CSIR FUTURE PRODUCTION: MANUFACTURING

ADVANCED MATERIALS ENGINEERING

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

CSIR
Touching lives through innovation

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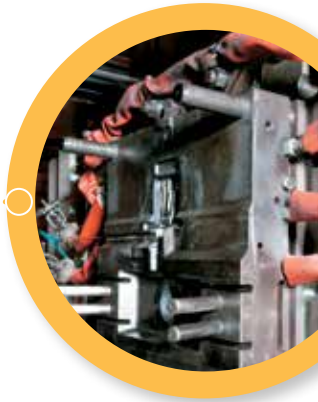


ADVANCED MATERIALS ENGINEERING

The Advanced Materials Engineering (AME) group at the CSIR has a significant track record in materials processing and development, and has provided services to local and international clientele. Development and commercialisation of high-value manufacturing processes focused on speciality metals, alloys and next-generation composite materials are key areas of interest. The group also has established capabilities in structural design and analysis, advanced casting and powder metallurgy technologies. Specific focus areas are casting (die, investment and vacuum), powder metallurgy (powder atomisation, hot isostatic pressing, metal injection moulding, press and sinter) technologies.

The group's efforts are underpinned by the beneficiation of national resources, skills development and technology transfer in support of re-industrialisation of the South African manufacturing sector. In this regard, the group hosts the Light Metals Development Network (LMDN) and the Titanium Centre of Competence (TiCoC), as multi-user national platforms supporting industrialisation of group technologies, as well as other SANAS-accredited facilities accessible to various stakeholders (science councils, industry and universities), including local and regional distributed small to large enterprises.

Expertise across the materials value chain to develop advanced materials and novel solutions to support beneficiation of local resources, re-industrialisation and exploiting fourth industrial revolution (4IR) technologies to give local industries a global competitive edge.

AME IS AN IMPACT AREA THAT FOCUSES ON THE FOLLOWING:

- Developing transformative technologies in support of the establishment of a local titanium industry via the CSIR-hosted TiCoC as an implementation platform;
- Enhancing the global competitiveness of our aluminium industry and developing national roadmaps (aluminium, magnesium and titanium);
- Establishing high-end infrastructure for training and skills development via the Centre of Competence Model, including research and innovation chairs in titanium;
- Supporting Small, Medium and Micro Enterprises (SMMEs) via technology incubation platforms whereby products (parts, components and systems) are manufactured for different industry sectors using CSIR-developed technologies;
- Offering technical support through directed research and consultancy services, accessing funding sources and building relationships between industry and academia;
- Housing SANAS-accredited (ISO/IEC 17025-2017) facilities that provide analytical and testing services to the private and public sectors, as well as tertiary institutions; and
- Offering forensic investigations, including engineering and metallurgical failure analysis, as well as Non-Destructive Testing (NDT).

The AME group works across the materials value chain to develop advanced materials to support the beneficiation of local resources and re-industrialisation. By exploiting 4IR technologies, the group aims to provide local industry with novel and unique offerings to achieve a globally competitive edge.

RESEARCH, DEVELOPMENT AND INNOVATION TEAMS AND CORE CAPABILITIES

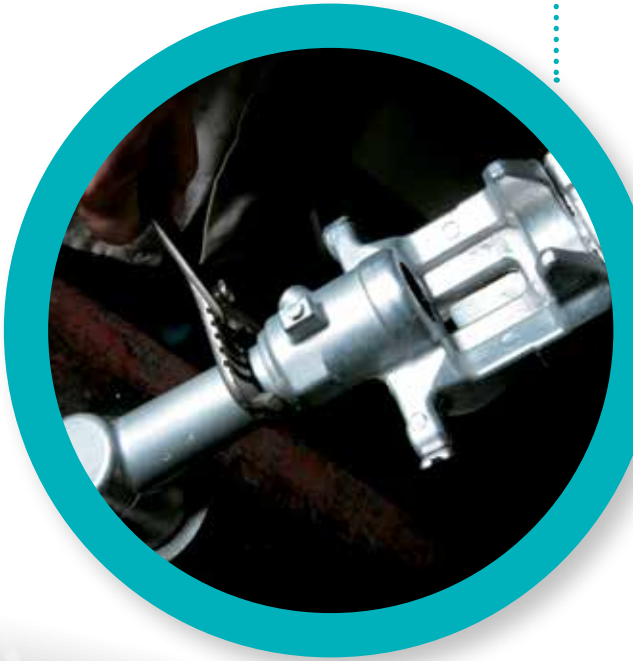
The impact area comprises three Research, Development and Innovation (RDI) groups with core capabilities outlined below.

