Determining the causes of the solenoid coils incorrect winding

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Abstract: Accurate placement of the wire is required during solenoid coils winding. Because many incorrectly wound coil were produced on the used winding machine, the analysis of this situation causes were to be realized. The winding machine precision measurement and simulation of the wire winding to the coil composite skeleton are described in this article.

Keywords: solenoid coil; incorrect winding; measurement; FE simulation.

1 Introduction

Accurate placement of the wire is required during solenoid coils winding. It means that the wire turns must be placed side by side, the wires must not be crossed (see Fig. 1). Because used winding machine produced a lot of incorrectly wound coil, the analysis of possible causes was realized. The homing head and coil rotation poor synchronization was the first possible cause of the incorrect winding so the machine precision measurement was first step which was carried. Because the bad winding cause was not revealed by this measurement, the winding process FEM modeling was done in the next step.

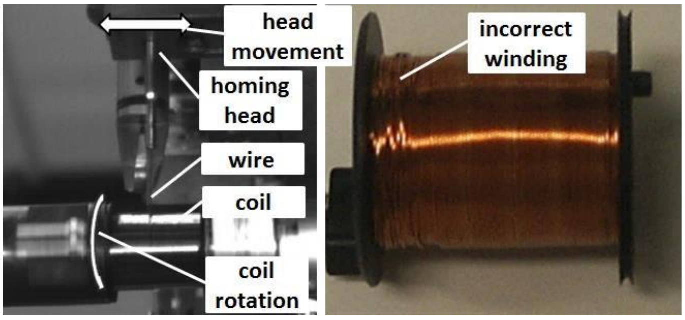

Fig. 1: The winding machine principle (left) and incorrectly wound coil (right).

2 The winding machine precision measurement

Determine of the winding machine synchronization precision was the main measurement task. The measurement arrangement is shown in the Fig.2.

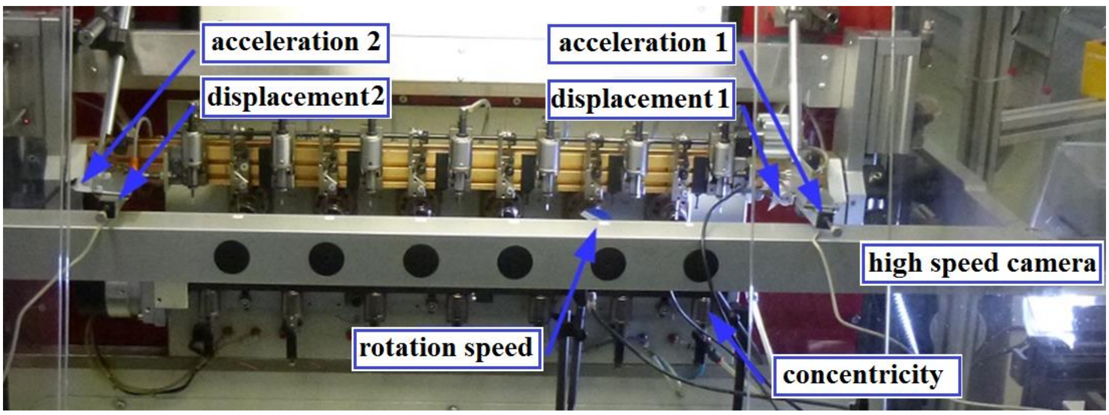

Fig. 2: The winding machine precision measurement.

One of the coils was supplemented by the aperture and rotation speed was measured by the digital laser sensor. Two very precision movement sensors were used for the homing head left and right side movement measuring and its vibrations were measured by two accelerometers as the additional information. One of the coils concentricity was measured by the contactless inductive sensor. The winding process was recorded by the high speed camera too. All sensors signals and the camera movie were synchronized by the Dewe5000 measurement unit [1].

Several cycles with different winding speeds and different head required displacement were measured and no problem with winding machine synchronization and displacement precision was found (see Tab.1).

Tab. 1: The homing head displacement error.

Measurement number	1	2	3	4
required homing head displacement	17.792	17.742	17.692	17.692
measured homing head displacement	17.750	17.693	17.690	17.690
homing head displacement error	**0.042**	**0.049**	**0.002**	**0.002**

The homing head displacement error is not greater than 0.05mm and this value is into the machine declared range. The example of the head displacement with the coil rotation synchronization is shown in the Fig.3.

