State of the Art
of
Modern Tire Testing

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- State of the Art Tire Testing with SDS
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- Laser Marking Systems

Curriculum Vitae - Stefan Dengler

- ***born*** 1963 in Calw-Stammheim
- ***Apprenticeship for Mechanics*** at Daimler Benz AG
- 1990 graduated as a ***Mechanical Engineer*** from
  University of Applied Sciences Esslingen
- 1990-1997 ***Employee*** in the field of Engineering, Marketing and Sales
- 1992 Start with ***Consulting Engineer Office (IBD)***,
  doing construction and manufacturing of components
  for tire test systems and other applications
- 1998 Foundation of ***SDS Systemtechnik GmbH***

SDS Product Range

- Interferometric Tire Tester
  in the Production, R&D, Test Labs, Racetrack, ….
  for new tire production and retreading of all type of tires

- Laser Marking Systems
  in the truck tire retreading and with Automotive Manufacturer (Testing)
  Handheld-Systems for OTR and Agriculture Tire Industry
  semi- and fully automated systems for OEM applications

- 2-D Measuring Systems and Color Detection
  Profile Measurement offline and inline for thickness, width, variation, symmetry, comparison of nominal and real profile in extrusion and calander applications
  Inline Tread Length Measurement systems, Splice verification, ..
  Color Line Detection inline and offline Layer Check System

- 3-D Contouring Systems
  PTS - pressure test system for casing inspection in the Retread Industry
  EMS - monitoring system for durability test, high speed test, ….
  CMS - automatic wear measurement of Aircraft Tire

From **Construction**
over **Production**
to the **Final Product**

out of “one Hand” !

Installation to **After Sale Support**
together with the **Worldwide SDS Network**

SDS facility
Southwest of Germany
(~ 30km from Stuttgart)

Administration, assembling
and production (total 3000m²)

22 employees at SDS in Germany:

- 5 administration and after sales support
- 4 construction and development (soft- and hardware)
- 10 production and assembly, installation and support
- 3 apprentices (electro mechanics and commercial)

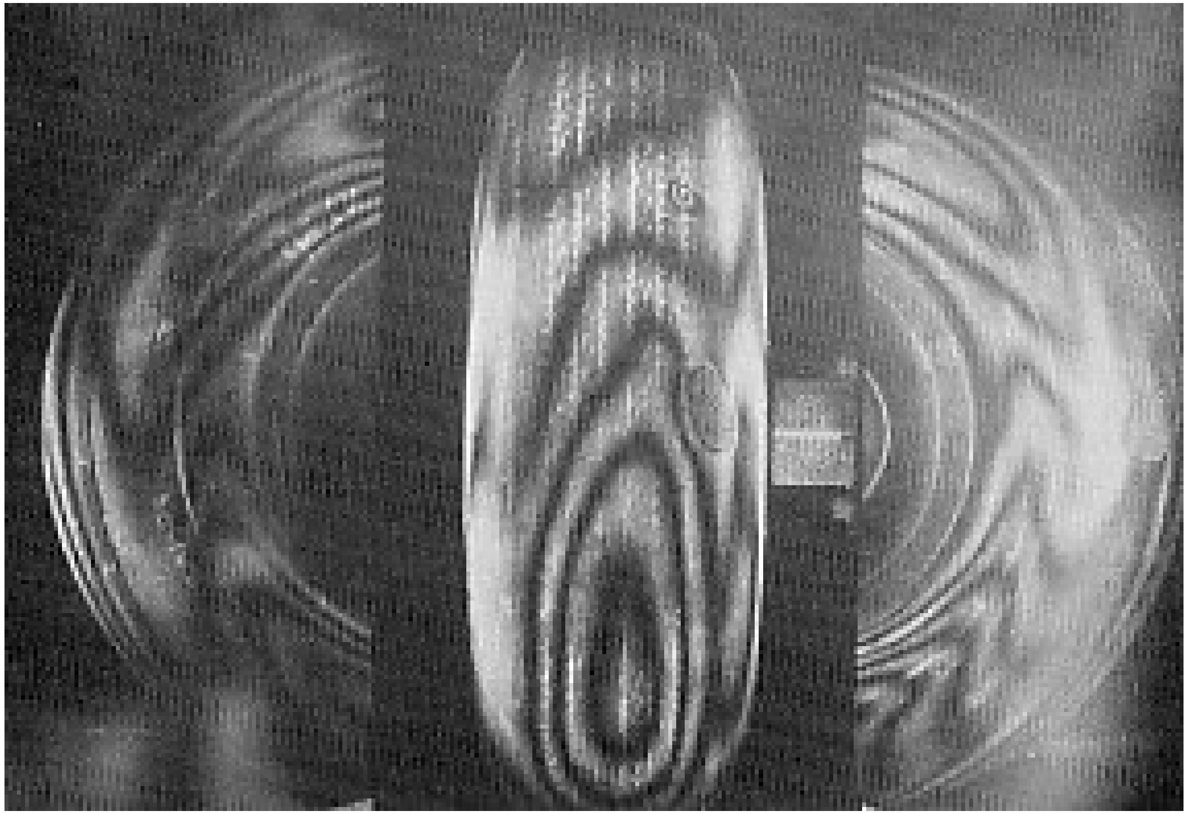
1 employee in Shanghai, China for sales and support

Today more then 500 installed systems..

Interferometric

Tire Inspection

“Milestones”

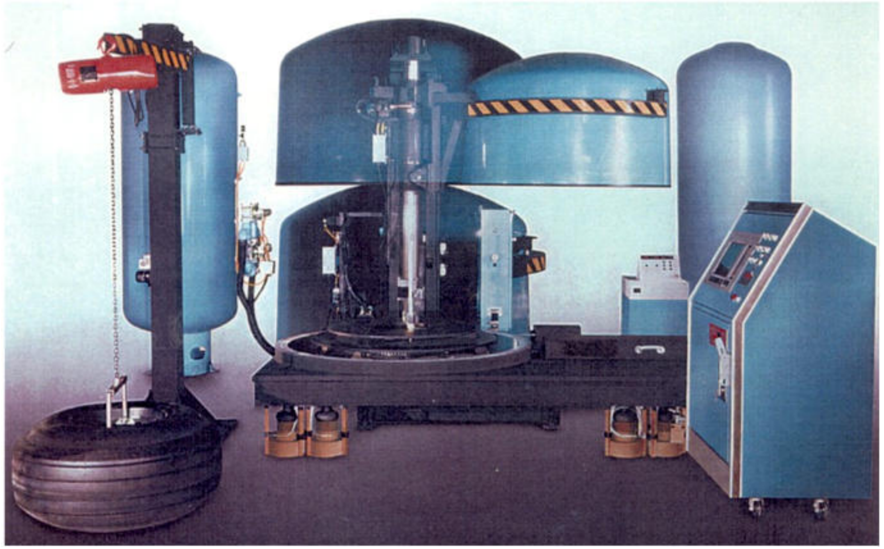


Dennis Gabor 1971
first double puls Hologram of a tire (Goodyear, Akron)

1973

IHI (USA) designed the first
Holographic Tire Tester (+ $ 500.000)
with film and gas-laser

Test time: 10 min/tire
+ long relaxation



Tires must be manually spreated

Manual tire loading and centering with crane

Manual positioning of measuring head

Chemical processing of the film and offline verification

1993

LTI (USA) developed the first shearing interferometer with electronic camera

Test time: 8 min/tire (bead to bead)

Manual loading by rolling in/out

The filmless system reduced the cost per tire significant

Bead to bead inspection with vertical test position of the tire!

