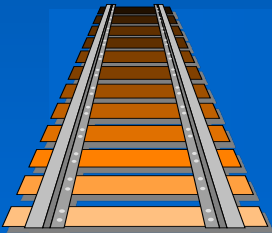


A Machine Vision Profile Measurement System for Effective Wheel Maintenance



Kambiz Nayebi, Ali Yousefi & S.
Gelichkhani

Sharif University of Technology

Signal Co. Ltd.

Iranian Railway Research Center

Goals:

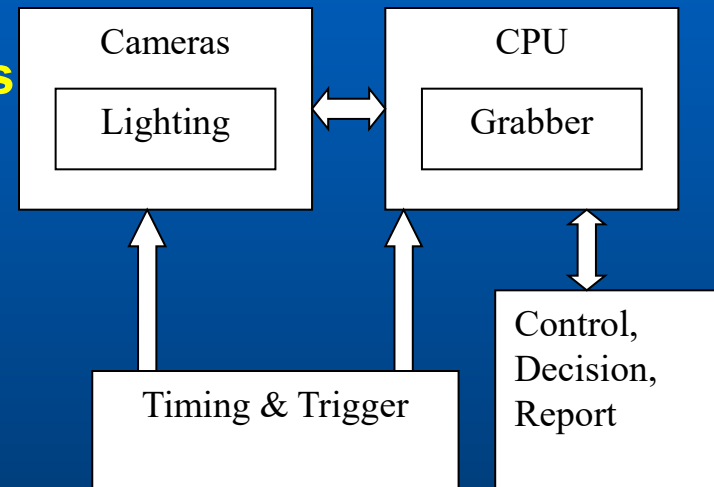
- Automatic wheel profile measurement
- Flange parameters : height, thickness & gradient
- Tread parameter : hollow
- Fast processing and alarming
- Easy installation
- Low maintenance
- Economic
- Reliable
- Repeatable measurements
- Future wheel tracking capability

Why Wheel Monitoring

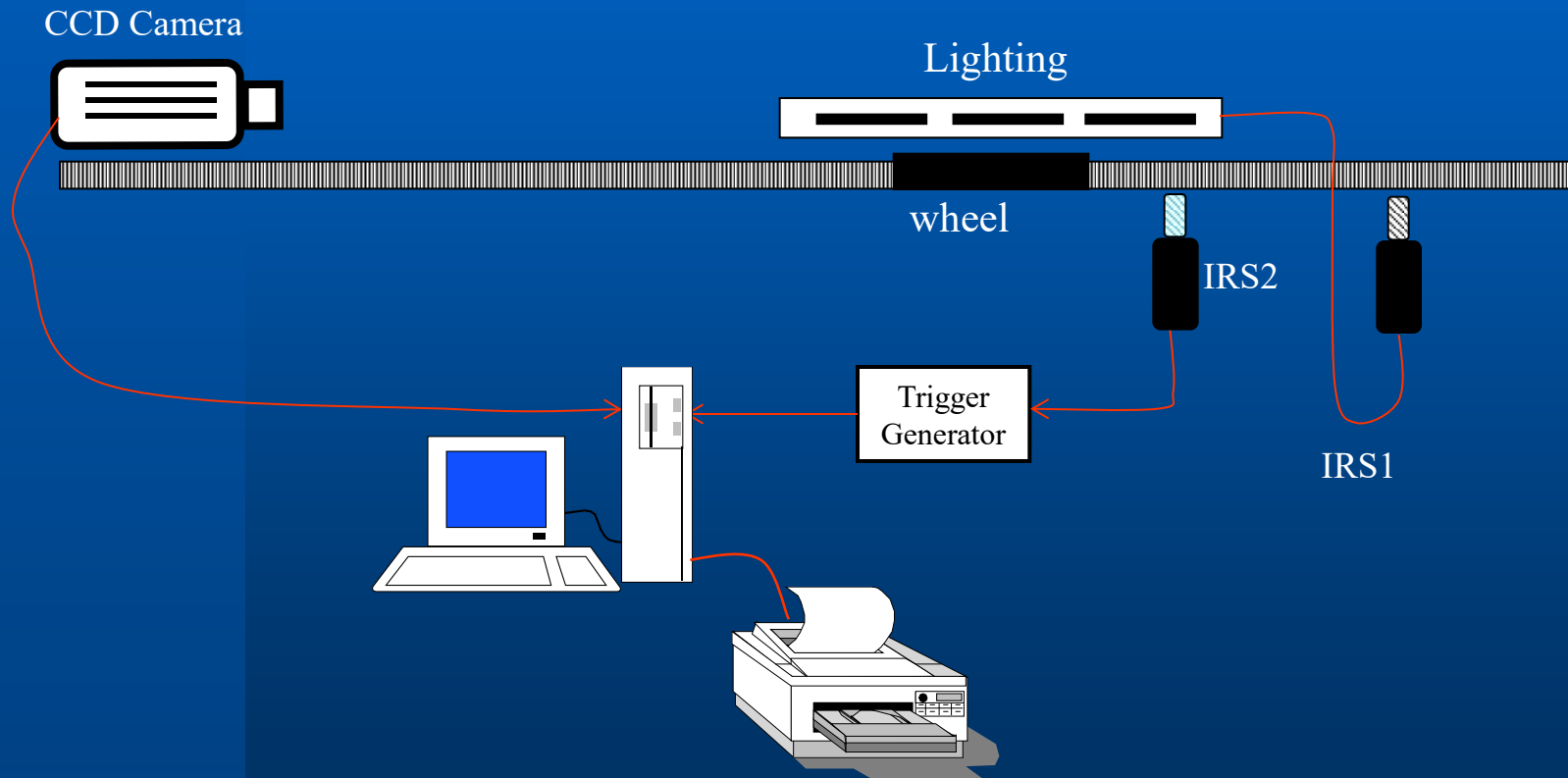
- Decrease life cycle maintenance cost
- Significant increase of inspected wheel percentage (approx. 5% for N. America)
- Accurate detection of condemnable wheels
- Preventing long inspection delays
 - Long cargo train inspection
- Prevent costly switch point disasters
- Increase system reliability
- Automatic warning & alarm
- Wheel marking and tracking

Machine Vision Technology

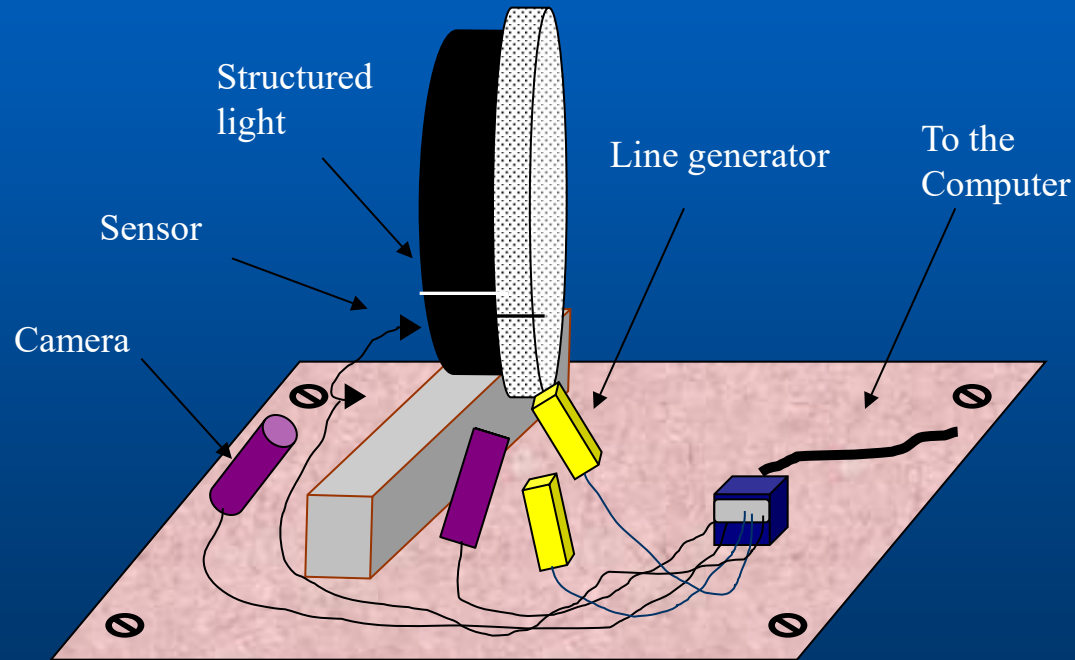
- **Machine vision system components**
 - **CCD camera**
 - **Lighting system**
 - **Image grabber**
 - **switching & triggering system**
 - **Digital image processing unit**
 - **Digital image processing algorithm**
 - **Environmental protection equipment**
 - **Automatic maintenance components**



