Factories of the Future – Impressions from a Study Tour to Germany
The New Zealand Heavy Engineering Research Association (HERA) is a non-profit research organisation dedicated to serving the needs of the metal-based industries in New Zealand. It is the national centre for steel construction, welding, metal fabrication and machining, and promotes the effective and efficient use of steel in structures.

HERA’s work includes the sponsorship of research and development, the provision of educational, advisory and information services, the dissemination of technical knowledge to specifiers, fabricators and suppliers, participation in the activities of relevant national and international bodies and in the writing of standards and codes of practice.

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Abstract

The Paper reports personal impressions gained from an industrial technologies study group tour organised as part of the European Commission/New Zealand FRIENZ (Facilitating Research and Innovation cooperation between Europe and New Zealand) project.

The objective of the tour was not only to create an insight into advanced manufacturing technologies and how they might shape the “Factories of the Future” but also to facilitate deeper existing and new science and innovation partnerships.

The author visited 13 German technical research institutions being part of either leading technical universities or the Fraunhofer Society, the world leading processing equipment fair Achema in Frankfurt and also 3 German metals based manufacturing companies.

The impressions were put together with a view to provide some insight into novel developments and strategic thoughts which might be of assistance to the New Zealand heavy and general metals-based engineering industry and its associated research community for shaping their sustainable future.

As a result of a consistent innovations-flow in metallic materials, manufacturing and associated information technology, the author’s overall conclusion is that there is a bright future for competitive metals-based manufactured products. This should give New Zealand fabricators and manufacturers the confidence to look forward to a sustainable future and actively forward-plan their business activities including investing in R&D in their respective fields of work.

Acknowledgement:
The author wishes to acknowledge the generous support of the FRIENZ network and in particular the excellent tour co-ordination provided by the Royal Society of New Zealand.
Executive Summary

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Key conclusions and recommendations are recorded in three topic areas plus a summarising conclusion:

- **IT Driven Metals Engineering Technologies**
  The main learning in respect to future changes in our metals-based engineering environment is the influence of IT thus creating the 4th industrial revolution and described in the German Economic Development politics as Industry 4.0. The consistent message from government, research providers and industry is that this is the most important item that German industry must focus on to remain competitive cannot be overemphasised. To the author this demonstrates how powerful it can be if a common strategic approach is taken to motivate everyone involved and led him to make the following recommendations:

  **Recommendations to IT Driven Engineering Technologies:**
  - That the NZ metals-based engineering industry is encouraged to take advantage of the opportunities offered by the IT based 4th Industrial Revolution. NZ industry is up with the international play when it comes to IT-savviness and engineering-related creativity and that there are endless opportunities available.
  - That HERA and the manufacturing industry specifically advocate that IT applied in conjunction with high value manufactured products is likely having a higher return to the country than IT based software product developments on their own. Maybe MBIE starting a NZ Industry 4.0 initiative is a worthwhile consideration.
  - That HERA research puts increased focus on the IT integration aspects and sponsors and supports more research in the IT interface to metals based manufacturing e.g. in mechatronic projects, use of smart (e.g. phase changing) metals, metals based additive manufacturing.
  - That the universities and research providers use the new and renewed contacts made to increase research co-operation with the German research providers and companies visited. In particular, the Industry 4.0 research opportunities with the FhG institutes provide an ideal opportunity to follow up. Organising the Heavy
Engineering Educational and Research Foundation (HEERF) or other bodies to support visiting scholars for technology transfer and inspiration are an easy target to achieve from the contacts made. For HERA specifically the fish-farming technology improvement with SS netting in conjunction with Konstanz University and the ORC co-operation with the Karlsruhe Institute of Technology are to be followed up.