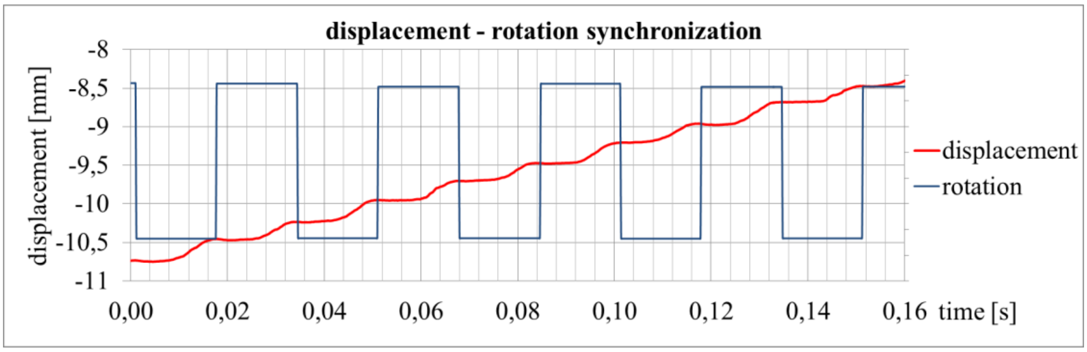

Fig. 3: The head displacement and the coil rotation synchronization.

Each coil turn is represented by one pulse from the digital sensor and regular displacement increment is evident in every step. So, the synchronization of the head displacement with the coil rotation is perfect too. It means that the winding problems are not caused by the imprecise machine function. Nevertheless some coils were incorrect wound during these measurements.

The analysis of video records showed that winding errors always start close to the coil sidewalls and it indicated a potential problem with their stiffness. The sidewall is probably pushed by the wire winding force and the wire is wound into incurred gap instead of the next layer. The homing head position and the coil winding position are out of sync, the wire is not guided perpendicular to the coil axis (see Fig.4) and incorrect winding is caused by them.

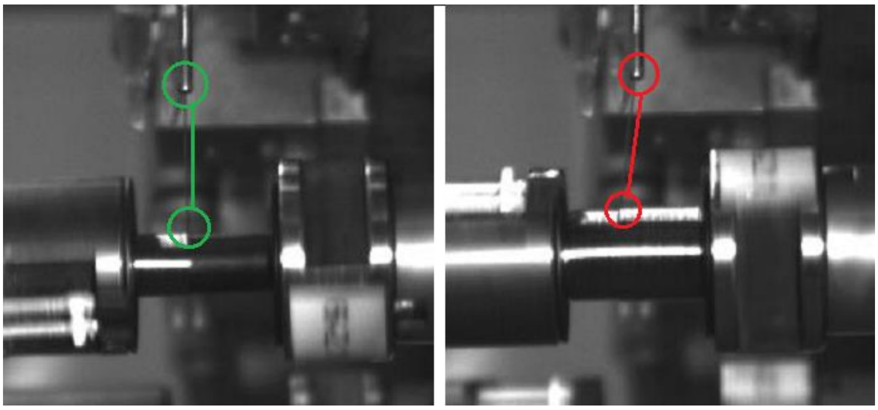

Fig. 4: The head and the coil winding good (left) and bad (right) position.

The coil sidewall dislodging could not be directly measured because no space for the sensor location is in the winding machine. Therefore the winding process was modeled by FEM for this presumption confirmation.

3 The winding process FEM modeling

The Ansys software was used for the winding process modeling [2]. Winding wire was loaded by axial force 20N. Between the wires was set frictional contact. The coefficient of friction was 0,1. Also between the wire and the composite bobbin was set frictional connections 0,1. The wire winding force is forced between the coils and the whole spool (see Fig 3), where the right part of the figure is a mesh and left part - deformation results for the wrap angle of the wire 40°. Maximum deformation is in bend of wire, but through the contact between previous coil and bobbin sidewall makes the deformation of sidewall.

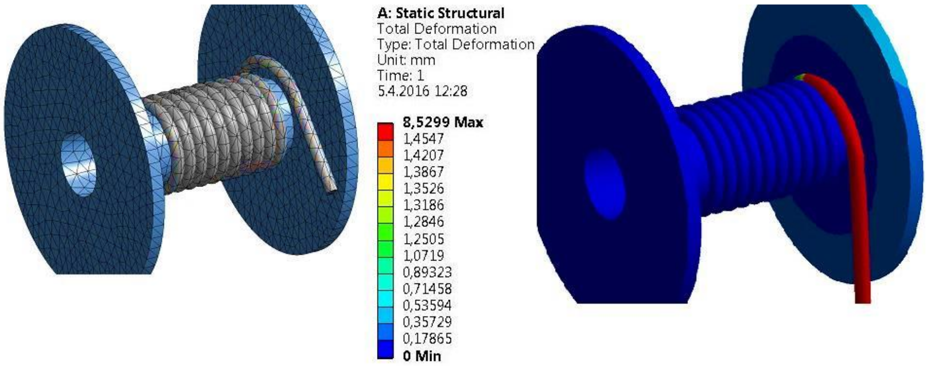

Fig. 3: The winding process FEM modeling net and deformation results.

