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ANALYSIS OF CLAMPING EFFECT IN HMF CONNECTOR MEASUREMENT

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Abstract

This paper focuses on the influence of HFM connector clamping quantification in evaluating the concentricity of internal contact against the external rosette in Automotive. The experiment was conducted in an accredited laboratory of a company that manufactures HFM connectors. The measuring devices used in the experiment were a VERTEX 311UM (3D coordinate measuring machine) and a Keyence VHX-5000 (digital microscope). This kind of concentricity check is implemented very often due to frequent customer complaints. Due to capacity reasons, the measurement is carried out by two different devices with two different operators. In order to determine the capability of each process and to evaluate it correctly, it is also necessary to know the effect of clamping and the measurement uncertainty. Determining the measurement uncertainty is also a guarantee that the measurement result is reliable. Through this processing, the influence of unstable connector clamping on the measurement result using the Keyence VHX-5000 was revealed and subsequently eliminated. This benefit is best demonstrated in the data obtained.

Keywords: measurement uncertainty; clamping; CMM ; digital microscope

1. Introduction

The automotive industry is one of the most competitive sectors in the engineering industry. Companies are constantly striving to prove their good reputation. For this reason, progressive technologies, product features and customer service are constantly being developed. While the information and telecommunication industry deals with life cycles of 0.5 to 3 years on average, the automotive industry designs its products with a life cycle of 6 to 10 years. Accurate measurement is an essential prerequisite for improving the quality of production in the automotive industry and is one of the fundamental ways of obtaining quantitative information about the variable under study. It has become an essential prerequisite for trust in the exchange of goods and is also one of the important conditions for efficient production. The experiment was carried out in an accredited laboratory. [1], [2], [3]. The entire research was carried out in an accredited laboratory of a company producing cable harnesses for the automotive industry. The company is certified according to IATF 16 949. The IATF 16 949 standard for the automotive industry clearly states that if a customer requires a manufacturer to take a measurement of one of the final products, the manufacturer is obliged to take the measurement.

If the conditions are not adequate, the manufacturer is obliged to provide a suitable alternative. The requirements for product accuracy are constantly increasing, especially in the automotive industry. It is therefore becoming essential not only to ensure the production of accurate dimensions, but also to control them by ensuring a reliable and competent measurement process. In practice, however, not only this fact but also time plays a role. The customer has clear requirements for product quality. Within the framework of IATF 16 949, he can obtain, and in most cases requires, proof of the dimensional accuracy of the required product. Due to frequent complaints, the company's customers have requested a concentricity check of the HFM connector. This parameter affects the assembly of the harness into the car. Failure to comply with the required concentricity may result in incorrect assembly or damage to the counterpart inside the car. The company has been forced to ensure regular inspection of the supplies. Therefore, there was a need to ensure the correct procedure, measurement and clamping strategy for this product. [3], [4], [5]

Two different measuring devices are used to measure HFM alignment (Micro-VU's VERTEX 311 UM coordinate measuring machine, KEYENCE VHX digital measuring microscope). Each device has its own measurement procedure, which will be briefly introduced in the following sections. To ensure the correct procedure and strategy, repeated measurements were performed and the measurement uncertainty was calculated. However, the results varied from device to device. Why? It was necessary to determine the cause of the unstable measurements.

2. Product characteristics

The HFM connector is part of a bundle of high-frequency cables used for high-speed data transmission in automobiles. HFM is capable of transmitting large amounts of data in a relatively short time. These harnesses are used for communication between, for example, sensors and the car control unit. These harnesses are produced in different variants and lengths according to the application and the needs of the end customers. The HFM connector itself consists of an internal two-segment contact, an insulator and an external rosette. The two segment contact is connected to the inner conductors of the cable by a crimp joint. Then the outer rosette together with the insulator is fitted onto the inner contact and crimped onto the outer sheath of the cable. Both components (inner contact and outer rosette) are made of spring bronze. The coefficient of thermal expansion of this material is α = 0,000018mm.