- In German and European applied research projects it is basically mandated that strong industry participation is required for a project to be funded and in NZ public funded projects putting more emphasis on industry participation may be a worthwhile consideration.
- It is positively noted that the NZ governments (CI) R&D funding programs put more emphasis on funding researchers from within companies and for specific company project's, however, it may be worth-while to even stronger promote the researcher to future industry managed pathways as applied in the FhG system.
- Noting the strong public sector funding support for applied industry research in Germany and its effectiveness on innovation, the author wishes to use this reporting opportunity to point out that in New Zealand sector-specific collective industry-levy based R&D funds are in general excluded from attracting government R&D co-funding and this also applies for HERA funding. This exclusion applies for both Callaghan Innovation R&D Growth Grants and the Independent Research Association Capability Fund and it is recommended that MBIE addresses this anomaly.

**Steel Construction Research**
The visits to German steel construction research facilities and funding agencies confirmed a continued level of activity and exciting new opportunities particularly in composite construction.

**Recommendations to Steel Construction Research:**
- For HERA and structural steel research parties to continue focus on reliability assessment of welded joints under seismic load conditions and strengthen international co-operation
- Use IT opportunities to cost effectively improve product quality and conformity assessment e.g. QA with WIFI torque sensing, or welding process related weld quality monitoring
- HERA to develop with composite material partners steel/composite material research road maps e.g. steel/glass
- Explore with NZTA and industry partners the establishment of a steel bridge life extension project covering e.g. bonded steel deck options and hot dip galvanised solutions

**Hydrogen Based Technologies**
Hydrogen as a cornerstone of renewable energy strategies continues to be a main interest of German research and development. The recognition that the two dominate renewable energy generators photovoltaic and wind and to a lesser extent hydro are weather-dependent and hence intermittent makes production of hydrogen from renewable electricity, its storage and conversion back into electricity or other uses such as for methane or fertiliser production very attractive technology options.
Recommendations to Hydrogen Based Technologies:

- That NZ government and interested parties have a renewed look at the NZ business case for entering into a hydrogen economy
- That HERA (and other NZ research facilities) performs preliminary research supporting the development of such a NZ Inc. business case

- **Summarising Conclusion**
  
  As a result of a consistent innovations-flow in metallic materials, manufacturing and associated information technology, the author’s overall conclusion is that there is a bright future for competitive metals-based manufactured products. This should give New Zealand fabricators and manufacturers the confidence to look forward to a sustainable future and actively forward-plan their business activities including investing in R&D in their respective fields of work.
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1. Introduction

1.1 Tour Objectives

The FRIENZ study group tour was part of the European Commission/New Zealand FRIENZ (Facilitating Research and Innovation cooperation between Europe and New Zealand) project. This is a three year European Commission FP7 project initiative in partnership with the New Zealand Government. The project partners include the Royal Society of New Zealand, Ministry of Business, Innovation and Employment (MBIE), Euro Research Support Limited, the French Centre National de la Recherche Scientifique (CNRS), The German International Bureau of the Federal Ministry of Education and Research and the Finnish VTT Innovation and Knowledge Economy.

The project seeks amongst other to:

- Create new and deeper strategic science and innovation partnerships
- Develop a greater understanding of the conditions needed to stimulate the engagement of private sector and commercial enterprises in NZ and EU schemes
- Create closer institutional bilateral collaborations
- Develop greater awareness among NZ and EU science and innovation communities of opportunities of mutually beneficial research related activities.

The task of the NZ delegation visiting Germany was to promote opportunities for collaboration in research and innovation with New Zealand; strengthen existing relationships; and stimulate new collaboration. Also a personal objective was to gain a deeper strategic insight in what way the technological developments observed will influence the future manufacturing environment particularly for the still relatively isolated and remote New Zealand metals-based manufacturing sector.

Additionally, as the author is from an industry research association with a membership base focusing on heavy engineering and steel construction, R&D and business opportunities were explored in this area including in steel construction, Organic Rankin Cycle (ORC) and hydrogen-based energy technologies.

