The Mechanics of Materials group focuses on the design, manufacturing and analysis of a variety of mechanical components, devices and structures, involving a variety of high-tech materials across a broad range of length scales. The mechanical performance is analysed and optimised in terms of the material’s constitution and composition, whereby tailored microstructures give tailored properties. Our research portfolio embraces both experimental, theoretical and computational mechanics. Our discipline is generally of key importance in any mechanical engineering department.

Focus of our research
The scientific research activities in the Mechanics of Materials group serve grand mechanical design questions in different application fields, e.g. Aerospace, Automotive, Energy, Health, High-tech Systems, Manufacturing, Materials, Micro-electronics and Micro-electro-mechanical systems. Our expertise builds on core disciplines like Solid Mechanics, Fracture and Damage Mechanics, Computational Non-linear Mechanics, Micromechanics and Materials Science. Bridging scales, by predicting mechanical properties at one scale on the basis of the complexity of the underlying scales is thereby leading. Our research spans a variety of materials, including metals, composites, ceramics, paper, textiles, biogenic hybrid materials (involving polymers as well).

Research topics & related application fields
Automotive: In automotive applications, our research concentrates on the performance of materials in crash situations, engines, tyres, powertrains, sensors, actuators, etc. Light-weight solutions and free-form composites with outstanding mechanical properties are key in automotive. Requirements are typically diverse and multi-functional. We focus on material performance, durability, reliability, lifetime, safety comfort and even aesthetics.

Aerospace: Lifetime and reliability engineering are decisive for aerospace applications. Our research programme here contributes to the development of light-weight and high-strength solutions, damage and failure of composites, high-temperature materials for jet engines, ultra-strong landing gears, etc.

High-Tech systems: Advanced high-tech systems often rely on position accuracies that are within the range of the intrinsic deformation of the components involved. Moreover, failure in such systems is always rooted in the mechanical performance, for which we seek adequate solutions.

Micro-electronics & Micro-electro-mechanical systems: These systems are characterised by a variety of materials with markedly different thermo-mechanical properties and interfaces, for which our discipline is again of crucial importance. The development of flexible displays, electronic textiles, stretchable electronics, complex Systems-in-Package, all necessitate state-of-the-art research on the underlying mechanics in direct relation to the structure of the materials involved.

Manufacturing technology: Manufacturing products and components involves processing and large deformations of materials, thereby affecting and changing their intrinsic properties. Our present focus here is put on 3D additive manufacturing problems. 3D printing techniques are unique in controlling material properties at small scales. Making future products by integrating different materials with conflicting properties constitutes a real challenge here.

Energy: Advanced materials play a key role in the storage and production of energy. We contribute to the development of ‘extreme’ materials for nuclear fusion reactors and materials for efficient battery systems. Plasma-facing materials constitute an enormous challenge, as they are exposed to severe thermal shock conditi-
ons, neutron and ion fluxes, etc. We also study fracture properties of rock formations in the surface of the earth for the stimulation of oil and gas wells or the creation of artificial geothermal energy sources.

Health: Within the health theme, we develop technical solutions for health care problems and injury mechanics. A typical example is the mechanics of devices for deep brain stimulation.

Materials technology: Our group supports the Dutch industry in developing materials with tuned and optimised mechanical properties. Over the past decades, the gain in strength and ductility in the recent generation of materials has been impressive. Our group specialises in the development of particular unique materials, i.e. dynamic metamaterials, designed to capture waves propagating in solids.

In all these application areas, the research program Mechanics of Materials aims for a substantial increase of the predictive power of state-of-the-art models, thereby enabling the optimisation of critical, high-tech products and manufacturing processes in direct relation to the complex loading history of the underlying materials and joining interfaces.

Highlights in the MoM-group

Development of advanced IDIC techniques: The group actively develops Integrated Digital Image Correlation (IDIC) as a technique to directly extract mechanical properties of a material, component or even a structure, using digital images.

Additive Manufacturing: properties of 3D printed materials: In 3D printing we establish the intimate relation between the ‘printed’ 3D microstructure and the resulting engineering properties (collaboration with the AM Systems Center at TNO).

Dynamic Metamaterials: We analyse and develop metamaterials, which have exotic properties. Dynamic metamaterials are thoroughly investigated, revealing superb sound absorption properties.

Wings for Aid: For this societal project, our students develop and test a ‘green’ resilient box, used to drop relief aid from an unmanned aerial vehicle in regions in great need. All quality and research metrics confirm that our group has a strong impact in our field. We received the highest citations scores and the top score in the most recent research assessment.

Multi-Scale Laboratory

The Multi-Scale lab operated by our group integrates mechanical testing with (real-time and in situ) microscopic observation. Our lab allows for quantitative in situ microscopic measurements during deformation and mechanical characterisation of a broad class of materials, structures, MEMS etc. on a wide range of length scales from nanometres to centimetres.

