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Solutions – Procedures and Materials

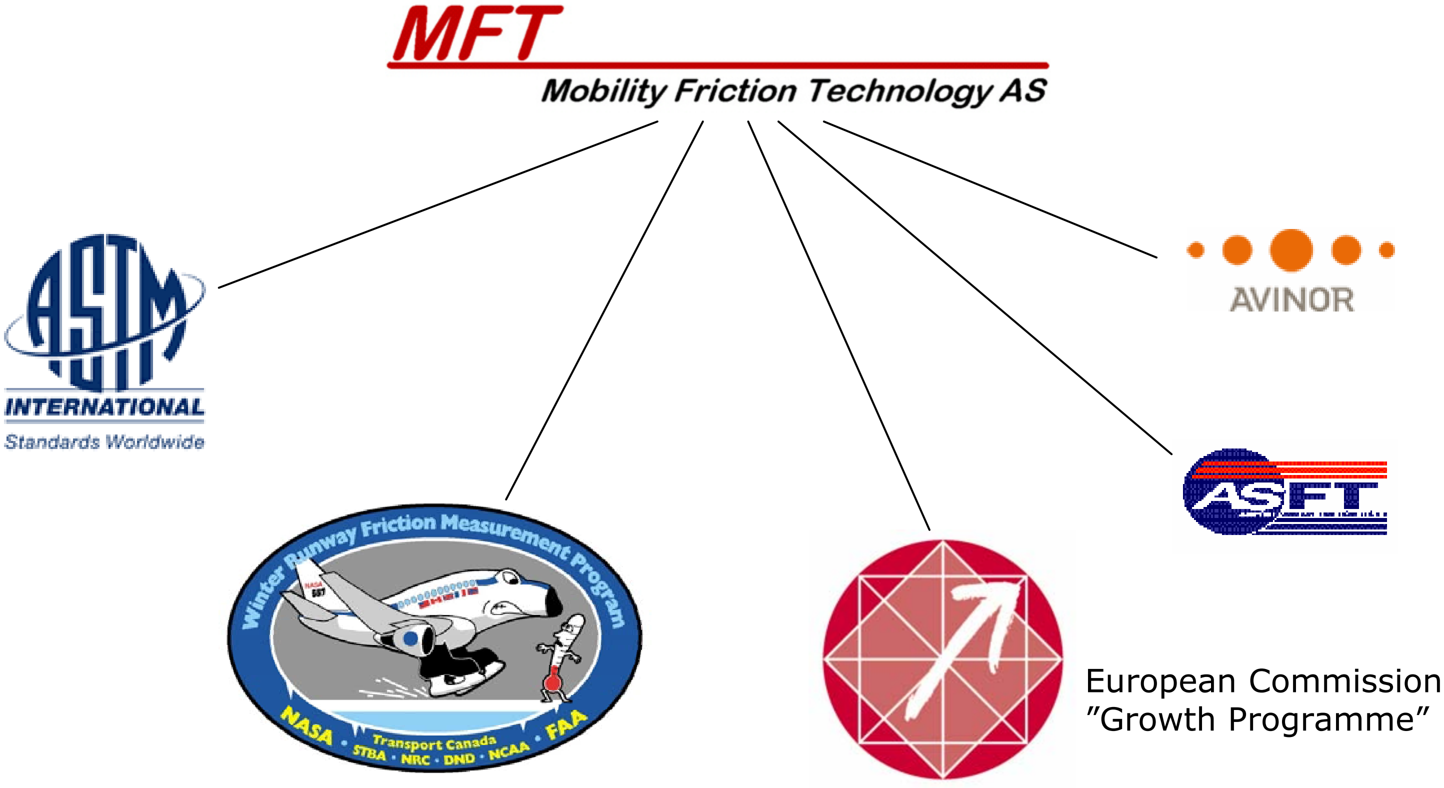
On research and standards development in general and for the aeroplane tyre-aerodrome surface interactions in particular

Arild Andresen, B.Sc. Mechanical & Aerospace Engineering

MFT
Mobility Friction Technology AS

Oslo, Norway

Where I Learned About Friction



Technology Problem Background I

- What is friction?
  - Surface-tyre pair interaction
  - Steered or accelerated tyre interactions with surfaces are functions of the actual tyre-surface pair within an actual environment
  - Performance criteria for only one component of the tyre-surface pair is meaningless without references to a defined other component and the applicable environment