1.2 New Zealand Participants

New Zealand participant’s in the tour consisted the author and:

- Professor Jim Metson, Chief Science Advisor, Science, Skills and Innovation MBIE
- Associate Professor Neil Broderick, Department of Physics, The University of Auckland
• Kevin Hurren, Group Manager, Business Development and Commercialisation at Lincoln Agritech Ltd.
• Professor Xun Xu, Chair of Manufacturing, Department of Mechanical Engineering, The University of Auckland

The study tour team jointly visited Mercedes Benz, FhG IPA in Stuttgart, the Dresden and Chemnitz research institutions and FhG FIT in Schloss Augustin. Individual programs followed with the author visiting the Achema Fair in Frankfurt, the Technical University in Aachen, the Research Association for Steel Applications (FOSTA) in Düsseldorf, FhG IPA Centre for Large Structures in Rostock and 2 associated heavy fabrication companies, the Karlsruhe Institute of Technology (KIT) and the University of Konstanz.
2. German Institutions Visited

2.1 Mercedes Benz Technology Center, Stuttgart-Sindelfingen

The New Zealand tour group was hosted by Prof. Dr. Ing. Thomas Weber who is a Member of the Board of Management of Daimler AG and heads the Group Research & Mercedes-Benz Cars Development. Mercedes-Benz Cars celebrated a record year in cars sales in the year just completed and expanded their production capacities around the world creating very favourable conditions for future growth.

The focus of the talk was on the general aspects of car development and how the requirement for increased individualisation of the car can be incorporated into mass production. This latter requirement is a key aspect of the German Education & Research Ministry’s Project of Future: Industry 4.0 which was discussed in detail including how an individual company such as Daimler is involved in this most important nationwide research effort (German Government Budget Euro 200 m). A reference to this project straight from the German government website is given in the inset below.

![The FRIENZ study tour team from left Kevin Hurren, Dr Neil Broderick, Dr Wolfgang Scholz, Prof Jim Metson and Prof Xun Xu with Prof Thomas Weber (3rd from left) at the Mercedes Benz Technology Centre](image)

**Project of the Future: Industry 4.0**

Industry is on the threshold of the fourth industrial revolution. Driven by the Internet, the real and virtual worlds are growing closer and closer together to form the Internet of Things. Industrial production of the future will be characterized by the strong individualization of products under the conditions of highly flexible (large series) production, the extensive integration of customers and business partners in business and value-added processes, and the linking of production and
high-quality services leading to so-called hybrid products. German industry now has the opportunity to actively shape the fourth industrial revolution. We want to support this process with the “Industry 4.0” forward-looking project.


Daimler’s involvement in industry 4.0, which was demonstrated at the visit of their “Technologiefabrik” which showcased testing of new manufacturing concepts, focused on the integration of the human operator into the complex robot focused assembly process. While in the past the industrial robots were fenced away so as not to harm the human operator, in the new concepts the robots work side by side with their human colleagues facilitating their tasks and making the overall operation more flexible.

It is amazing to experience how easy it is to teach a new generation soft robot e.g. an assembly task and then see it repeated. The argument is that the new concepts put the human being back in the centre of the operation within more flexible and less complex automated manufacturing facilities but incorporating potentially more people.

The logic of the concept was explained when we visited the single most complex robotic assembly operation on the S-class assembly line. The factory manager explained that due to the extreme complexity of the automated job it is a big challenge to firstly achieve operational conditions but you also need to be constantly worried about ongoing performance and reliability of a key workstation.

In the context of “mass production individualisation” reducing the complexity and adding flexibility overall will benefit the future concept of flexible automation, Prof Weber notes he can see the time where a client receives a note on his smart phone saying that his car just got into production and asking “do you want this new Extra as well?”

Equally from a manufacturer’s perspective there will also be big shifts in the services provided by their suppliers. For example, the supply of welding consumables will become a service whereby the supplier is solely in charge from getting informed e.g. on the storage level of spot welding tips and automatically replenishes if at a critical level.