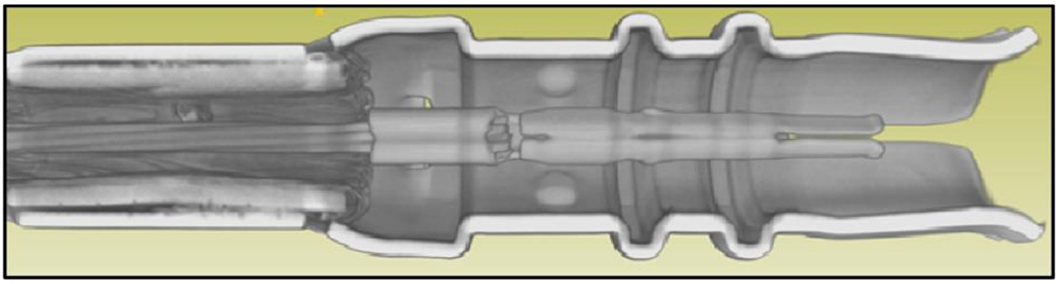

Fig. 1. Ilustrative example CT scan - longitudinal cut through the HFM connector

3. CMM – Vertex 311UM

The Vertex 311 UM coordinate measuring system is used for dimensional inspection of products. The principle of the Vertex 311 UM is to scan the part to be measured with a CCD camera and then measure it on the captured image. The machine contains a precision electromechanical table that sends X, Y, Z coordinates to the measuring software. If the table moves, the linear encoder sends the position change information to the computer. [6]

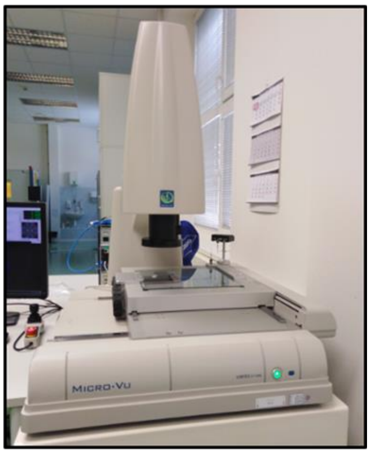

Fig. 2. CMM - Vertex 311UM

3.1. The measuring procedure

The clamping of the FHM connector is carried out with a steel vise with prismatic jaws supported by steel gauges in the case of measurements with the Vertex 311 UM measuring instrument to prevent the sample from being affected by the bending of the cable. Tightening of the sample must be gentle to avoid damaging the crimp joint and consequently damaging the sample.

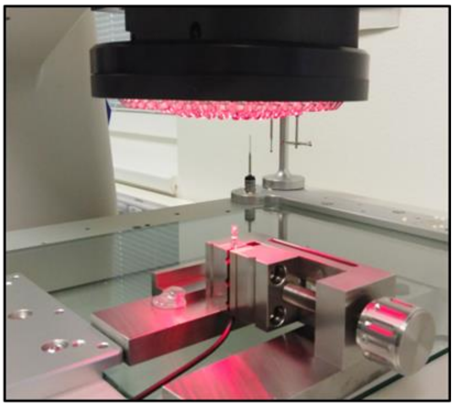

Fig. 3. Clamping of the connector

The actual measurement is performed using the corresponding program created with the InSpec software. The first step of the program is to enter a starting point, in this case a circle, which is taken in manual mode. This circle defines the zero point of the coordinate system for the X and Y axes. Once the starting circle is removed, the machine switches to CNC mode. The next step is to scan the plane at the top of the outer rosette to determine the Z-axis zero point. The coordinate system is calculated from all scanned features. Next, each edge of the outer reference circle is scanned to evaluate concentricity (see Figure 4).

