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Optimal design of 5 axis grinding machine considering wear effects

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ABSTRACT

Grinding machines are normally designed to increase the stiffness of the structure to increase their precision. A key aspect to consider during the estimation of the machine global stiffness are the guiding system where roller linear guides and its preload. The friction forces acting at the rolling linear guides causes wear that changes the stiffness of the machine during its life. A simplified model of the rolling linear guide is proposed and implemented in the vertical movement of a 5-axis gantry type machine and the effect of the wear is analysed over time. As expected, when increasing the preload of the guiding system and the stiffness of the machine, the static stiffness is increased, but on the other hand the friction forces and the wear is also increased, reducing the life of the machine. A procedure is proposed to find an optimal design considering the tradeoff between the stiffness and wear performance of the machine, taking into consideration a reference work cycle and the loads generated by the eccentric mass of the tool axis.

1 METHODOLOGY

The wear evolution and the stiffness of the rolling linear guides has been studied in previous works [1,2] with respect to the running distance. This wear evolution can lead to reduce the guiding system preload and even generate back slash, reducing drastically the machine precision at this point. This evolution has been validated by experimental results, showing a good correlation.

In a first step a global model of the 5-axis grinding machine has been built considering all the elements as rigids, except the horizontal gantry beam.

Additionally, a simplified model of the rolling linear guiding system has been implemented considering an equivalent contact stiffness of the ball and the race and the body stiffness. The model parameters have been calibrated to obtain a similar behavior of the force displacement graph provided by the manufacturer. A wear model of the ball has been implemented based on the Archard wear theory and a Hertz contact pressure estimation. The forces and running distances of each contact are estimated by the multibody dynamic simulation of the whole machine for a reference work cycle.

For each simulation the static stiffness at the beginning of the cycle and the wear estimation is computed in an iterative way until the preload of the guiding system is reached.

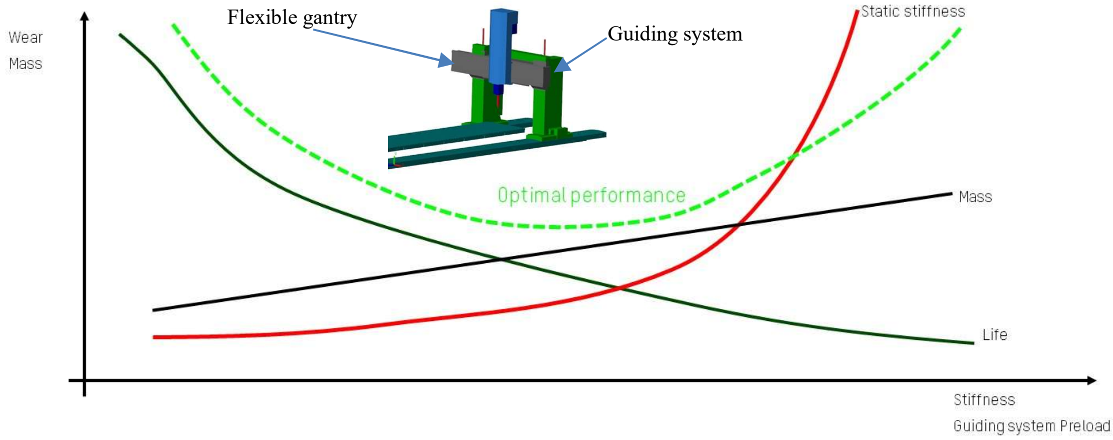

Figure 1. 5-axis machine model and schematic trade off behaviour of the machine

An optimization procedure is then implemented by means of a reduced order model generated by means of a Design of Experiment sampling technique where several performance indicators are estimated, the static stiffness and the cycles to wear.

Different optimization analyses are performed for different scenarios with different optimization criteria.

Given that the development of new precision machines will need to deal with the new requirements of increasing quality and also reducing the environmental impact, this approach helps to define machine design where an optimal compromise between stiffness and wear life of the rolling linear guiding system for the development of the future precision machines.

REFERENCES

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