for following reasons: First is that CMM give the measurement result on same alignment and use all work planes "X +" and "X-", "Y+" and "Y-", "Z+" and "Z-" this cause dimensions to be with plus or minus regarding to the position of each element positioned in the alignment system. Second is that CNC use machine alignment system and here we can create only one origin for each operation and rotation of the gage. The CNC axis will always have the same "X" and "Z" orientation, but when the part is rotated to be machined the axis must be oriented according to machine axis. "Y" axis of CNC remaining always the tool machining axis [4]. Differences between these evaluations consist in the fact that CMM movement is around the part and all measurement are made by rotating the indexed head of CMM for all needed positions while for CNC the movement of part is given by it's position on the gage, and here we rotate the gage around "Z" axis and in the direction of tool and the tool movement on "X" and "Y" axis [10]. Another aspect is that if we observe the positioning between Fig. 2 and Fig. 3, we can observe that CNC rotation axis around Y axis is made with 57°, this strategical rotation is performed to ensure the machining process for all elements that need to be machined.

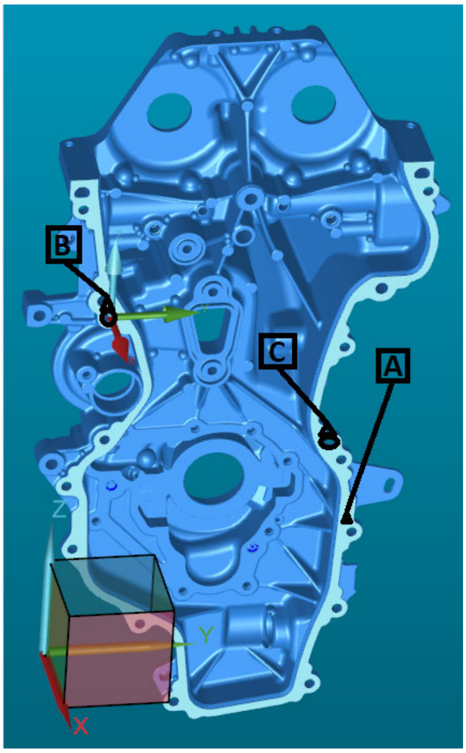


Fig. 1: ABC drawing references = XYZ CMM axis [12].

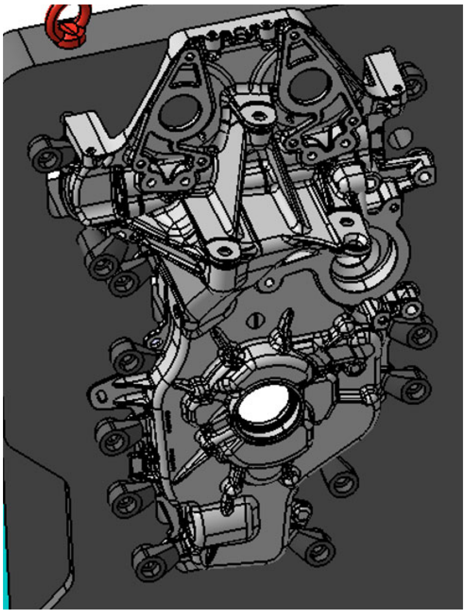


Fig. 2: Clamping estate of part on CMM [12].

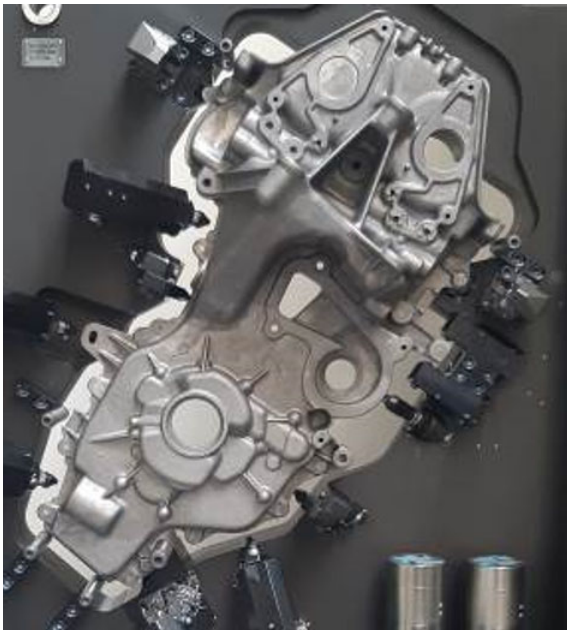


Fig. 3: OP10 positioning [12].

