



Development of the Inspection System for Detecting the Internal Defect in the Cold-rolled Steel Strip

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Background

▶ Requirement of Internal Defect Detector



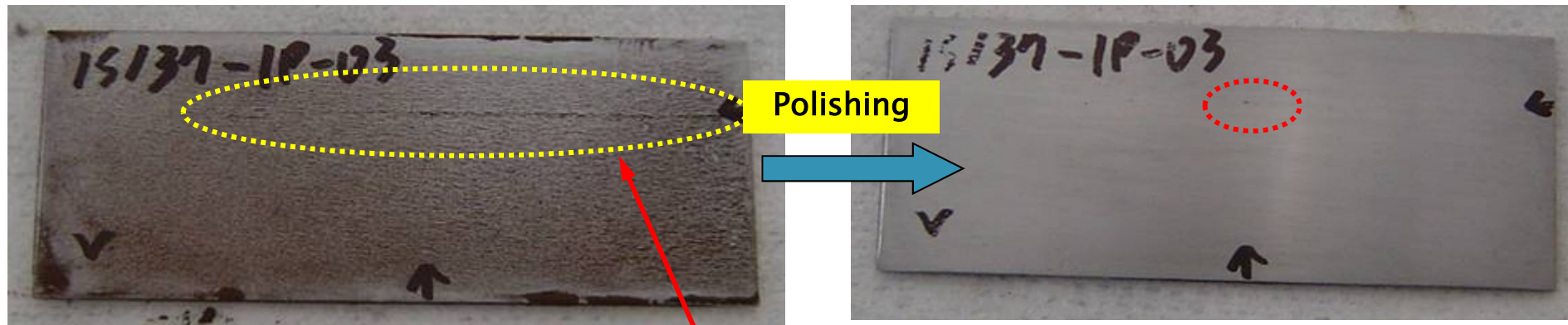
< Failure during forming due to internal defects in the steel sheet >

SDD (Surface Defect Detector) systems are well used and detecting most of defects. However, internal defects could not be detected because of invisibility on surface of the steel strip.

IDD (Internal Defect Detector) systems are required to supply good steel strip without harmful internal defects to customer.

▶ Internal defect

(Visualization of internal defect by polishing)

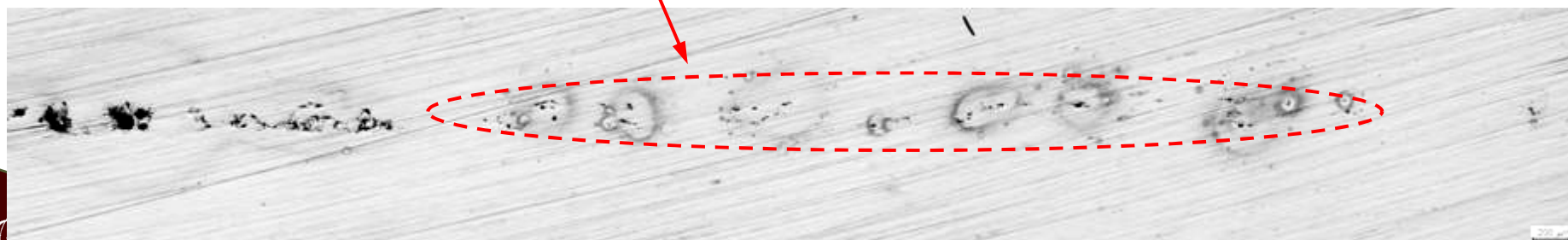


Magnetic particle indication

Although there was a long line of the magnetic particle that shows internal defect, the large parts of internal defects visible with naked eyes after surface polishing are very short.

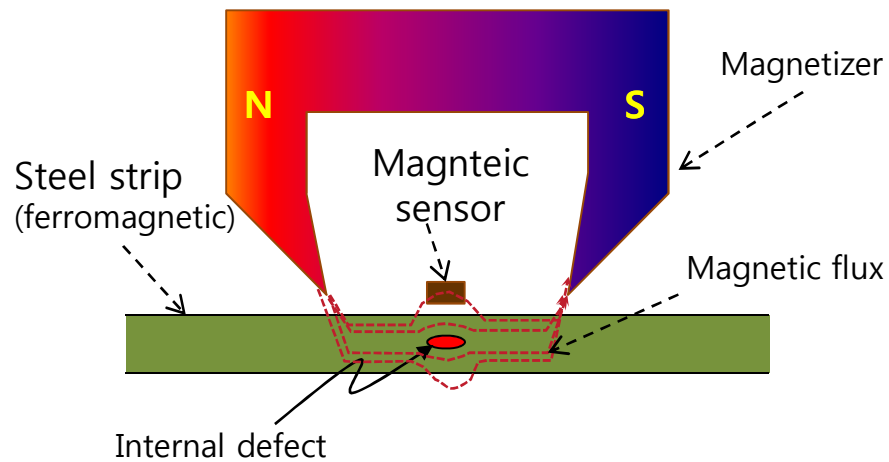
However there were invisible tiny inclusions around this large inclusion.

Most of times, inclusions in samples were missed during polishing verification.