ADVANCED CASTING TECHNOLOGIES

- Sand casting, investment casting, permanent mould casting (gravity and high-pressure die-casting), and semi-solid metal forming.
- Casting of common industrial alloys, typically copper-based alloys, light metals (aluminium, magnesium and titanium), and high-temperature alloys (nickel and cobalt-based superalloys).
- The group will host a state-of-the-art Hot Isostatic Pressing (HIP) facility for post-processing and heat treatment of additive manufactured parts, castings, Metal Injection Moulding (MIM) and powder metallurgy components.

DESIGN, ANALYSIS AND TESTING

- Design, development and testing within a product lifecycle management framework, e.g. light-weight vehicle armour, prosthetic devices and mobility systems, and liquefied petroleum gas (LPG) cylinders.
- Development of manufacturing technologies including prototype manufacture, testing and qualification of automotive or aerospace components, as well as medical devices.
- Predictive modelling of materials in relation to manufacturing, processing and performance.
- Mechanical testing of all metallic alloys, composites (metal, fibre, glass, carbon and basalt), and polymers to determine material properties under static (tensile and compression) and dynamic loading (low- and high-cycle fatigue), including fracture toughness.
- Part or component testing coupled with finite element modelling predictions of material and component response tailored towards specific engineering applications.



RESEARCH, DEVELOPMENT AND INNOVATION TEAMS AND CORE CAPABILITIES

POWDER METALLURGY TECHNOLOGIES

- Development of low-cost manufacturing processes aimed at mass production of components for the manufacturing sector (automotive, medical and consumer products).
- Supporting industrialisation, localisation and technology commercialisation in MIM, press and sinter (P&S) and powder metallurgy-hot isostatic pressing (PM-HIP).
- Alloy development through first principles materials modelling and validation.
- Co-development of commercial products in collaboration with local companies via localisation of the manufacture of imported products (substitution).
- Manufacture of powders of difficult to alloy metals that are amenable to further downstream processing such as atomisation and plasma spheroidisation.
- Developing PM-HIP procedures for the near-net-shape production of parts and components for advanced applications.
- Toll manufacture of products, including customised powder feedstocks via the MIM facility.

RDI FACILITIES AND INFRASTRUCTURE

The AME group is home to a significant suite of advanced manufacturing facilities and related infrastructure where industry, SMMEs and research institutes can undertake collaborative projects in partnership with the CSIR.

The facilities and associated capabilities include the following:

METAL INJECTION MOULDING FACILITY

The MIM facility enables the cost-effective, mass production of complex near-net-shaped small components from metal powder feedstocks.

The MIM facility offers tooling design, feedstock preparation and manufacturing capabilities for the mass production of a wide range of small metal parts. High dimensional accuracy and repeatability on an almost unlimited choice of materials is a key advantage. While the existing metals industry is already benefiting from the facility, a future downstream titanium industry is also set to benefit significantly. There is only one facility in South Africa that can successfully develop in-house methods of fabricating products and custom feedstocks using MIM.

In-house design and engineering expertise are part of a one-stop shop for designing and making complex precision parts. The facility is in the process of acquiring a new 4IR-enabled, industrial-scale debinding and sintering furnace to scale up production towards technology commercialisation

INVESTMENT CASTING FACILITY

The CSIR Investment Casting (IC) facility is the only foundry in South Africa with production-level vacuum casting capability. The foundry produced single-crystal, nickel-based superalloy blades for gas turbines that were bench-tested on commercial military jet engines. The technology has been transferred to industry.