Technology Problem Background II

- Missing calibration reference and calibration method of a friction coefficient
  - Accuracy (Bias) cannot be determined
  - Every device type has its own scale of measurements
  - Missing universal conversion factors for measurement values of one device type to another

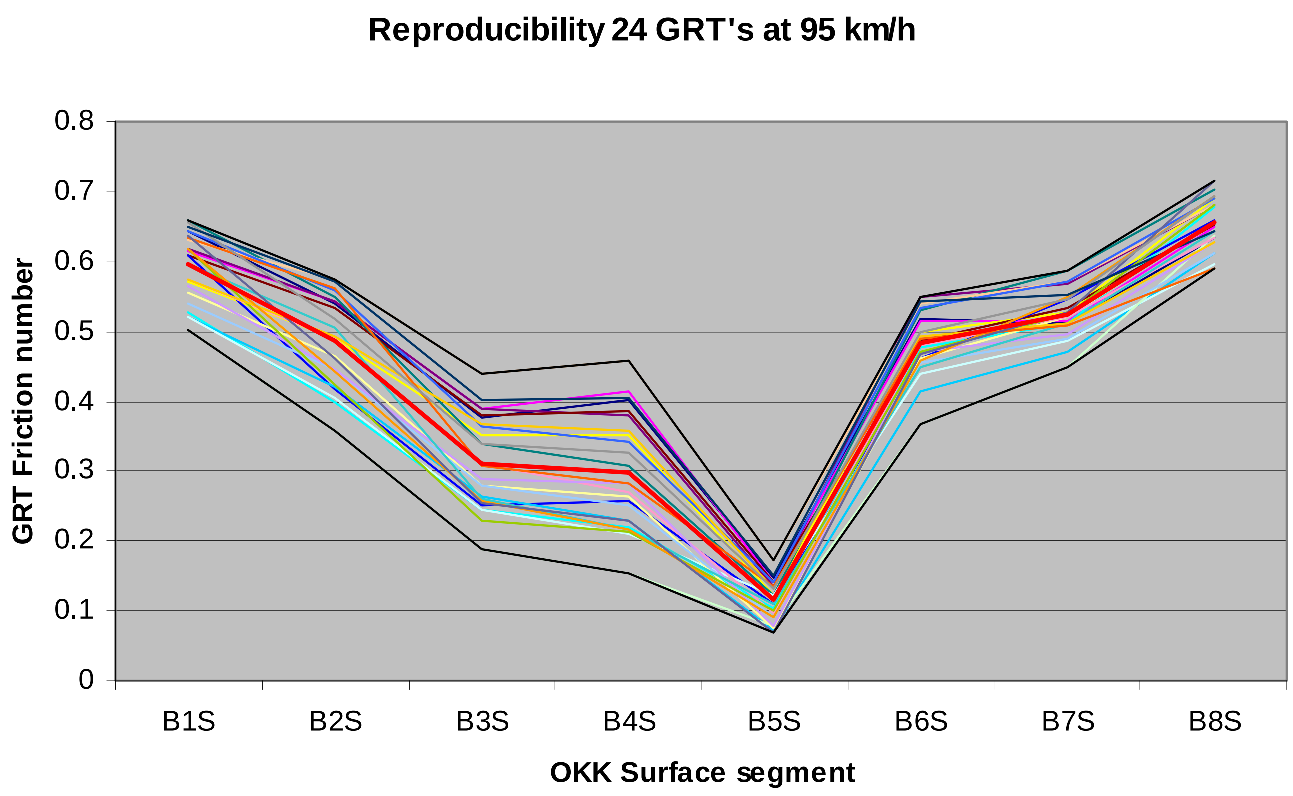
Technology Problem Background III

- Missing application standards
  - End-use of reported friction values determine scope and objectives of standards for devices and procedures
  - Device manufacturers have no end-use specifications to engineer product compliance with (there are standards for standardized equipment)
  - Lack of device performance standards for application (repeatability, reproducibility, time stability, scope of tyre-surface pairs)