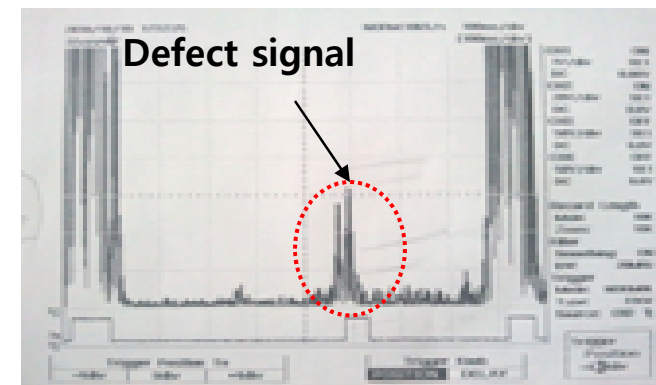
<Typical microscopy of polished surface>

▶ Principle of MFL (Magnetic Flux Leakage)



<Schematics of magnetic flux leakage>

Sample test with conventional Internal Defect Detector



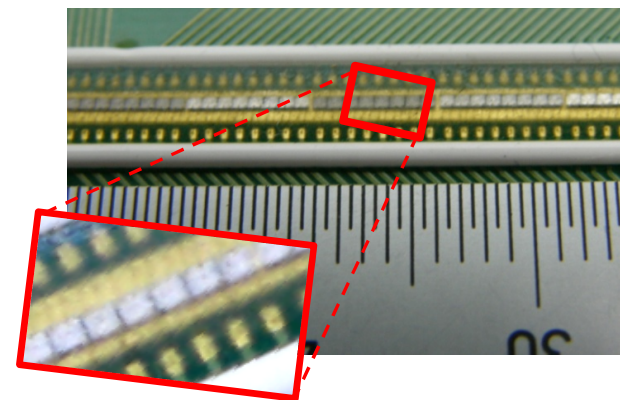
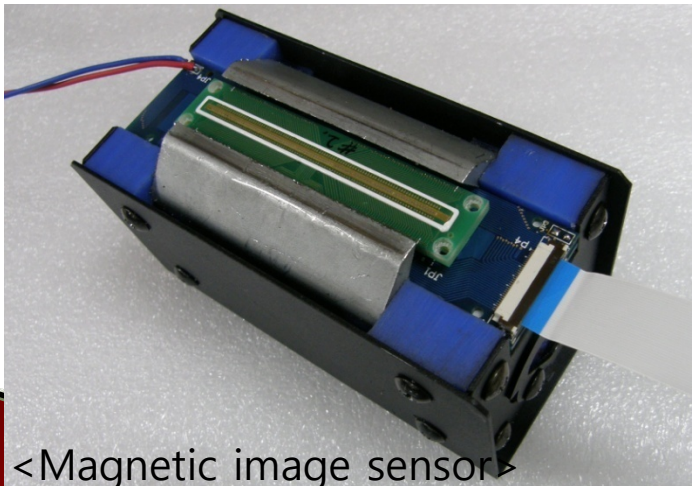
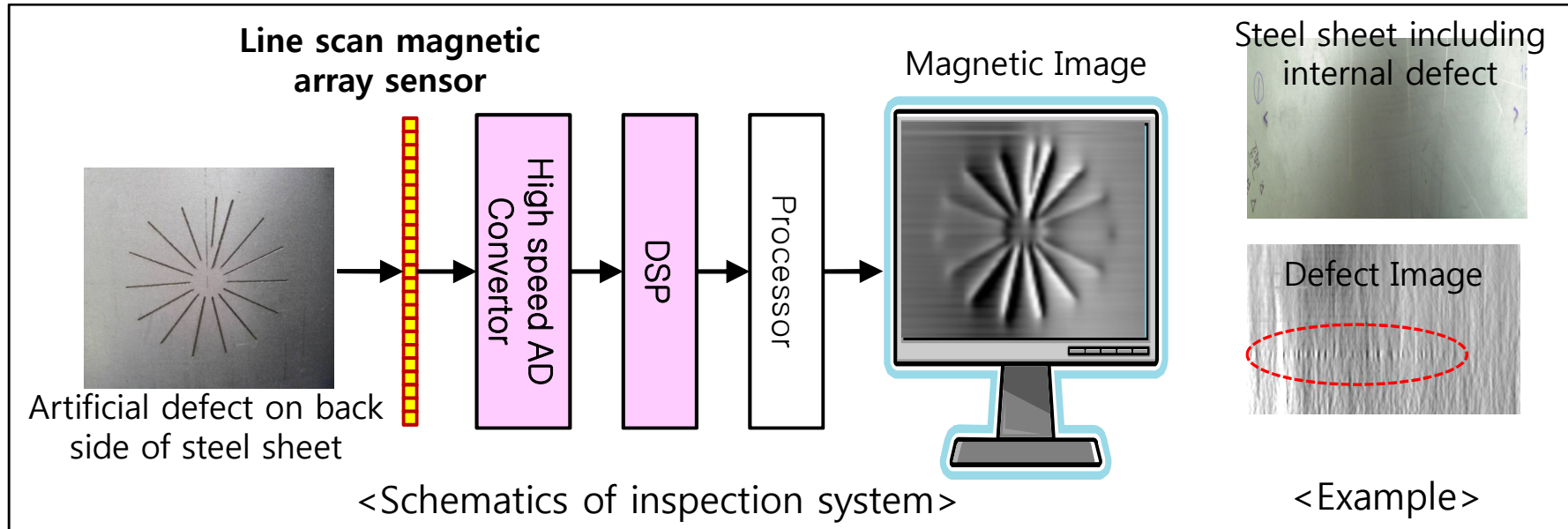
<Signal(Analog)>

