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The System of Measurement for Revealing of Micromovements While Testing of the Thigh Endoprosthesis in the Simulator

The application of the endoprosthesis on the thigh joint is one of the most frequent 10 operations performed in Germany in terms of prothesis [1]. There are a lot of technologies of producing of prothesis, which are different regarding material (alloy) from which the prosthesis is produced. Moreover, the structure of technological process, the ways of processing, using of the equipment, cutting (abrasive) tools and the regime of processing can be different as well.

The components of prosthesis are processed with the help of three axes lathes and 5 axes multitasked processing centers. Depending on regimes of cutting and instrumental material, the samples are received with different parameters of durability and corrosion stability.

Before using of the new material (a new combination of the materials) or a new technology of producing of the artificial thigh prosthesis it is necessary to carry out a great number of the experiments. In the special simulators (figure 1) given cycles of loading are applied to the prosthesis. After that, the durability is measured and the damage of the surface is analyzed.

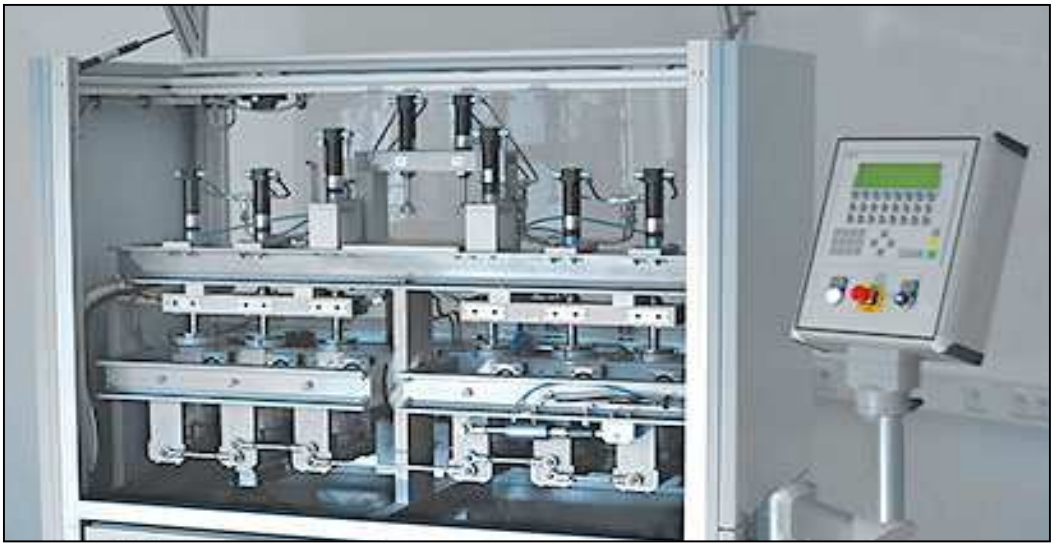


Fig. 1. Walking simulator in Uniklinikum OVGU Magdeburg

The aim and problems of the measurements in the simulator:

- the micromovements are occurred in the head which lead to fretting corrosion and corrosion cleft;

- in order to compare different geometric options of the endoprosthesis such as different sizes of heads and shapes of the cones, it is desirable to have impression about micromovements;

- the exact dependence between the momentum of friction and wearing of the cone is still the subject of the exploration.

All modern thigh prosthesis of the thigh joint are not monolithic, they consist of many parts (figure 2). The standard structure consists of three parts: the rod, the head (ball-shaped) and the cavity.

a b c

Fig. 2. The main components of prosthesis:
а – rod, б – head (ball-shaped), в – cavity

The research must be carried out in the places of joining of the components, because these places are epicenters of destruction and wearing.

The head and the rod are joined with the help of cone connection. The fretting corrosions has the biggest influence on destruction (figure 3). Such kind of wearing occurs at relative moving of surfaces with amplitude from 0,025 mkm [1], which can be explained by destruction of the oxide pellicle in the points of moving contact. It is necessary to measure the values of microscopic relative movements which arise between the head and the rod in the process of cyclic loading in the simulator for defining of the fretting.

