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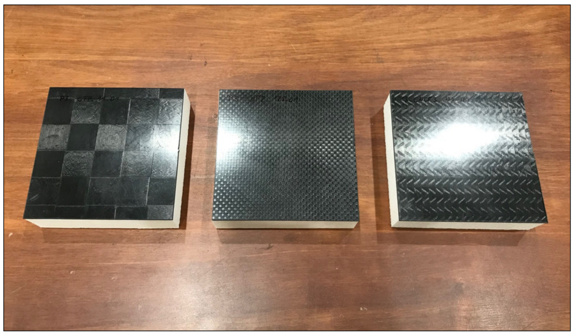
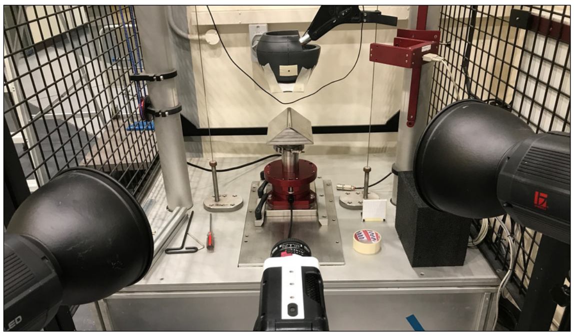
Subject Area	Innovation in Products, Processes and Materials - Industrial Technologies
Project Partner	ISR Institute for Sports Research, Nanyang Technological University, Singapore

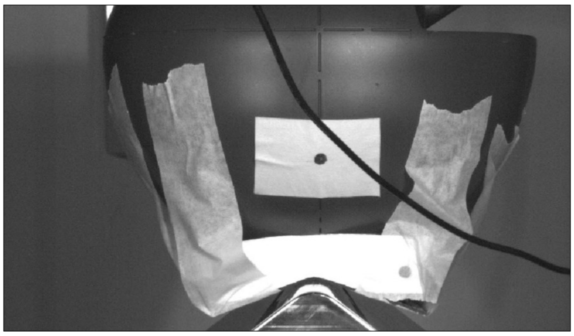
Understanding Composite Shells Response to Impact



Samples with different carbon composite shells (from left to right: woven thin ply, woven thick ply, non-crimp fabric)



Impact test with high speed camera and two illuminates in the front and head form,sample and curbstone anvil in the back



High speed camera picture of a fully compressed sample with carbon composite shell

Introduction: Bicycle helmets protect the wearers head against the impact in various situations. Therefore it contains an inner liner which is mainly expanded polystyrene (EPS) foam and an outer shell. Often an acrylonitrile butadiene styrene (ABS) or polycarbonate (PC) thermoplastic material is used for this purpose. In previous work at the Institute for Sports Research (ISR), different tests with helmet samples have been conducted. The current project investigates the different thermoplastic and carbon composite materials for the helmet shell with an aim to improve the safety of a cyclist. Also, a curbstone anvil was used as opposed to the flat anvil to recreate a realistic fall against an edge, for example, a border stone.

Objective: Composite materials are currently getting wide attention and majorly used in all kind of sports equipment. The main goal of this project is the acquisition of a better understanding of the mechanism of impact on composite shells for helmets. Simplified samples containing flat EPS foam and composite shell are used, fabricated and tested with an impactor which is used by helmet testing laboratories and following the helmet testing standard by the U.S. Consumer Product Safety Commission (CPSC). For using a curbstone impactor anvil during the project, a new testing methodology using flat samples was aimed to be designed. Also, the different carbon shell configurations were planned to be tested and evaluated.

Result: The peak acceleration measured in the head form of the impactor arm is of main interest since the helmet safety standard only prescribes a limit in this value. Besides acceleration and force, energy absorption has also been investigated during this project. Various studies with different shell materials, varied shell thicknesses, varied foam thicknesses and with different bonding between foam and shell have led to the following conclusions.

- Even if the foam was not of major interest in this project, it could be shown that the thickness of the EPS foam has a significant influence on the results of acceleration and force. In case of thickness, the influence of the foam is many times greater than the influence of the shell. Concerning the thickness, the foam pieces must, therefore, be manufactured as exactly as possible to ensure results that only depend on the shell and not also on the foam.
- The way the bonding between shell and foam is accomplished also influences the testing results. Epoxy resin and double side tape have been used in the context of this project. The influence of double side tape on the results could be seen to be much smaller than the one of the epoxy bonding.
- The use of carbon composite shells instead of the used ABS thermoplastic ones led up to 20% lower peak acceleration and peak force values when using comparable shell thicknesses.
- The behavior under impact differs a lot between thermoplastic and composite shells. While ABS gets only less plastically deformed, the composite shell failed in most of the cases with a crack when using the same impact energy for all the materials.
- Different fabric architecture and different matrix resins lead to different results. Among all tested material configurations, non-crimp fabric with an epoxy resin led to the lowest values for peak acceleration and peak force.