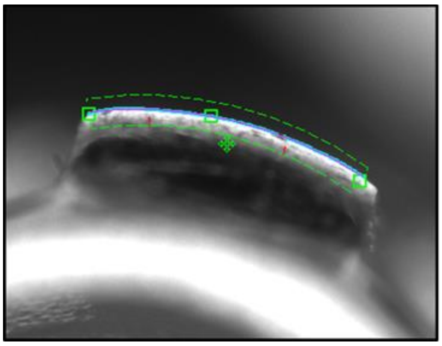

Fig. 4. Segment of the reference circle

The last step is to photograph the leading edges of each segment of the internal contact (Figure 5). A circle is constructed from these segments and then the concentricity to the reference circle is calculated.

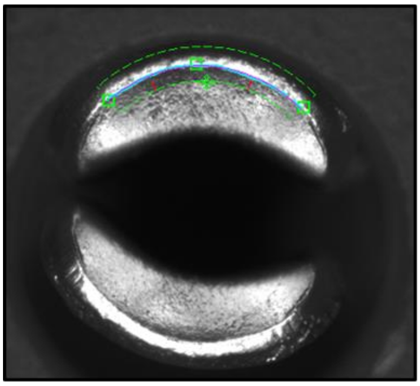

Fig. 5. Segment of the inner circle of contact

3.2. Determination of measurement uncertainty for CMM - Vertex 311UM

The part was repeatedly clamped at each measurement. From these measurements, the uncertainty of the type A measurement was calculated. Other uncertainty components were determined: temperature variation and MPE of the measuring device. The input data and calculations are presented in the tables.

Measured parameter - concentricity - tolerance	0,23mm
MPE (2,6+L/170) µm	(2,6+0,23/170) = 2,6 µm = 0,0026mm
Temperature in the laboratory	23°C
Temperature fluctuations	2°
Coefficient of thermal expansion α spring bronze	0,000018mm

Table 1. Input data

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0,113mm	0,119mm	0,103mm	0,110mm	0,110mm	0,110mm	0,112mm	0,112mm	0,118mm	0,118mm

Table 2. Measured values (10 repetitions)

Systematic error at 23°C	$\Delta L_{20°C} = \propto \cdot \Delta T$	L=0,000018*3	0,00001242mm
Fluctuation 2°C	$\Delta L_{kol.} = \propto \cdot \Delta T$	L=0,000018*2	0,00000828mm

Table 3. Calculation of the effect of temperature change

Average of measured values	=PRŮMĚR()	0,113mm
Selection directional deviation	=SMODCH.VÝBĚR.S()	0,0048591mm
Average correction to 20°C	$\overline{X\ korigovan\acute{y}} = \bar{X} - L_{20°C}$	0,112mm
$\boldsymbol{u_A}$	$u_A = \mathrm{k_{UA}} \cdot \frac{\mathrm{s}}{\sqrt{\mathrm{n}}}$	0,00154mm

Table 4. Calculation of Type A measurement uncertainty based on repeated measurements

	Zmax	χ	$\boldsymbol{u_{bi}}$	$\boldsymbol{u_{bi}}$
MPE Vertex 311 UM	0,0026mm	1,732051	$u_{bi} = \frac{Zmax}{\chi}$	0,001501111
Fluctuation 2°C	0,00000828mm	1,732051	$u_{bi} = \frac{Zmax}{\chi}$	0,000000478
Calculation of the standard combined uncertainty				
$\boldsymbol{u_y}$	=ODMOCNINA(SUMA.ČTVERCŮ($u_A; u_{bivertex;}\ u_{bikol}$))			0,002148131
Calculation of the expanded combined uncertainty				
U	=2· u_y			0,005mm

Table 5. Calculation of type B measurement uncertainty and expanded combined uncertainty U [8]

The measurement result is with a specified expanded combined uncertainty = 0.112 mm +/- 0.005 mm.