1998 SDS started with the serial production of industrial tire test systems

Vergölst, Bad Nauheim

At that time one of the largest retreaders in Europe

For initial inspection and partly final inspection

Test time: 2 min/tire crown only
5 min/tire bead to bead

Innovation:

Introduction of multiple laser diodes to minimize operation cost and downtime

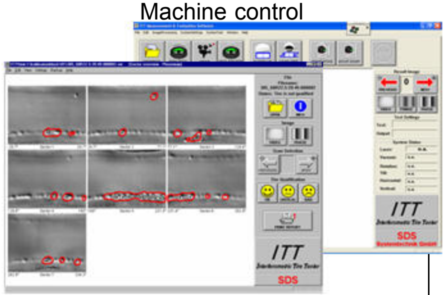
Automated tire handling with conveyor system
Automatic positioning of measuring head

Barcode System to identify production number for archiving and traceability

Interferometric Tire Tester for all tire applications:

Machine control

Result verification



- from 8” inner diameter up to 63”
- up to 1800 mm tire width and 7 ton weight
- from manual to fully automatic testing

- ITT *Easy*
  type 1280
  Truck tire retreading
- ITT-1
  type 1280,1680
  R&D, retreading
  New Tire Production
- ITT-2
  type 1080, 1280, 1680
  New tire production
  and industrial retreading
- ITT-*OTR*
  up to 63” tires
  R&D, retreading
  New Tire Production

ITT systems in new tire applications and retreading:
(1998 – April 2018)

Retreading	286 Truck tire 3 OTR tire 35 Aviation tire	*2,1x*
New tire + R&D	147 Truck tire 5 OTR tire	
scrapt machines	**only 6 since 20 years !**	

Application and “location” of ITT systems:

Europe	**105** Retread **29** New Tire **11** Aviation	*3,6x*	
USA + Canada + Mexico	**150** Retread **29** New Tire **10** Aviation	*5,2x*	
Japan	**4** Retread **8** New Tire **1** Aviation	*2,0x*	
China	**2** Retread **39** New Tire **5** Aviation	*19,5x*	
Germany + Austria	**32** Retread **7** New Tire **0** Aviation		

“state of the art”

tire testing

with SDS

With "State of the Art" in Shearography

the focus goes to:

- **Cost** per tire

- **Test capacity** or **cycle time** per tire

and

- **Standardization** of **test conditions** and **validation**

- Automated **material**, **test** - and **result handling**

Cycle Time per Tire

previously **film-based** Interferometry and Shearography with B/W film

today **film-less** “Speckle-Shearing” with digital cameras

- No chemical process with film
- Instant test result directly after test is completed
- Short exposure time and fast data transfer with CMOS and GigE
- Automatic tire handling and multiple cameras (and machines)

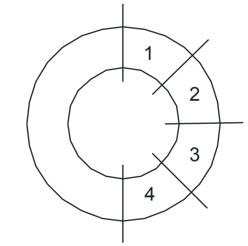
Cycle time: (bead to bead)	**1973 ~ 10 min**	(not including film processing, offline)
	1998 ~ 6 min	
	2018 ~ 1 min	(Twin machine setup)

Twin machine : less than 1min per Tire, bead to bead

- 2 Triple head machines
  1x center camera
  for crown only, no tilt
  2x sidewall cameras
- Turn over fixture
  between

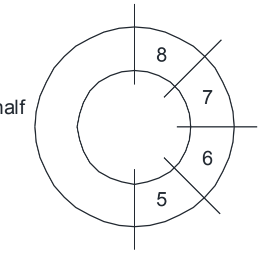
1. Cycle:

first half
of crown

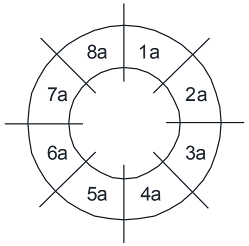


2. Cycle:

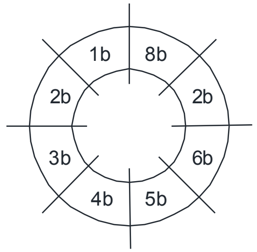
second half
of crown



first
sidewall
(a)



second
sidewall
(b)



Inspection Cost per Tire

previously Interferometry and Shearography with **Gas-Laser**
=> This was **High tech for physicist**
today electronic “Speckle-Shearing” with **CMOS camera** and **Laser-Diodes**
=> still **High tech** but low skill

- No consumables (film, chemicals, etc.)
- Less maintenance, less downtime
- Less electric energy consumption for laser: ~ 20 kW -> ~ 1 W
  vacuum system: ~ 4.6 kW -> ~ 2 kW
- Longer laser lifetime: from ~3000h today typically more than 20000h

Cost per tire:	**1973 ~**	**10,00 €**	(not including depreciation)
	1998 ~	**0,05 € to 0,15 €**	(converted from DM)
	2018 ~	**0,02 € to 0,05 €**	

Standardization of test procedure and validation

To get a reproducible test result:

- test conditions and parameters have to be defined and controlled
  (within one organization or even in the industry)

