Image analysis of defects of railway wheels: a challenge for mathematicians

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Overall scope

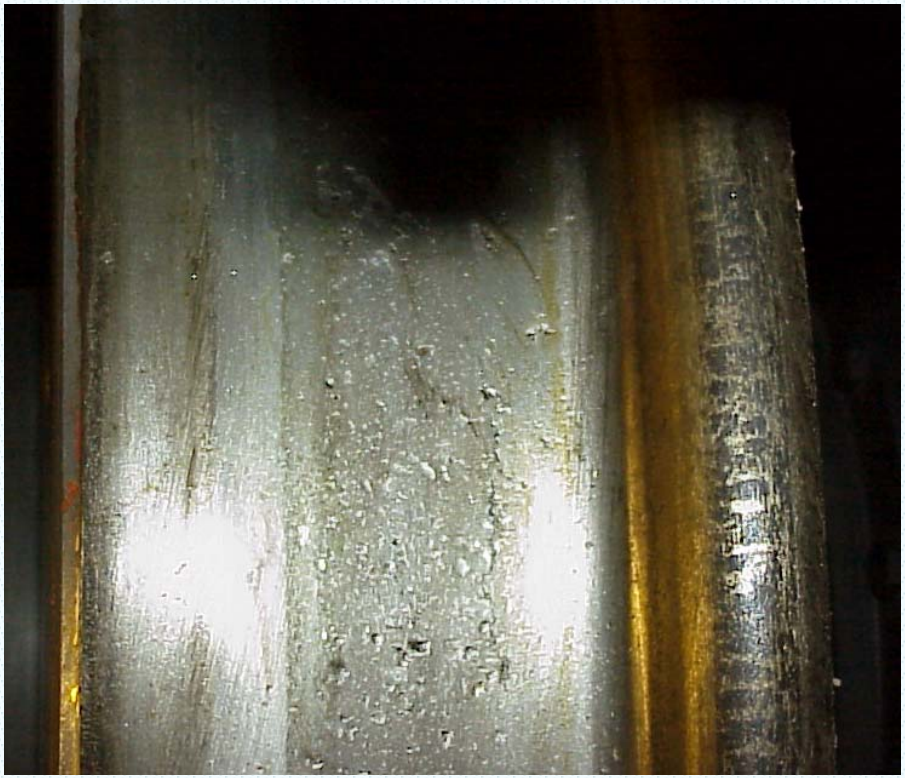
- Railway operations need to ensure
  - safety
  - reliability
- Railway wheels are safety critical components
  - regularly monitored
  - re-profiled as needed

- Reprofiling
  - is costly
  - causes operational disturbances
  - ensures safe operations

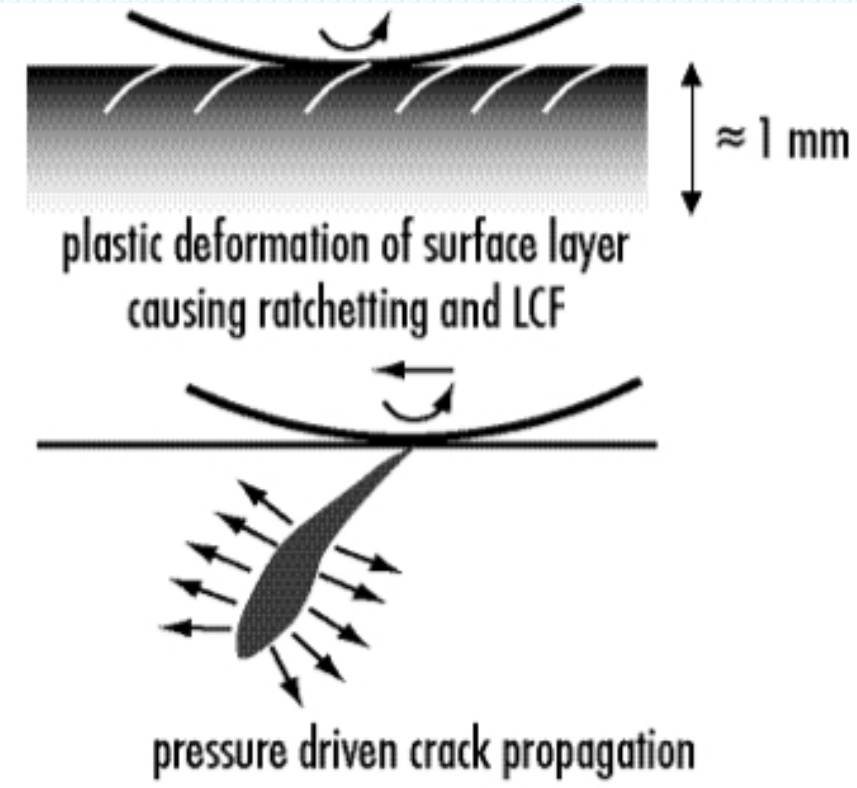
$\therefore$ Need to classify wheels to ensure optimal reprofiling intervals