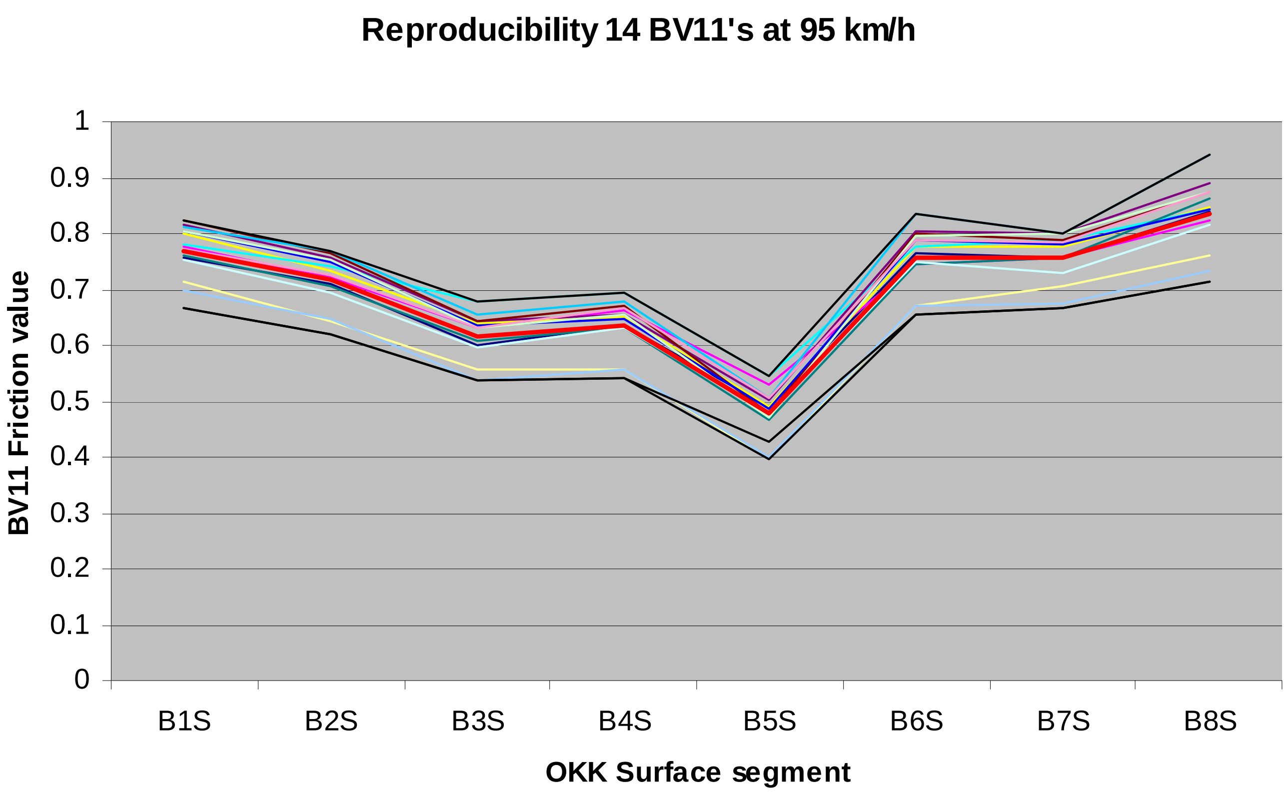
Technology Problem Background IV

- Demonstrated poor reproducibility of friction measurement devices of the same type
  - Reported values from a device at one location differ from a device of same type at another location (everything else being equal)
- Unknown time stability of devices
  - If harmonized, how long is harmonization valid?

Reproducibility of 24 Griptesters



Reproducibility of 14 BV11's



Technology Problem Solutions

1. Education
2. Harmonization is the state of the art approach to solve the calibration issues
3. Develop end-use standards
4. Operate device overhaul/repair and harmonization centers, or find other methods and means to monitor surfaces or infer surface conditions
5. Choose other measurement methods than friction measurements to infer friction