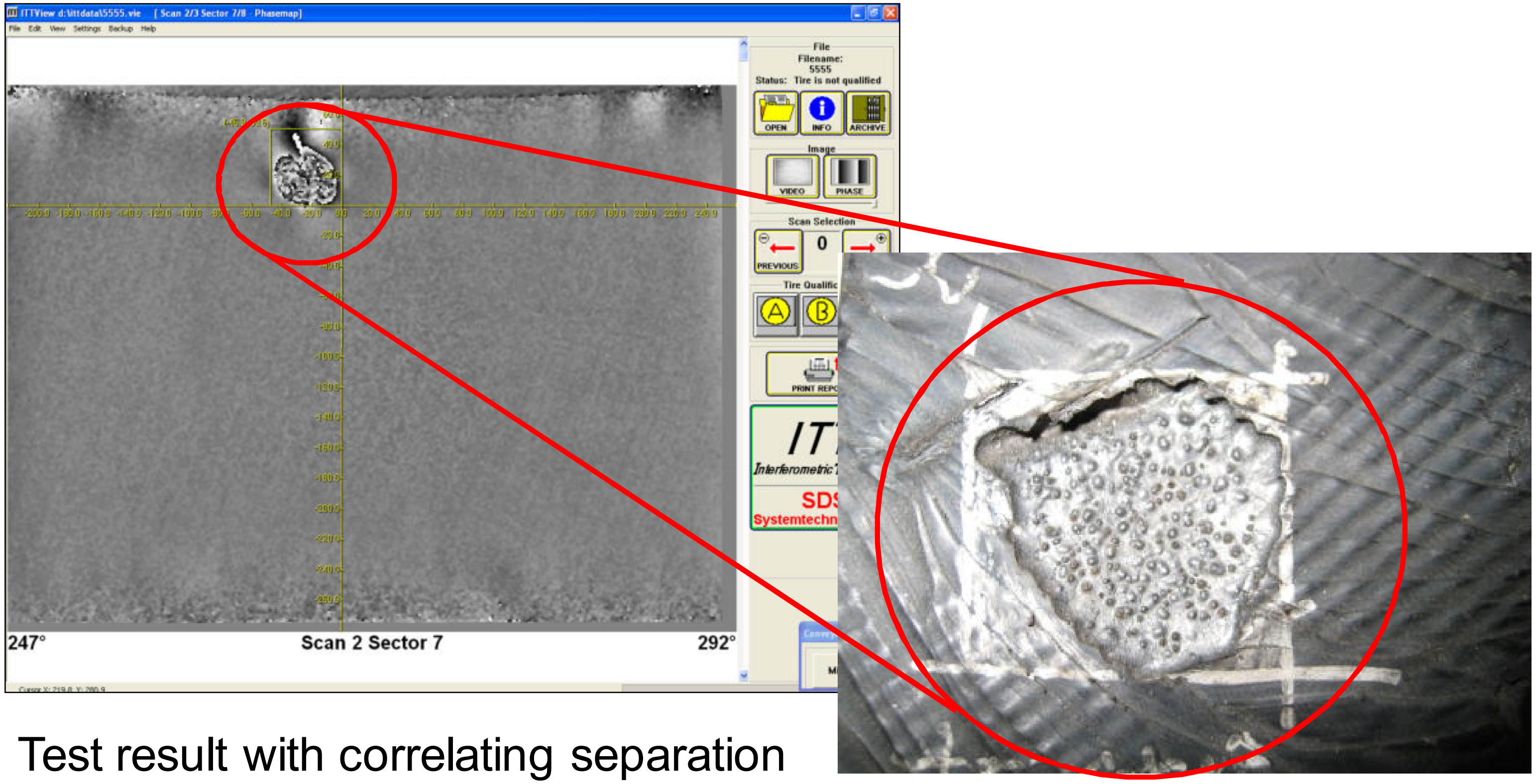
SDS provide **Automated Processes**

To get a reproducible validation

- Criteria have to be defined ("anomaly library")
- Operators have to be skilled

SDS provide **Automated Evaluation**
to reduce variance of manual measurement

How to do a traceable and repeatable validation of a test result ?



Test result with correlating separation

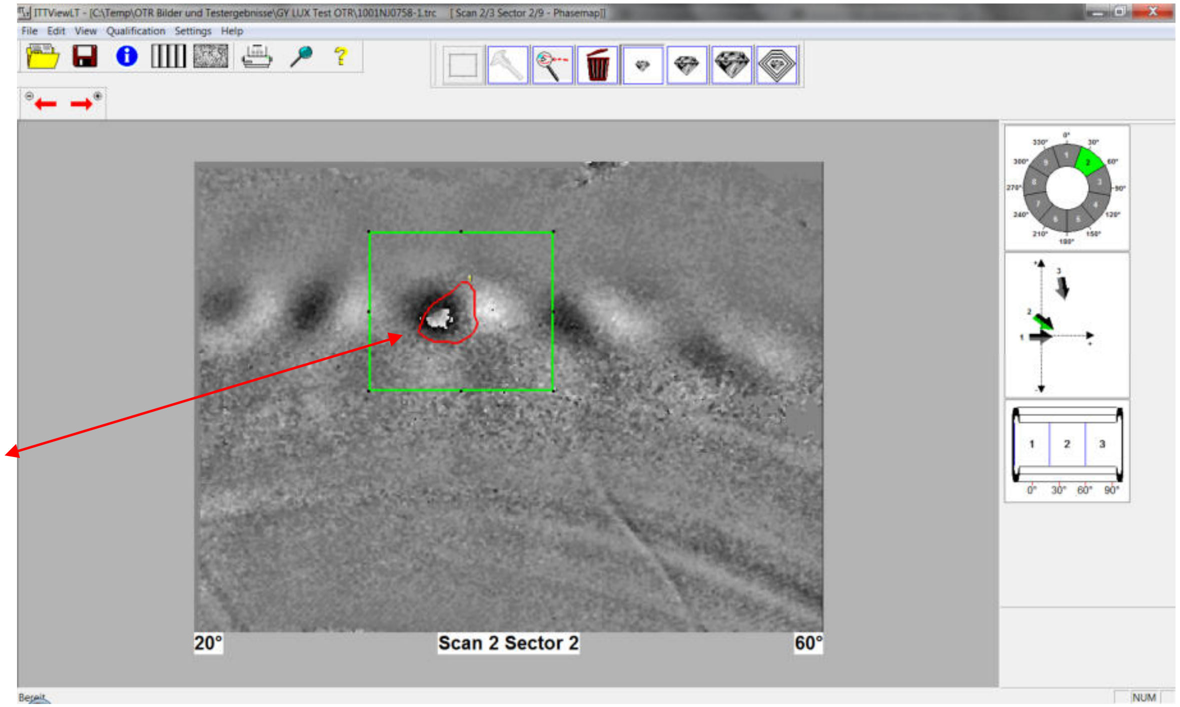
Simplified Solution for an **operator independent evaluation**

by an **automated validation** of anomalies **by Software**

"Flexible" evaluation zone
(within the green borderlines)

moved over critical area

Evaluation done by software
with predefined criteria



or **fully automatic detection** of anomalies **by Software**

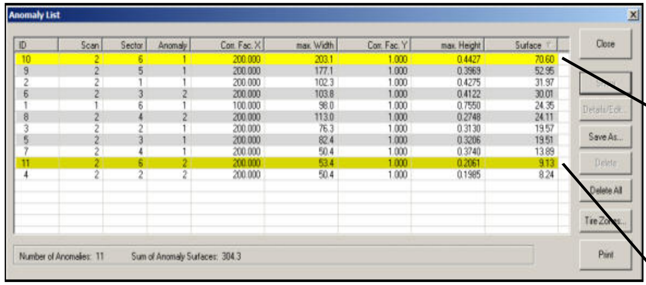
Automatic **A**nomaly **D**etection (AAD) with specific tire zones

Detected anomalies with

- ✓ Always correct scaled dimensions
- ✓ Correct assignment to tire zone
- ✓ Individual criteria depending on zone

The step into an **automated processing**

for a **repeatable and traceable validation**

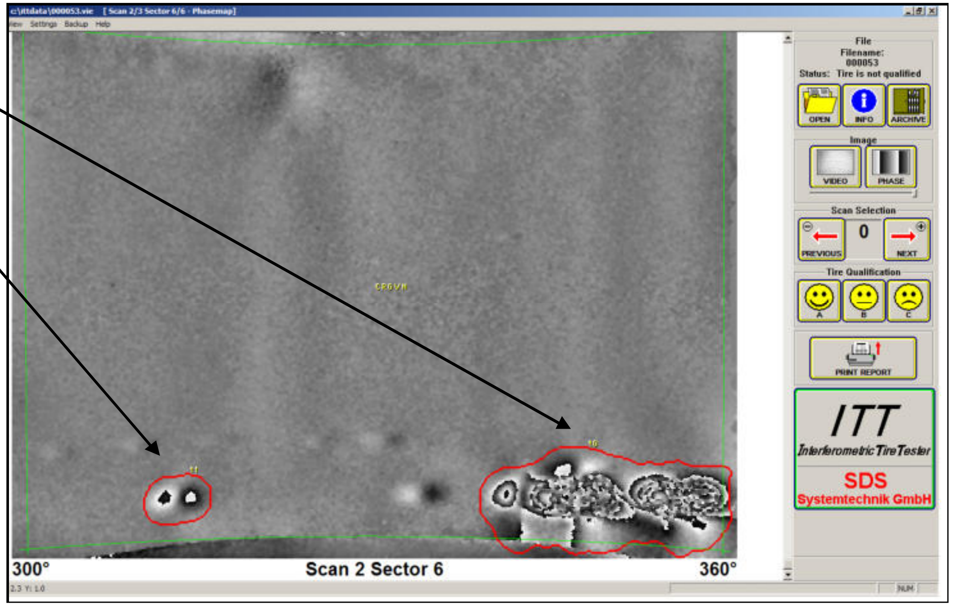


Anomaly List

ID	Scan	Sector	Anomaly	Corr. Fac. X	max. Width	Corr. Fac. Y	max. Height	Surface
10	2	6	1	200.000	203.1	1.000	0.4427	70.60
9	2	5	1	200.000	177.1	1.000	0.3969	52.95
2	2	1	1	200.000	102.3	1.000	0.4275	31.97
6	2	3	2	200.000	103.8	1.000	0.4122	30.01
1	1	6	1	100.000	98.0	1.000	0.7550	24.35
8	2	4	2	200.000	113.0	1.000	0.2748	24.11
3	2	2	1	200.000	76.3	1.000	0.3130	19.57
5	2	3	1	200.000	82.4	1.000	0.3206	19.51
7	2	4	1	200.000	50.4	1.000	0.3740	13.89
11	2	6	2	200.000	53.4	1.000	0.2061	9.13
4	2	2	2	200.000	50.4	1.000	0.1985	8.24