-Sample Test Result : **Lack of detectability**

→ **Impossible for application**

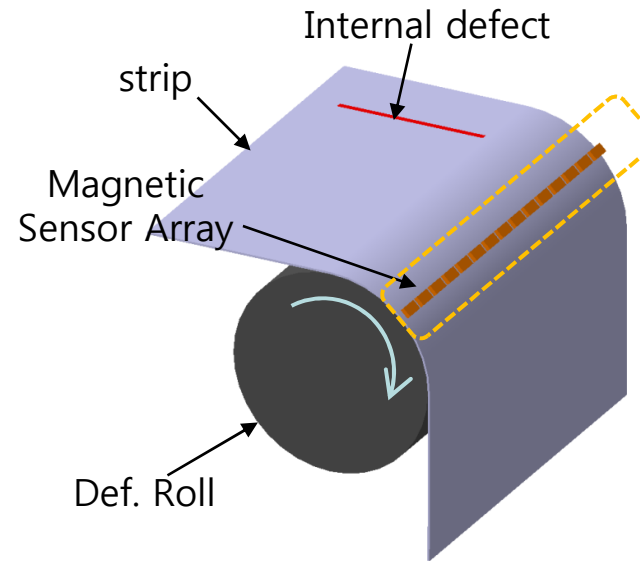
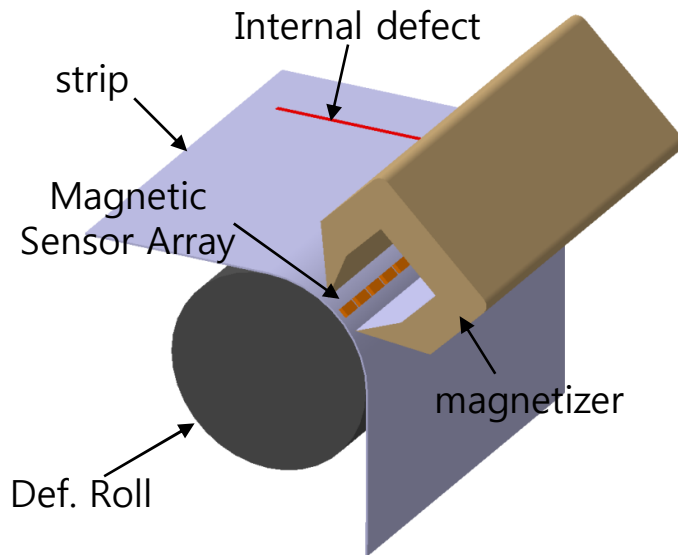
Only huge defects can be detected with conventional Internal Defect Detector

► Core Technology (Magnetic image sensor for Internal Defect Detection)



Problems

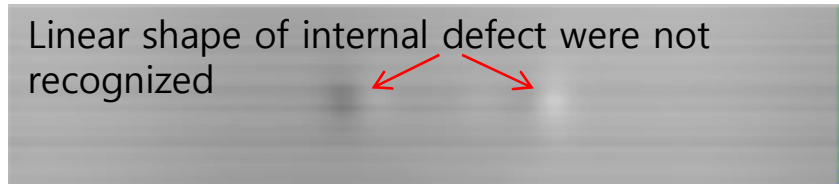
Operating Zone : Deflector Roll,
Steel Strip on the Deflector Roll,
Magnetizer, Magnetic Sensor Array



(If the magnetizer is invisible)

Problem 1. Lack of detectability of the internal defects

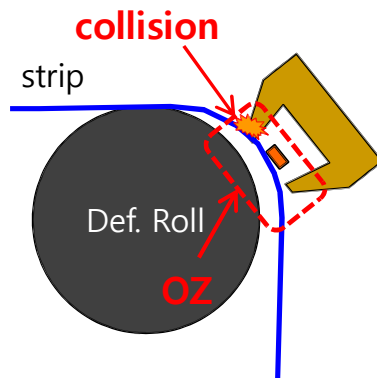
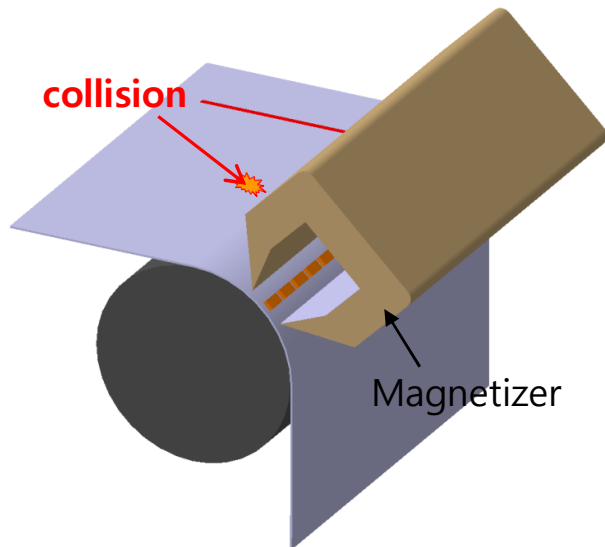
Operating Time :
Internal defect passing under the magnetic sensor array



Problem 2. Collision of the sensor and the strip

(Contradiction : collision vs. signal intensity)