Default values for effective wheel/tyre braking coefficient AMC 25.1591

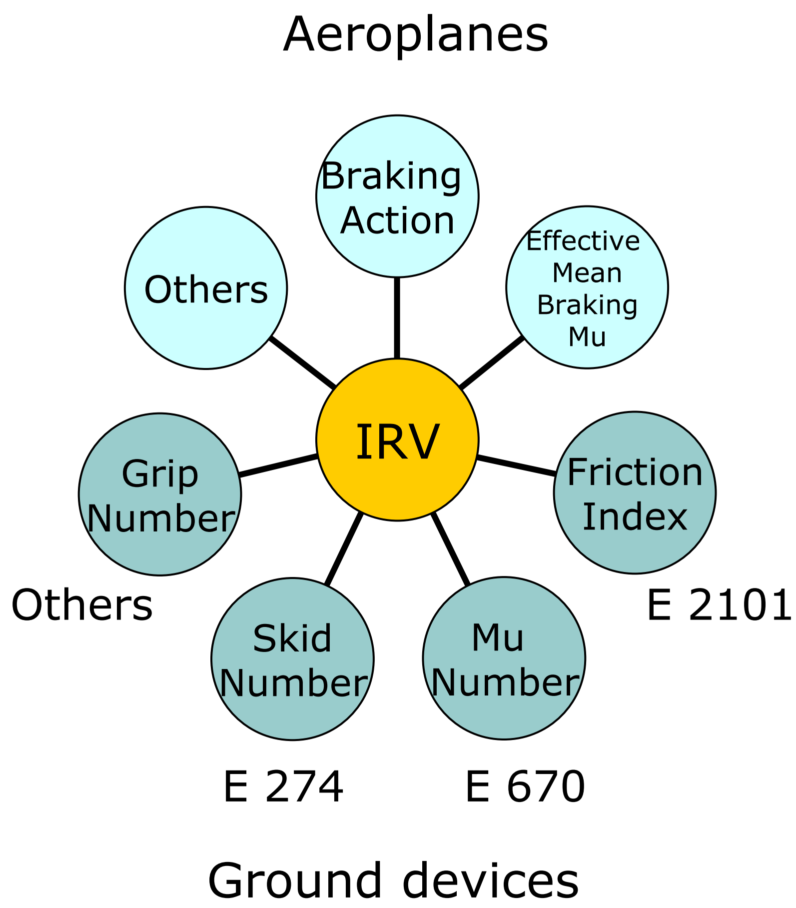
Contaminant	***Default Friction Value*** ***μ***
Standing Water and Slush	$= -0.0632\left(\frac{V}{100}\right)^3 + 0.2683\left(\frac{V}{100}\right)^2 - 0.4321\left(\frac{V}{100}\right) + 0.3485$ Where V is groundspeed in knots. Note: For V greater than aquaplaning speed, use μ = 0.05 constant
Wet Snow below 5mm depth	0.20
Wet Snow	0.17
Dry Snow below 20mm depth	0.20
Dry Snow	0.17
Compacted Snow	0.20
Ice	0.05

The Suite of ASTM Harmonization Standards on the Books

- E 1960-03 Standard Practice for Calculating International Friction Index of a Pavement Surface
- E 2100-04 Standard Practice for Calculating the International Runway Friction Index

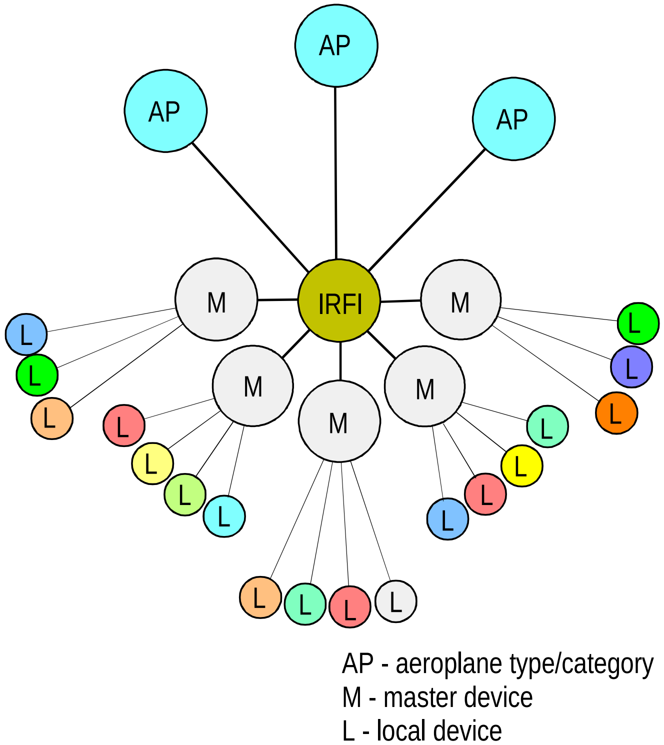
IRFI Basic Idea – JWRFMP Tests

- Common Reference
- Linear regression between local friction device and IRFI reference
- Linear regression between IRFI reference and airplane