Number of Anomalies: 11 Sum of Anomaly Surfaces: 304.3

Close Details/Edit... Save As... Delete Delete All Tire Zones... Print



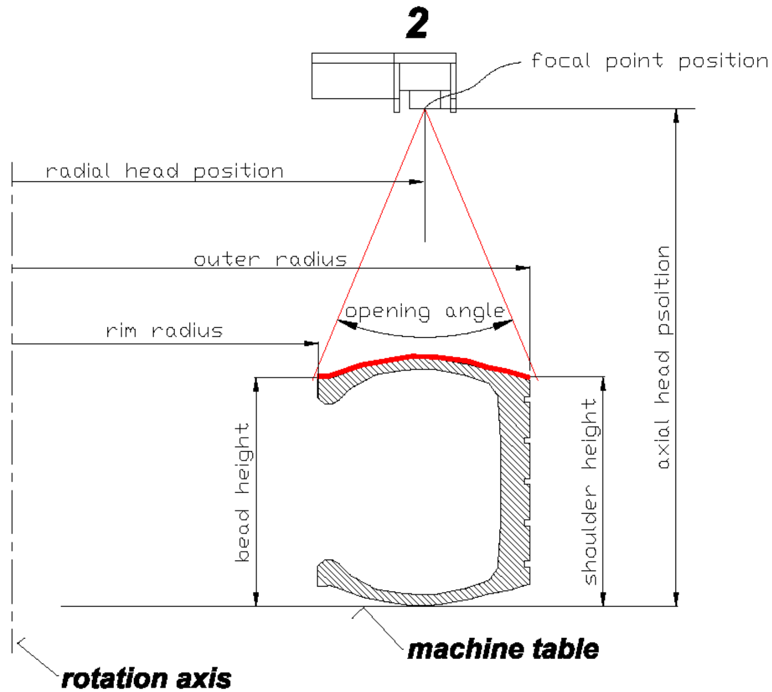
Findings are listed in a table:

- automated classification
- sorting on conveyor
- statistical evaluations, etc:

For a **fully automatic detection** of anomalies with tire zones the contour of every tested tire is required

Calculation of tire contour based on:

- Tire data
  - Rim radius
  - Outer radius
  - Bead height
  - Shoulder height
- Machine parameter
  - Opening angle of viewing field (lens)
  - Camera position relative to tire center

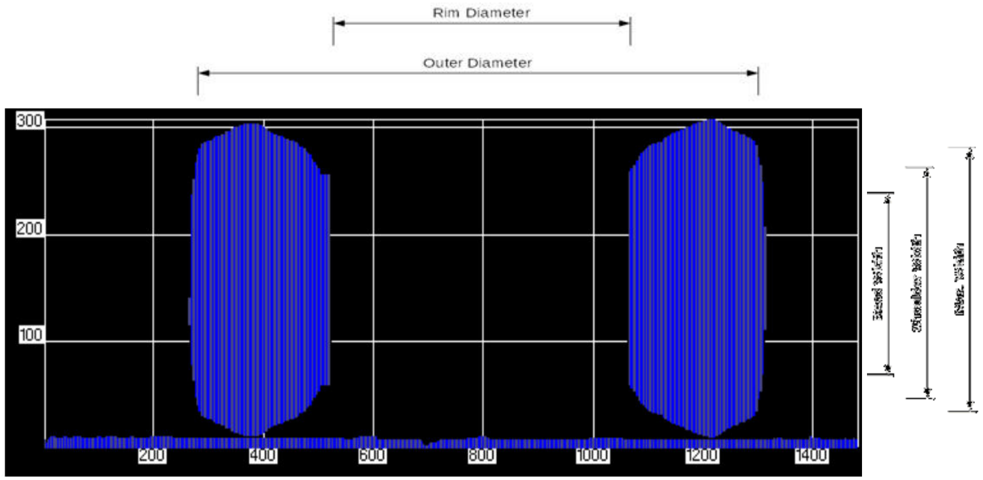


Automatic Tire Contour Detection (TCD)

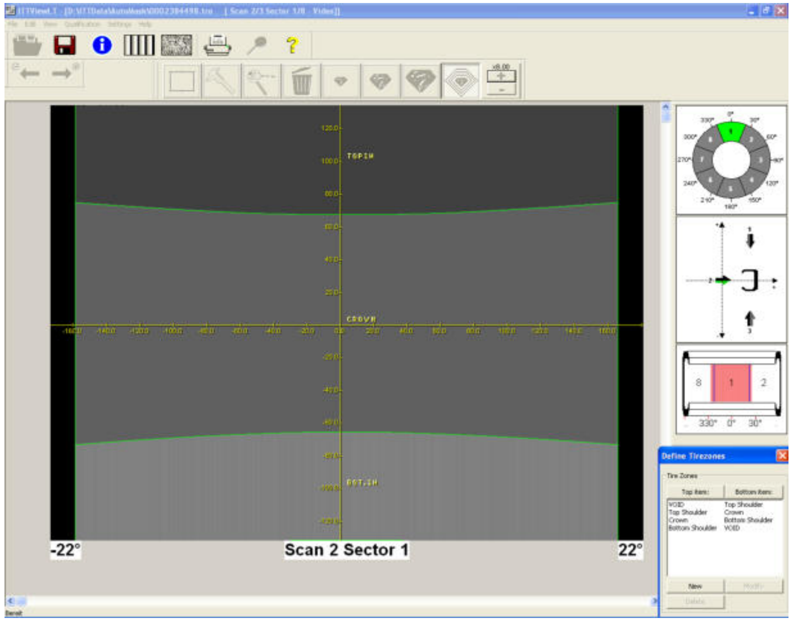
- Verification before loading into tire test system
- Interface with process control to match tire information for test result handling
- Measuring complete tire contour for
  - Correct positioning of all cameras (triple head – bead to bead operation)
  - Calculation of evaluation zones for Automatic Anomaly Detection (AAD)