Mechanics of Materials and the industry

Our group has an extended and diversified industrial network. Important companies and technological institutes with which we collaborate are: Philips (Microelectronic devices, System-in-package, Solid State Lighting components, Stretchable Electronics), Tata Steel (Advanced High Strength Steels), NXP (MEMS), Océ (Paper mechanics), DAF (Thermo-mechanical fatigue), ASML (Actuators) Fokker Landing Gear (Composites), EPCOS (Metallic MEMS), NLR (Lightweight materials and structures), TNO (Additive manufacturing), HOLST (Flexible electronics), DSM (Dyneema composites), ExxonMobil (Semi-crystalline polymers), BMW (crash tests), Teijin.

PhD-student Sandra Kleinendorst

‘During my graduation research I realised that I enjoy studying a subject in depth for a longer period of time. Really delving deep is something that appeals to me. So that was the main reason for me to start a PhD. I am halfway through my research, and I have not regretted my choice for a moment. My research, which I do in the Mechanics of Materials group, focuses on the properties of stretchable electronics. Stretchable electronics are used predominantly for medical applications to bridge the difference between the traditional stiff and hard electronics and the soft and flexible structure of skin and organs. One such application is an echo sensor that is used in keyhole surgery. By using flexible and stretchable electronics the sensor head will be able to produce a 3D image of the inside of the body. By learning more about the materials that stretchable electronics are made from, the design can be optimised further and maximum stretchability achieved.

As a PhD-student, I work independently, but I can always consult my professor and supervisor. What I especially like is that I experience the developments in my field. What my future will bring? There are a number of options, including going into academic research full-time or working in a R&D department in a company, or at TNO. I really enjoy research, with a concrete application.

Master’s student Ruben Weerts

‘There is a lot of freedom in the Mechanics of Materials research group. You can choose between numerical and experimental mechanics, or you can take courses in both disciplines. Another thing
that I liked about this research group is that many subjects are taught to relatively small groups of students. As a result, many exams are taken orally, which is very instructive because you get immediate feedback.

I have a personal interest in automotive, so I chose a course program that tied in with that. The practical aspect really appealed to me. My research, which was part of a collaboration project between the industry (BMW and Abaqus) and the TU/e, focused on improving simulation models of ‘crash test barriers’, which are used as collision partners in vehicle crash tests.

As car development is increasingly computer simulation based, reliable and accurate simulation models of these barriers are vital. The barriers are built up from a honeycomb core surrounded by thin aluminum layers that are glued together. I developed an improved model for the honeycomb core. I also characterised glue layers experimentally, in order to optimise the modelling of these layers. I have now finished my studies. I have now found a job (numerical simulations) that perfectly matches with my graduation project. So I can’t wait to get started.’

Associate professor Joris Remmers

‘Can we improve the properties of materials? Can we make them stronger, or stiffer? In the Mechanics of Materials group we investigate the mechanical properties of materials ranging from metals and composites to glued structures; from materials that are processed in traditional ways to 3D printed structures; from everyday materials like paper to materials that are exposed to extreme conditions, e.g. in nuclear fusion reactors.

Studying and improving the properties of materials demands a fundamental approach, so tenacious researchers are what we need. Our students are not afraid of delving deep, and in fact that is what we expect from them. In research projects, every student is a full member of the team from day one. Together we investigate the behaviour of materials and work on the development of new materials research models. What attracts many students to our research group is that we both do fundamental research and work on applications. The latter often happens in collaboration with industry, both in the region and far beyond. So our Master’s students get the best of both worlds. And they will benefit from this for the rest of their lives.

Over time we have built up a broad network of many universities and companies that we regularly collaborate with. So graduating in collaboration with industry or foreign universities is a definite possibility. Many of the Master’s students that graduate in our research group remain at the university and go on to do a PhD. Others leave academia behind and opt for a career in industry. But whatever they choose, one thing is certain: they will make a swift start. I am absolutely convinced of that.’

Master’s student Tim van Nuland

‘For my graduation research I am extending a numerical model to predict the behaviour of acoustic materials. I am studying a composite with an epoxy matrix filled with rubber-covered lead balls that are very efficient in absorbing vibrations. Due to the weight of the lead inclusions and their soft rubber shell, they can move independently from the epoxy matrix and absorb vibrations with a specific frequency.

My numerical model should give us more insight into the (im)possibilities of these kinds of materials. What exact properties should a material have to protect buildings from earthquakes or to absorb certain sounds? My work is mostly numerical. But at the same time a colleague of mine is working hard in the lab to experimentally characterise different composites. It is an inspiring and nice collaboration.

Collaboration is in fact a key driver in this research group anyway. Supervision is excellent – you can get advice from the staff or PhD student whenever you are stuck. And what I also like, is the freedom you have within your Master’s degree program. For example, I did my internship for three months at Harvard University in the US working on a material that converts vibrations into static shrinkage or expansion. I have never regretted my choice. This is the right place for me.

The way it looks now, I’m likely to stay in this research group after my Master’s degree, because I would like to get a PhD. Industry would be another option. Because I am especially interested in doing research based on numerical models, a company with a good R&D department would be an obvious choice.’