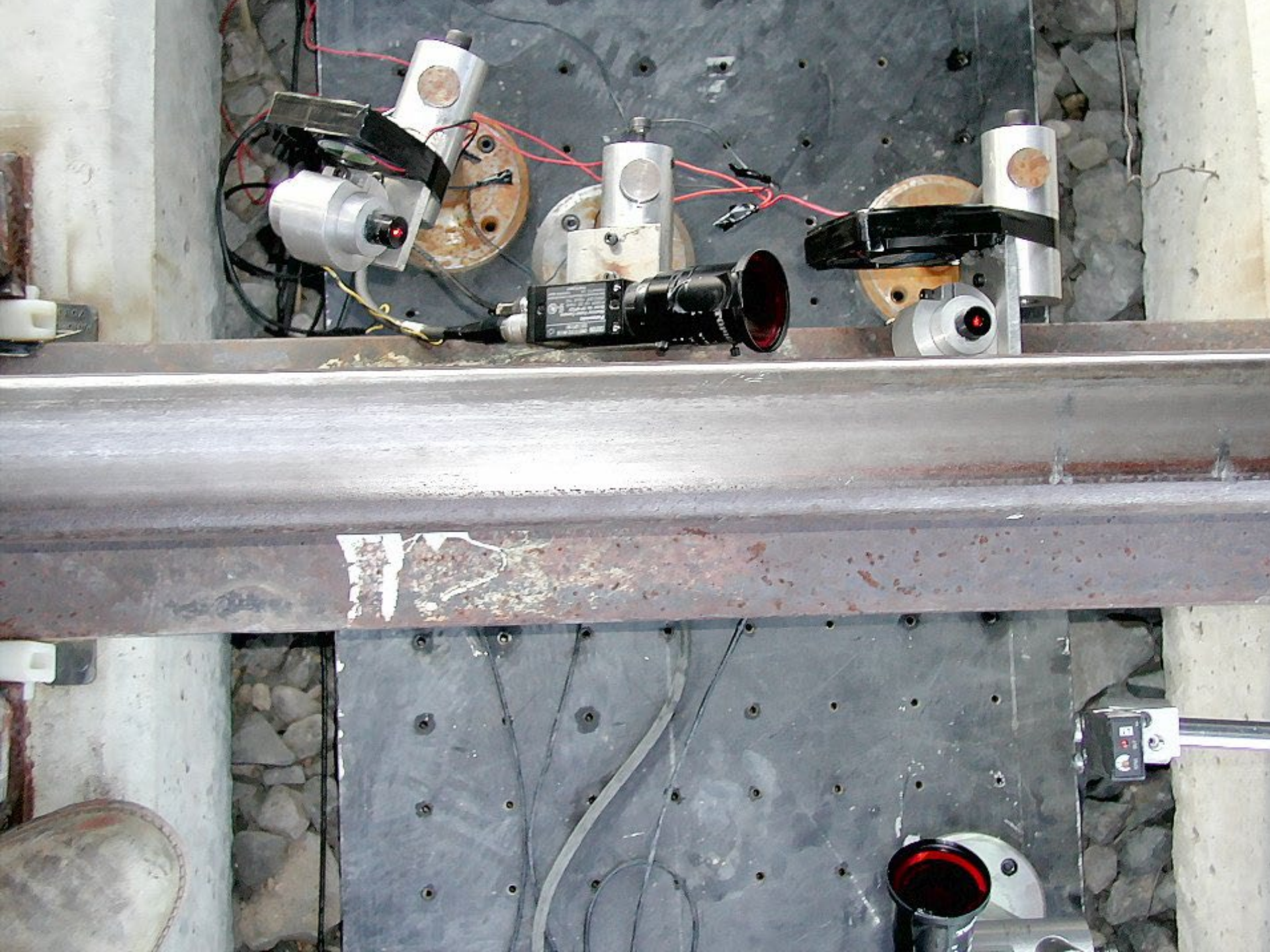
Old System Block Diagram



A Typical System

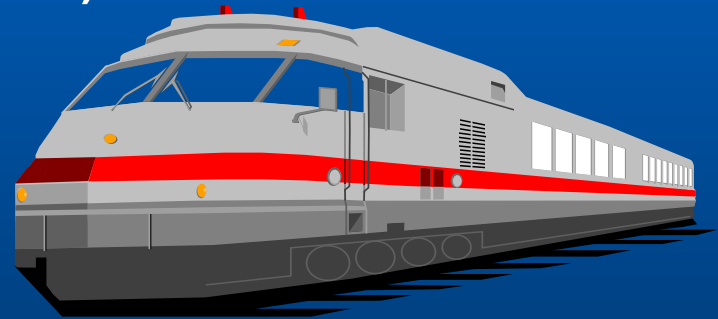






Important Points

- **Imaging procedure**
 - Sharp images
 - Insensitive to train speed (No blur)
 - Precise triggering
 - Precise calibration
- **Processing method**
 - Low complexity
 - Real-time or close to real-time implementable
 - Repeatable
 - Accurate parameter measurement