TCD module attached to vacuum chamber

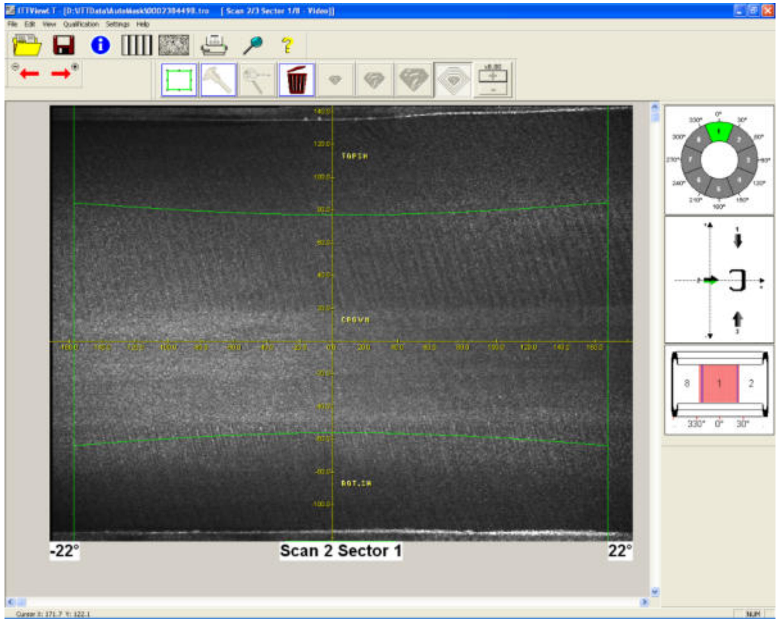
Result of contour measurement with computed main dimensions for positioning