IRFI Deployment

- An intermediary reference device called Master device added for reasons of logistics practicality



$$FR_{ref} = A + B \times FR_{master}$$

$$FR_{master} = a + b \times FR_{local}$$

$$IRFI = A + B \times a + B \times b \times FR_{local}$$

Benefits from IRFI subscription

- Less confusion for pilots interpreting broadcasted friction values with common units of measure
- Protection of investments in ground friction measurement devices
- Increased quality of runway condition reporting
- Platform for further progress

Before Subscribing to IRFI

- Master devices need to be identified
  - Harmonization constants A,B,a,b not determined for master and local airport devices
- Temporary IRV selected
  - Access to IRV and identifications of master device needs industry organization
  - Specification of a permanent IRV embedding JWRFMP findings

Related ASTM standards now being developed

- Specification of the IRFI Reference Vehicle (IRV)
  - Possibly designing and building an IRV headed by ASTM's Contract and Project Management Services Department
- WK5710-Standard Practice/Guide for Friction Measurements of Aerodrome Runways
- WK5711-Standard Practice/Guide for Calculating an Aircraft Friction Index

WK5710 Scope

- This practice outlines measurement procedures of surveys for the assessment of surface friction characteristics of aerodrome runways using continuous measurement devices for tire-surface friction, or a combination of continuous measurement devices for tire-surface friction and surface texture.
- The types of surveys included in this practice are:
  - a) runway classification survey for annual or other long term periodic assessment, or when a runway has been newly constructed, re-surfaced, surface treated or re-textured,
  - b) runway monitoring survey for the detection of surface aggregate polishing wear or rubber deposits,
  - c) <u>runway monitoring survey for the detection of winter contaminants</u>.
- This practice defines standard formats for the survey results to be made available for aerodrome owners, licensees, users or agencies performing classification or monitoring of the runway surface characteristics.
- This practice does not include definitions of standard reporting formats for the dissemination of survey results to runway users (airmen, airlines).

WK5711 Scope

- This practice covers the calculation of an Aircraft Friction Index, AFI, from measurements obtained by paired aircraft wheel-braking tests and local friction-measurement devices on aerodrome movement areas under winter conditions. When the values of the friction measurement devices are converted to IRFI values, the index is designated the International Aircraft Friction Index, IAFI.

- The AFI or IAFI values obtained by using this practice may be used for the calculation of predicted landing distances on winter contaminated runway surfaces.

WK5711 - the mean effective wheel-braking coefficient with full anti-skid braking , μ_B

μ_B is calculated from the measured airplane deceleration along the runway for each full anti-skid braking test run by solving the equation (Newton’s 1st law)

$$\frac{1}{g}\cdot\frac{dV}{dt}=\frac{T}{W}-\frac{D}{W}-\frac{D_{CONTAM}}{W}-\varepsilon-\mu_B\cdot\left(1-\frac{L}{W}\right)$$