The facility also has a specialised capability for investment casting of titanium alloys. The IC facility works closely with industry partners to localise manufacturing, an example being the casting and qualification of the 9 mm hand pistol for the South African Police Service (SAPS), in collaboration with Hausler. The first batch of 500 pistols was produced via the facility, having also assisted with limited production for Hausler.

Thin-walled casting of aluminium has also been developed as shown for prosthetic knee parts in the attached photo. A shell system for reducing solidification stresses and ease of cleaning without damage to parts is used. Significant progress has also been made in the reduction of distortion during heat treatment of thin-walled aluminium components with improvements in mechanical properties.

RDI FACILITIES AND INFRASTRUCTURE

HOT ISOSTATIC PRESSING FACILITY

The CSIR recently acquired a state-of-the-art, Quintus HIP facility for post-processing and heat treatment of additive manufactured parts, castings and powder metallurgy components, which will be operational at the Pretoria site from quarter 4 of 2022 onwards.

Hot isostatic pressing (HIPing) is a process for consolidating metal powder compacts or eliminating defects in materials (pores and voids internal cracks) to densify the material to near theoretical density. The process utilises high temperature and high isostatic gas pressure acting on all surfaces of the component. The process eliminates porosity and defects imparting full density in:

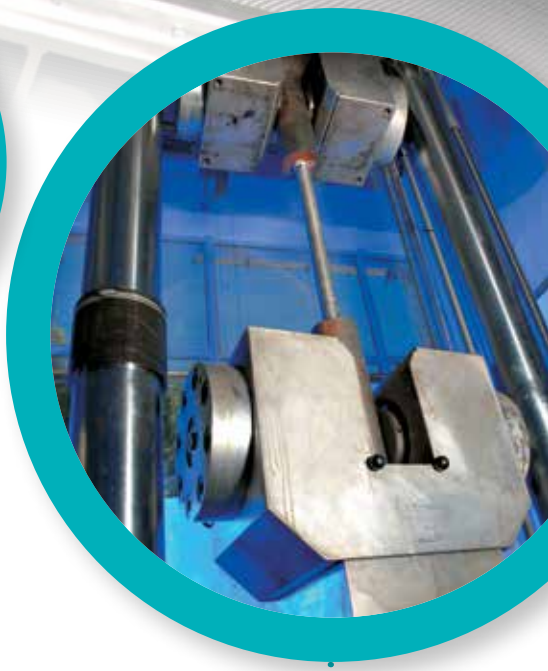
- castings;
- additive manufactured parts;
- powdered metallurgical parts;
- metal injection moulded parts; and
- impart compressive residual stresses to improve fatigue performance.

HIPing is a critical step in many of the manufacturing processes being developed by the CSIR. Nearly all titanium components, including castings, MIM and additive manufactured components must be HIPed in order to improve structural integrity. It is used extensively for aluminium, nickel, cobalt and iron-based alloy components where structural integrity is of critical importance. There are currently no industrial HIP facilities in South Africa suitable for the processing of titanium products.

HIPing consolidates metal powder compacts and eliminates defects. It is a critical step in many manufacturing processes to improve structural integrity. The CSIR houses the only industrial facility for processing of titanium products in South Africa.

Equipment specifications:

- Maximum operating pressure: 207 MPa
- Design pressure: 228 MPa
- Pressure vessel volume: 242 dm^3
- Maximum operating temperature: 1 400 °C
- Maximum height of workload: 890 mm
- Maximum diameter of workload: 300 mm
- Maximum workload (including basket): 350 kg
- Temperature control: ± 8 °C
- Number of heating zones: 3
- High quench capability for in-situ heat treatment