Computation of tire zones in crown scan

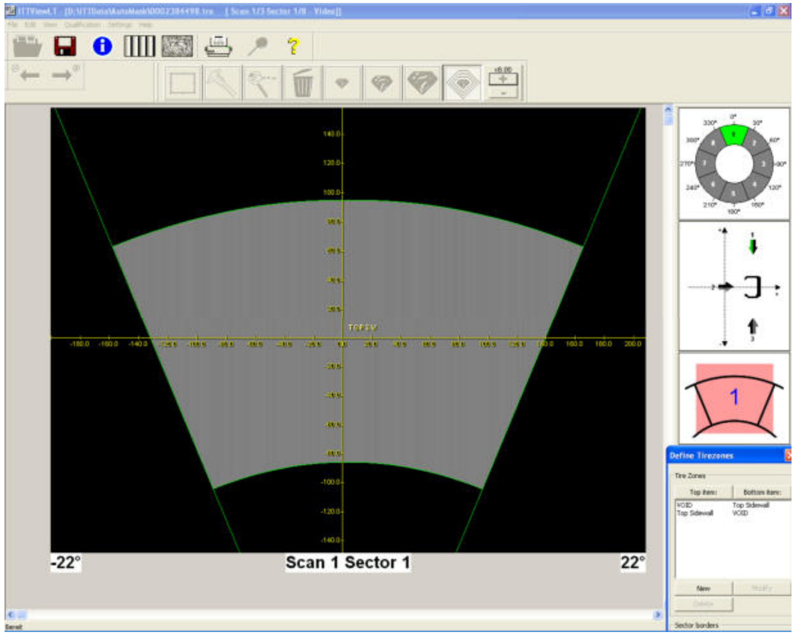


Tire zones crown

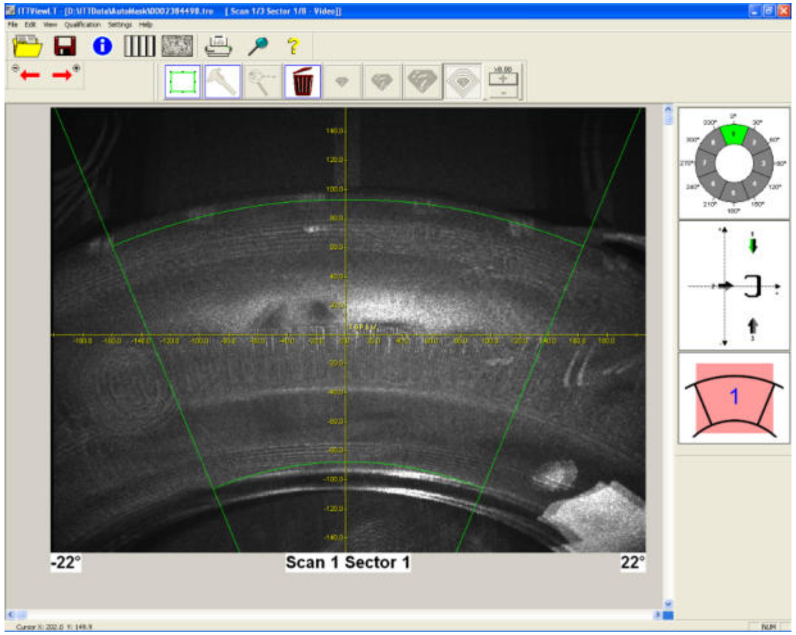


Tire zones crown superpositioned over sector image

Computation of tire zones in sidewall scan

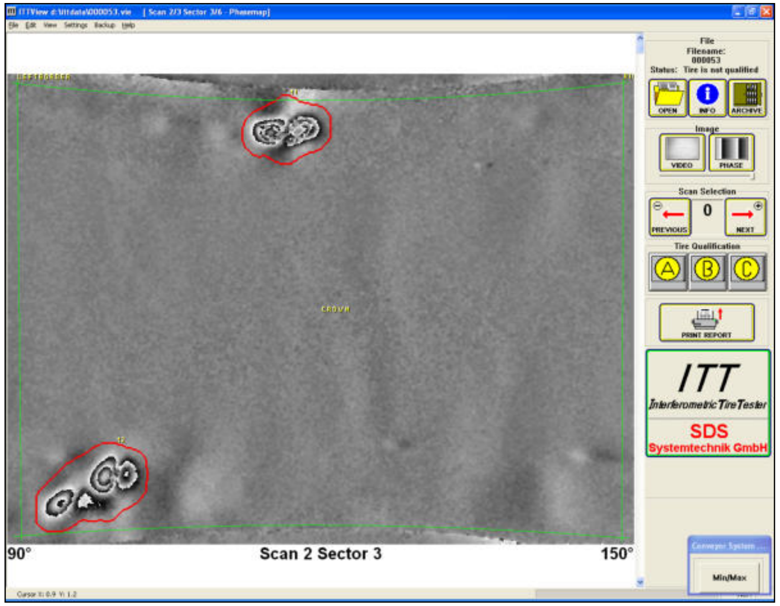


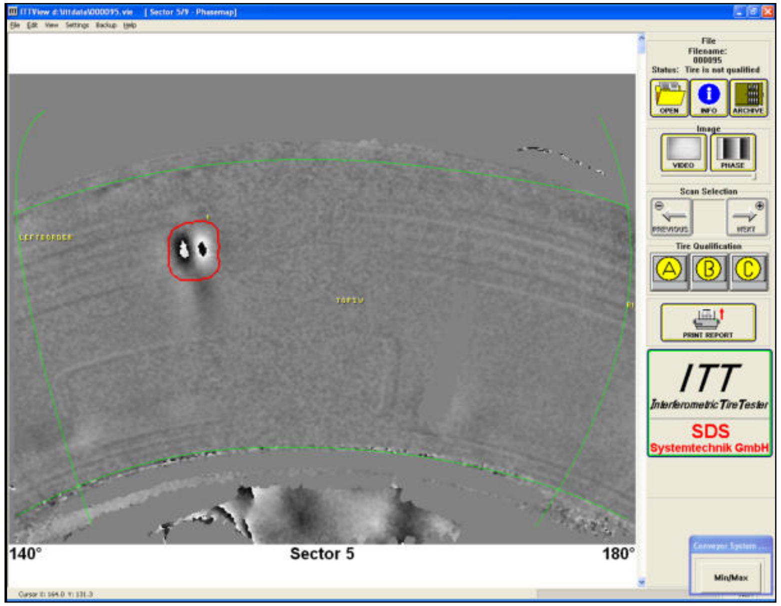
Tire zones sidewall



Tire zones crown superpositioned over sector image

Automatic Anomaly Detection combined with Tire Contour Detection





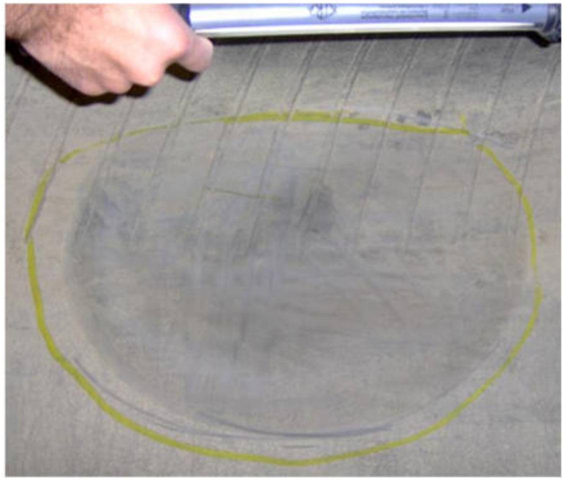
Tire zones for crown and sidewall superpositioned over sector image

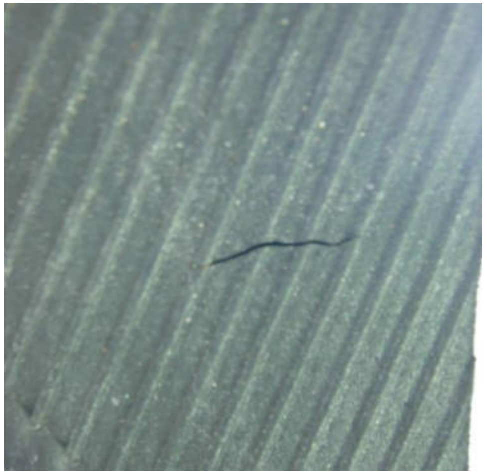
- for automated evaluation with different criteria
- for eliminating overlap in automatic evaluation

Automatic Anomaly Detection combined with Tire Contour Detection

- ✓ Head positioning is adapted to each individual tire
- ✓ All results are calibrated
- ✓ All results show correct location of tire zones (crown, shoulders, sidewalls)
- ✓ Automatic anomaly detection is executed tire zone specific
- ✓ Avoidance of anomaly detection outside regions of interest

ATTENTION: Interferometric Tire Testing can **NOT** eliminate a visual inspection!!





These indications are open to atmosphere
The vacuum can not cause a deformation !

⇨ **The ITT will show no anomaly !!**

automated
Pressure Test System

for
Structure Testing of Casings

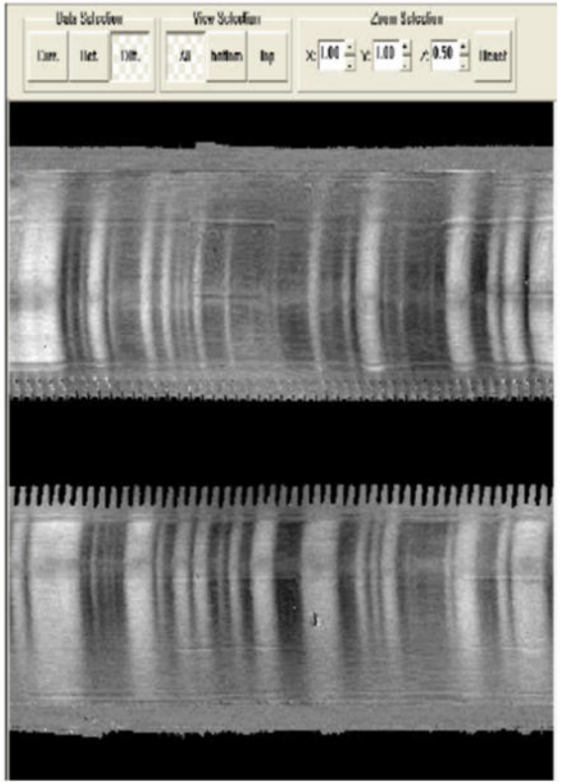
With all the advantages –
Shearography has some restrictions

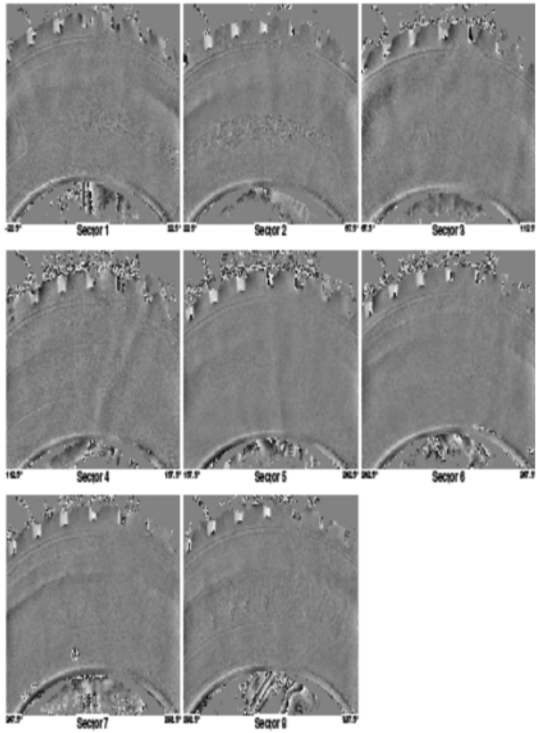
Limited sensitivity to <u>structural</u> defects, because:

- they are often open to the atmosphere
- they do not necessarily cause separations or they are not large enough to be detected
- the structure is not stressed during test

Comparison

ITT – PTS Results

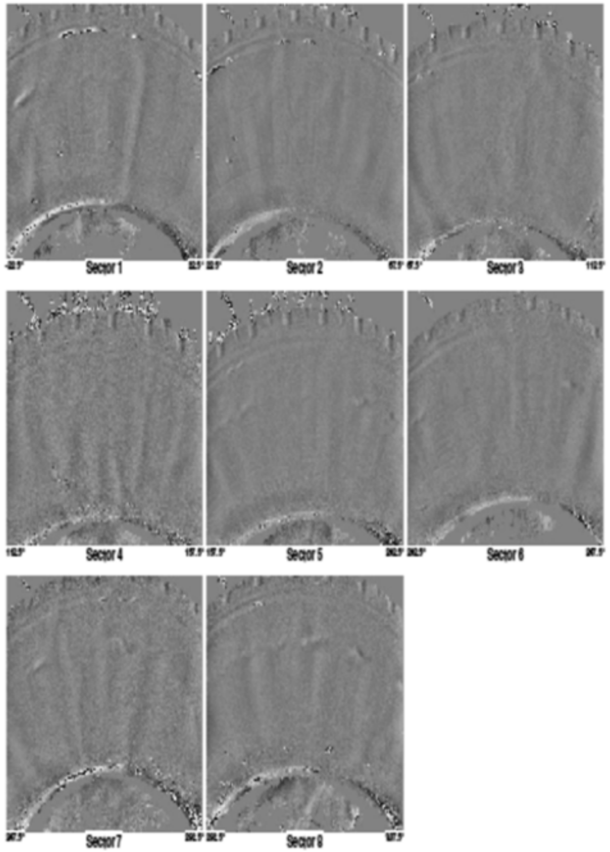




- Clear indication of broken/fatiguing cables in both sidewalls with PTS

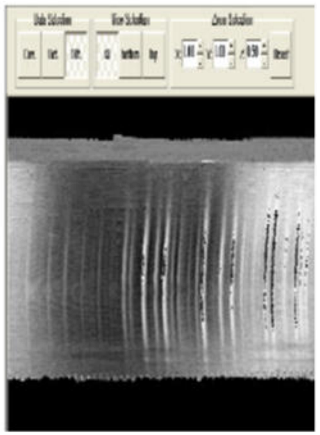
Comparison

ITT – PTS Results



- Some minor shadows
  in the ITT- result of the sidewall,

- Clear indication of broken/fatiguing cables in the same sidewall with PTS



Scope of Inspection *(ECE 109, 6.7.2. structural test during process)*

- Detect structural anomalies in casings,
  - such as fatigue, broken cables, ..
- Verify tire repairs - structure of repaired area
- Geometrical measurement such as run-out, diameter,..