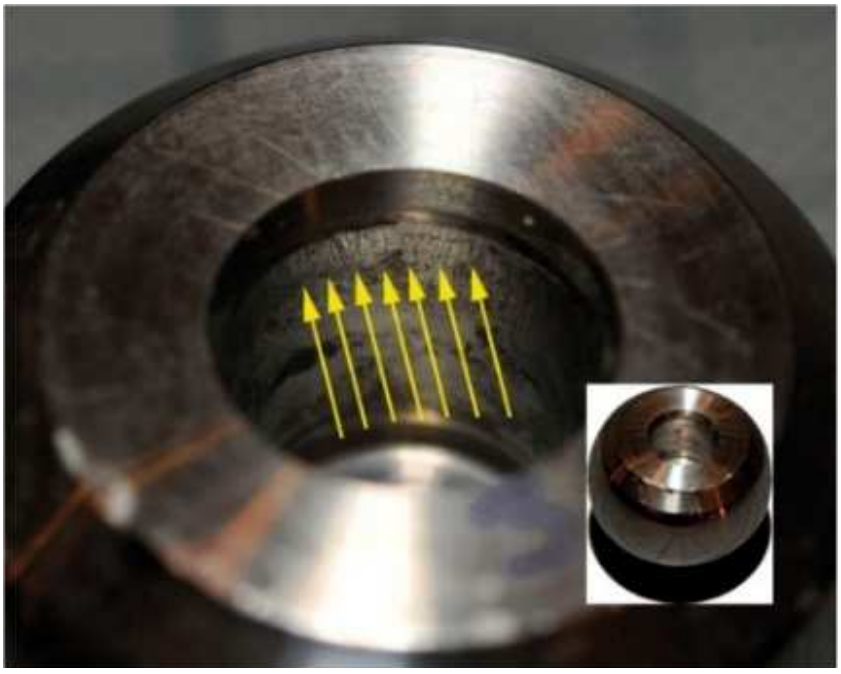


Fig. 3. Visible traces of fretting wearing on the head of the prosthesis

The imperfection of existing measurement systems for defining of influence of outcome factors of technology of producing of endoprosthesis on their durability and longevity is still a problem.

The aim of this work is increasing of the productivity of trials of the endoprosthesis on durability by means of improvement of a sensor system of the simulator.

The construction of the existing analog of the sensor for defining of relative movements is represented in figure 4. Three eddy current sensors are used for the acquisition in the system. Two additional elements are used for fixing eddy current sensors. They are supporting surface and the holder of the sensors.

Some problems arise in the course of exploitation of the experimental samples of this construction:

- the restricted place for the location of the heads of screws in axes and radial directions, which slows down the assembling process;

- demountable fastening of sensors increases the overall dimensions of the system;

- unreliable fixing of the sensors (the sensors can shift in the process of the simulation) considerably increases the error of the measurement.

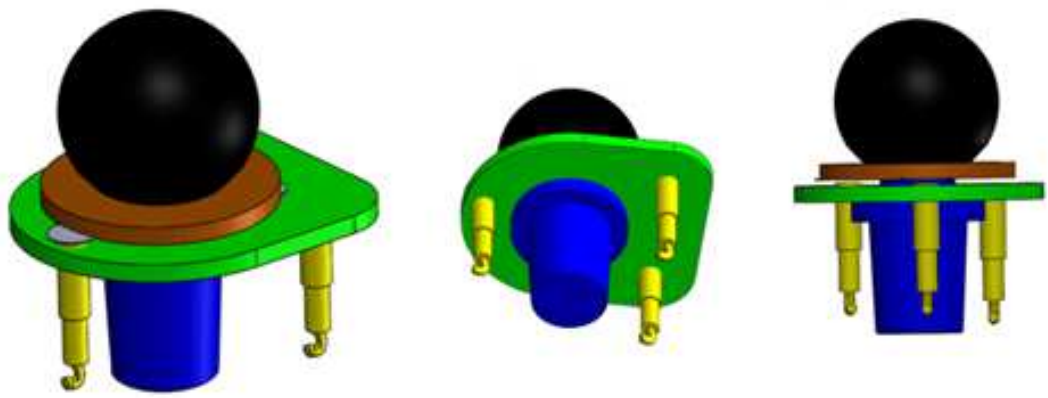
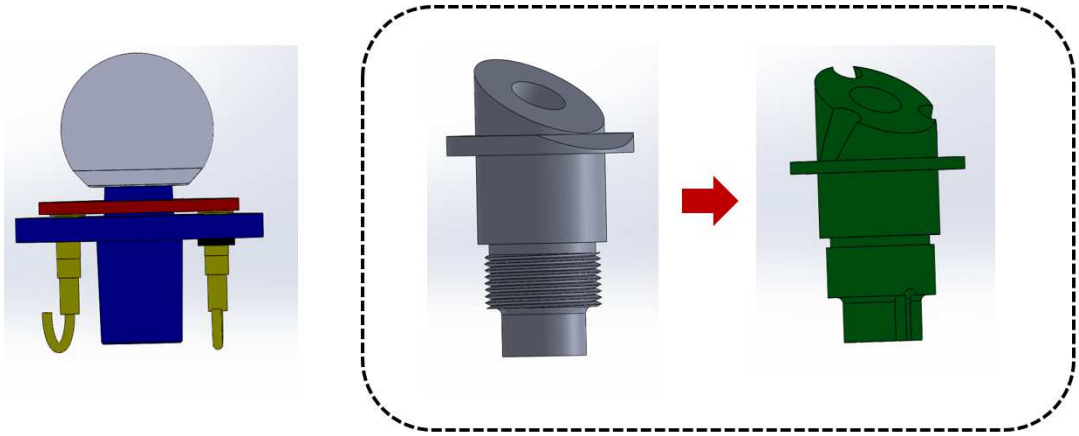


Fig. 4. The existing analog of the construction of the sensor system for defining of relative movements

The sensor system has been offered the authors (figure 5), which has a number of advantages.



a b c

Fig. 5 – The design of the sensor system for the determination of relative displacements
(a – scheme of the sensor system; b – existing analogue of the sensor;
c – the proposed design of the sensor)

The construction suggests only one additional detail, which is simultaneously supporting surface for installation of prosthesis into the simulator and changes the surface of the holder of the cone (figure 5, b). It serves the additional holder for the sensor.