Operating Time : Steel strip move slow or stop

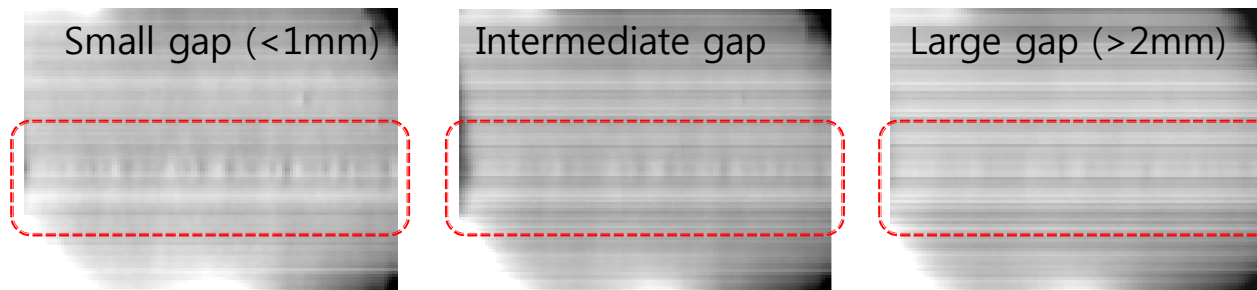


Gap between sensor and strip should be

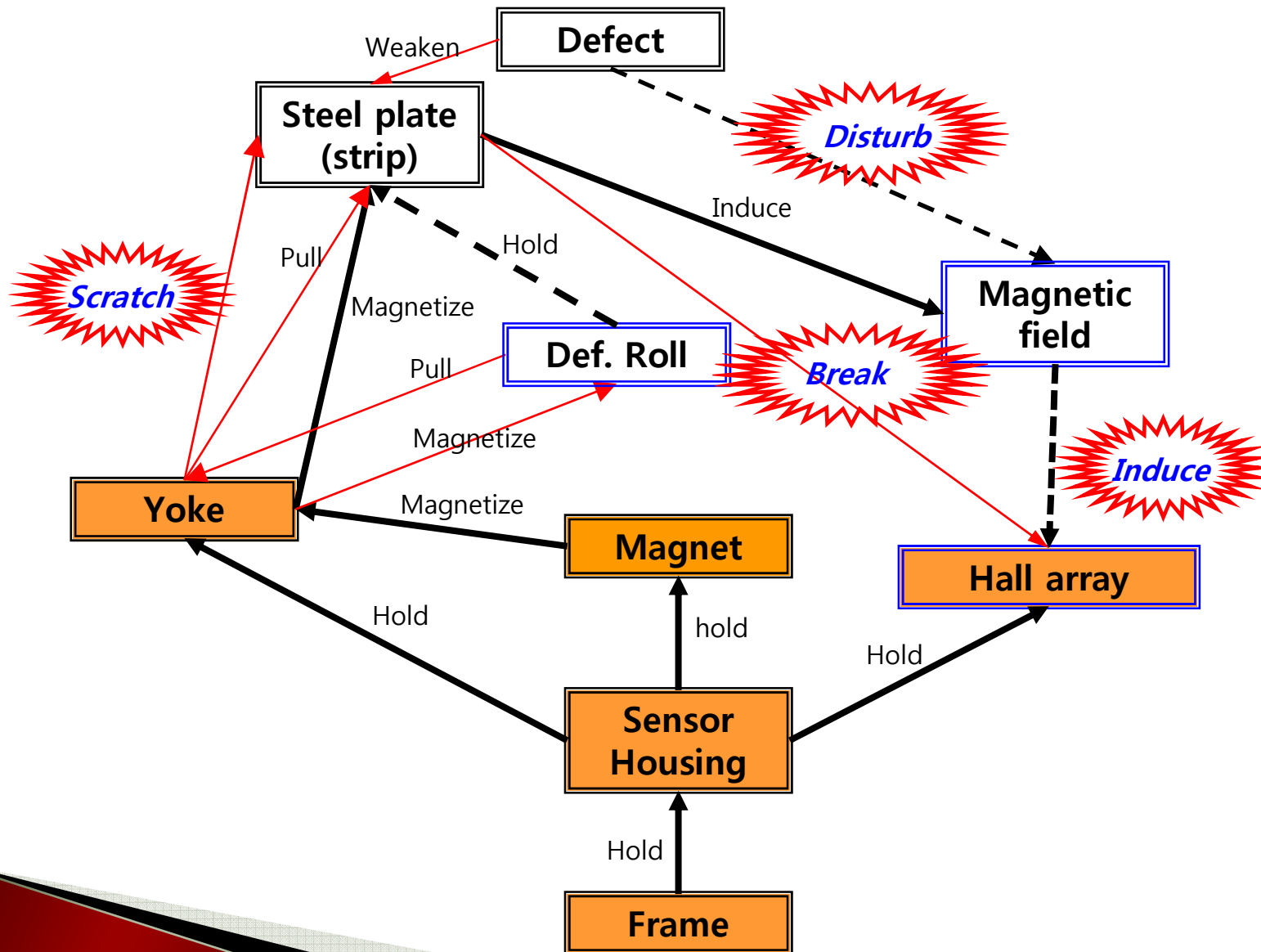
- Small (For defect signal intensity)
- Large (For preventing collision)

Line operators don't want the steel strip touched by anything at all !