This deformation makes the stress in wire, also in sidewall of bobbin. On the Fig. 4 is maximal reduced stress in the wire. The wire is during winding bended and tensioned. But this stress is mode bigger than in the side of bobbin. Stiffness of bobbin is too small and sidewall is easy bended. Stress in beginner of winding is given by small diameter of coil on core of bobbin and often make permanent deformation of wire. This is only static calculations; in real the speed has affects on value of stress.

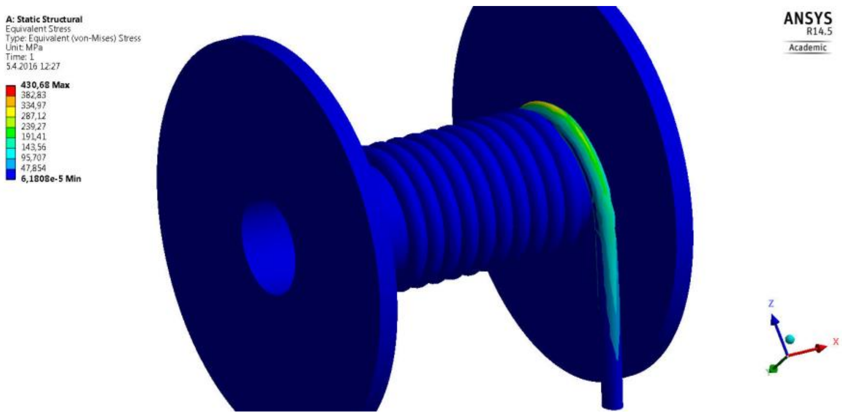

Fig. 4: The winding process FEM calculation of stress HMH.

The following graph (Fig. 5) shows the results of successive static calculations. Calculations were made from the first contact with the face of the coil wire. It was also made of the wire winding 5 degrees. The calculation was deducted deformation forehead and plotted for each angle in the graph.

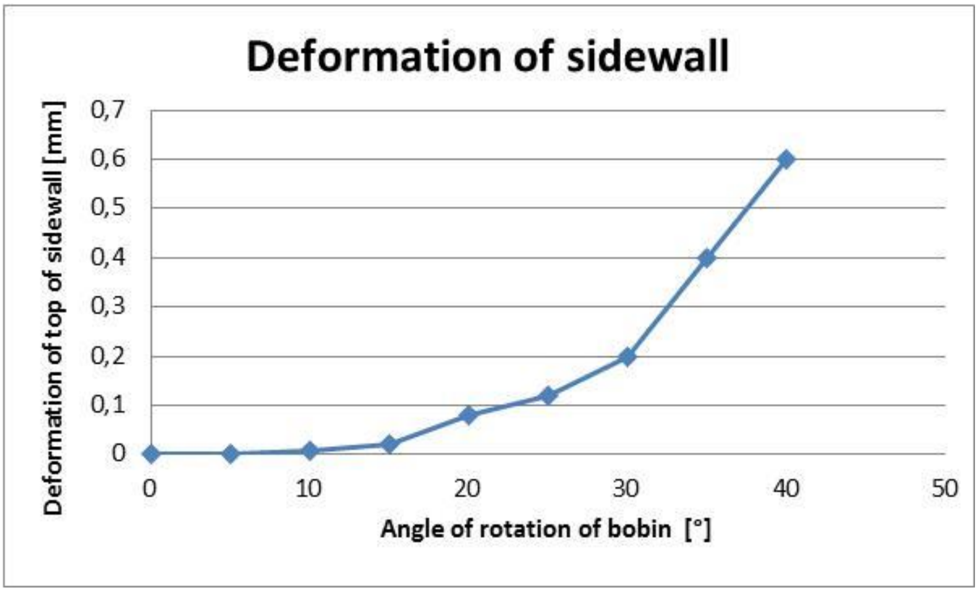

Fig. 5: Deformation of sidewall depending on contact angle.

This effect may or may not always occur. It depends on the position of the rack, on the contact points and the state of the shape geometry of the wire. In practice, the error usually occurred in the fifth layer of coils. The highest cost layer number can cause the greater the probability of errors.

4 Conclusion

The carried measurement confirmed that the winding machine works correctly, all monitored signals are into prescribed accuracy limits. Video records showed problems with the coil sidewalls, their distance increases due to the winding wire tension force. It was confirmed by FEM model, too. The coil body will have to be redesigned (sidewalls thickness increased) for the winding problem solving [3].

Acknowledgement

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References

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