Another innovation with possible relevance to our industry was the application of a remote torque measuring system during the assembly of bolts. In every Mercedes S-class car all safety critical bolts are monitored in respect to the actually applied torque via a remote sensing unit attached to the bolting device. This also appears to be a viable idea for structural steel connections e.g. in multi-storey buildings and probably a worth-while R&D effort for our industry to implement.
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Remote torque measuring system – without the bolt torque being ok no car leaves the production line

As to future car technology development which might have a major influence on the New Zealand fuel supply landscape and may provide opportunities for the NZ heavy engineering industry, we discussed Daimler’s involvement in hydrogen fuelled car development. The best known example is probably the Mercedes-Benz Citaro Fuel Cell Hybrid buses which are in operation in several cities and the author also saw them in operation later on in his tour as the Campus bus of the Karlsruhe University. Prof Weber remarked that “Mercedes is very much up with the play of the hydrogen based fuel technology and it is more a question of availability of a hydrogen fuel infrastructure which will drive its application. Currently Mercedes are settling on the Plug-in Hybrid technology as the next generation of more environmentally friendly car technology.”

2.2 Fraunhofer IPA, Stuttgart-Vaihingen
The Fraunhofer Society is the largest applied research organisation in Europe. The Fraunhofer Institut for Production and Automation Technology (IPA) in Stuttgart-Vaihingen, apart from being a former workplace of the author, is one of the largest Fraunhofer institutes. It has around 1,000 employees and a turnover of Euro 60 Million and more than 1/3 being from industry. Structured into 13 divisions it covers six areas of operation automotive, machine tools, electronic control and microsystems technology, energy, medicine and biotechnology, as well as process engineering technology. The study group visited the Laboratory Automation and Bio-manufacturing Engineering, the Applications Centre Industry 4.0 and the Motion Laboratory of the Medical Technology division.

Focus of the current strategic IPA research initiatives also under the Industry 4.0 program is on long-term projects with high industry participation. The program “Mass Sustainability” aims at minimising resource use and maximise living quality and includes programs such as ultra-efficient factory and smart materials or the program “Mass Personalization”, which aims to combine economies of scale with individual scope. In their program ARENA 2036, for which currently a massive new research factory is being built, the researchers aim to manufacture...
personalised products with a lot size of one at the cost of mass produced components.

Due to the formal co-operative research link between the FhG IPA and the University of Auckland (UoA) Bioengineering Institute, the tour was able to see the advances made and research undertaken in the bio-mechatronic systems area. Great to see the high regard the New Zealand contribution in the area is rated and that both sides were actively seeking research co-operation. The impact for both sides maintaining or improving their world-class status cannot be underestimated.

2.3 ACHEMA 2015, Frankfurt
ACHEMA is held every 3 years and is probably the most significant process engineering fair in the world, attracted 166,444 visitors to the Frankfurt exhibition grounds and 3,813 exhibitors from 56 countries. The extensive range of new products and initial product introductions underline the importance of ACHEMA as the “world innovation summit”.

On his one day visit the author was only able to see a small part of the items exhibited, the focus being on general heat exchange in the context of HERA’s renewable energy program and hydrogen technology in the context of renewable fuel sources for New Zealand.

To his great surprise he stumbled across the exhibition stand of HERA member Cuddon Engineering, which was successfully selling its freeze drying technology to the world. It is worth- while to note that a small New Zealand company in a remote location such as Blenheim can compete on the world market by selling their unique solution as a complete service package (see HERANews story
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describing the Cuddon approach
http://www.hera.org.nz/Story?Action=View&Story_id=2291). Key to the success is that the company must develop and own its IP and must be committed to whole of life support for the entire package as a business proposition. Based on a strong local market to proof the technology this is certainly working out for the Blenheim innovators.

Excellent contacts were made relating to the HERA AGGAT (Above Ground Geothermal and Allied Technologies) research program. Contacts were made with several ORC systems suppliers and a visit to the INTEC GMK ORC Energy Systems stand led to an invitation to visit their assembly plant in Rostock. The subsequent visit of the plant in Rostock allowed exploring options for cooperation in the actual AGGAT program.

In depth discussions were held in respect to the hydrogen technology topic at the stands of several solution providers but also two German research entities. At the Siemens stand the entire concept of a hydrogen based future could be explored.
The core concept is their electrolysis system based on Proton Exchange Membrane (PEM) technology which can produce, with absolutely no Co2 emission, hydrogen from renewable energy. It was agreed to co-operate in the exploration of the technology’s potential for the New Zealand energy landscape and learn from the vast amount of pilot and real applications explored by Siemens worldwide.