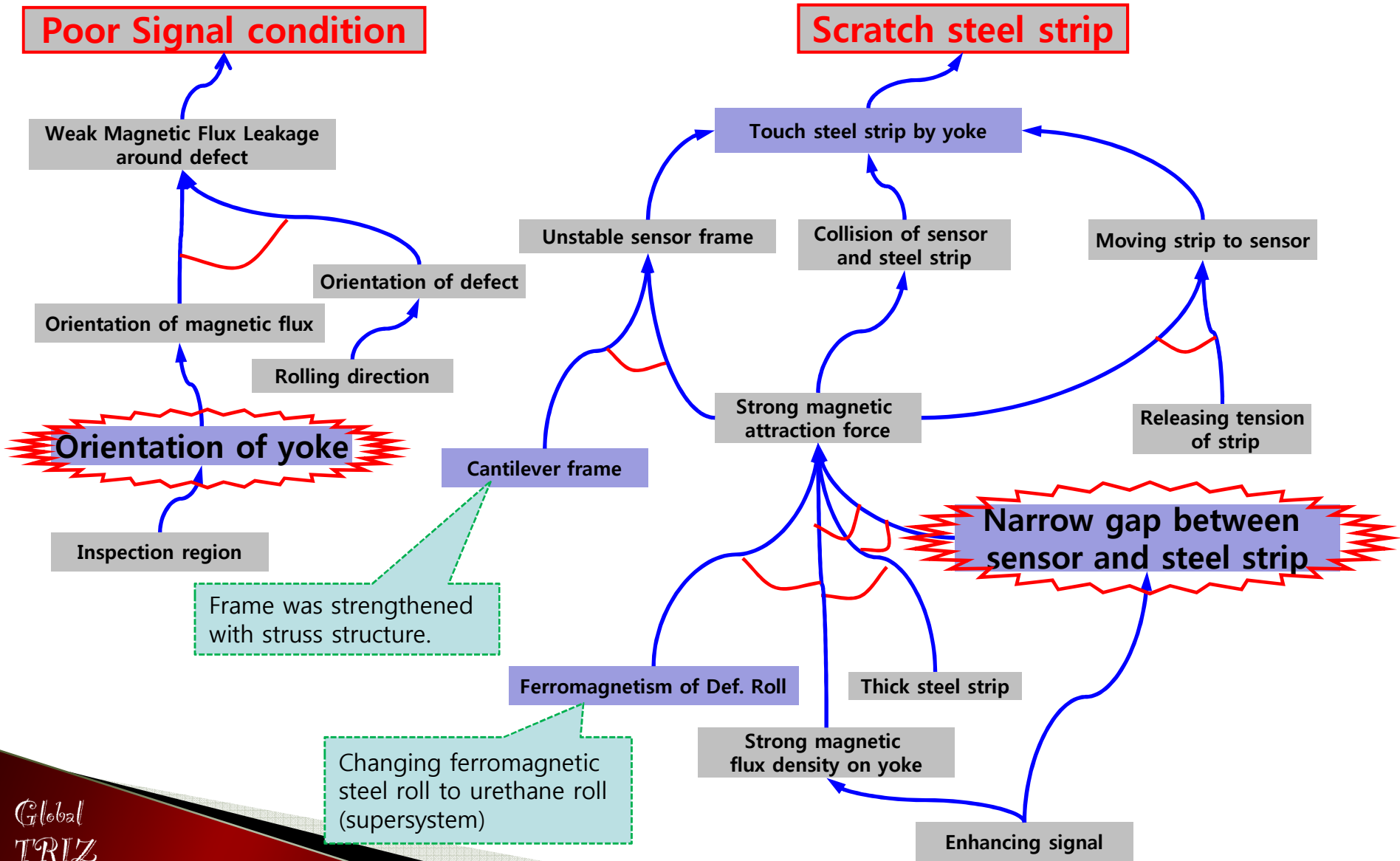
<Defect signal became weak according to increase of gap between steel strip and sensor>



Function Analysis



R. C. A.

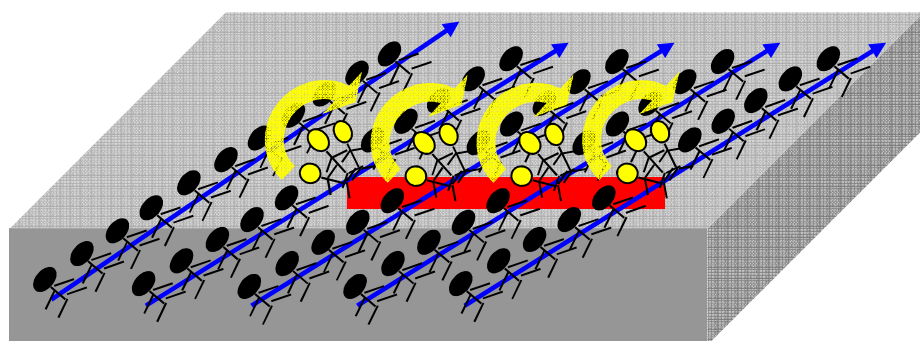
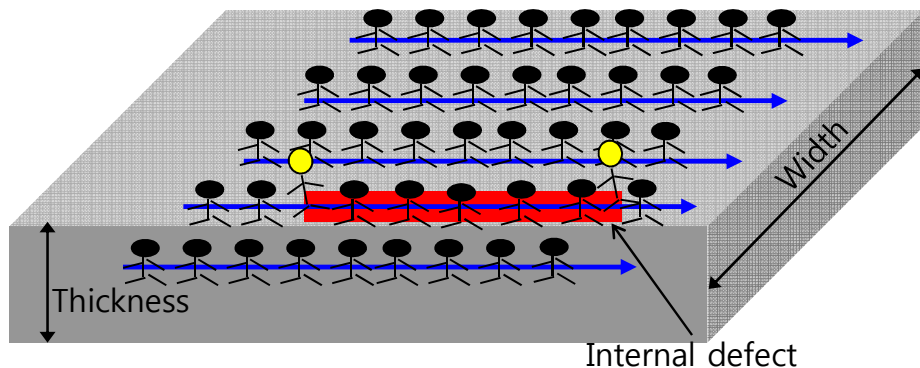