MECHANICAL TESTING FACILITY

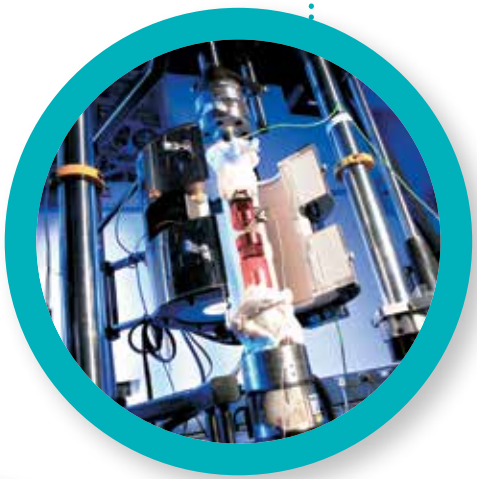
The determination of mechanical properties of engineering materials and structural components is important for predicting performance under static and dynamic loading conditions. The CSIR mechanical testing facility (MTF) is SANAS accredited (ISO/IEC 17025: 2017) and conducts mechanical and material properties tests on a broad range of engineering materials (metallics, composites, ceramics and polymers), and components for industry (aerospace, chemical, construction, medical, mining and transport).

The MTF is extensively used by local industry, state-owned enterprise (SOEs), science councils and universities, including international clients for materials and component test and qualification.

Key testing services offered are:

- Tensile and compression testing (to 1000 kN)
- Fatigue testing up to 800 kN
- Low and high cycle fatigue testing
- High temperature fatigue and tensile (0 °C to 800 °C)
- Fracture toughness testing*
- Crack growth rates, threshold stress intensity,
- S-N curves
- ASTM E466 constant amplitude axial fatigue
- ASTM E606 strain controlled fatigue testing
- ASTM E647 fatigue crack growth rates
- ASTM E399 K1c plane strain fracture toughness
- ASTM E813 Jlc testing
- ASTM E1820 fracture toughness (metallics)
- ASTM E561 R-curve determination
- ASTM E1290 crack tip opening displacement
- Creep testing up to 1000 °C

Testing of manufactured rebar, multi-strand wire cabling and composite materials are routinely conducted as part of client quality assurance requirements. Some large projects include materials testing for construction of the SKA Antenna Reflector, wire rope for Nelson Mandela Bridge, 2010 Soccer World Cup stadia and Eskom power stations. Collaboration with other test facilities is ongoing, including private companies and South African Bureau of Standards (SABS).



RDI FACILITIES AND INFRASTRUCTURE

POWDER CHARACTERISATION LABORATORY

The CSIR Powder Characterisation (PC) facility is accredited under the ISO/IEC 17025: 2017 quality system offering standardised testing and qualification of metal powders for additive manufacturing, MIM and general powder metallurgy processes.

The facility also supports national programmes such as the CSIR Photonics Centre, the Centre for Rapid Prototyping and Manufacturing (Central University of Technology), amongst others. The SANAS-accredited facility performs a range of procedures from high-volume testing to complex materials analysis or in-depth investigations for a large variety of sectors. Capabilities offered include apparent density, tap density, chemical composition analysis, powder sieve analysis, particle size distribution, powder flow analysis, Brunauer, Emmett and Teller (BET) surface area and gas pycnometry.

METALLOGRAPHIC FACILITY

The AME impact area offers unique and broad ranging heat-treatment capabilities to serve domestic and international customers to a high level of standards demanded by the medical, military, stampings, high-speed tools and forging industries.

The facility houses a fully equipped metallurgical testing lab offering the full complement of sample preparation, cutting, polishing and lapping capabilities, high-resolution microscopes, elemental analysis and hardness testing. Diverse expertise is available, spanning the disciplines of microscopy, materials science and metallurgical engineering. These capabilities are complemented by a comprehensive suite of in-house facilities for materials characterisation, mechanical testing and forensic analysis (failure investigations).

NON-DESTRUCTIVE TESTING FACILITY

Non-destructive testing (NDT) is the process of inspecting materials, components and assemblies to find discontinuities or anomalies in their characteristics that negatively impact their integrity, without destroying the serviceability of the part or system.

The CSIR houses a range of NDT capabilities, viz.