Relating back to the German Government’s Industry 4.0 R&D programme the author noted also a strong response from German process equipment manufacturers. One particular company, Poerner Gruppe, responded with their own interpretation of the strategic development effort in respect to engineering plant and equipment and called it “Anlagenbau 4.0”(http://www.poerner.at/en/anlagenbau40.html). Recognising that the main gains come from the IT sector developments, the concept covers the optimisation of plant under the five focus areas product quality, optimised plant operation, energy efficiency, human/equipment interface and environmental considerations.
The new IT based plant modelling options allow for new ways of trying out alternative designs, training in virtual reality environments similar to pilots in the flight simulator and even the capability of processing plant to learn to improve itself is moving out of utopia.

### 2.4 Research Facilities in Dresden and Chemnitz

Technically the visits to the facilities of the Universities of Dresden and Chemnitz and their associated institutions were a real highlight. Being situated in the state of Saxony and being close to the Erzgebirge (or Iron Ore Mountains) it has a rich industrial background due to its iron ore related activities.

With its former industrial role relating to machine tool manufacture, automotive and textile industry equipment in the former eastern-bloc countries union, Saxony was destined to play again a strong industrial role following the industrial restructuring after the re-unification of Germany. It was a very tough time for the local industries leading to a strong outflow of skilled people from the region. The local and federal governments focus was to turn this around and support settlement of new competitive industries and the resulting training and R&D infrastructure, led to the settlement of companies such as BMW and Volkswagen and the development of new capabilities in the R&D environment.

No question a lot of thinking was put by the “new” states of the unified Germany into what to do to encourage people to stay and develop a future in their region. This was strongly featured in the talks the group had with the heads of the Technical University (TU) of Dresden, Prof Mueller-Steinhagen, who for several years was working at the University of Auckland, and of the Technical University of Chemnitz, Prof Arnold van Zyl. No doubt our visiting party felt the energy coming from those new evolving places in the East of Germany which appear to
now successfully compete with the established research facilities in West Germany.

The TU Dresden is one of eleven German universities that were identified as an “excellence university”. TUD has about 37,000 students, 4,400 publicly funded staff members – among them over 500 professors – and approximately 3,500 externally funded staff members, and, thus, is the largest university in Saxony, today. Dresden under the “Dresden Concept” now has in addition to the university itself, 20 non-university research institutions. 10% of the population of Dresden are students and of this 13% are international students. This attractiveness for students is probably helped by the fantastic historic background of the city and the ambience offered combined with very cost effective living conditions if compared to West Germany.

In Chemnitz Prof Zyl pointed out the long tradition of Chemnitz University which had its origin in 1836 and nowadays has 8 Faculties with 27 institutes and a total of around 12,000 students of which 20% are international. It was proudly reported that for the last two years Chemnitz – which was named Karl Marx Stadt in GDR times – has turned the migration loss of approximately 220,000 people since German unification around and has since grown its working population. In his view the university with its growth has played a significant part in this.

The centre stage visit to Dresden and Chemnitz has been to the Fraunhofer Institute for Machine Tools and Forming Technology - Fraunhofer IWU in short. Seeing the amount of metals engineering R&D going on with clear innovation outcomes certainly helps to balance the assumption that innovation is only happening in the IT sector and brings to the forefront the recognition that it is the IT advance which actually does drive innovation on the traditional metals engineering front.
One example of a novel “adaptronic” system in the area of traditional metals machining technology aims to illustrate this. Achieving improvement of machine tools in the conventional ways such as higher machining speeds or more accurate machining seems to have reached the limits of the existing technology and further improvements challenges the resource efficiency of the improvement process.

In this context the usage of “adaptronic” components such as piezoelectric stack actuators offer great potential. The integration of these components into energy transfer through the creation of additional axis of movement allows significant increase in dynamics and accuracy of existing machine tools. Furthermore, the corresponding systems offer the possibility to determine the system state and to compensate for disturbances.