Core problem and IFR

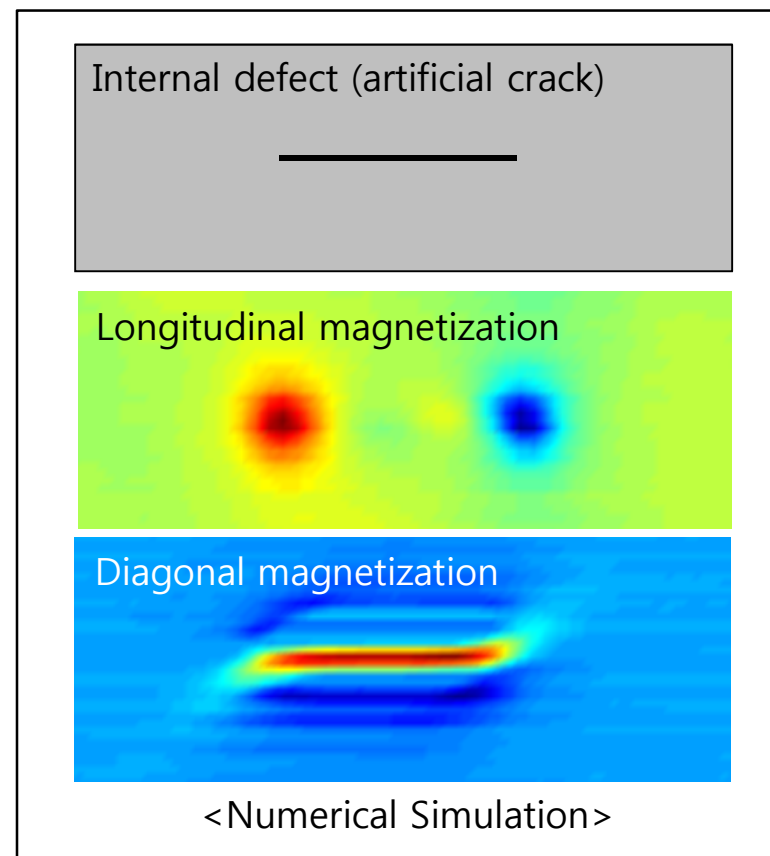
Problems defined by Function Analysis	Core problems defined by R.C.A	Ideal Final Result
<p>Unsufficient detectability at detecting linear internal defects elongated in rolling directoin.</p>	<p>The detecting sensor is placed along lateral direction.</p>	<p>The sensor placed along lateral direction can well detect the linear internal defects elongated along the rolling direction.</p>
<p>Collision of the sensor and the steel strip when the gap between the sensor and the strip is small.</p>	<p>Gap between the sensor and the steel stip is too small.</p>	<p>Collision is not happened when the gap between the sensor and the strip is very small.</p>

Solution

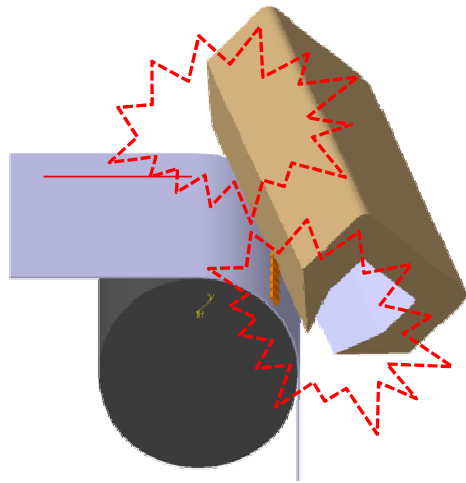
▶ Smart Little people



♁ Magnetic flux in steel ♁ Magnetic flux leakage

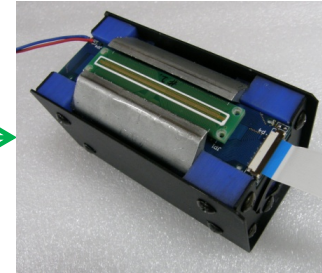
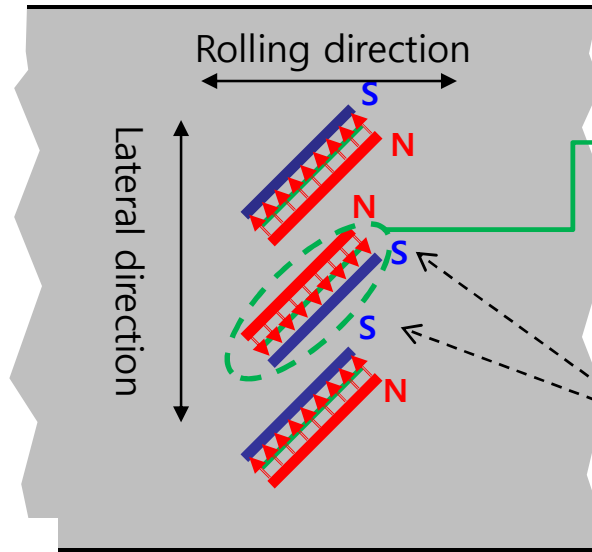


► Solve : Seperation in system scale



- Diagonal magnetization
- Diagonal sensor alignment

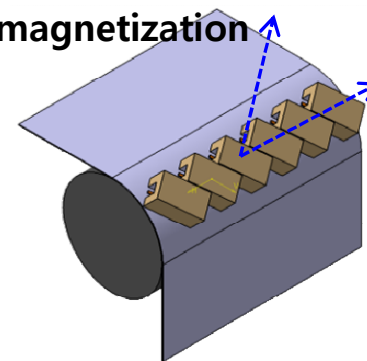
Distance between yoke(for magnetizing) and strip becomes larger at both sides of yoke