Fig. 4: OP20 positioning [12].

Starting from mentioned points from above we need to start to rotate the CMM "XYZ" coordinate alignment system to correspond to CNC "XYZ" alignment of each position that need to be machined. The rotation that are needed are for all axis, and to do this we'll use the translation and rotation of the axis to the coordinate origin. The corresponding transformation matrix is calculated as in matrix 1, where (a0, b0, c0) are the coordinates of Origin center point "0".

The matrix presented in equation (1) is applied for all rotations that are needed and for these rotations we have the results presented in relations (2), (3) and (4) [1], [2].

$$T(x_1, y_1, z_1) = \begin{bmatrix} 1 & 0 & 0 & -a_0 \\ 0 & 1 & 0 & -b_0 \\ 0 & 0 & 1 & -c_0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

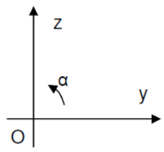
$$T = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\alpha) & -\sin(\alpha) & 0 \\ 0 & \sin(\alpha) & \cos(\alpha) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} = RX(\alpha) \quad (2)$$

$$T = \begin{pmatrix} \cos(\alpha) & 0 & \sin(\alpha) & 0 \\ 0 & 1 & 0 & 0 \\ -\sin(\alpha) & 0 & \cos(\alpha) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} = RY(\alpha) \quad (3)$$

$$T = \begin{pmatrix} \cos(\alpha) & -\sin(\alpha) & 0 & 0 \\ \sin(\alpha) & \cos(\alpha) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} = RZ(\alpha) \quad (4)$$

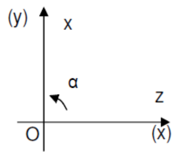
3. Results

The applied matrix presented at (2), (3) and (4) will become equations presented in Fig. 5, Fig. 6 and Fig. 7, [1], [2].



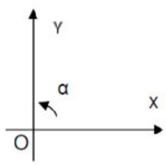
$$x' = x; \quad y' = y*\cos(\alpha) - z*\sin(\alpha), \quad z' = y*\sin(\alpha) + z*\cos(\alpha);$$

Fig. 5: For rotation around X axis



$$z' = z*\cos(\alpha) - x*\sin(\alpha), \quad y' = y; \quad x' = z*\sin(\alpha) + x*\cos(\alpha);$$

Fig. 6: For rotation around Y axis



$$x' = x*\cos(\alpha) - y*\sin(\alpha), \quad y' = x*\sin(\alpha) + y*\cos(\alpha); \quad z' = z;$$

Fig. 7: For rotation around Z axis

To obtain rotations that are needed for CNC alignment axis we need to start for clamping operation "OP10" with the rotation of "Y" axis with 90°, then rotation of "X" axis with 90° and again once more a rotation around "Y" axis with 57°. With all these rotations we are positioning in first rotation gage position that will be machined. From Table 1 to Table 4 we can observe the modifications of coordinates between all these rotations. Table 4 represent the coordinates mentioned in CNC program that are used during machining to perform the drilling operation. The clamping gage rotate from this position around CNC "Z" axis with 180°, 75° and 127°. Table 5 and Table 6 give the same example as in Tables 1 to 4 with the mention that all translations are made as presented in these tables plus one additional rotation of 180° presented in Table 6.

Table 1: Drawing nominal examples.

CMM and Drawing coordinate			
Nominal	X	Y	Z
Circle 1	0.00	-24.00	-10.70
Circle 2	0.00	-10.00	-117.80
Circle 3	0.00	77.00	8.00

Table 2: Rotation around Y axis.

Y axis rotation with 90°			
Nominal	X	Y	Z
Circle 1	-10.70	-24.00	0.00
Circle 2	-117.80	-10.00	0.00
Circle 3	8.00	77.00	0.00

Table 3: Rotation around X axis.

X axis rotation with 90°			
Nominal	X	Y	Z
Circle 1	-10.70	0.00	-24.00
Circle 2	-117.80	0.00	-10.00
Circle 3	8.00	0.00	77.00

Table 4: Rotation around Y axis.