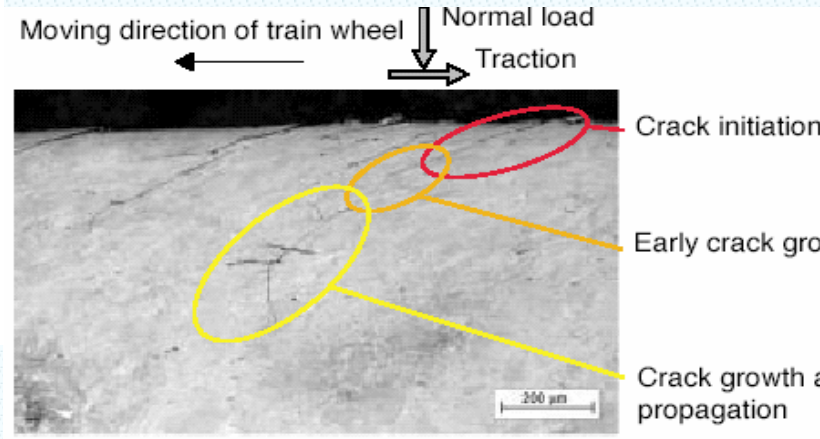
Contents

- Wheel damages – appearances and mechanisms
- Wheel reprofiling – short introduction
- Image analysis – an overview of some challenges
- Examples of workshop images

