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THE INFLUENCE OF THERMAL DEFORMATIONS OF MICROMETERS AND DIAL INDICATORS OVER THE PRECISION FOR PRODUCT QUALITY MEASUREMENT

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Abstract: *Measurement devices like micrometers and dial indicators are in general used in machining production, which is a process that involves heat release during operation. Taking in consideration that temperature is influencing the dimensions, in the paper are presented the simulated results obtained with the finite element method for the thermal deformation variation of the above instruments and based on them introducing a set of instructions that must be used in choosing any measuring instrument for a specific product.*

Key words: *micrometer, dial indicator, finite element, product quality control, thermal deformations.*

1. Introduction

Micrometers and Dial indicators are devices used for dimensional and geometrical control deviation, due their nature are not highly productive or economical and the operator using them must have a specific training [5].

Measuring with accuracy, down to micron and in challenging environments can be sometimes very expensive, reason why mistakes in the choice of instruments used are not allowed and dealing with compatibility issues will increase the final cost. That’s why choosing the best measurement device for the product must also take in consideration the environment where is used, the number of products that need to be measured during the life of time of the project and return of investment. Most of the measurement devices suppliers have a vast range of products that will suite all customers and all conditions, but customers should always take decisions based on cost, quality and productivity [3].

When it comes to quality assurance, only what is proven or what is provable matters, precision in product quality control demands guarantees regarding the measurements. That’s why simulation is the best way in finding quick, less expensive and reliable data on the measurement device that is planned for the life time of the project [4].

Product quality measurement is a non-productive time which increases the cost of manufacturing, for this reason the process must be limited as much as possible and

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problems with the reliability of measurement instruments could increase the final cost of the product.

Measuring with micrometers and/or dial indicators are not as productive as GO/ NOGO gauges for example, but because these instruments return a value to the operator is imperative to be used for first part verification or machine setting, that's why finding such devices in the production floor of any machining factory is very common [1].

The aim of the paper is to demonstrate that micrometers and dial indicators could have a high impact in production numbers and most important in the product quality, with implications in after sales or customer dissatisfaction.

2. Finite Element Modelling of the Micrometer and Dial Indicator

For companies that want their products to be benchmark, simulation or modelling is a tool that will return the investment from preliminary stages of the project. The benefit is the opportunity to ask questions to the behavior expect from the products and the environments in which they operate. In minutes, designers can look at more combinations of all the variables that compromise the chaos of product development and manufacturing than could ever be evaluated in physical tests.

To reduce the rejected products, manufacturing is constant checking the product in various stages and separate locations. These means the product is checked at different temperatures, which could go as high as 37 °C the temperature of the human hand, for cases when the measurement devices are used near a machine in the production floor for a quick feedback, minimum being the final measurement made on a final product at a temperature of 20±2 °C [2], [9].

For the simulation, the micrometer and the dial indicator, are simulated using the material RP3, which has the chemical composition listed in Table 1 and international equivalence in Table 2.

Catia V5 simulation tool has the next material properties assigned [6], [8]:

- Young Modulus = 2e + 011 [N/m^2] = 2 * 1011 [N/m^2];
- Poisson Ratio = 0.266;
- Density = 7860 [kg/m^3];
- Thermal expansion = 1.17e-005 [Kdeg] = 1.17 * 10^{-5} [1/Kdeg];
- Yield Strength = 2.5e + 008 [N/m^2] = 2.5 * 108 [N/m^2].

Brand and chemical composition for high-speed steel [7] Table 1

Steel brand	Chemical composition, [%]					
	C	**W**	**Cr**	**V**	**Mo**	**Co**
Rp1	0.90÷1.00	9.00÷10.00	3.8÷4.4	2.3÷2.7	≤1.00	5.0÷6.0
Rp2	0.75÷0.83	17.5÷18.5	3.8÷4.5	1.4÷1.7	0.5÷0.08	4.5÷5.0
Rp3	0.7÷0.78	17.5÷18.5	3.8÷4.5	1÷1.2	≤0.6	≤0.6
Rp4	1.17÷1.27	6.0÷6.7	3.8÷4.5	2.7÷3.2	4.7÷5.2	-
Rp5	0.84÷0.94	6.0÷6.7	3.8÷4.5	1.7÷2.0	4.7÷5.2	≤0.6
Rp9	0.95÷1.03	2.7÷3.0	3.8÷4.5	2.2÷2.5	2.5÷2.8	≤0.6
Rp10	0.78÷0.86	1.5÷2.0	3.8÷4.2	1.0÷1.3	8.0÷9.2	≤0.6
Rp11	0.97-1.07	1.5÷2.0	3.8÷4.2	1.8÷2.2	9.0÷9.2	≤0.6

For simulation purposes the diameter to be measured was determined for 9 specific dimensions intervals, from which the most relevant diameter was calculated with relation (1), where D_{min} is the minimal diameter from the group and D_{max} is the maximal one. The intervals and the calculation results are presented in Table 3.

