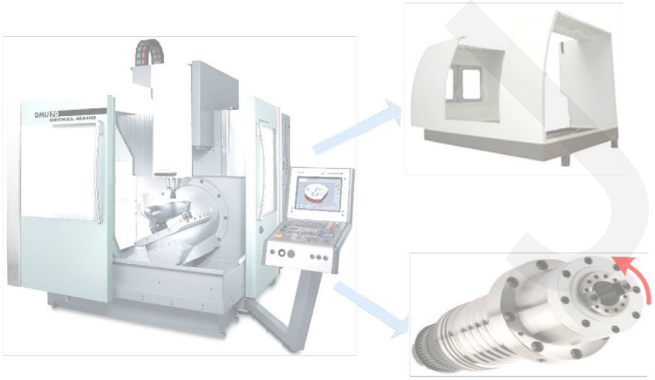
Journal of Zhejiang University-SCIENCE A
(Applied Physics & Engineering)

Cite this as: Cong-cong LUAN, Xin-hua YAO, Qiu-yue CHEN, Jian-zhong FU, 2017. Research on transmission performance of a surface acoustic wave sensing system used in manufacturing environment monitoring. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 18(6):443-453. http://dx.doi.org/10.1631/jzus.A1600259

Research on transmission performance of a surface acoustic wave sensing system used in manufacturing environment monitoring

Cong-cong LUAN, Xin-hua YAO, Qiu-yue CHEN, Jian-zhong FU



Key words:
Transmission performance, Surface acoustic wave, Sensor, Manufacturing environment, Monitoring

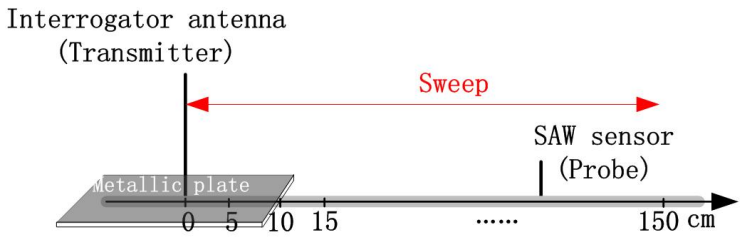


Introduction

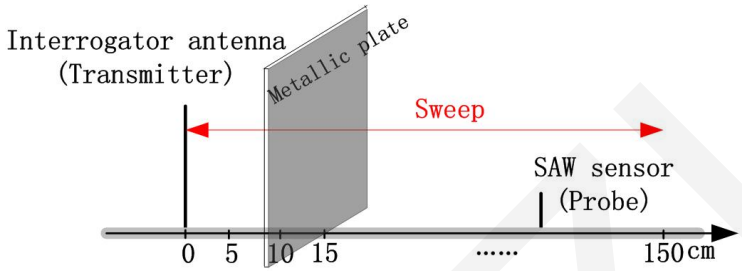
- Integrating advanced sensor systems into machine tools enables improved understanding of the process conditions and facilitates optimization and control of the quality of the formed part
- Due to the necessary intrusion of the rotating process, wired sensors are typically not feasible for monitoring spindle units
- Enclosure structure of the spindle unit poses a challenge for the power supply to wireless sensors
- Surface acoustic wave (SAW) sensors have emerged as favorable alternatives, due to their passive operation, wireless installation, freedom from maintenance