Wheel Parameters

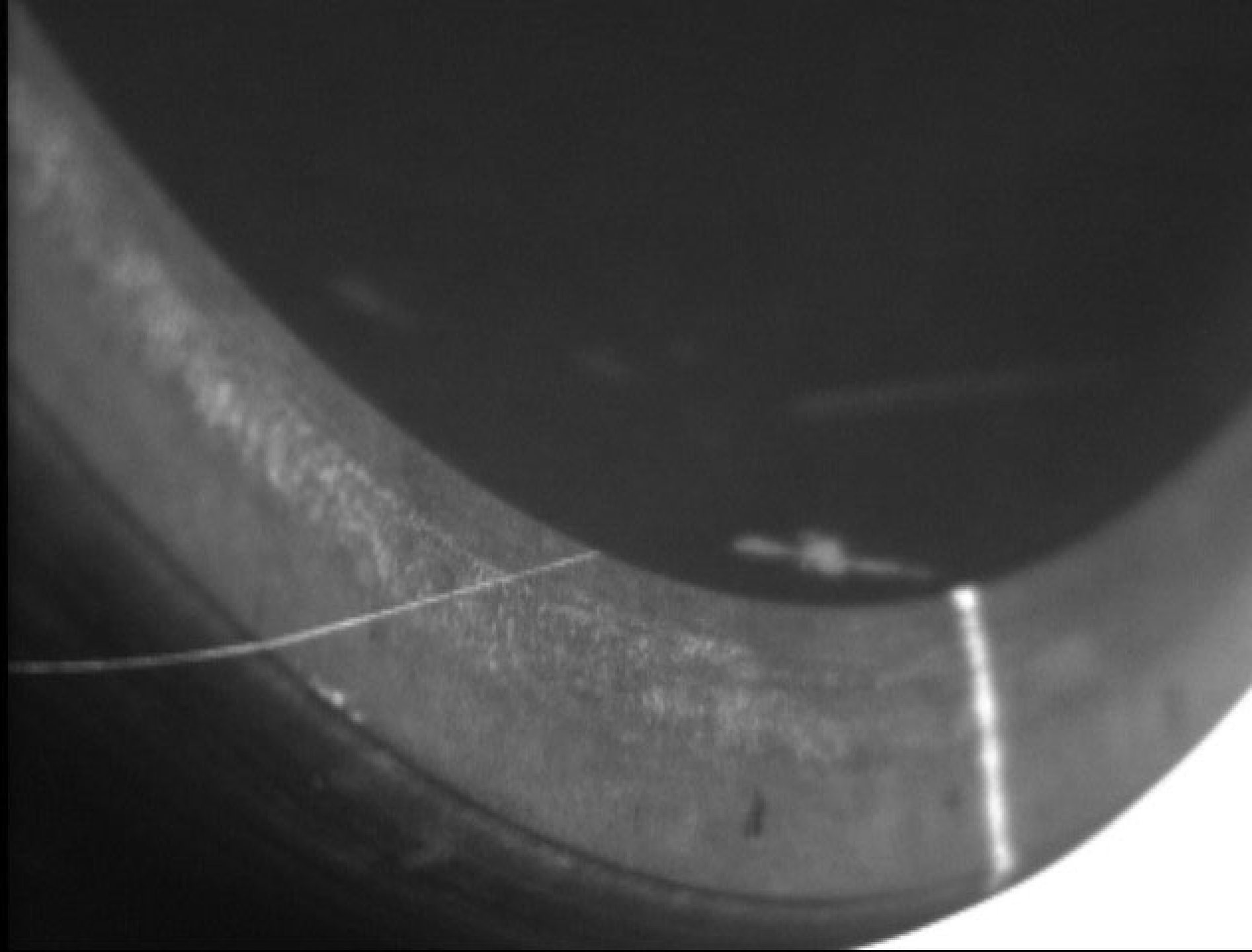
- **Flange height:** From tapeline of the tread to the top of the flange
- **Flange thickness:** Measured at the 10mm above the tapeline of the tread
- **Tread hollow:** Measured across the width of the tread

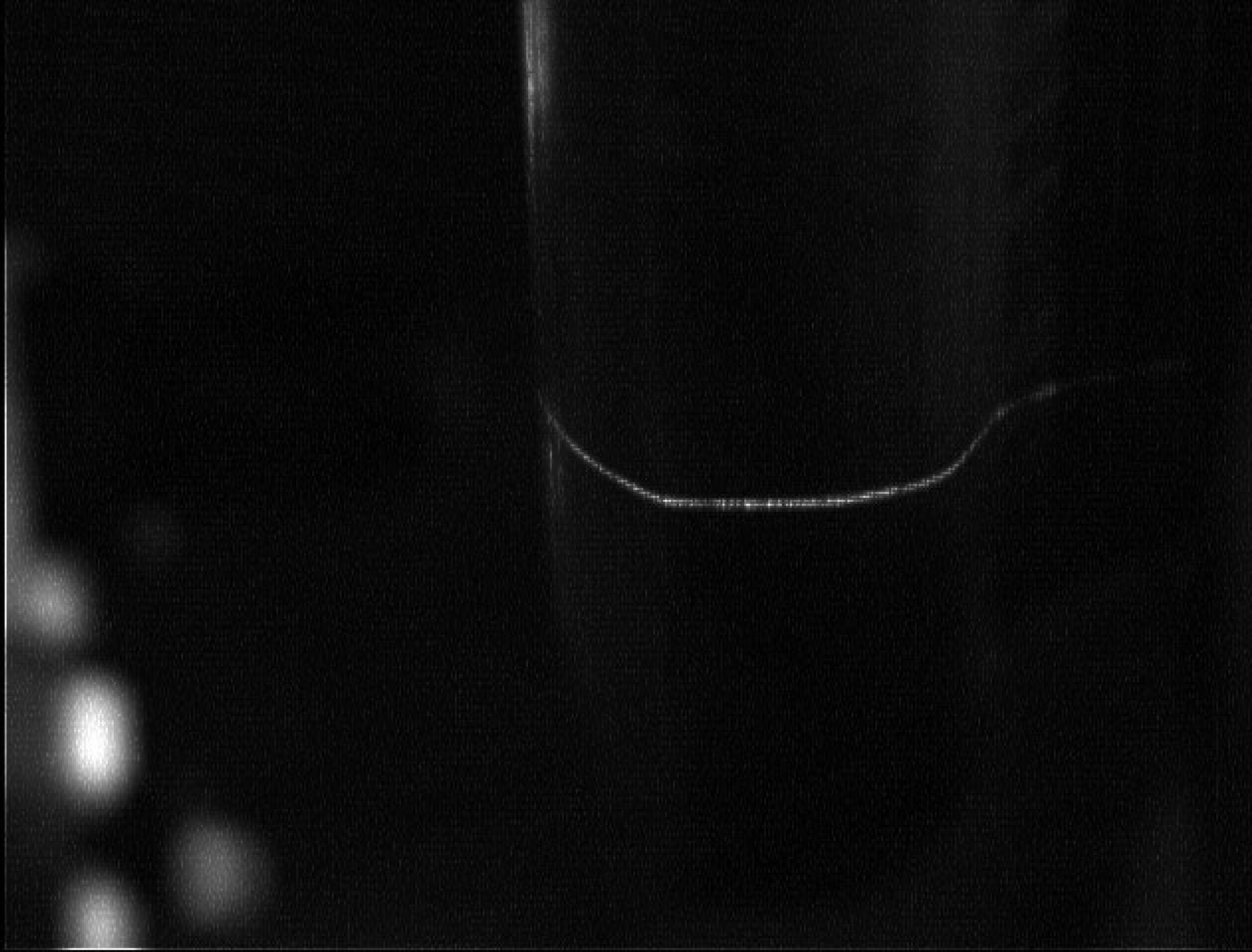
Wheel Parameters (insert picture)

Practical Problems

- Rail and train vibration
- Train speed
- Environmental protection
- Ambient light
- Camera type and shutter speed
- Camera and lighting positioning
- Calibration
- High speed grabbing
- Dirty wheels (Oil tankers)
- System maintenance