Y axis rotation with 57° (33°)			
Nominal	X	Y	Z
Circle 1	14.300	0.00	-22.045
Circle 2	-55.772	0.00	-104.242
Circle 3	-60.221	0.00	48.647

Table 5: Drawing nominal examples.

CMM and Drawing coordinate			
Nominal	X	Y	Z
Circle 4	0.000	162.380	58.750
Circle 5	0.000	126.97	71.00
Circle 6	0.000	68.10	71.00

Table 6: Rotation around Z axis.

Z axis rotation with 180°			
Nominal	X	Y	Z
Circle 4	104.186	0.000	137.710
Circle 5	67.817	0.000	128.698
Circle 6	18.444	0.000	96.636

To obtain rotations that are needed for CNC alignment axis for clamping operation "OP20" we need to rotate only around "Y" axis with 90° to be in device alignment, and then to be in all positions that are needed to be machined around "Z" axis with 82°, 180° and -90°.

4. Discussion

The present article is part of a PhD thesis which will try to align all these aspects to meet the needs of manufacturing processes in the phase of checking the manufacturing flow, adjusting deviations, or changing processes from one reference to another.

Modelling and correlation of coordinate systems, resulting from measurements on the CMM, with the coordinate systems of the CNC are the elements that we want to simulate by analyzing the measured results transposed into the manufacturing flow parameters for program adjustments during setup or changeovers on the process [8].

All results are evaluated by the CMM in the impose measurement strategy, were we need to clamp the part as described in Fig. 8 and illustrated in Fig. 9.

The values that are presented as drawing require are used to create the "Measurement protocol", protocol that is used to validate the parts true PPAP (Part Production Approval Process) validation steps, next the client validates the parts and the process true the measurement report and true tests that are described in PPAP documents. Now we use all this approved data to improve the CNC setup and changeover process by inputting true CMM program the new strategy approach.

- BR10 TIGHTENING PROTOCOL ON 3D MEASUREMENT ASSEMBLY

1- PINING THE 12 SCREWS (A) AND 3 SCREWS (B)
2- TIGHTEN THE 3 SCREWS (B) INTO
ORDER INDICATES: 1-2-3
3- TIGHTEN TO THE COUPLE THE 12 SCREWS (A) IN
the ORDER INDICATES: 4-5-6-7-8-9-10-11-12
13-14-15

Fig. 8: Clamping order for CMM measurement [12]

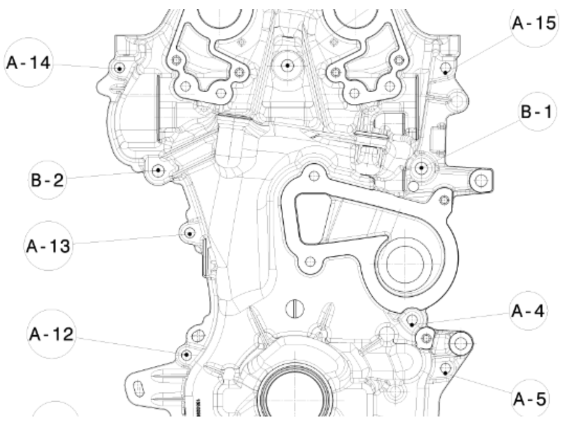


Fig. 9: Clamping ID illustration example [12]

5. Conclusions

The results obtain by this article give the possibilities to enlarge the CMM capacity and the automation of processes to obtain more potential with this approach [6]. Starting from this idea the concept was developed to give 2 types of result, one as the result are required from drawing specification, and the other as CNC program need to be corrected at all rotation and clamping estate.

With the proper CNC correction report given by CMM the machine setuper technician doesn't need to elaborate a strategy to correct the program and all result are presented to him.

Furthermore, the CNC program parameter can be developed to receive the data and to input automatically into variable program all correction given by CMM, and the values to be received via intranet to the CNC or by copy the correction parameters setup program given by CMM [8].

To increase the measurement precision, we can conduct another development of this article based on analyzation and integration of geometric errors given by practical fact that for CNC there are 3 linear guideways with 6 motion errors influenced by accelerations and braking, including 3 translation and 3 angle errors [9].

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