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ACHILLES: Advanced CHaracterIsation of PhotovoLtaics for HaiL RESistance

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ABSTRACT

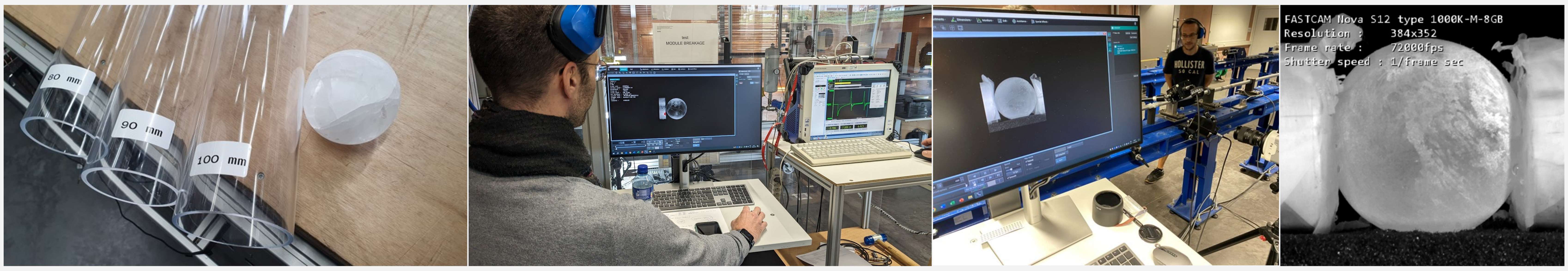
The rapid changing in solar module technology, with increasing dimensions of silicon wafers (from M2, 156.75mm, in 2018 to M12, 210mm today and even larger in the next future), increased options for inter-cell contacting technologies (multi bus-bar, shingled, tiling ribbon, smartwire, IBC), reduced thickness of cells (now typically 130µm with respect to 200µm only few years ago) and glasses (from 3.2 mm to 2.85 mm and 1.6mm), reduced section of aluminium frames, is generating questions on the reliability of the new mass products that are entering the market. Among the critical points for insuring long lifetimes to the photovoltaic modules on the Swiss Alps, is the resistance to hail stones with larger diameters.

SUPSI matched together with OST and Swissolar in the project ACHILLES, funded by the Association of Cantonal Fire Insurance Companies ACFI, with the scope of issuing a guideline to judge the damage on PV plants hit by hailstorm.

The main questions to be answered during the project, started in 2023 with a timeframe of five years are:

- Which damage occur ? With which module and cell types?
- What is the effect of cracks on different cell technologies?
- Does the previous module categorisation need to be adapted?
- How do cell cracks age and what is the long-term behaviour in terms of safety and performance?
- Which modules can continue to be operated and which should be replaced when?

Setups and test execution: characterisation of ice



- A panel's degree of damage is largely determined by the force history generated during the impact between the hail stone and the PV panel.
- This task can be challenging due to the difficulty of directly measuring the force history: two calibrated Hopkinson's bars were used for wave recording of the impulse generated by the impact of ice balls.
- Spherical ice specimens with nominal diameters of 25, 30, 35, 40, 45, 50, 60, 70 and 90 mm were prepared using industrial ice.
- These specimens were then accelerated using an aircompressed gun, improved to shoot according to VKF pr.25 standard up to 90mm, to achieve the desired theoretical speeds (25, 50, 75 and 100 m/s).
- Three different ice temperatures were adopted: -4°C, -10°C and -20°C.

