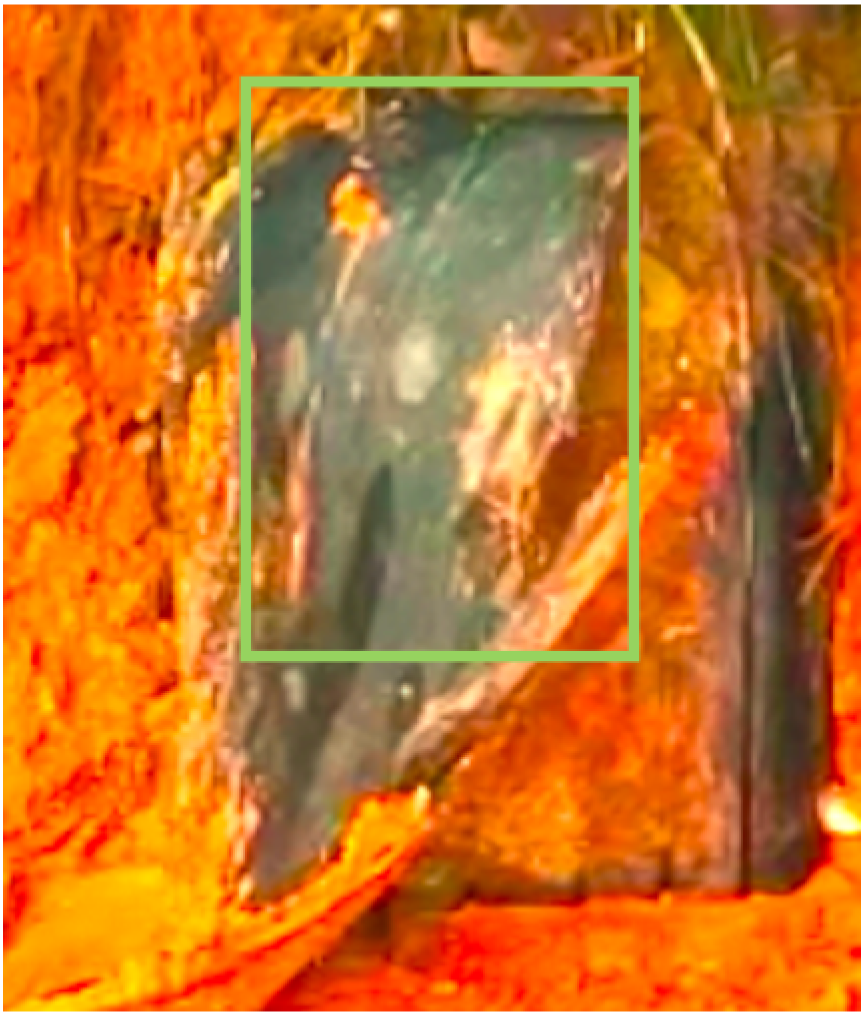
The Air India Express IX1344 accident at Khozikode and the ensuing investigation will focus on the deceleration devices of the aircraft, their effectiveness, the prevailing environment and the interaction with the runway surface.

Prima facie, a look at the aircraft tire post accident raises suspicion of hydroplaning. **Reduced friction between the tires of an aircraft and the runway is a very common factor in runway excursions.** On wet or flooded runways this reduction in friction is related to hydroplaning of the tires.



VT-AXH Left Main Gear Tire

Aircraft tire performance

Performance is based on a “cycle” (taxi, takeoff, landing, taxi). Many factors cause differences in tire wear. Different materials used for taxiways and runways will wear tire tread rubber differently, particularly rough and abrasive materials. Fast turns, heavy braking, hard landings, and long roll distances are examples of operating conditions that will have a negative impact on tire wear. High taxi speeds (> 35kts) and long taxi distances can cause greater tread wear, greater heat buildup, and more lateral scuffing during turns.

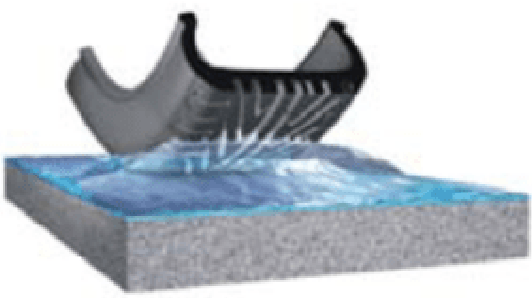
Hydroplaning

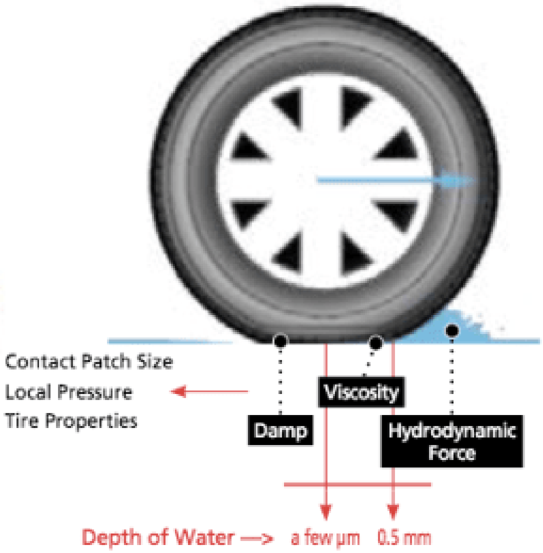
Tire hydroplaning is a condition that occurs when a tire is operated at speed on a partially flooded surface. At some speed, the tire becomes supported (totally or partially) by the fluid pressure generated as the fluid is being removed from under the footprint. At a critical speed, the water cannot be removed fast enough and the tire will be completely lifted from the surface. Hydroplaning is influenced by many factors:

- Depth of fluid (water, snow, slush…)
- The density of the fluid (water, snow, slush…)
- Tire inflation pressure
- Tire footprint length and width
- Surface texture
- Pavement grooves
- Pavement crown
- Speed of the vehicle
- The tire inflation pressure is the most important tire parameter affecting the critical speed.

There are two types of hydroplaning.

- Dynamic Hydroplaning
- Viscous Hydroplaning





Hydroplaning

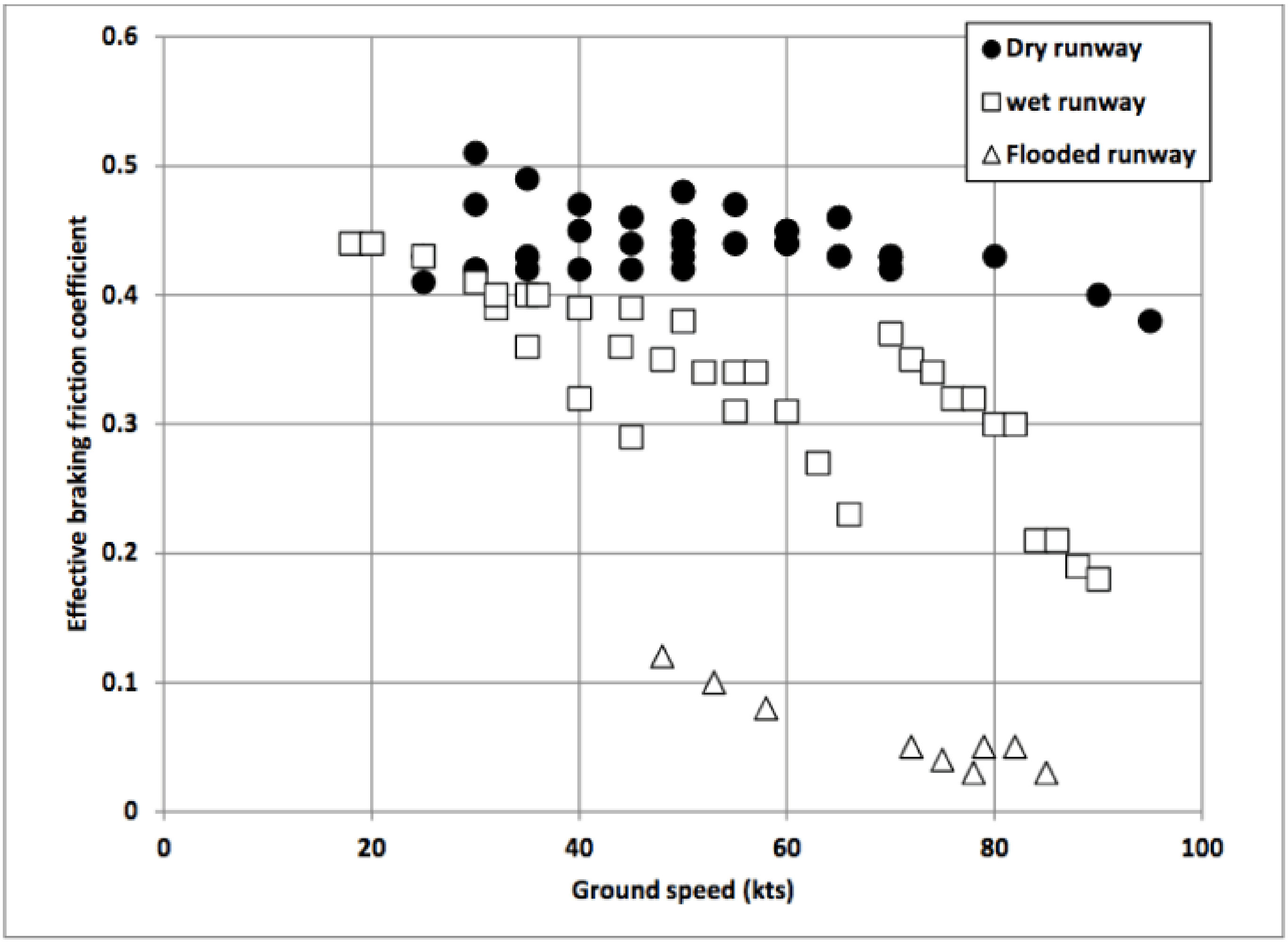
Singapore Airline hydroplaning incident tire

Tire damage due hydroplaning

Dynamic Hydroplaning is a high speed phenomenon which occurs on any surface and requires a minimum fluid thickness.