Characteristics in metallic environments

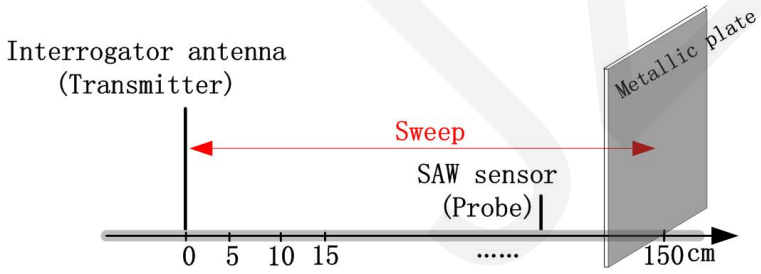
Simulation with CST



(a) with the metallic plate underneath



(b) with the metallic plate in between



(c) with the metallic plate on the side

Fig. 1 Simulation models

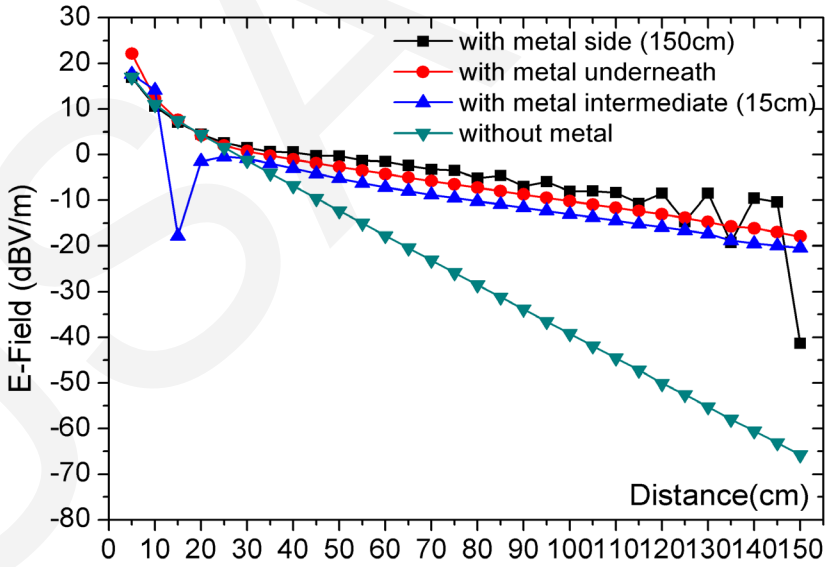


Fig. 2 Simulation results

$$10\lg P_r = 10\lg P_u + 10\lg\left(\lambda^2 / 4\pi\right) + 10\lg G_r$$

Possible explanations

- Metal reflective effect
- Electromagnetic induction effect
- Metal shielding effect