Results

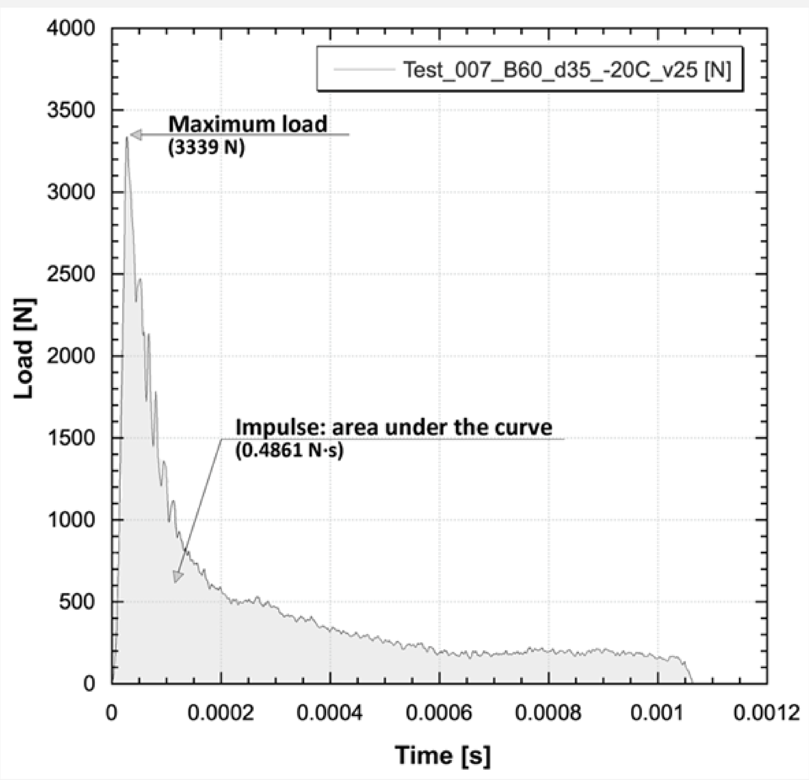


Fig 1 Typical load versus time signal

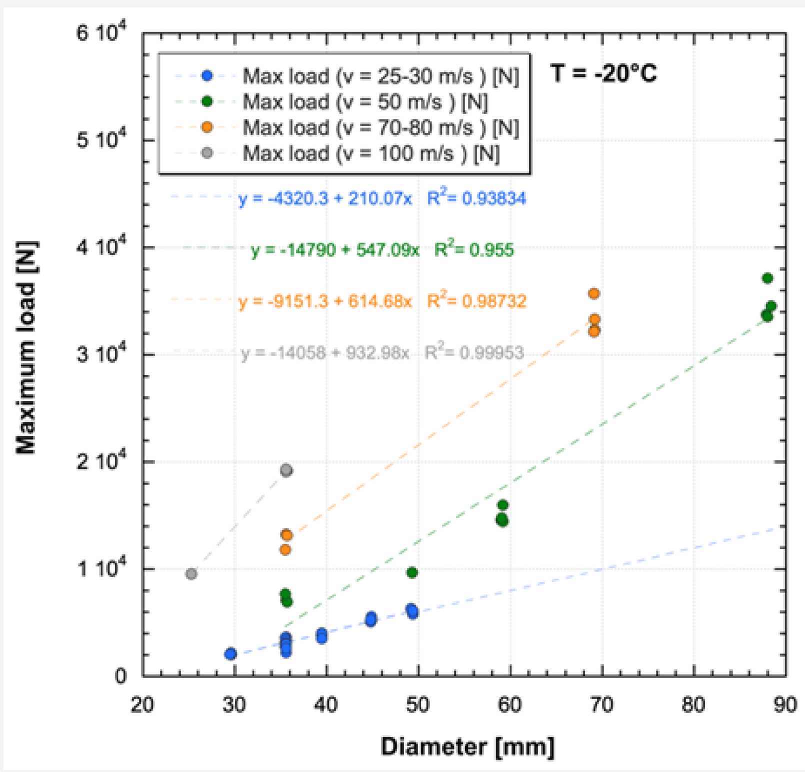


Fig 2 Maximum load for different diameters

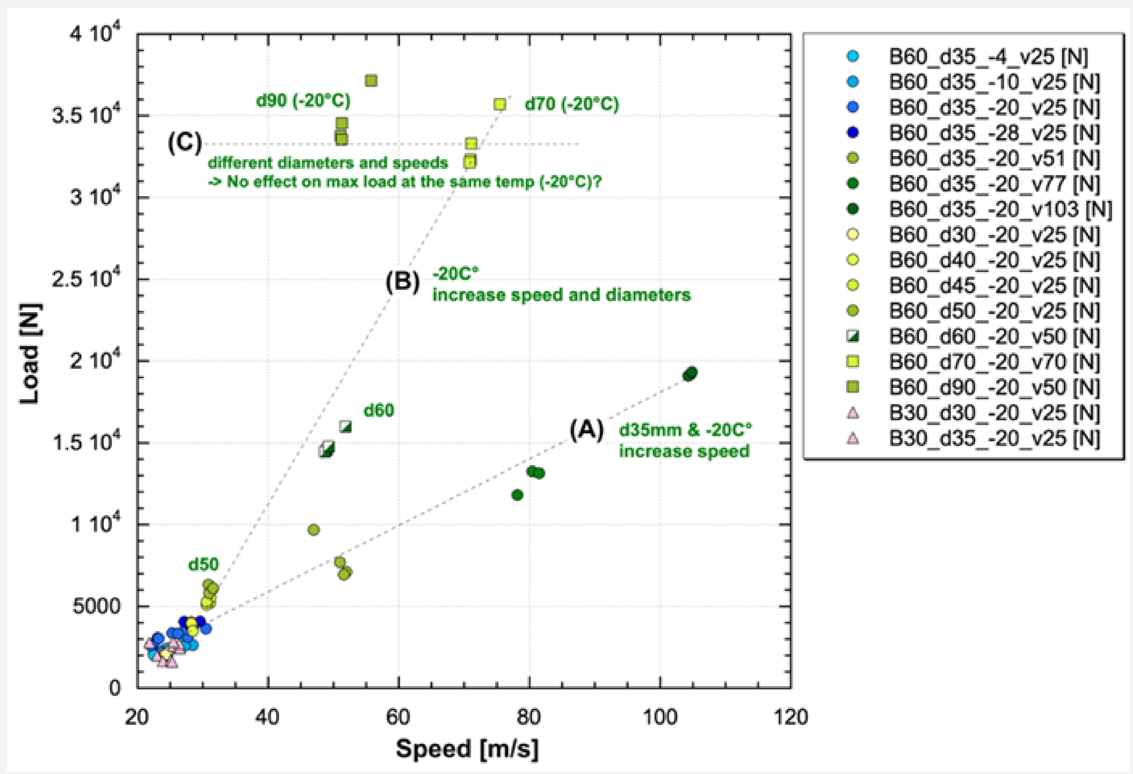


Fig 3 Maximum load as function of speed

- It can be seen (Fig.2) that the values follow an almost linear trend for the different speeds analysed. In particular, for the lowest speed (25-30 m/s), the interpolating line has a lower slope than for the higher speeds. This suggests that as the diameter of the ice balls increases (80-90 mm), loads more than approximately 14000 N (≈ 1400 kg) cannot be reached for low velocities (25-30 m/s).
- Moreover, it is possible to observe the influence of increasing velocities on a specific diameter of the ice balls: the same ice ball shot at increasing speeds leads to a minimum load of about 3000 N (≈ 300 kg) if the ball is shot at 25 m/s, while a maximum load six times higher of about 19000 N (≈ 1900 kg) if the ball is shot at 100 m/s.
- Our testing campaign seems to have reached an upper limit of the maximum load under two specific conditions. Specifically (Fig.3), a maximum load of about 34000 N (≈ 3400 kg) is obtained for ice balls of 70 mm and 90 mm shot at 70 m/s and 50 m/s, respectively. In both conditions, the conserving temperature is equal to -20°C.

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