Considering the various fluids reasonably encountered by aircraft tires, slush is the most likely to cause dynamic hydroplaning. It is less dense than water but is deeper due to its viscosity. Slush, along with snow or ice, deserves particular attention.

Viscous Hydroplaning results when a thin film of fluid (water) on the runway becomes a lubricant. It may mix with the contaminants present or the water alone may be sufficient if the surface texture of the runway is smooth as on a painted portion of the runway markings. Generally, the irregular condition of the runway surface is sufficient to break up this film.



Comparison of the effective braking friction coefficient as function of ground speed on a dry, wet, and flooded runway for a B737-100(source; NASA flight tests).

Analysis of Hydroplaning in runway excursions

The first thing that can be examined is how wet a runway actually was during the accident. This is not easy to answer since a number of factors play a role. The wetness of a runway is determined by the amount of rain falling, the duration of the rainfall, the macro-texture of the runway, the cross slope of the runway, the longitudinal slope of the runway and the surface wind. All these factors together determine how much water is build-up on top of the asperities of the runway surface.On a well constructed runway there is less build up near the centreline and more towards the runway edge.

Rain fall measurements at and around the time of the accidents should be retrieved from the meteorological office.The runways slopes and macro-texture depth can vary along the runway. This should be considered in the analysis since it could lead to local differences in the water depth (puddles).

Security camera footage that has recorded the aircraft moving on the runway (or other video images) can also be used to get an idea of the runway wetness. While rolling on a flooded runway, **significant spray will becoming off the nose and main gear tires** which should be visible on the video images. On wet surfaces this spray is much less visible and less intense. This information can be used (together with the estimated water depth) to determine how wet the runway was during the accident. Note that when thrust reversers are used on wing-mounted engines, the video images could be obscured, as the reversers tend to recirculate some of the water spray around the wing.This could provide a false indication of the actual wetness of the runway.

During some accident investigations, water was manually put on a part of the runway using e.g. a hose with a controlled amount of water flowing through it to analyse the drainage characteristics. This does not simulate the way water is actual drained by the runway during periods of rainfall. For instance the water droplets falling on to the runway affect the turbulence levels in the water flow on top of the runway surface which influences the actual run-off.

When there are reason to believe that the drainage characteristics are poor, due to slopes & depression, the friction level should be judged under natural conditions.

Estimating full dynamic hydroplaning speed

Dynamic hydroplaning is generally associated with water depths greater than 0.1 inch (which is normally rounded up to 3 mm). However the critical depth depends on the characteristics of the tyre-pavement surface. **Smooth tread tires operating on smooth**

pavements surfaces require the smallest fluid depth for dynamic hydroplaning, whereas rib treads tires operating on an open textured or grooved-pavement surface require the largest fluid depths.

Dynamic hydroplaning is strongly influenced by the ground speed. At a certain speed the tyre footprint is completely separated a by a film of water. The ground speed for this full dynamic hydroplaning condition (under spin-down conditions, e.g. rolling tyre) is often estimated by accident investigators using the classic NASA formula relating the dynamic hydroplaning speed (in kts.) with the tyre inflation pressure (p in psi) as9xUnder-root(p).Unfortunately this equation over-predicts the hydroplaning speed for modern aircraft tires. The formula for modern tires is much lesser in the range of 6.5-7.

Example of a landing overrun accident on a wet runway

The accident concerns an Embraer EMB-145 that landed on Runway 07 at Ottawa/MacDonald-Cartier International Airport, and overran the wet runway.

During a post-accident examination, no reverted-rubber burns were found on the aircraft's main landing-gear tires. The investigators did mention that there were steam-cleaned marks at the end of the runway, which according to the investigators would indicate that the temperature had reached a value at which steam is formed.It should be noted that such marks on the runway are not always present during viscous or dynamic hydroplaning. The absence of those or any other marks does not proof that hydroplaning did not occur!

Runway friction tests conducted by the airport authorities using a Saab friction tester before the accident did not indicate that the runway was deficient in its micro-texture.

In theory hydroplaning will always occur when operating on a wet or flooded runway. Depending on different factors like such as runway texture and wetness the influence on braking performance can be small or significant. During an accident investigation that is related to stopping or controlling of aircraft on a wet or flooded runway, it is important to understand if and how hydroplaning might have contributed to the event. The investigators can analyse different data sources to determine the type of hydroplaning that might have occurred. Data from the flight data recorder (and quick access recorder), runway surface texture characteristics, video images, rain fall data etc. are examples of such sources.

AIRCRAFT TYRE HYDROPLANING AND HOW TO ANALYSE IT IN RUNWAY EXCURSION EVENTS BY GERARD VAN ES NETHERLANDS AEROSPACE CENTRE –NLR PAPER PRESENTED AT THE ISASI 2018 SEMINAR DUBAI, UNITED ARAB EMIRATES.

> *Must consider Human Factors in Air India Express Accident, few other Boeing accidents*