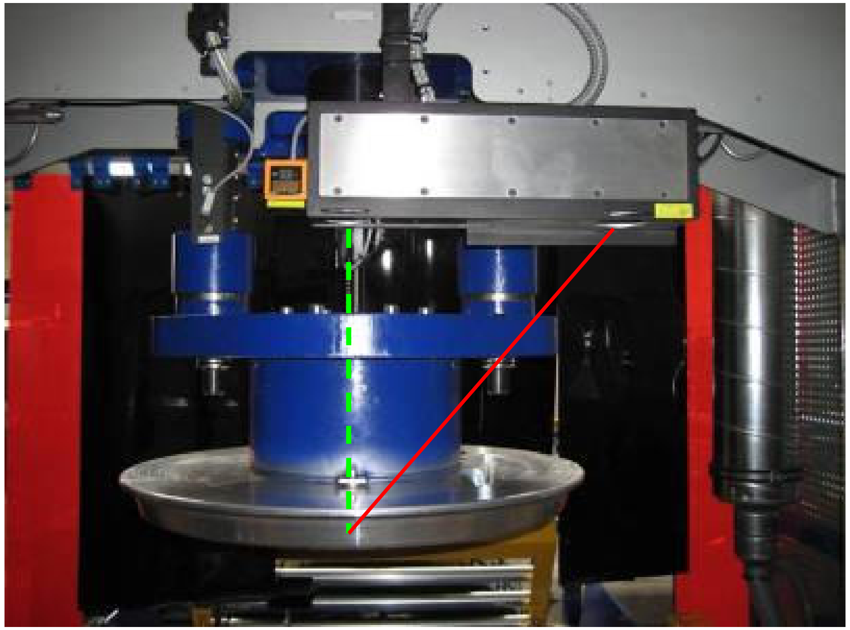
but

- Non contacting (by operator)
- With lower test pressure (max. 4bar)
- With a traceable test result: stored, printed etc.
- Automated, could be inline with an ITT

Automatic Pressure Tester “PTS”

PTS inline with an ITT

PTS stand alone with pneumatic loader/unloader

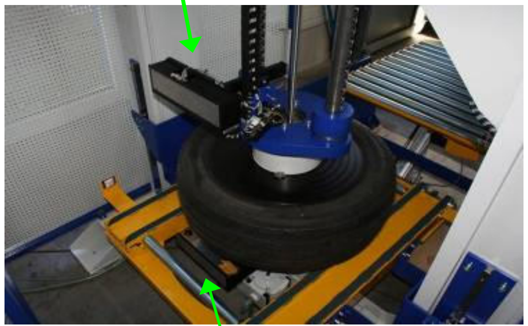


Camera

Line-Laser

Triangulation with projected line
„Sheet of Light“ - Triangulation

upper measuring system



lower measuring system

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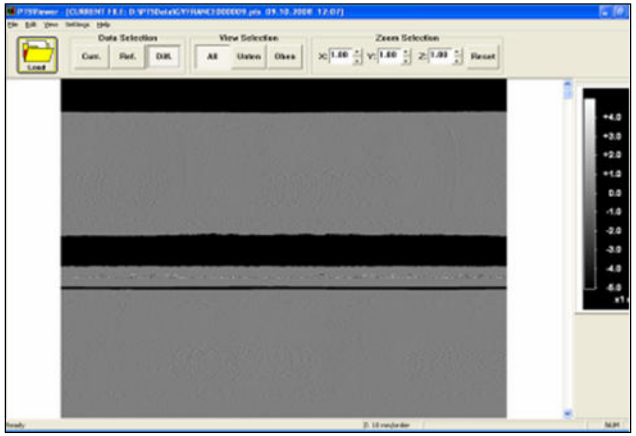
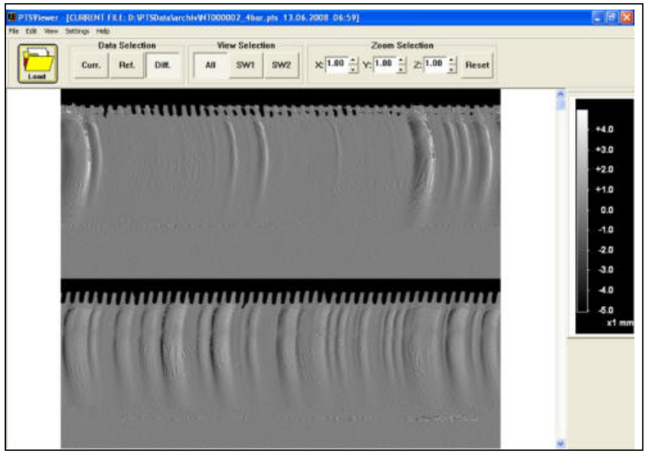
Test Result and Verification

Data from both sidewalls are displayed together in one view
(optional tread measurement will be display between the sidewalls)

and the deformation (z) displayed with a “grey scale”



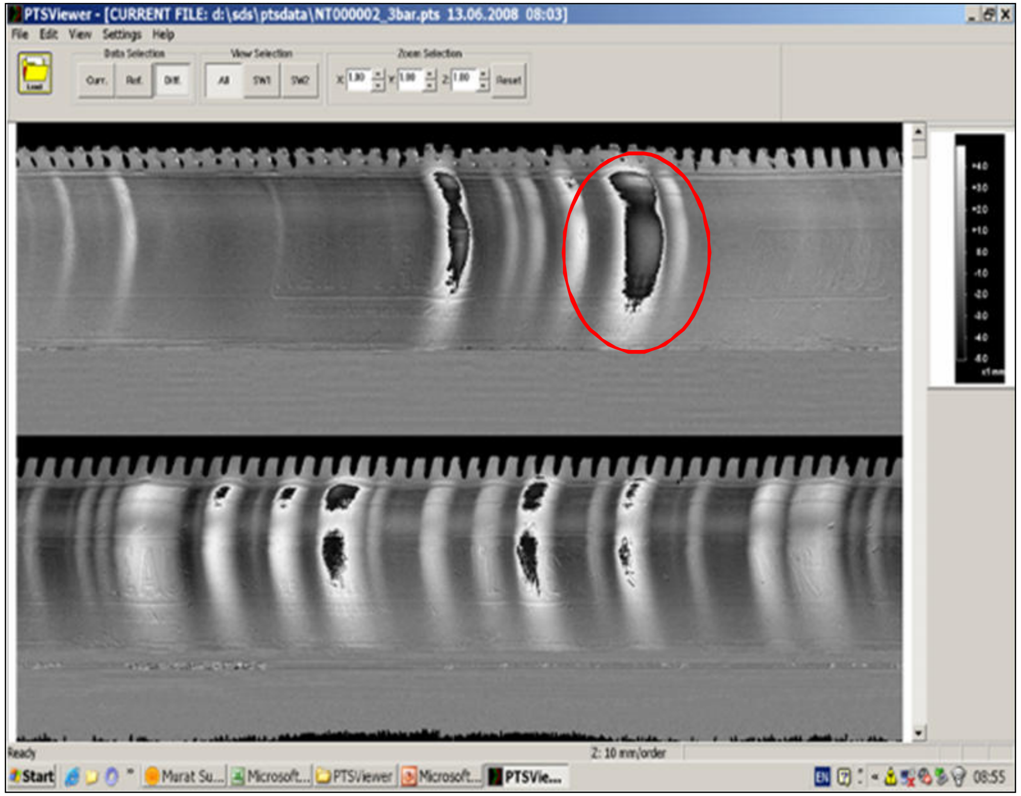
An intact casing structure makes a steady grey scale dispersion.