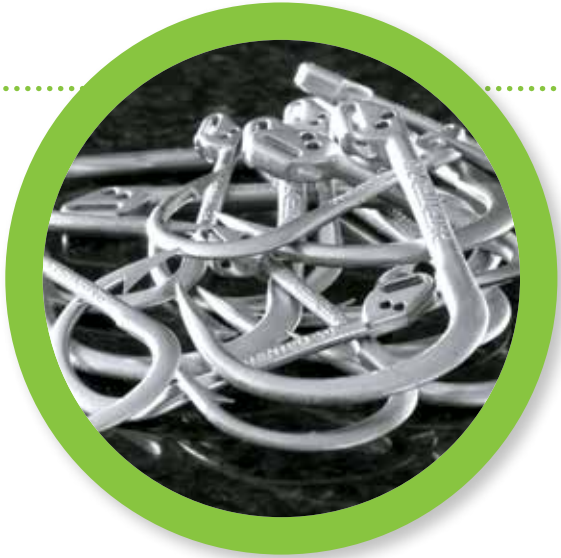
- Ecco Phased Array UT system
- Dual Frequency Nortec ET system (complete probe set)
- Micro-focus X-ray system (160 KeV)

The facility provides the manufacturing industry with effective, application-oriented NDT solutions in sectors where the operational reliability of high-value components is crucial (aviation, automotive, power generation, transportation and medical).

TYPICAL PROJECTS

PRODUCTION OF SINTERED COPPER BUSHINGS

Bushings are manufactured for an industrial appliance manufacturer. These are single piece components used in rotating machinery to reduce friction and wear. They are manufactured via pressing and sintering and are usually oil-impregnated, hence maintenance-free. The South African market is currently serviced by imports. The CSIR has generated intellectual property (IP) that can be used to localise manufacture to the benefit of local sectors and is currently working with an industrial partner towards this end.



DEEP SEA FISHING HOOKS

MIM tuna fishhooks were made from 17-4 PH stainless steel for a commercial client. The fishhooks are for deep sea tuna fishing and recreational game fishing. The design of the fishhook gap offers consistent hook-ups and better rigging with worm and plastic rubber baits. A batch of the fishhooks was successfully produced and tested against commercially available fishhooks for strength and corrosion performance. Engagements with a potential customer are ongoing for the manufacture of up to 100 000 units per annum.

TITANIUM INVESTMENT CASTING PROCESS

2006 - 2009: Establishment of main infrastructure.

2009 - 2012: Established key enabling technologies (mold shell and face coat systems, vacuum refractory melting process and chemical milling of alpha case).

2012 - 2014: Process optimisation and specification development for industrial demonstration; Proofing trials of mold system and skull melting against refractory melting.

2014 - 2015: Generation of fatigue data and heat treatment optimisation to achieve properties.

2015 - 2020: Product and material developments, including business development and marketing.

HOSPITAL INTENSIVE CARE UNIT BED PROTOTYPE DEVELOPMENT

Hospital beds for nursing, general wards, high care and intensive care are a national requirement - particularly in emergencies such as the onset of the Covid-19 pandemic. Nursing beds are available locally as flat packs with a few local ward bed manufacturers, but most are imported from China. The CSIR developed a prototype ICU bed during the pandemic to address an impending shortage. This was tested to SANS/SAHPRA standards. The CSIR plans to engage with local companies to establish local manufacturing or transfer technology to local bed manufacturers. The utilisation of local content and technology is a key objective.

ABOUT THE CSIR

The CSIR, an entity of the Department of Science and Innovation, is one of the leading scientific and technology research, development and implementation organisations in Africa. It is an independent agency, geared towards localising transformative technologies and accelerating their diffusion to improve the competitiveness of high-impact industries; and driving socioeconomic transformation by supporting a capable state.

The CSIR is known for its specialist, multidisciplinary knowledge base, which – combined with world-class infrastructure – ensures the translation of research into outputs with real value for industry and society. The CSIR focuses on 9 clusters to deliver the desired impact, namely Advanced Agri and Food; NextGen Health; Future production: Chemicals; Future production: Mining; Future production: Manufacturing; Defence and Security; NextGen Enterprises and Institutions; Smart Logistics; and Smart Places. The CSIR engages in positive, impactful relationships with partners of all sizes and places emphasis on skills development to enrich the local knowledge economy and global technical standing.

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