Characteristics in metallic environments

Experimental verification

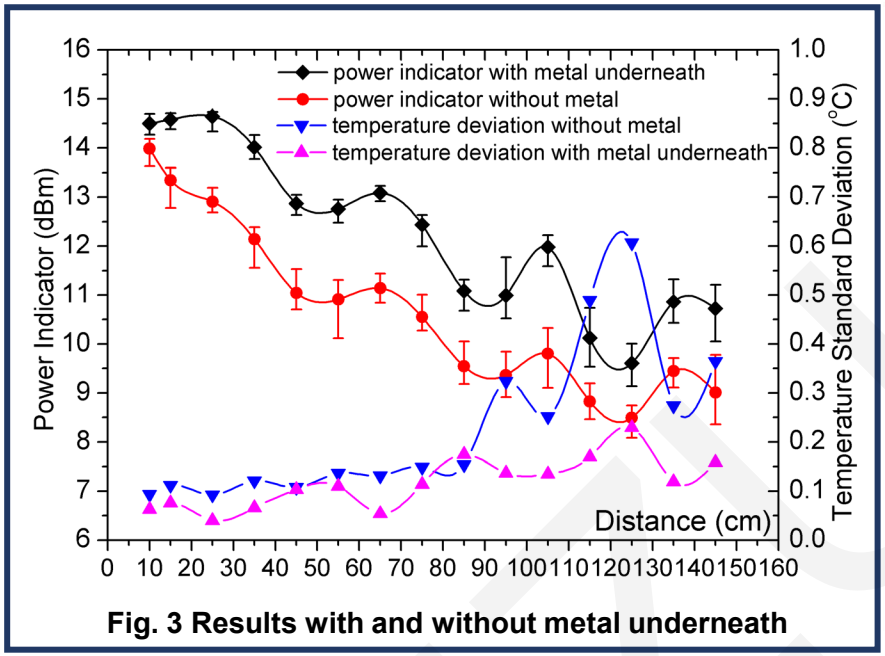


Fig. 3 Results with and without metal underneath

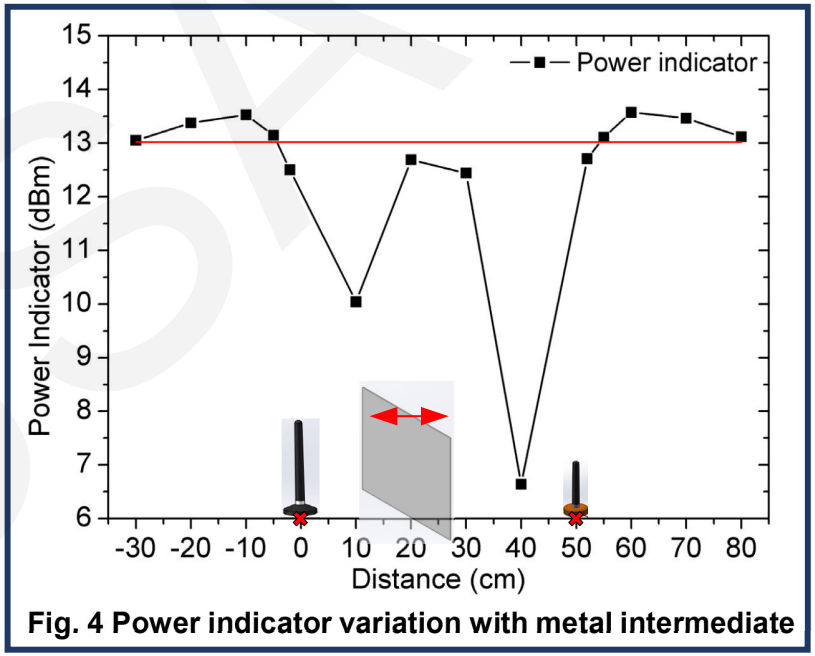


Fig. 4 Power indicator variation with metal intermediate

Results

- Metallic plate could strengthen the E-field when it was placed under the interrogator antenna.
- Power strength decreased in the distance of 0~50 cm and increased in the other distances except -2 and 52 cm.

Performance with rotation experiments

Antenna angle influence

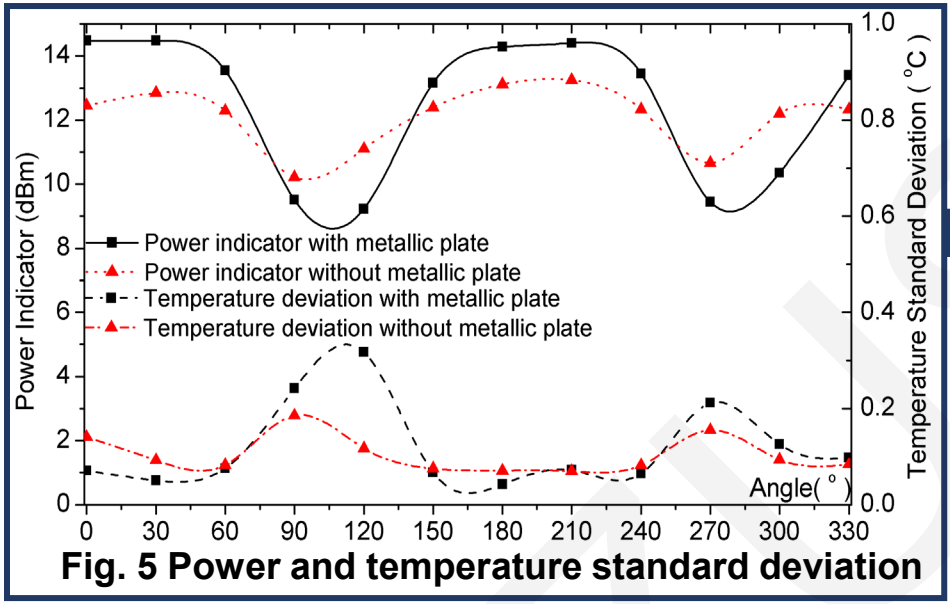


Fig. 5 Power and temperature standard deviation

Results

- Power strength decreased with an increase of antenna angle in the range of 0~90° and increased in the range of 90~180°.
- Metallic plate is undesirable for temperature measurement.

Antenna location influence

Results

- The observed pulling effect is related to both the angular position and the distance.
- Angular position has major influence when the distance is more than 15 mm.