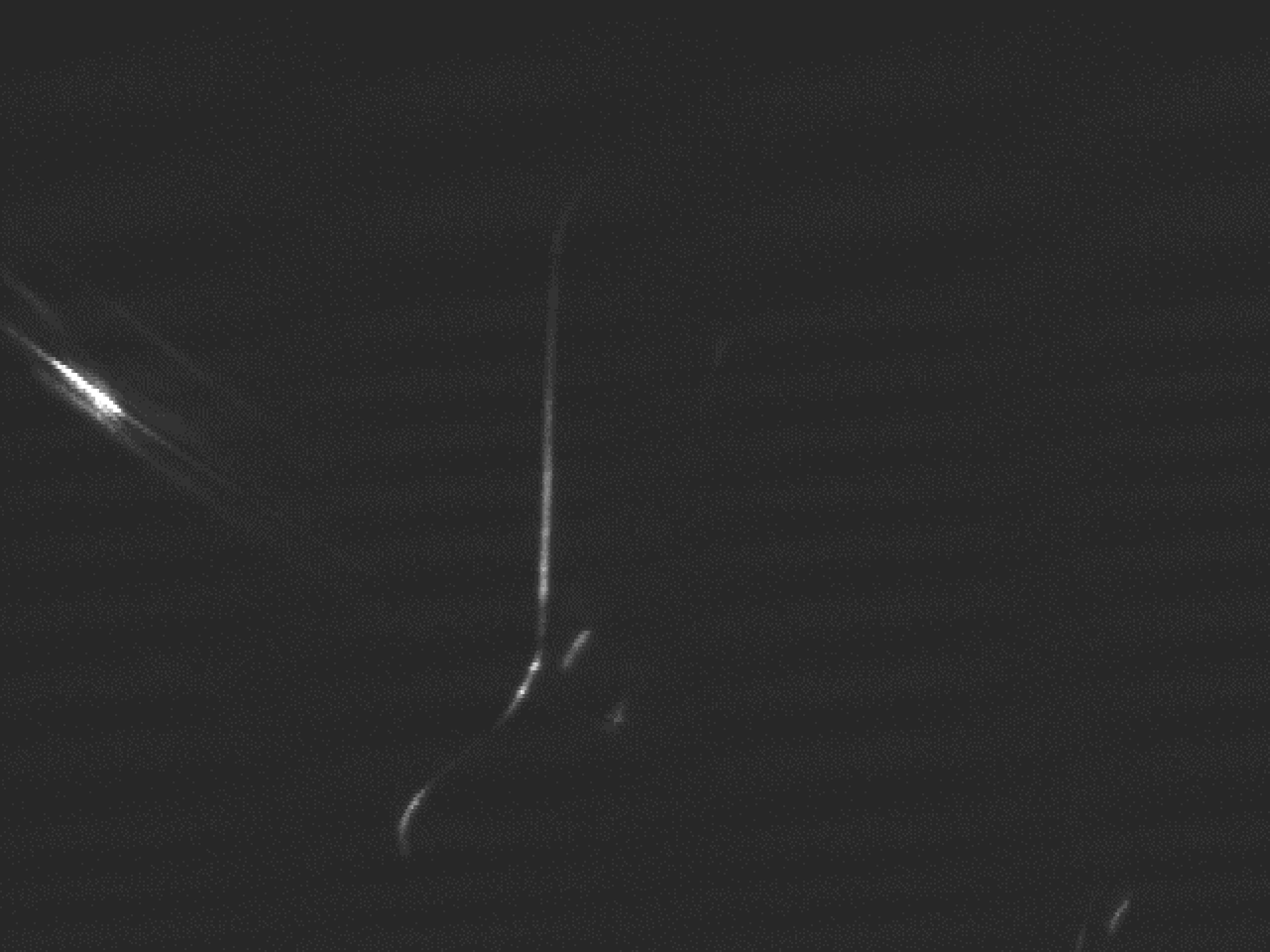




Typical Images

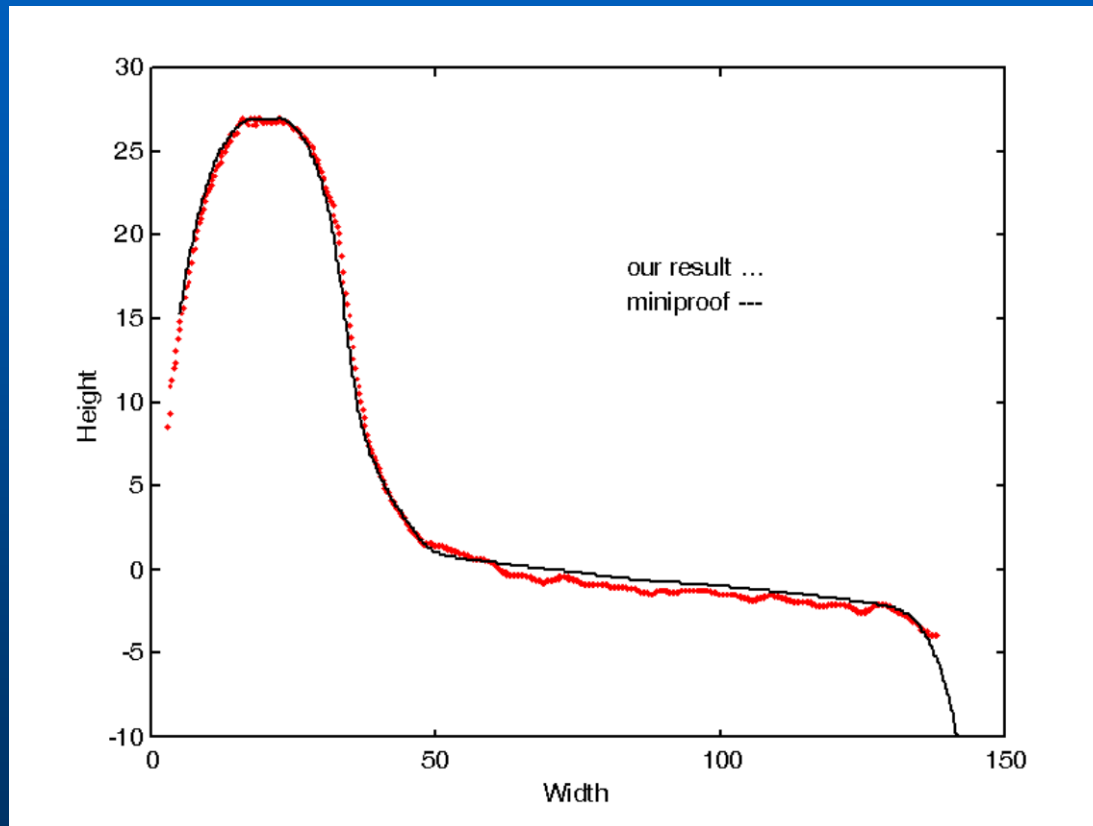






1

A Typical Measured Profile



Some Test Results: Accuracy

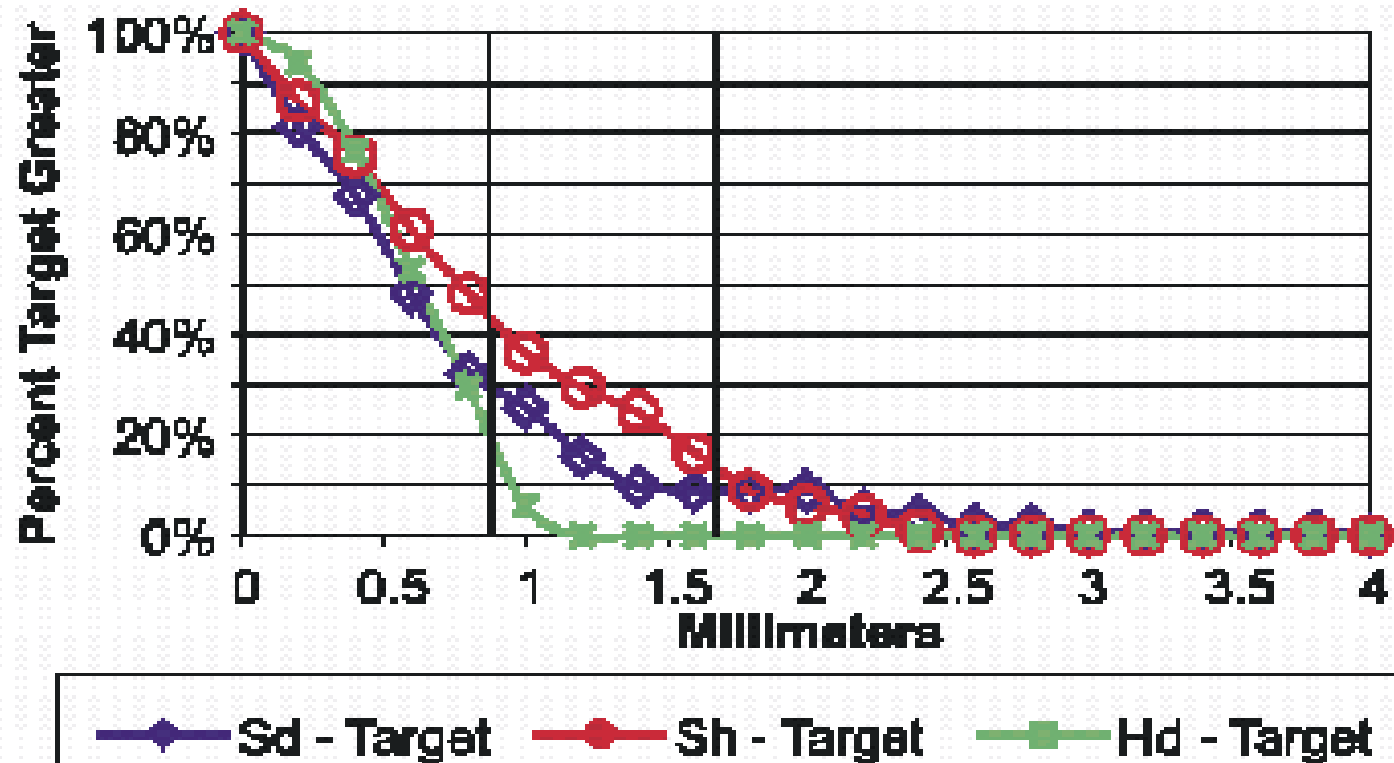
Parameter	Accuracy +/- 0.8mm	Accuracy +/- 1.6mm
Flange Height (Sh)	60%	83%
Flange Thickness (Sd)	72%	91%
Tread Hollow	81%	100%