4. Keyence VHX-5000

A digital measuring microscope is a device composed of several components. One of the main parts of the microscope is a fully motorized stage in the X and Y axes. This stage is fully controlled by the microscope operator software. Another integral part of the microscope is the vertically mounted objective. The objectives can be changed directly on the microscope. In this case, a variable magnification objective with a total magnification range of 20x - 200x is mounted on the instrument. Above this interchangeable objective is a high-speed camera with a high resolution of 1600x1200 pixels. This camera transmits the image to the imaging unit, which is also an integral part of the complete measuring microscope set. The entire microscope, including its components, is controlled partly manually and partly digitally via a software interface supplied by the manufacturer. [7]

Fig. 6. Keyence VHX-5000

4.1. The measuring procedure

Measurement of the HFM connector is performed at 50x magnification. The part is clamped with a vise and then placed under the microscope objective. The position of the part should be as close as possible to the centre of the field of view of the objective and perpendicular to the objective.

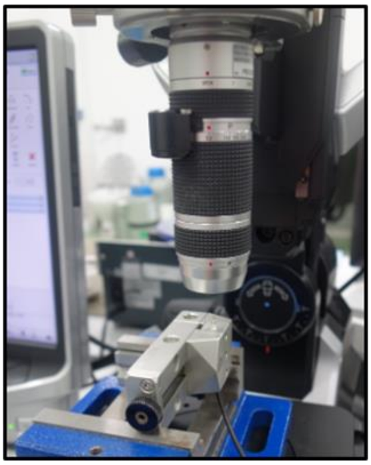

Fig. 7. Clamping of the connector

After the object to be measured has been located and photographed, a reference circle on the outer edge of the connector and an inner circle on the leading edge of the contact are captured with the measuring tool. The circles are captured manually using three points. The KEYENCE VHX-5000 cannot automatically evaluate the geometric concentricity tolerance, but only the distance of the centers of the circles. It is therefore necessary to convert the center distance to concentricity (concentricity = 2* measured center distance of the circles). A graphical representation of the measurement is shown below (Figure 8).

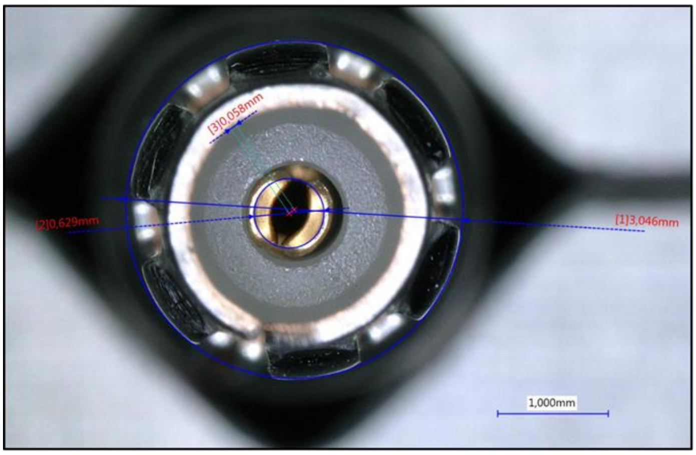

Fig. 8. Graphical representation

4.2. Determination of measurement uncertainty for Keyence VHX-5000

The part was repeatedly clamped at each measurement. From these measurements, the uncertainty of the type A measurement was calculated. Other uncertainty components were determined: temperature variation and MPE of the measuring device. The input data and calculations are presented in the following tables. Since this equipment can be operated by more than one laboratory personnel, two personnel were selected to make the specified measurements independently and the uncertainty was then calculated for each of them so that they could be compared with each other.

Measured parameter - concentricity - tolerance	0,23mm
MPE (2,6+L/170) µm	0,0038mm
Temperature in the laboratory	23°C
Temperature fluctuations	2°
Coefficient of thermal expansion α spring bronze	0,000018mm

Table 6. Input data

Systematic error at 23°C	$\Delta L_{20°C} = \propto \cdot \Delta T$	L=0,000018*3	0,00001242mm
Fluctuation 2°C	$\Delta L_{kol.} = \propto \cdot \Delta T$	L=0,000018*2	0,00000828mm