<Small modular sensor>

Alternative pole
→ Intensify magnetic field in measuring region

Diagonal magnetization

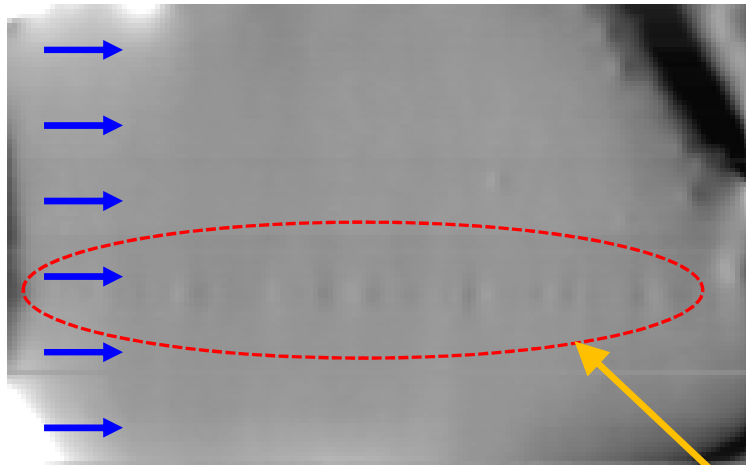


Lateral sensor alignment

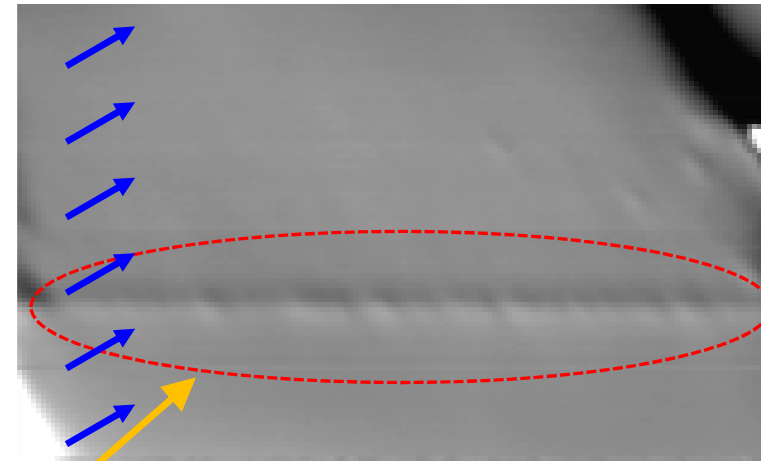
<Modular sensor arrangement>

▶ Sample Test Result

Conventional longitudinal magnetization



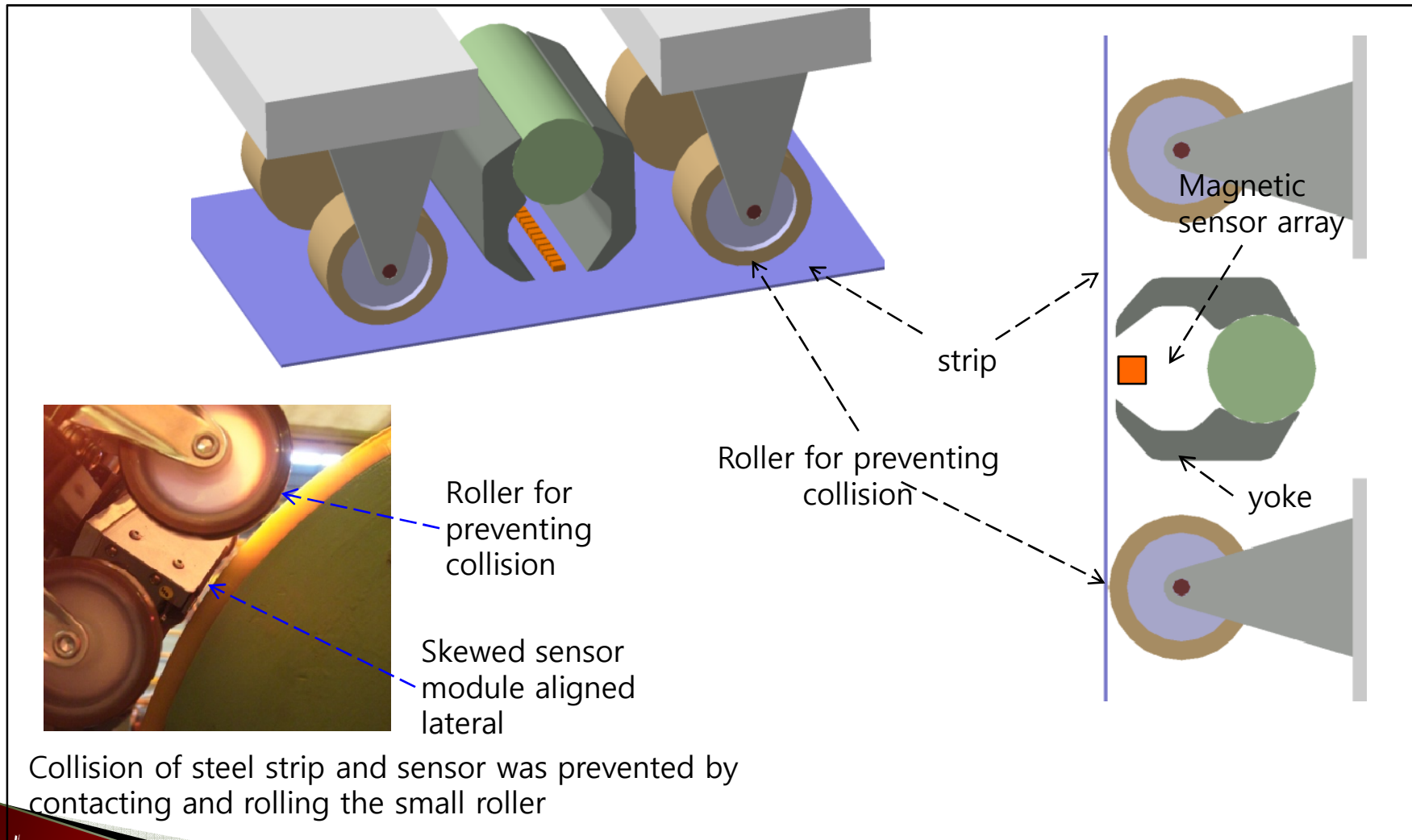
Diagonal magnetization



Internal defect (Non metallic inclusions)