Some Test Results: Repeatability

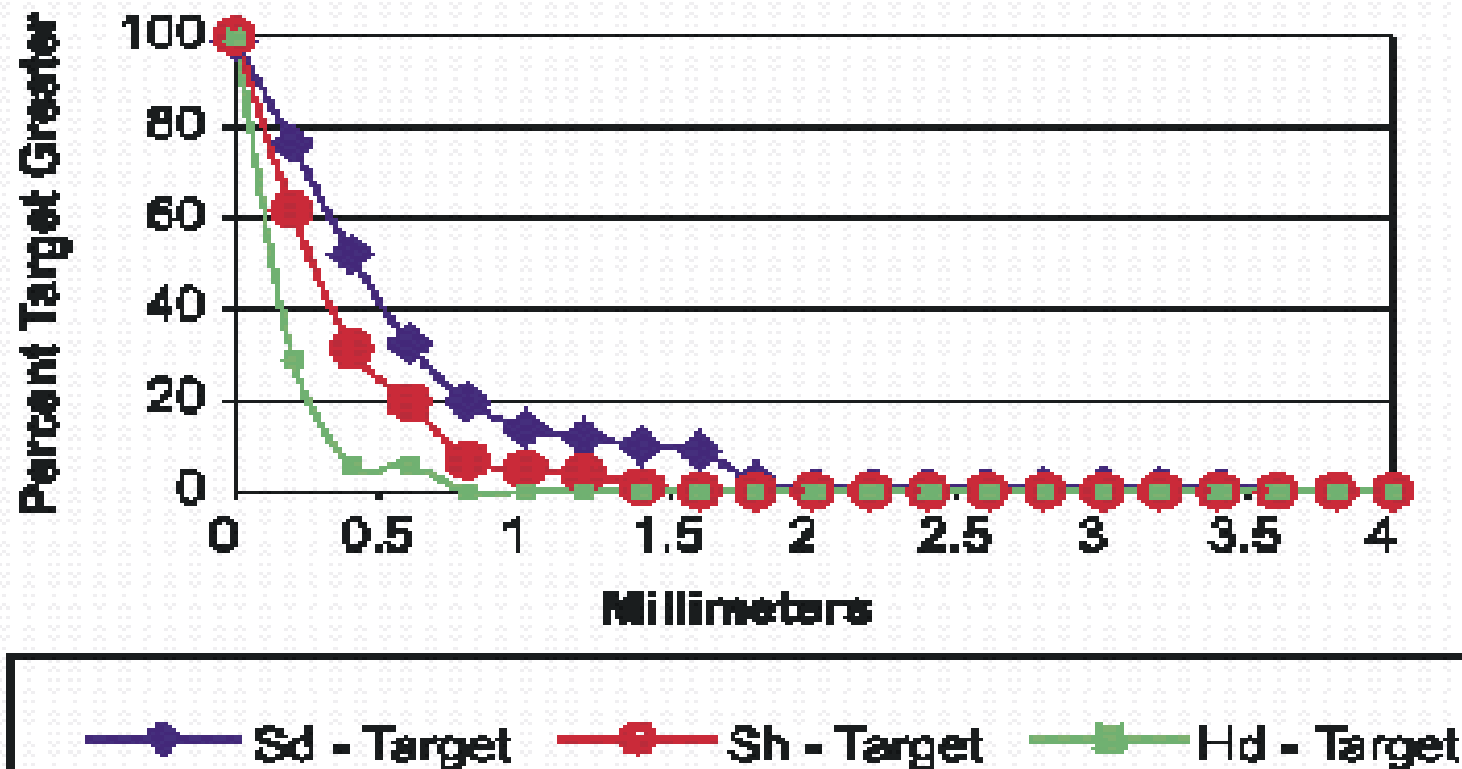
Some Test Results: Accuracy

- **90 %** of the measurements are consistent to within ± 1 mm of the average of all measurements.
- **Standard deviation of measurements**
 - 0.78 mm for flange thickness
 - 0.47 mm for flange height
 - 0.21 mm for read hollow

