State of the Art of Modern Tire Testing

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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

Installation to After Sale Support together with the Worldwide SDS Network

out of “one Hand”!
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 pulse 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 spreaded
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:

- 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

Global Retreading Conference
**ITT systems in new tire applications and retreading:**
(1998 – April 2018)

<table>
<thead>
<tr>
<th>Retreading</th>
<th>286 Truck tire</th>
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<tbody>
<tr>
<td></td>
<td>3 OTR tire</td>
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<tr>
<td></td>
<td>35 Aviation tire</td>
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</table>

<table>
<thead>
<tr>
<th>New tire + R&amp;D</th>
<th>147 Truck tire</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>5 OTR tire</td>
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</table>

*script machines only 6 since 20 years!*
## Application and “location” of ITT systems:

<table>
<thead>
<tr>
<th>Region</th>
<th>Retread</th>
<th>New Tire</th>
<th>Aviation</th>
<th>Multiplier</th>
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<tbody>
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<td>105</td>
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<td><strong>USA + Canada + Mexico</strong></td>
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<td><strong>5.2x</strong></td>
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<td><strong>China</strong></td>
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</table>
“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:  
1973 ~ 10 min (not including film processing, offline)  
1998 ~ 6 min  
2018 ~ 1 min (Twin machine setup)
Twin machine: less than 1 min per Tire, bead to bead

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

- Turn over fixture between
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?
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 Anomaly Detection (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**

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)
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 **structural** 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

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

- Some minor shadows in the ITT- result of the sidewall,
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 stand alone with pneumatic loader/unloader

PTS inline with an ITT
Triangulation with projected line „Sheet of Light“ - Triangulation

Camera
Line-Laser

upper measuring system
lower measuring system
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

- 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
see us in hall 9 at booth 8017 - 8019