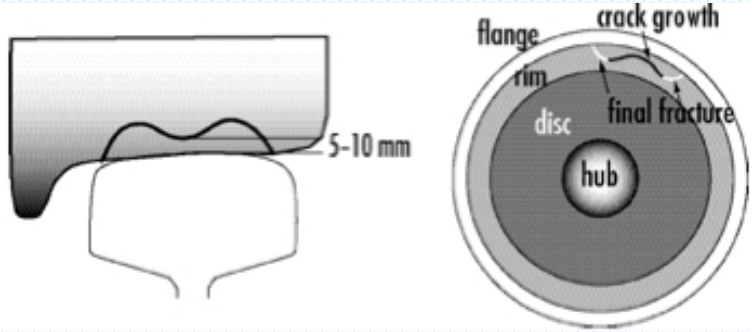


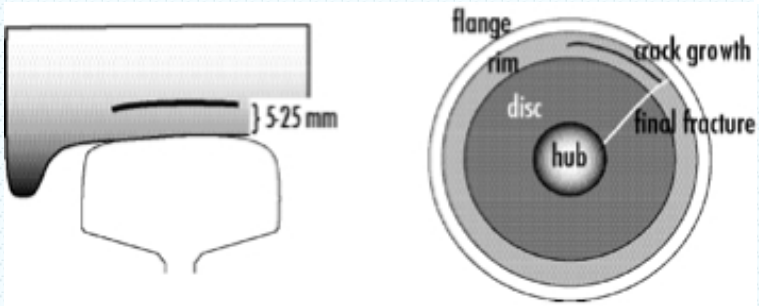
Wheel damage – surface fatigue

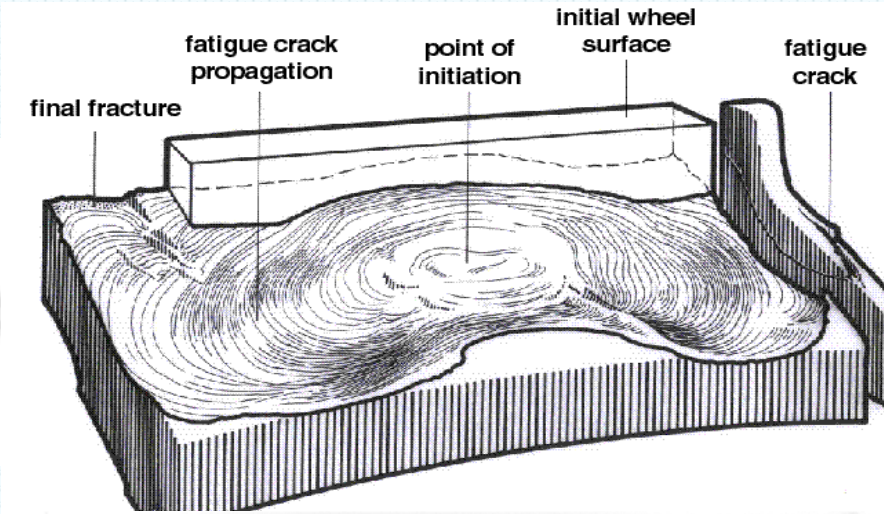




Wheel damage – subsurface fatigue

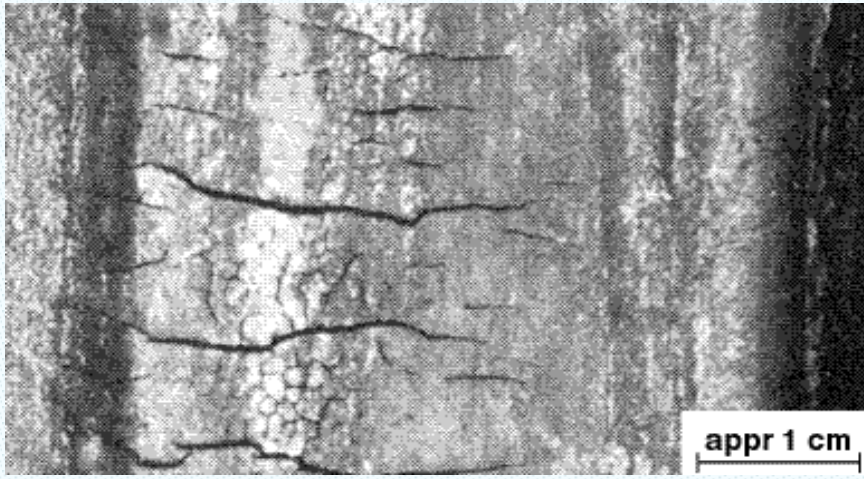


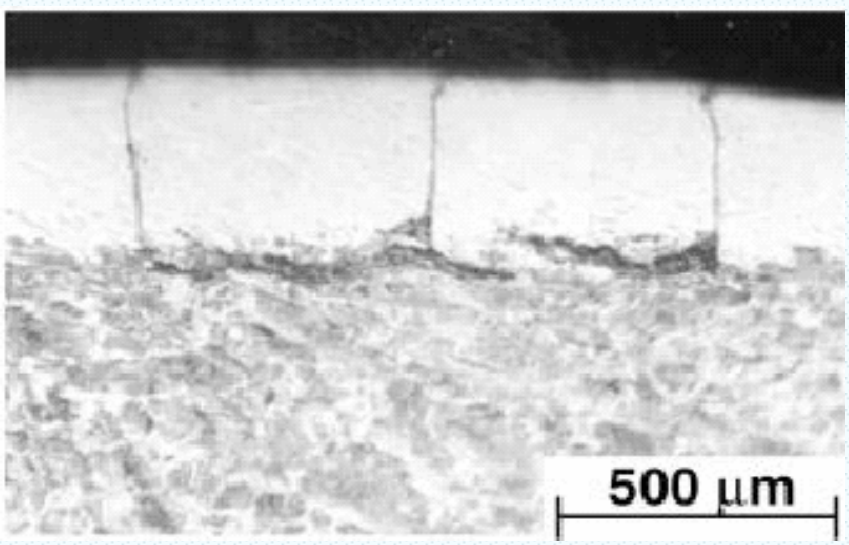




Wheel damage – thermal damage

- Heating (due to tread braking) followed by rapid cooling causes tensile surface stresses
- Result
  - vertical cracks in typical "dry clay" pattern
  - martensite (white etching layer)