The advantages of the offered construction:

- the structure is simpler. It decreases its cost and time which spends on production of experimental samples;

- it occurs less space in the simulator. This fact considerably makes the process of assembling easier and opens access to its parts. It allows the replacement of the details without dismantling, increases the process of simulation and launching of the production of the prosthesis on the market;

- the cone can be used for producing of “ordinary series of measurements”;

- eliminates the problem of unreliable and non-rigid fastening of the sensor;

- decreases the average error 1,73 times.

This designed sensor system can be used in the process of testing of new materials and combination of the materials, forecasting of longevity of the prosthesis according to the given values of the cyclic loading and combination of the materials of the head and the rod, defining of friction corrosion.

The system of receiving and processing of the signal which consist of the source of the current, the controller, sensors and the receiver (figure 6) is created for assessing and comparing of the accuracy of the measurements.

Fig. 6. Sensor system of receiving and processing of the signal

The program was worked out for the processing the signal and its transformation from analog to digital online. The program is designed in the software of “National instruments” in LabView (figure 7).

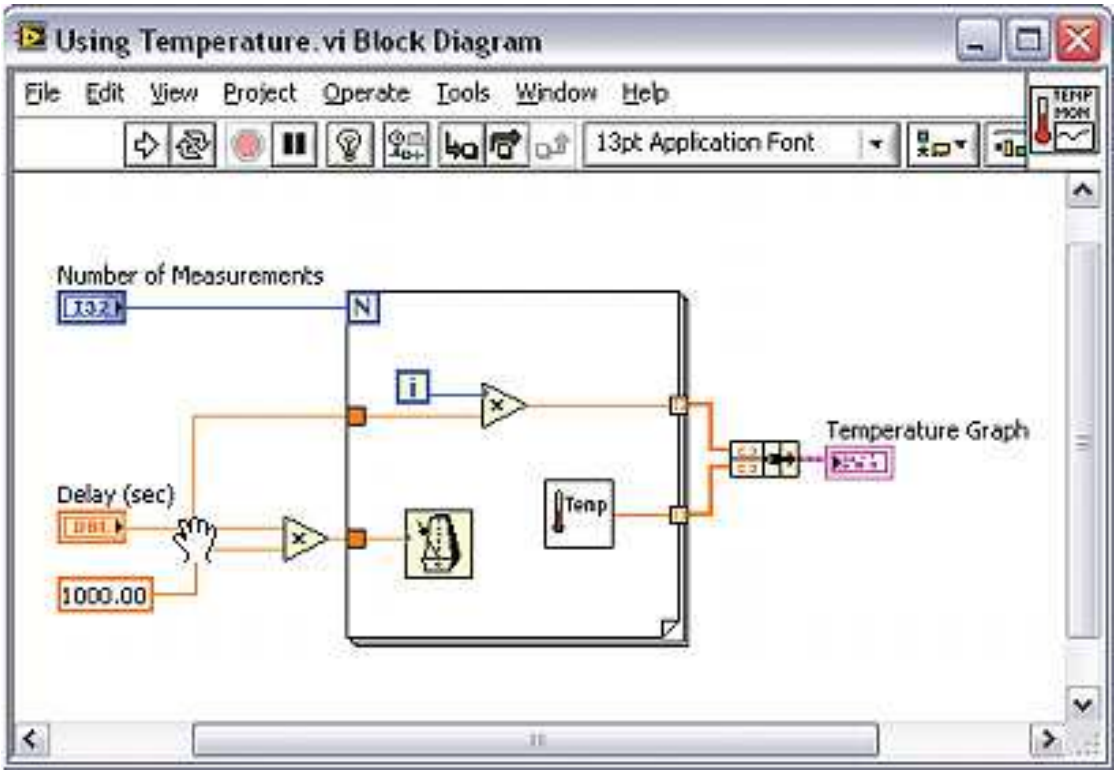


Fig. 7. The program for the processing the signal and its transformation from analog to digital online

Conclusion

The improvement of the sensor system of the simulator of the work of endoprosthesis of the thigh joint allowed to increase the productivity of the trials on durability of the prosthesis and raise the accuracy of the obtained results 1,7 times.

References

1. M. Windler, Korrosionsverhalten von modularen Verbindungen bei Hüftendoprothesen - DISS. ETH Nr. 15284, Zürich: ETH Zürich, Research Collection, 2003.