where the measured parameters are

$\frac{1}{g}\cdot\frac{dV}{dt}$ is the airplane deceleration

V is the aircraft velocity along the runway

T is the engine thrust

D is the aerodynamic drag

D_{CONTAM} is the contaminant drag

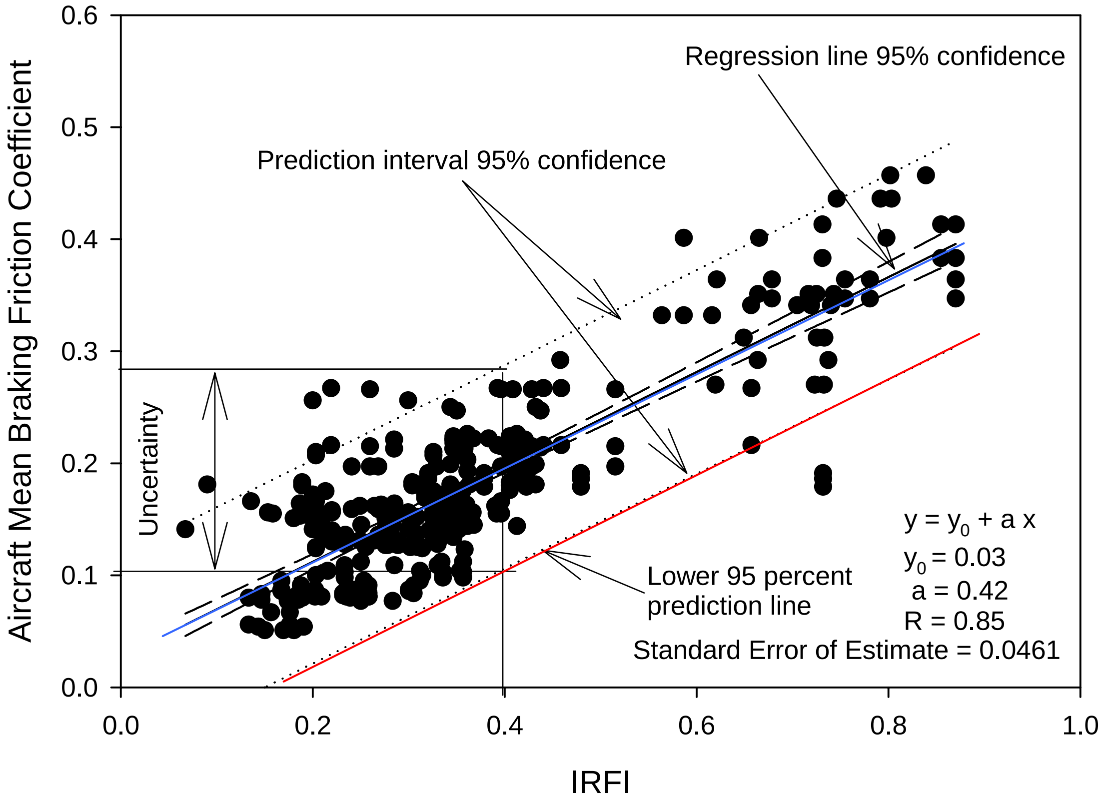
W is the aircraft weight

ε is the runway slope (positive uphill)

L is the aerodynamic lift

WK5711 – International Aircraft Friction Index

Regression based on JWRFMP preliminary test data 1999-2001



μ_B = a + b x IRFI

Sample plot values:

μB = 0.03 + 0.42 x IRFI

Adding a factor of safety to the predicted μ_B makes it an International Aircraft Friction Index: IAFI = A + B x IRFI

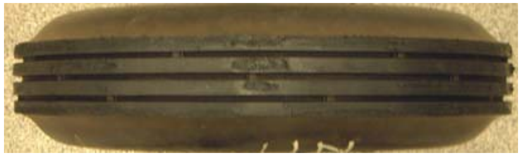
Sample plot values: IAFI = -0.06+0.42 x IRFI