Wheel damage – wheel flats

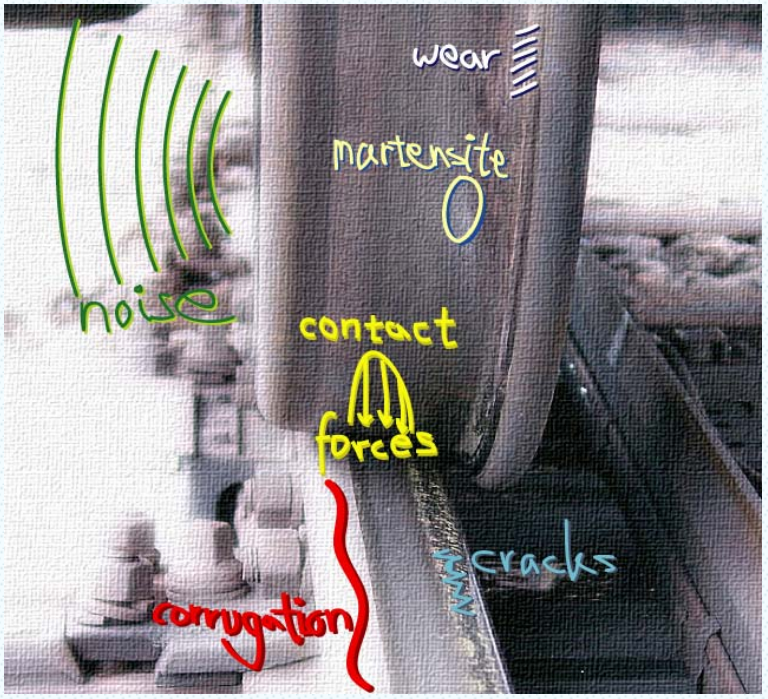
- Formed by a locked wheel sliding on a rail
- Part of the wheel becomes flattened
- Thermal damage (and martensite) may form at the flat
- Causes high impact loads that may result in cracking, noise and discomfort

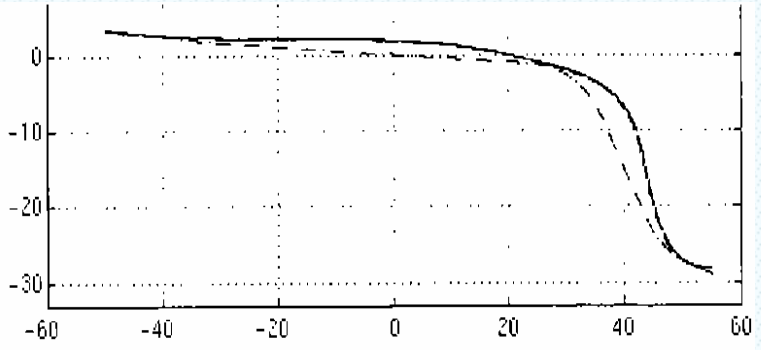
Wheel damage – indentations

- Gravel (or other objects) are trapped between the wheel and the rail
- Typically results in smooth pits that are benign (no further crack growth)

Wheel damage – wear

- Wear occurs from sliding between the wheel and rail, typically in the flange root area
- Benign (slow process). Too high wear is monitored by geometry measurements

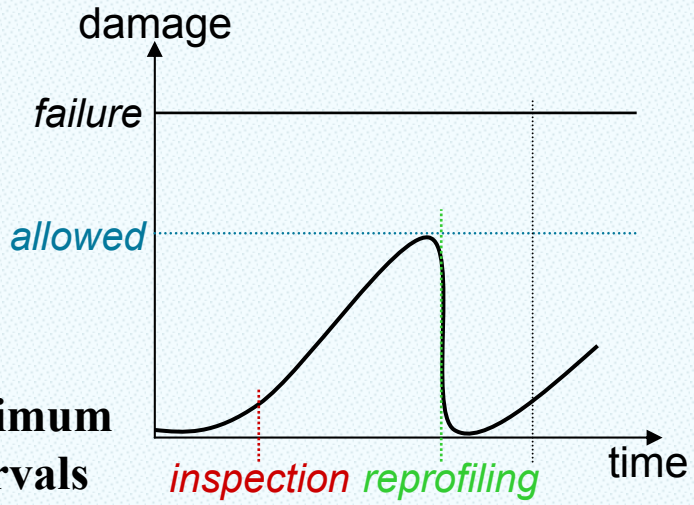




Wheel reprofiling

- Owing to surface cracks and/or unacceptable geometry, wheels are reprofiled.
- Decision based on:
  - ultrasonic testing (subsurface cracks)
  - measurements (e.g. flange thickness)
  - visual inspection (surface cracks)