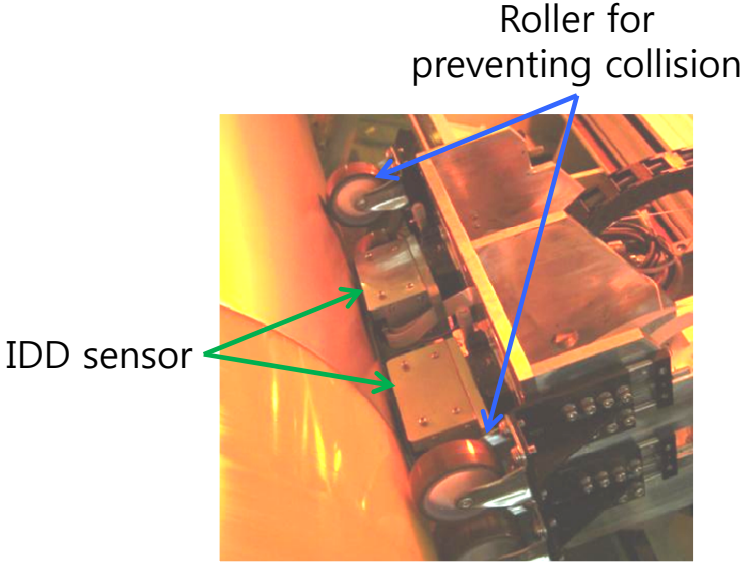
► Sove : Inventive Principle

(Prepare safety/Rescue means in advance)



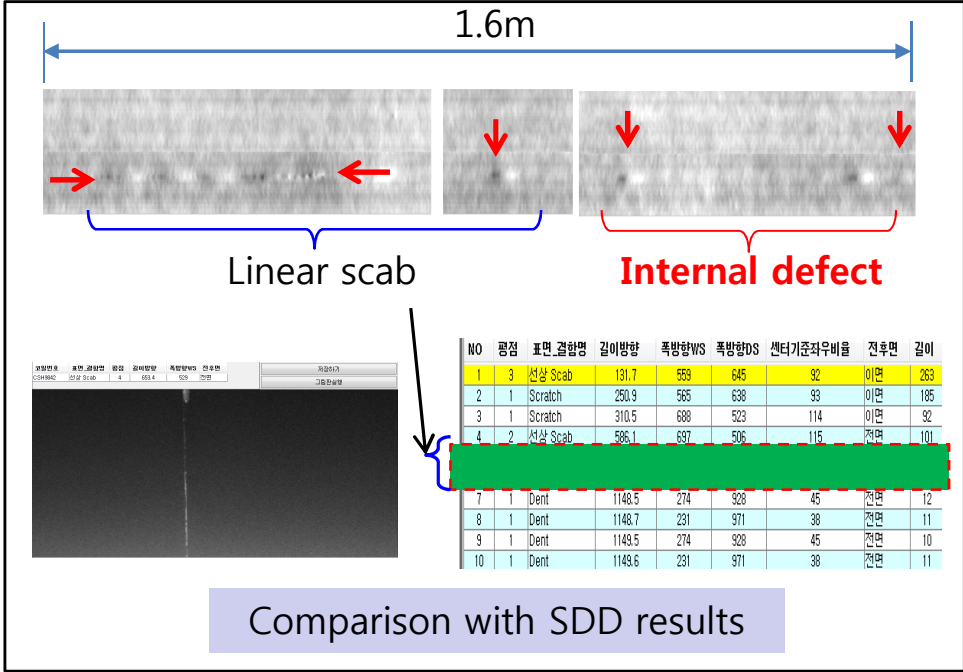
Results (testing at actual steelworks)

■ Pilot test at RCL (Re-Coiling Line)

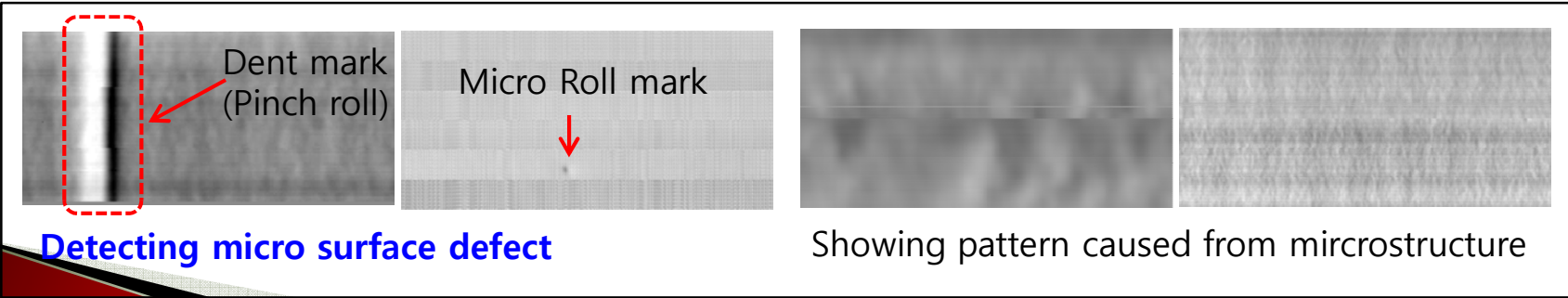


No additional flaw on the steel strip surface !

■ Additional benefit



※ SDD : Surface Defect Detector



Summary

The pilot internal defect detection system with small number of sensor modules was installed around the deflection roll in the re-coiling line where the final inspection was carried out before shipment.

If the the internal defect detection system had longitudinal magnetization, the linear defect could be shown as array of spot with weak amplitude because of weak interference of the internal defect and the magnetic flux.

On the other hand, clear linear defect images were shown when the sensor module had diagonal magnetization by skewing.

Since the internal defect resists magnetic flux, the interference became strong by diagonal magnetization.

Small module of the sensor can provides lateral arrangement for covering full width of the steel strip with high detectability of linear defects.

Reference

- [1] Pelkner, M.; Neubauer, A.; Reimund, V.; Kreutzbruck, M. : Local magnetization unit for GMR array based magnetic flux leakage inspection, Review of Quantitative Nondestructive Evaluation, 31A (2012), 1005-1012
- [2] Choi, S.-W.; Kim, G.; Bae, J. : Inspection of internal defects in cold-rolled steel sheets using Lamb wave, Review of Quantitative Nondestructive Evaluation, 28B (2009), 1426-1433