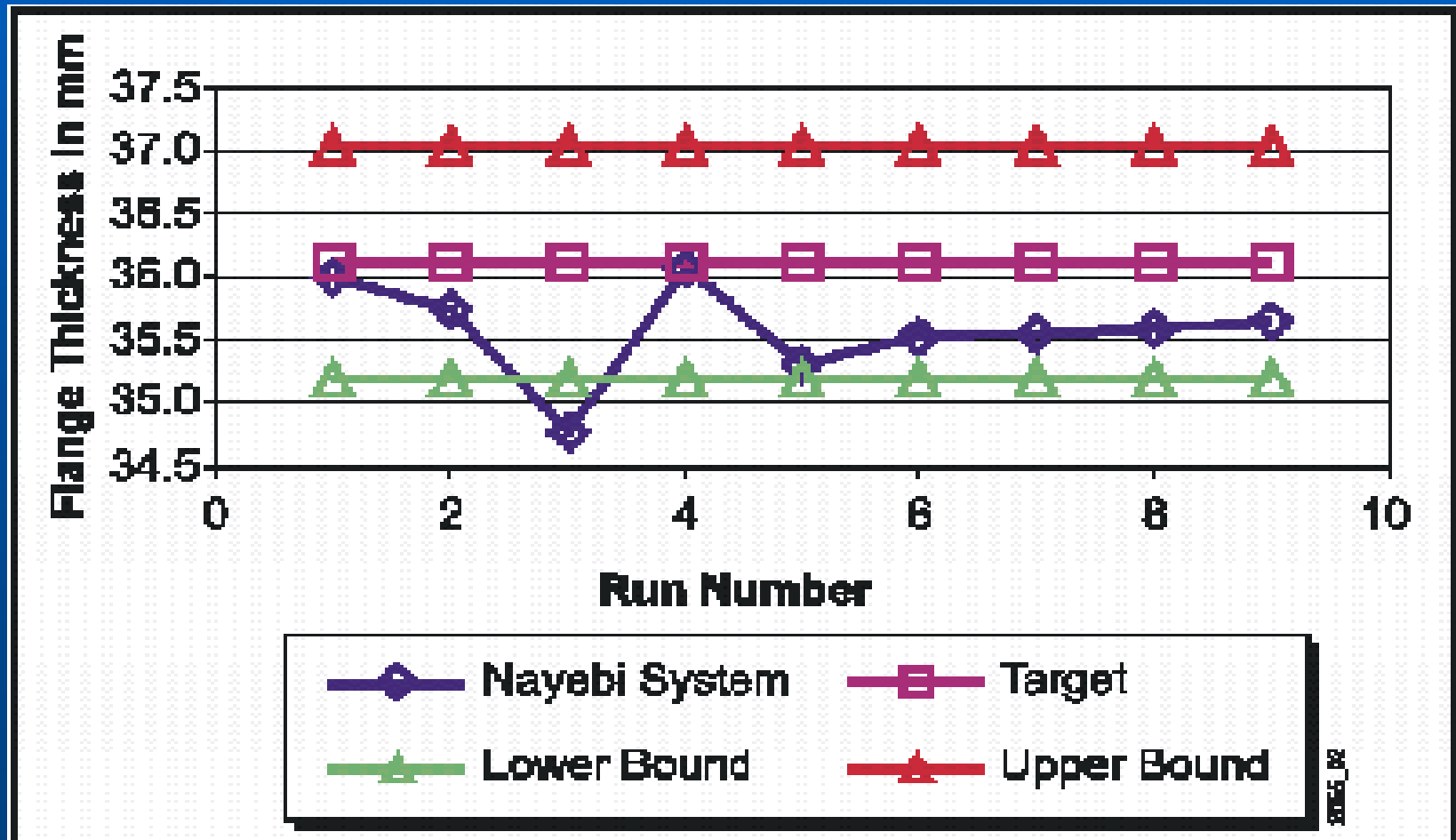
System Accuracy Plot



System Repeatability Plot



Sample Wheel Flange Thickness Plot



Lighting Effects

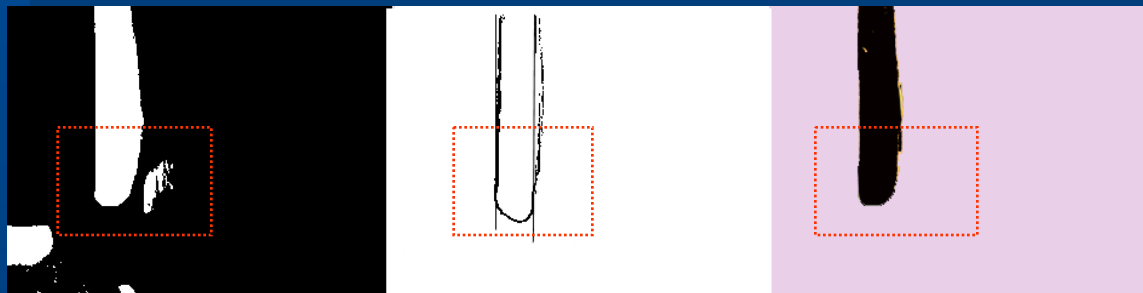
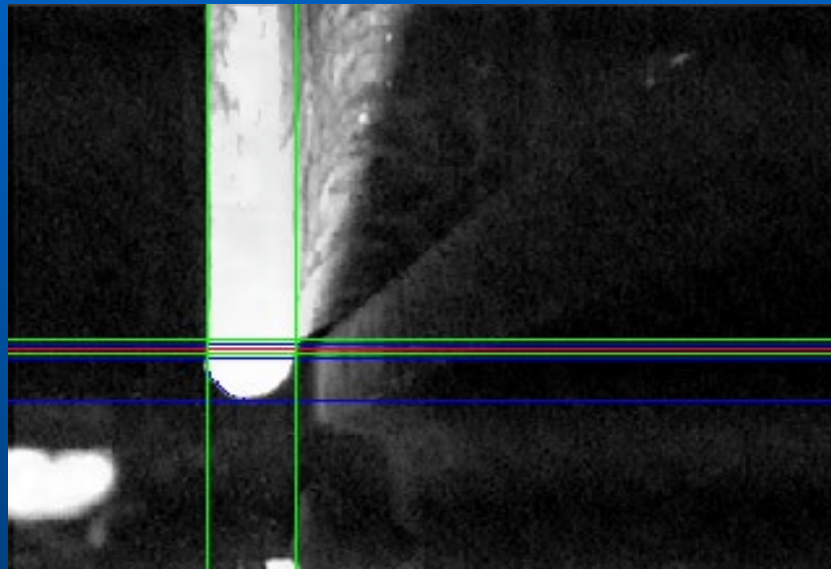


No lighting
Daytime



with proper lighting
daytime

Measurement



Digital Image Processing Algorithms

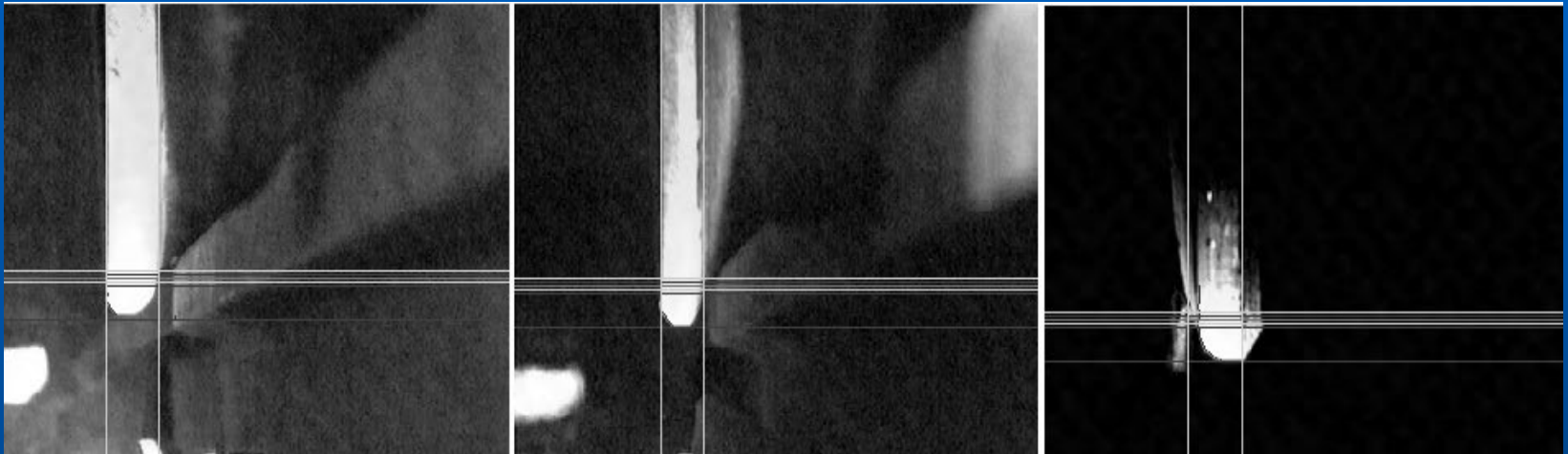
Algorithms:

- Image Enhancement
- Edge Detection
- Segmentation
- Contouring
- Filtering
- Threshold

Procedure:

- 1- Contrast Enhancement
- 2- Search for the wheel Location
- 3- Search for the Flange lower point
- 4- Detect Left Flange Border
- 5- Detect Right Flange Border
- 6- Measure Flange Thickness
- 7- Obtain Flange Profile

Examples



Acceptable

Failed

Mistake (Bad Lighting)