- Typically 250 000 km between reprofilings ≈ 6 times around the earth (depends on operational conditions). Typically three reprofilings before scrapping of the wheel



Principle between optimum wheel reprofiling intervals

Image analysis – some challenges

- Damage identification
  - seldom a single damage, but a mix with different origins and formed at different times (overlapping may occur)
  - often similar appearance (e.g. indentation and surface fatigue)
  - a single damage is sometimes owing to a mix of different mechanisms (e.g. a surface crack may be formed due to sliding which causes thermal damage and surface fatigue)

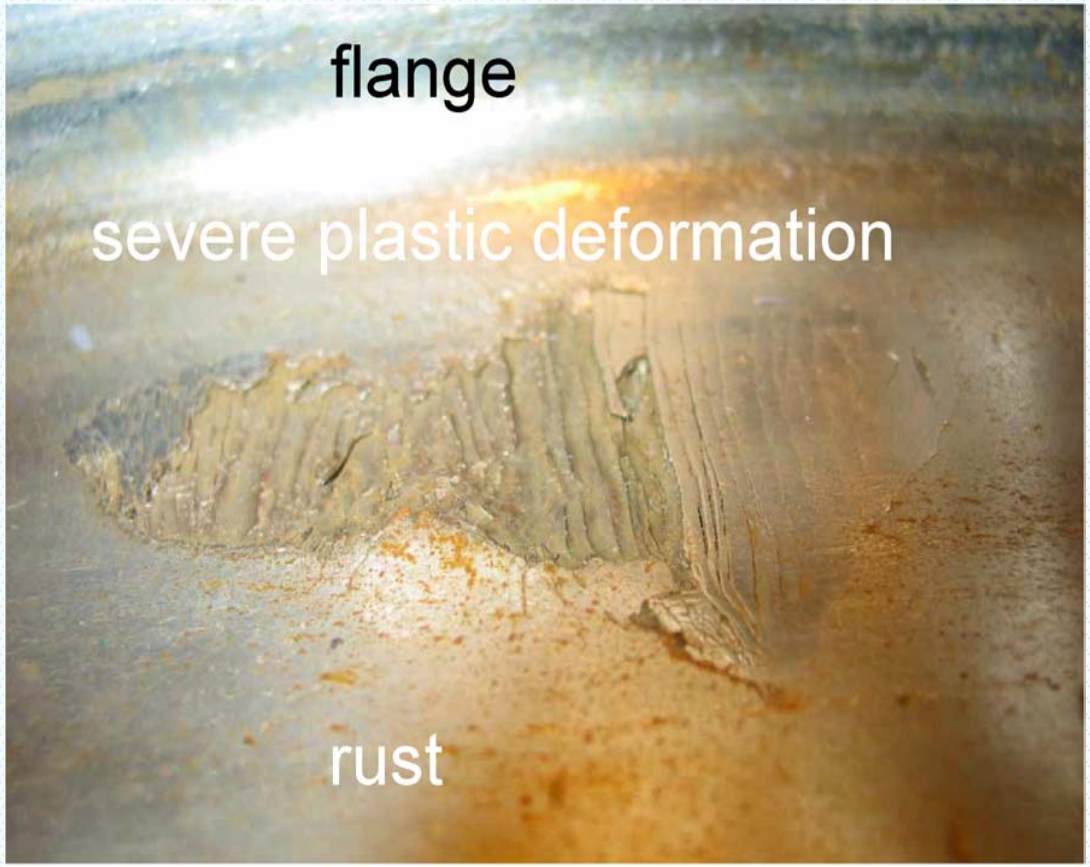
Image analysis – some challenges

- Inspection conditions
  - light conditions may vary between workplaces
  - reflection of light may occur
  - the surface of the wheels may be dirty and/or corroded
  - the whole circumference of the wheel needs to be inspected – need for position identification
  - the process must be (reasonable) fast owing to operational constraints