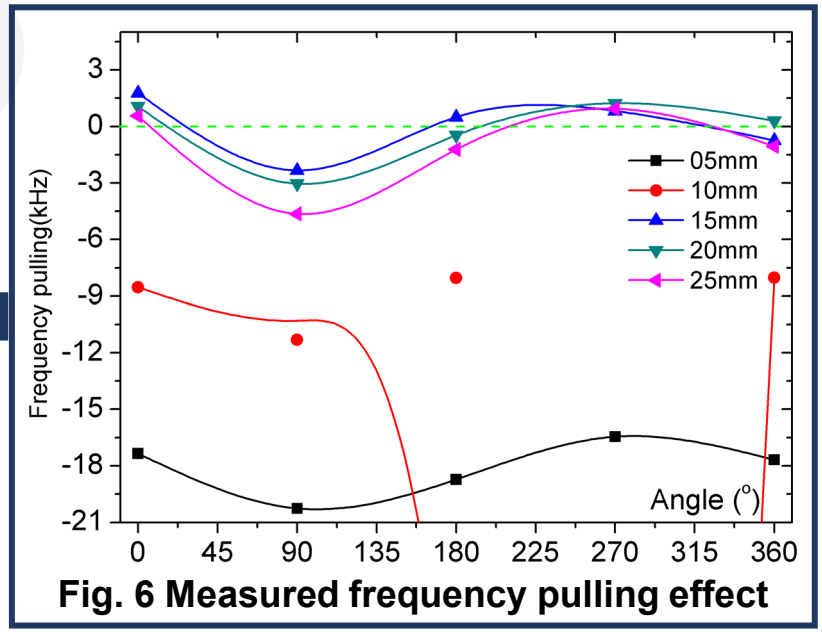


Fig. 6 Measured frequency pulling effect

Performance with rotation experiments

Experiment with spindle model

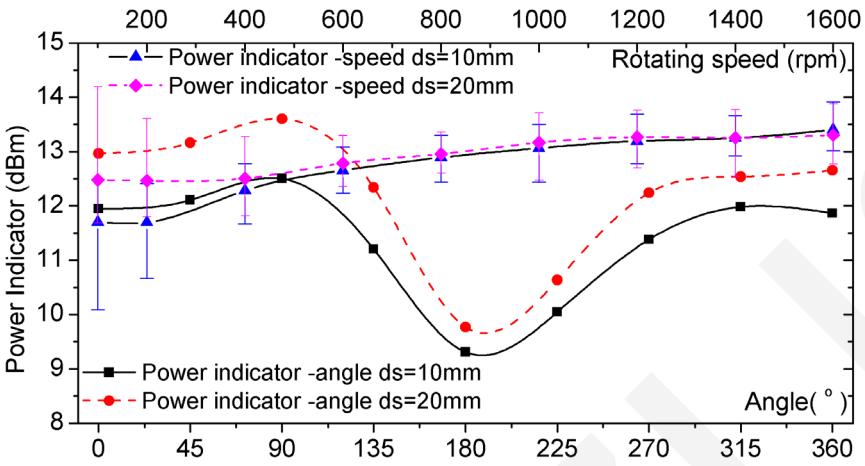


Fig. 7 Power indicator variation with angles and speeds

Results

- Average power increased slightly with the rotation speed
- Power indicator standard deviation decreased remarkably when the speeds were less than 600 r/min.

Temperature sensing

Results

- Temperature outliers occasionally occurred during spindle rotating.
- Fluctuations decreased with increasing rotation speeds.

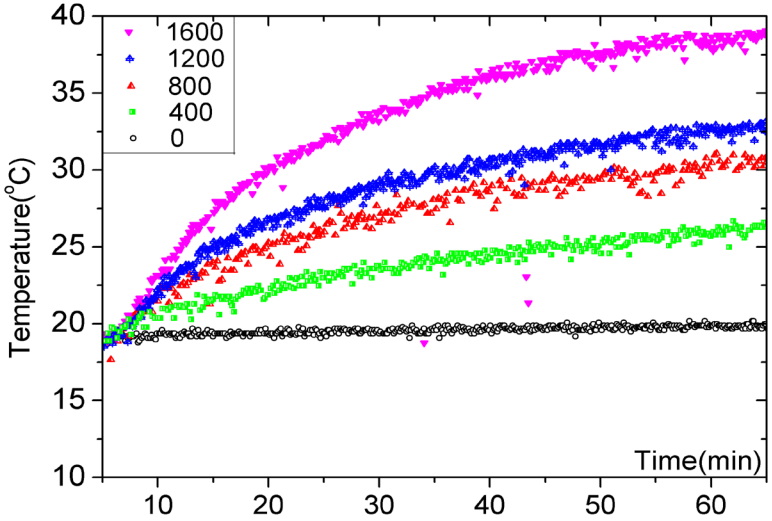


Fig. 8 Temperature rise with different rotation speeds

Conclusions

- **Metal** can strengthen the power when it is placed below the interrogator antenna, but it can weaken or even block the power when it is placed beside the antenna
- **Angle** between the interrogator and sensor antennas should be considered for different types of antennas
- **Distance** between the sensor antenna and shaft affects the power and temperature measurement capability
- Dynamic experiments in a rotating spindle apparatus demonstrate that **using wireless passive temperature SAW sensor on spindle monitoring is feasible** but some large temperature fluctuations exist