Flange Thickness < 21 mm

Failed

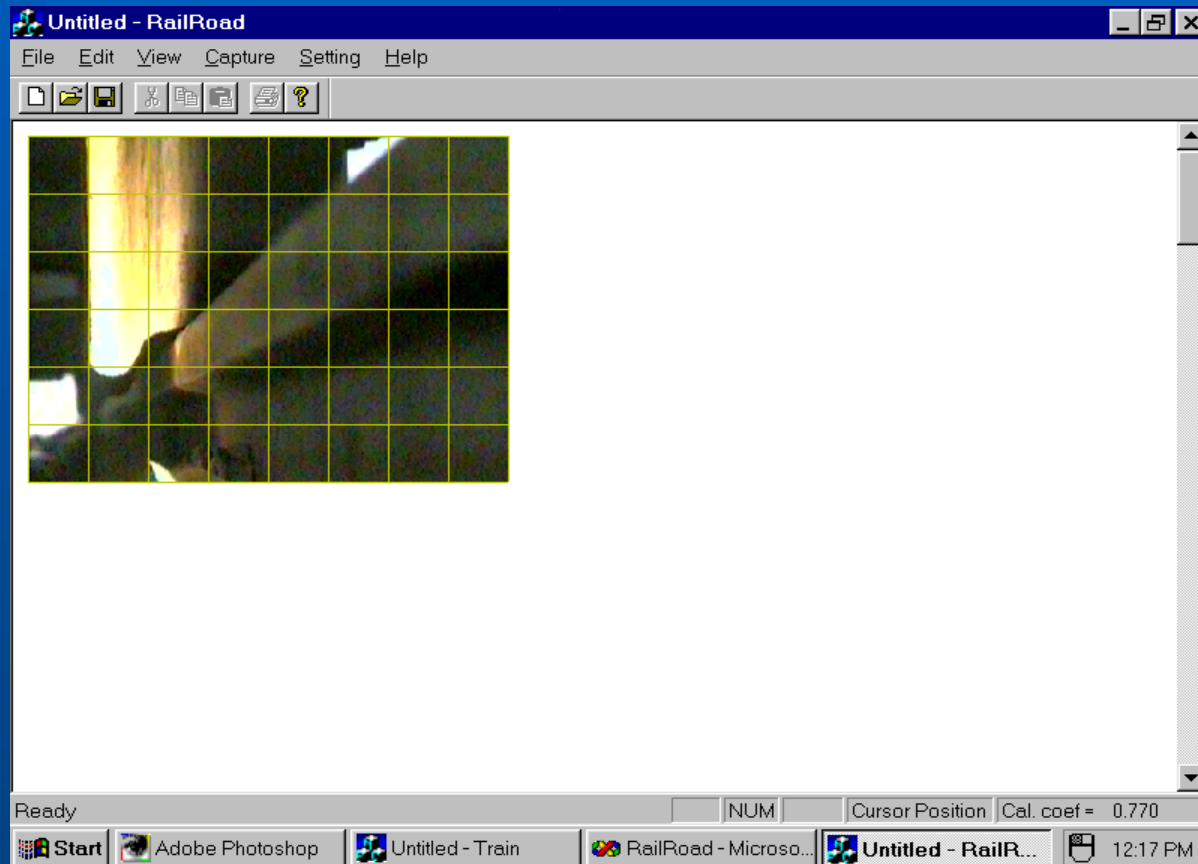
$21 \text{ mm} < \text{Flange Thickness} < 24 \text{ mm}$