Table 7. Calculation of the effect of temperature change

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0,126mm	0,108mm	0,116mm	0,102mm	0,118mm	0,110mm	0,106mm	0,120mm	0,106mm	0,114mm

Table 8. Measured values (10 repetitions) - worker A

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0,142mm	0,112mm	0,102mm	0,134mm	0,116mm	0,130mm	0,124mm	0,128mm	0,142mm	0,104mm

Table 9. Measured values (10 repetitions) - worker B

Average of measured values	=PRŮMĚR()	0,113mm
Selection directional deviation	=SMODCH.VÝBĚR.S()	0,0074863mm
Average correction to 20°C	$\overline{X\ korıgovaný} = \bar{X} - L_{20°C}$	0,113mm
$\boldsymbol{u_A}$	$u_A = \mathrm{k_{UA}} \cdot \frac{\mathrm{s}}{\sqrt{\mathrm{n}}}$	0,00237mm

Table 10. Calculation of Type A measurement uncertainty based on repeated measurements - Worker A

Average of measured values	=PRŮMĚR()	0,123mm
Selection directional deviation	=SMODCH.VÝBĚR.S()	0,0144852mm
Average correction to 20°C	$\overline{X\ korıgovaný} = \bar{X} - L_{20°C}$	0,123mm
$\boldsymbol{u_A}$	$u_A = \mathrm{k_{UA}} \cdot \frac{\mathrm{s}}{\sqrt{\mathrm{n}}}$	0,00458mm

Table 11. Calculation of Type A measurement uncertainty based on repeated measurements - Worker B

	Zmax	**χ**	$\boldsymbol{u_{bi}}$	$\boldsymbol{u_{bi}}$
MPE Keyence VHX	0,0038mm	1,732051	$u_{bi} = \frac{Zmax}{\chi}$	0,002193931
Temperature fluctuation 2°C	0,00000828mm	1,732051	$u_{bi} = \frac{Zmax}{\chi}$	0,000000478
Calculation of the standard combined uncertainty				
u_y	=ODMOCNINA(SUMA.ČTVERCŮ($u_A; u_{bivertex;} u_{bikol}$))			0,003227662
Calculation of the expanded combined uncertainty				
U	=2· u_y			0,007mm

Table 12. Calculation of type B measurement uncertainty and expanded combined uncertainty U - worker A [8]

	Zmax	χ	u_{bi}	u_{bi}
MPE Keyence VHX	0,0038mm	1,732051	$u_{bi} = \frac{Zmax}{\chi}$	0,002193931
Temperature fluctuation 2°C	0,00000828mm	1,732051	$u_{bi} = \frac{Zmax}{\chi}$	0,000000478
Calculation of the standard combined uncertainty				
u_y	=ODMOCNINA(SUMA.ČTVERCŮ(u_A; $u_{bivertex;}$ u_{bikol}))			0,005078935
Calculation of the expanded combined uncertainty				
U	=2· u_y			0,011mm

Table 13. Calculation of type B measurement uncertainty and expanded combined uncertainty U - worker B [8]

The measurement result of operator A with the specified expanded combined uncertainty =0.113mm +/- 0.007mm. The measurement result of operator B with the specified expanded combined uncertainty is 0.123mm +/- 0.011mm.

5. Conclusion

This paper focused on determining the effect of clamping quantification for concentricity measurements of HFM connectors in an accredited laboratory using non-sensitive measurements. This type of inspection is common due to the nature of manufacturing and the proliferation of customer complaints. Therefore, the requirement to verify the measurement system using. With the Vertex 311UM measuring device, the result obtained was expected, however the difference in the measurement results obtained with the Keyence VHX-5000 when changing the operator is already apparent at a glance. The result obtained with operator A is 0.113 mm +/- 0.007 mm. The result obtained with operator B is 0.123 mm +/- 0.011 mm. Analysis of the measuring system due to differences between operators A and B revealed a significant proportion of unstable part clamping increasing the measurement uncertainty. This analysis including clamping optimization and subsequent verification will be part of further research.

6. Acknowledgments

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