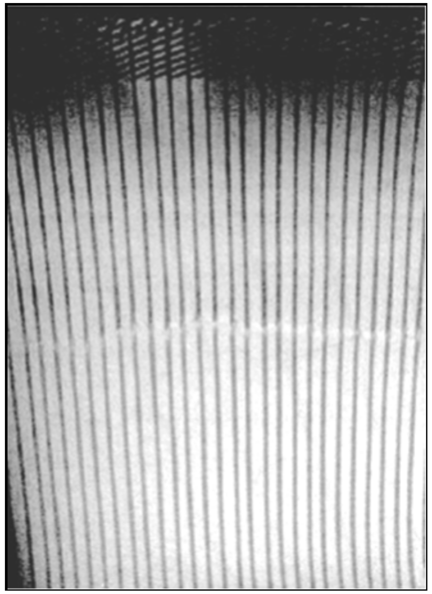


A defect casing structure causes an deformation in the sidewall, displayed by a changing of the grey value

Multiple broken steel cords:

The test result is indicating fatigue causing a zipper-failure in the inflated tire





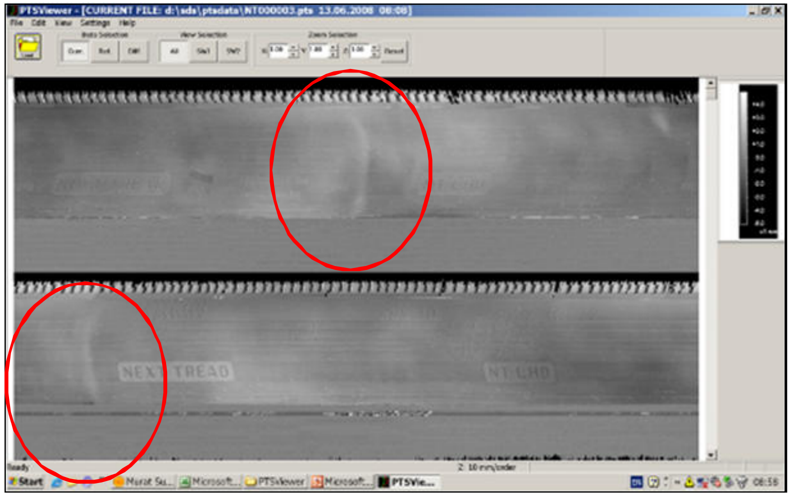
X-Ray result from the marked area showing fatiguing and broken steel cords.

Upper sidewall with local strong deformation and lower sidewall with deformation around the complete sidewall

Other Sidewall Indications

Low pressure (0,7 bar)

Upper pressure (3 bar)

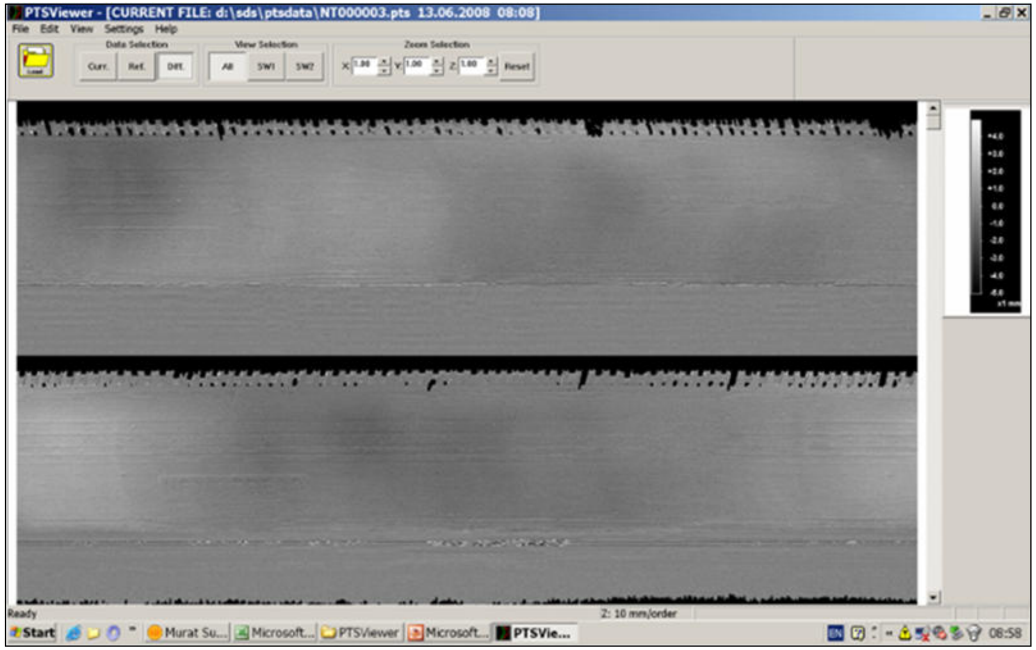


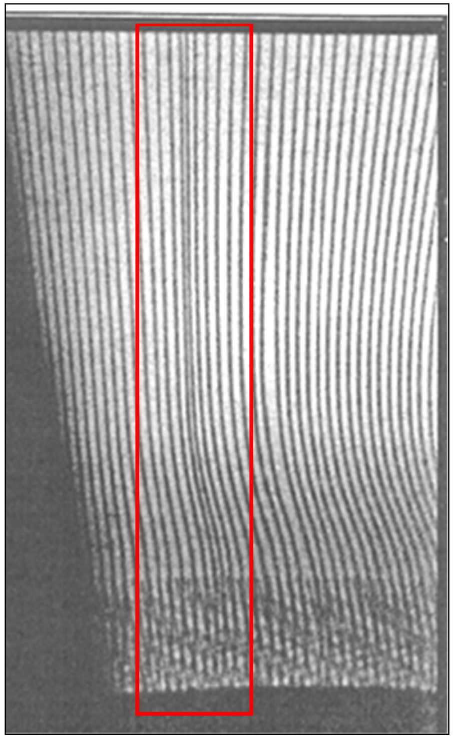
- This bulge is visible on the tire sidewall
  => typically it will be read as kinked cables and the tire is scrapped

- With the PTS with low and high pressure a slight bulge is also indicated

- But in the result image no anomalies are visible

  => no indication for a structural defect





=> This casing is ok

- The X-Ray result is showing too narrow cables causing the sidewall indication

Thank you for your attention !!

SDS - *Systemtechnik* - **GmbH**

- **Focused on customer's ideas and needs**
- **Staying ahead with leading edge technologies**
- **Available and responsible**

for more information

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