For simulation purposes the micrometer used has a resolution 0.001 mm and accuracy of 0.002 mm that can be used for measuring exterior diameters and the dial indicator used has the resolution 0.01 mm and accuracy of 0.020 mm.

High-speed steel symbols and international equivalence [7] Table 2

SR	**JIS**	**GOST**	**Werkstoff**	**Bohler**	**AISI/SAE**	**UNE**
Rp1	-	-	-	-	-	-
Rp2	SKH3	-	W.1.3255	-	T4	F.5530 18-1-1-5
Rp3	SKH2	R18	W.1.3255	S200	T1	F.5520 18-0-1
Rp4	SKH52 SKH53	-	W.1.3344	S607	M3	F.5605 6-5-2
Rp5	SKH51	(R6AM5) R6M5	W.1.3343	S600	M2	F.5604 6-5-2
Rp9	-	-	W.1.3333	-	-	-
Rp10	-	-	W.1.3346	S401	H41M1	-
Rp11	-	-	W.1.3348	S400	M7	F.5607 2-9-2
Rp10 Sp	SKH59	-	W.1.3247	S500	M42	F.5617 2-10-1-8

$$D = \sqrt{D_{min} \cdot D_{max}} \,. \tag{1}$$

Diameter dimensions intervals Table 3

Diameter [mm]	**Min [mm]**	**Max [mm]**
7.745	6	10
23.237	18	30
44.721	40	50
109.544	100	120
129.614	120	140
149.666	140	160
169.705	160	180

Modelling of the measurement devices are presented below in Figure 1 and Figure 2.

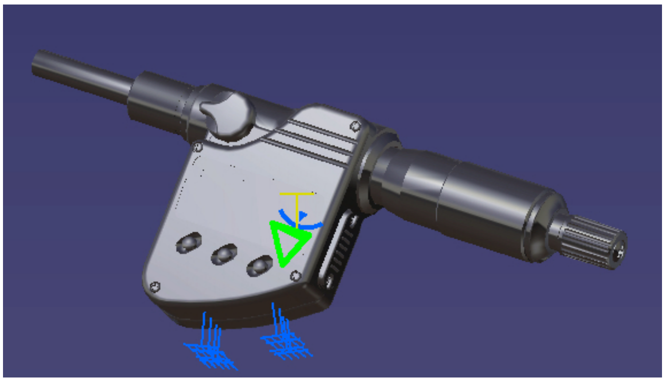

Fig. 1. *Exterior diameter micrometer simulated in Catia V5*

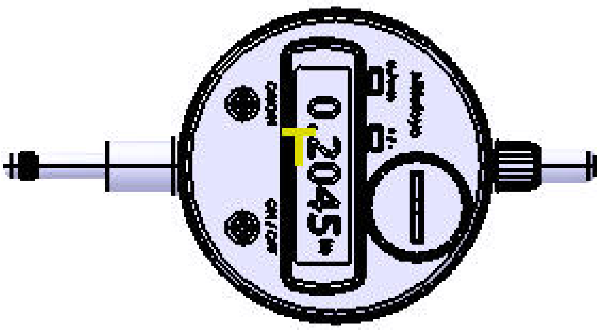

Fig. 2. *Dial Indicator simulated in Catia V5*

Simulation result, with Gauss R6 method, Clamp fixation at a temperature of T_1 = 310.15 °K (37 °C) considering the gauge at a temperature of T_0 = 20 °C, are presented in Figure 3 for Dial Indicator and Figure 4 Micrometer.

The results obtained by modelling and simulating the micrometer and the dial indicator with the finite element method at steady state are presented in Table 4 for Micrometer and Dial indicator.

3. Conclusions

Taking in consideration everything presented in this paper the next conclusions and recommendations could have an impact on any production facility that uses this type of measurement devices:

1. Most production facilities have two separate floors, one for production and one for product quality measurement, where due to legislation might be that temperature is different and even if the operator and the method are the same, it can be seen a different quality control outcome.

2. Depending on the diameter used the expansion due to higher temperature can have values between 0.002-0.034 mm, which can sometimes make the difference between producing a good part or a bad part, by giving wrong input to the setup operator.