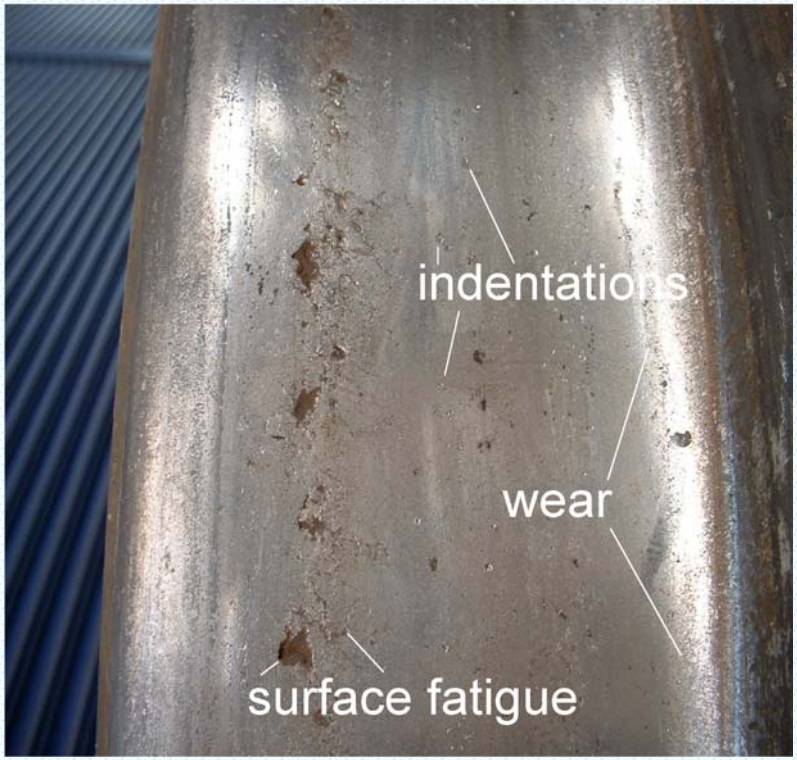
Image analysis – outcome

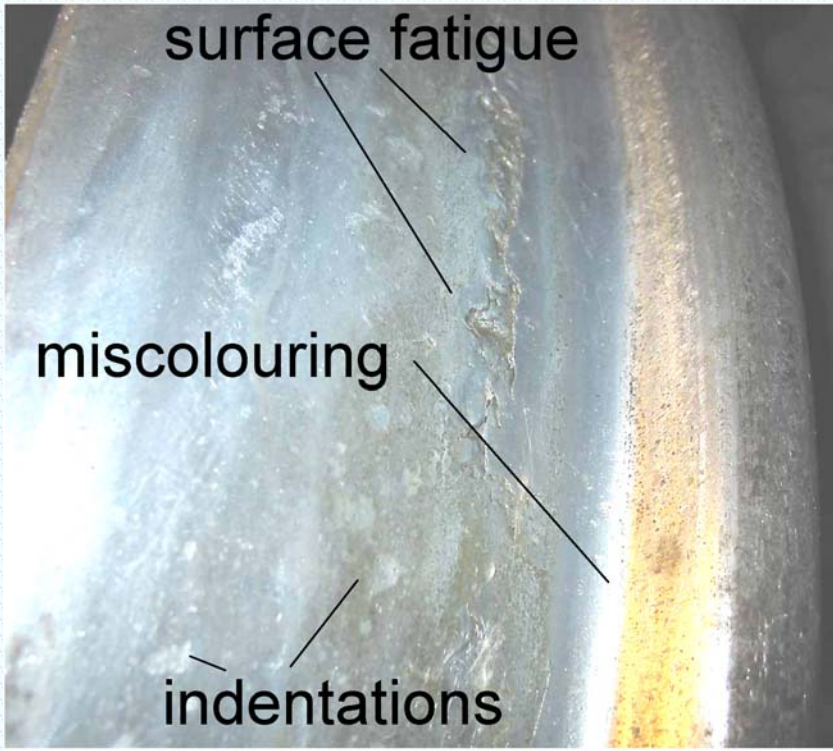
- A "perfect" image analysis should be able to identify:
  - causes of damage (or at least benign vs detrimental)
  - degree of deterioration (e.g. how much of the total circumference is affected and to what degree)
- A working image analysis would:
  - aid the workshop staff
  - improve the standardization of inspections and classifications
  - provide a statistical database of wheel damages

Wheel flat / surface plastification



Surface fatigue and indentations





Thermal damage