Warning

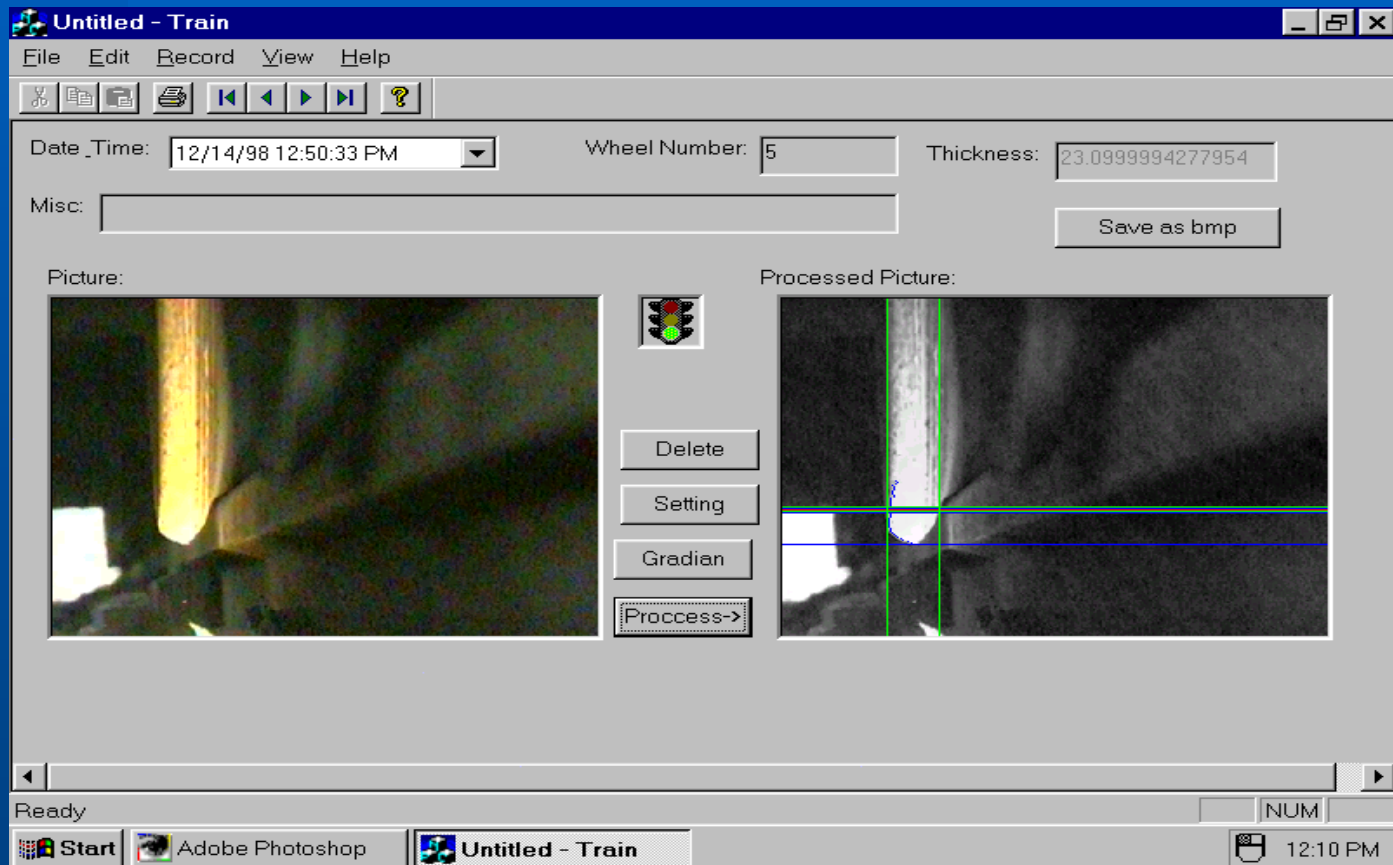
Flange Thickness > 24 mm

Acceptable

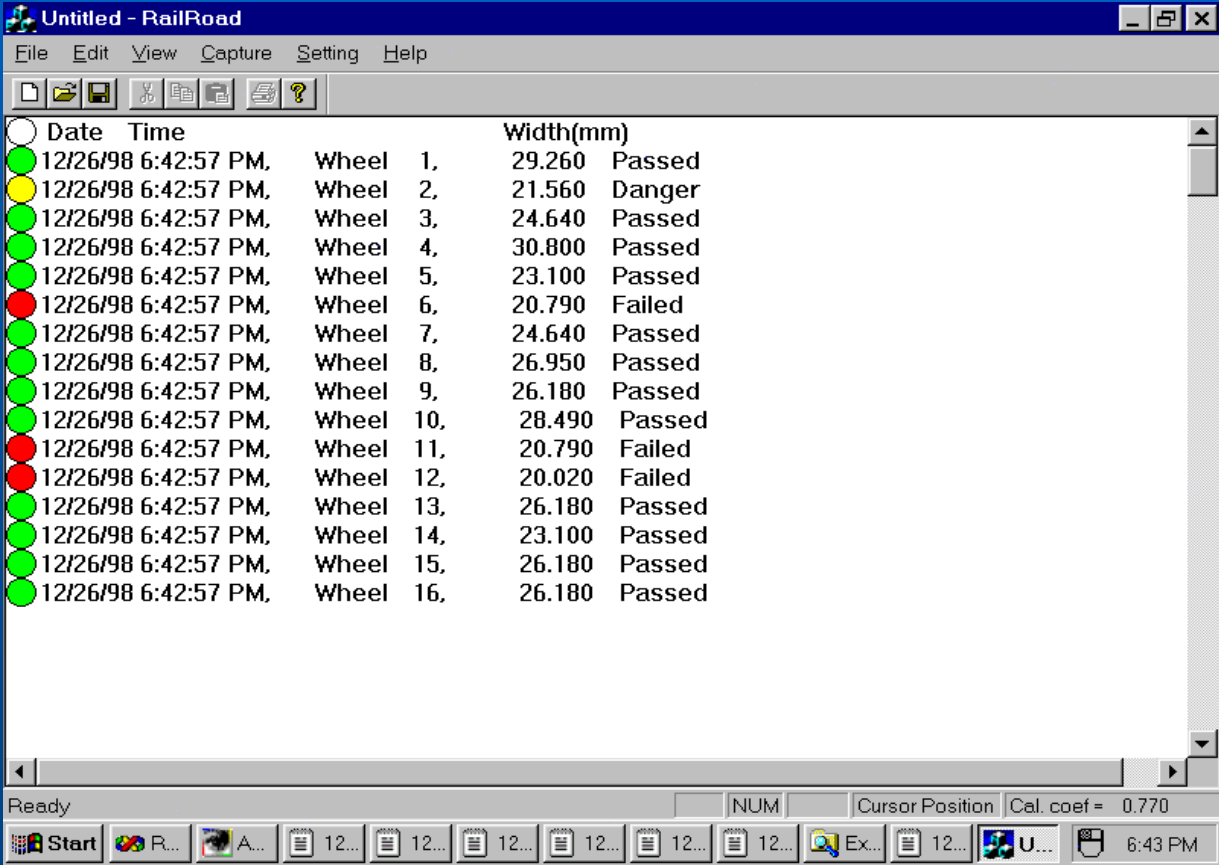
User Interface Software



Review Software



Sample Report



Untitled - RailRoad

File Edit View Capture Setting Help

Width(mm)

Date	Time	Wheel	Width(mm)	Status
12/26/98	6:42:57 PM,	Wheel 1,	29.260	Passed
12/26/98	6:42:57 PM,	Wheel 2,	21.560	Danger
12/26/98	6:42:57 PM,	Wheel 3,	24.640	Passed
12/26/98	6:42:57 PM,	Wheel 4,	30.800	Passed
12/26/98	6:42:57 PM,	Wheel 5,	23.100	Passed
12/26/98	6:42:57 PM,	Wheel 6,	20.790	Failed
12/26/98	6:42:57 PM,	Wheel 7,	24.640	Passed
12/26/98	6:42:57 PM,	Wheel 8,	26.950	Passed
12/26/98	6:42:57 PM,	Wheel 9,	26.180	Passed
12/26/98	6:42:57 PM,	Wheel 10,	28.490	Passed
12/26/98	6:42:57 PM,	Wheel 11,	20.790	Failed
12/26/98	6:42:57 PM,	Wheel 12,	20.020	Failed
12/26/98	6:42:57 PM,	Wheel 13,	26.180	Passed
12/26/98	6:42:57 PM,	Wheel 14,	23.100	Passed
12/26/98	6:42:57 PM,	Wheel 15,	26.180	Passed
12/26/98	6:42:57 PM,	Wheel 16,	26.180	Passed

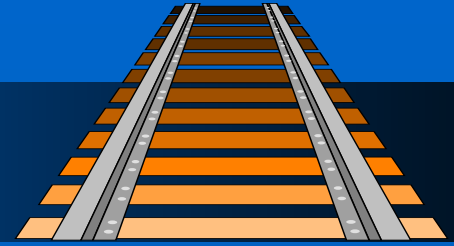
Ready

NUM Cursor Position Cal. coef = 0.770

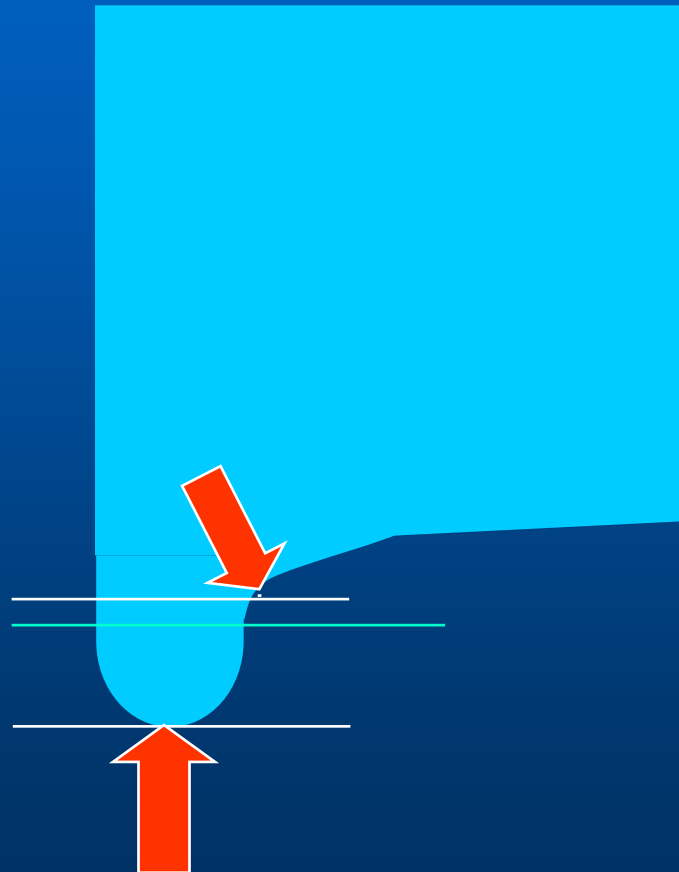
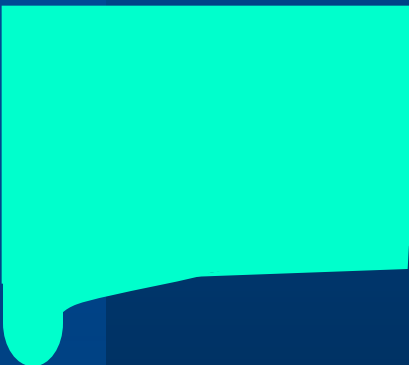
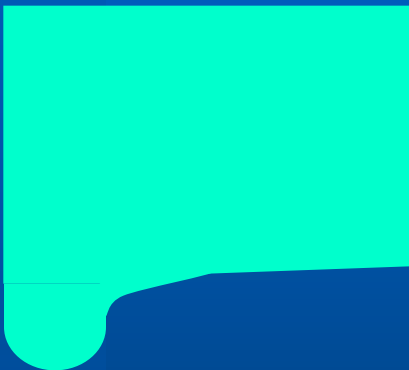
Start R... A... 12... 12... 12... 12... 12... 12... Ex... U... 6:43 PM

[illegible]

Conclusions



- **An Automatic Flange Thickness and Profile Measurement System**
- **Industrial PC based or DSP based**
- **Simple to Install**
- **Relatively Low maintenance**
- **Relatively Inexpensive**
- **Accurate for Flange Failure Detection**



Imaging Procedure

- Direct lighting
- 2000 watts
- 40 cm length
- Light concentrated on flange
- 320x240 resolution
- One or two images per wheel
- Color imaging