Finite element simulation results for micrometer and dial indicator Table 4

Nr. crt.	*D*, [mm]	*t*, [°C]	Thermal expansion for for Dial Indicator, [mm]	Thermal expansion for Micrometer, [mm]
1	7.745	37	0.002	0.002
2	23.237	37	0.005	0.005
3	44.721	37	0.009	0.008
4	109.544	37	0.013	0.018
5	129.614	37	0.019	0.021
6	149.666	37	0.023	0.026
7	169.705	37	0.027	0.031

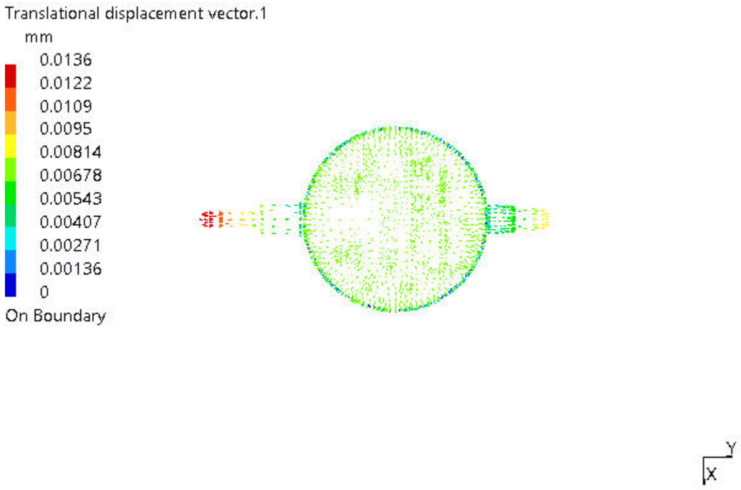

Fig. 3. *Dial Indicator finite element simulation in Catia V5 for diameter no. 4*

3. High precision products are much more affected by temperature expansion then the normal ones and by calculating a breakdown between products, high precision vs lower precision, can raise a business case to improve devices, methods and even the production environment.

4. The cost for the equipment and method used for product quality measurement must be justified and balanced by the precision and productivity of them.

5. The device and method complexity for product quality measurement takes in consideration: productivity, verification cost, but also the qualifications needed by the quality inspector: a higher complexity could mean a simple method and an increased productivity which doesn't necessarily mean a higher qualification for the quality inspector, instead a higher complexity and method means for the quality inspector a higher qualification, which is only justified by a very high productivity.

6.Testing remains the final decision for using the micrometer or the dial indicator, but with upfront environment simulation, the expensive measurement device that is either virtually or physically tested will be the most likely to succeed at that point.

7. Simulation of the workflow enables companies to find the right way to approach the precision problem, and then come up with less expensive products that perform better.

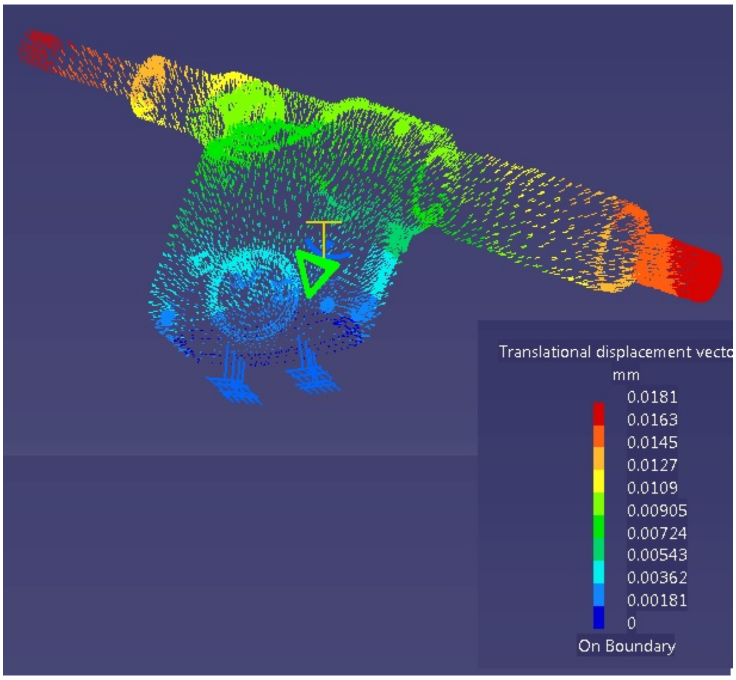

Fig. 4. *Micrometer finite element simulation in Catia V5 diameter no. 4*

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