Reference Test Tyre Data

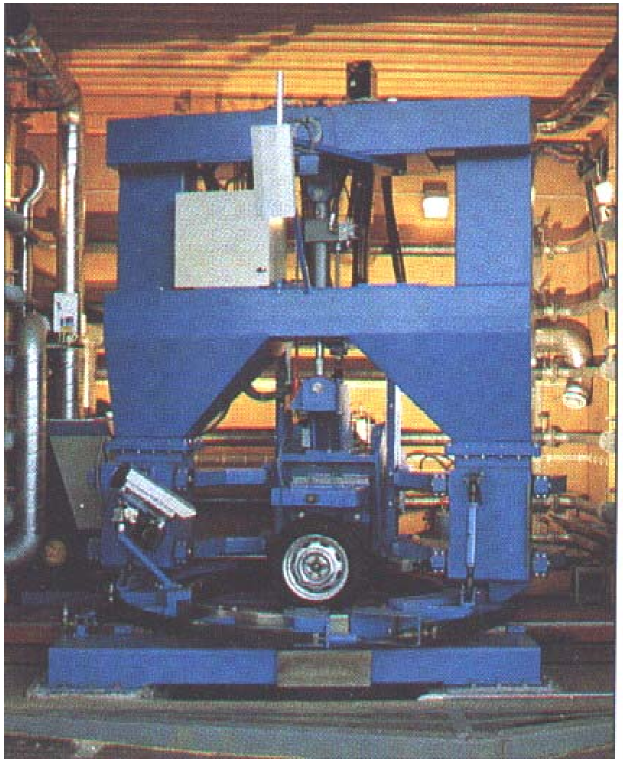
Michelin Air 6.00x6

ASTM E1551

Trelleborg AERO



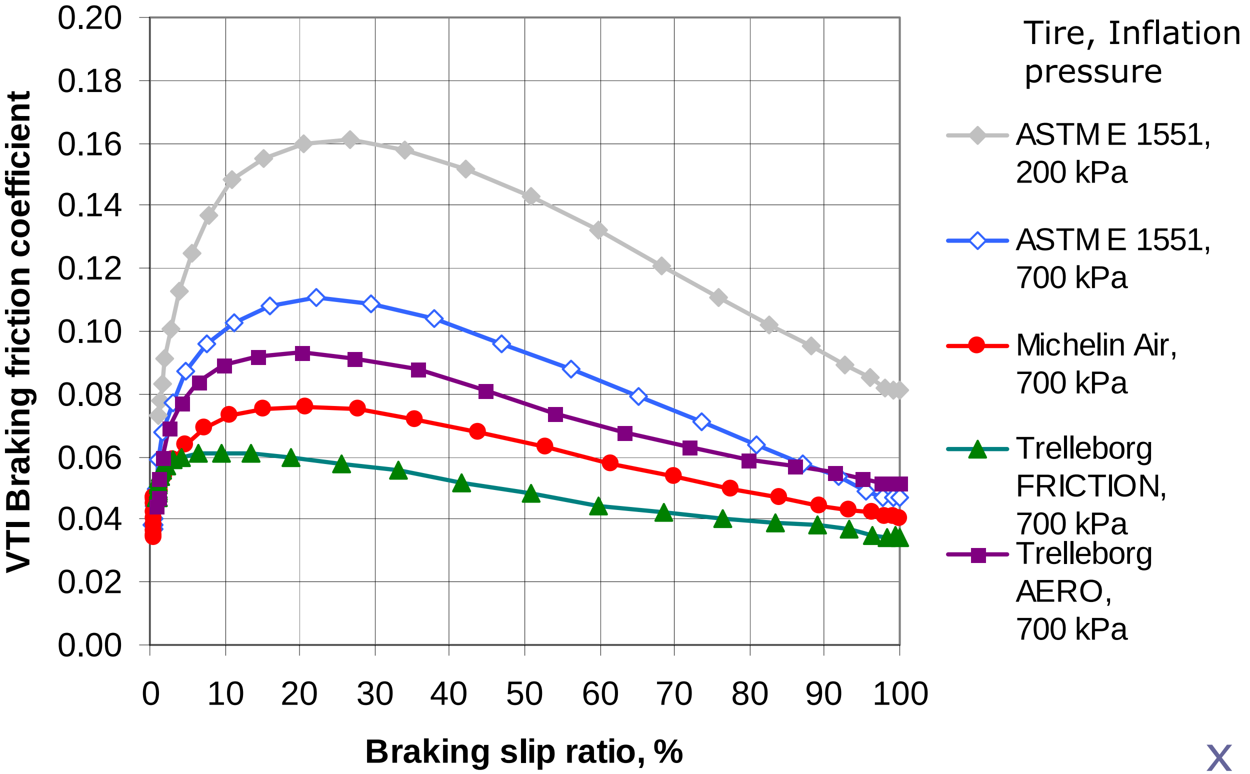
Trelleborg FRICTION



VTI tyre test facility

Tire Comparison Smooth Ice -3°C

Wheel load 1300±100 N Travel speed 30 km/h



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Tyre Comparison Numbers

Tyre	**Mu Peak**	**Crit Slip %**	**Conv factor at ~15 %**
E1551 200 kPa	0.16	27	0.48
E1551 700 kPa	0.11	22	0.69
Trelleborg AERO	0.09	20	0.82
Michelin Air	0.08	21	1
Trelleborg FRICTION	0.06	9	1.23

Thank you!

Arild Andresen,

Chairman ASTM E 17.22

Mobility Friction Technology AS

Oslo, Norway

arild.andresen@mft.as