One possible approach for function extension of machine tools is the use of an adaptive spindle holder. For this purpose, a hexapod kinematic system using piezoelectric stack actuators was developed and combined with a conventional high speed cutting motor spindle allowing movement of the motor spindle in five degrees of freedom.

Using the adaptive spindle holder the actual machining process can be superimposed with highly controlled dynamic movements in the micrometer range. Integrated into an existing machine tool system, it provides new manufacturing possibilities and improves the efficiency of existing processes e.g. eliminating vibrations or, as the opposite, applied as an additional movement of freedom it can achieve supplementary machining operations. In this way complex freeform drill holes can be made or thermal machine wear can be decreased increasing machining accuracy or tool life.
Equally mind-blowing are the metals-based additive manufacturing examples produced by either laser sintering or electron-beam melting. The dimensions of parts to be produced are ever increasing as is the material range of metals powders successfully trialled. Also the lines between parts manufactured just for rapid prototyping but now also for low volume production are blurring.

Good to see that New Zealand is an early follower of this technology with TIDA and its follow-up corporate organisation R.A.M., the local universities and Zenith Technica all operating in this space.

Other examples of smart metals based materials application have been demonstrated in the shape memory alloy space via Phase Changing Metals.
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(PCM). Although not new anymore, the developed examples are now becoming manufacturing reality as e.g. the demonstrated example of a car tank lid cover being operated with electrically activated PCM switches saving weight and being simplified components.

However, also the more conventional manufacturing technologies are being advanced. Examples being the expansion of the previous 2D water jet cutting technology into the 3D space acting like an etching tool.

Or another example being the advancement of metal foamed components including the associated joining technology. The most impressive example was the manufacture of a pilot ICE train cabin being claimed to weigh less than the comparative glass-fibre reinforced version.

Interesting also to see the availability of standard foamed metals panels ready to be used for fabrication.
And the list of metals based innovations went on with examples from technologies for metals forming of hollow shaft geometries from hot rolling to hydroforming or process modified sheet metal forming which would allow producing different material properties at different location in a single part.

2.5 Technical University of Karlsruhe – KIT

The Karlsruhe Institut fuer Technologie (KIT) is one of the largest and most prestigious technical research and education institutions in Germany. KIT was created in 2009 when the University of Karlsruhe merged with the Karlsruhe Research Zentrum, which originally was established as a national nuclear research centre. With the phasing out of nuclear power in Germany, KIT still has a major role in ensuring safe close down of nuclear power stations in Germany and the world. Using its extensive knowledge in energy technology, KIT is building capability in renewable energy concept’s which includes focus on hydrogen based energy and also geothermal and waste heat.

The main focus of the visit was the Institut fuer Kern- und Energiertechnik (IKET) or Institute for Nuclear and Energy Technologies covering hydrogen-based energy technologies and Organic Rankin Cycle (ORC) research.

KIT has its own hydrogen campus bus based on the Mercedes Citario. Currently diesel is still too cheap to make a hydrogen bus an economic proposition even if
the technical conditions for buses are ideal as they only require refilling once per day typically at the buses’ overnight depot. Also there still appears to be technical refinements required to increase the reliability of the buses. Larger hydrogen bus trials in places such as Hamburg, Vancouver, and Perth proved that the technology is working and Europe is continuing with the second stage trial. However, Perth and Vancouver opted out of the second round due to a lack of improvements on the economic side. Additionally in Perth with the challenge of running the buses at higher outside temperatures it was felt that Mercedes was not committed enough with a more rapid development of the hydrogen bus. The latter argument appearing to be in line with what our study group heard at the Mercedes Benz visit in Stuttgart.

IKET’s main role in the hydrogen energy applications are relating to the safe storage and handling of hydrogen. However, as the hydrogen program leader assures us, the safety side of hydrogen as a fuel can be competently handled and in his assessment the associated risks are lower than those in New Zealand’s introduced LPG and CNG technologies.

IKET’s ORC research focus is very close to HERA’s AGGAT program and seeing the development of the supercritical ORC pilot plant called Monika coming together is encouraging closer co-operation and follow up actions between HERA and IKET.
2.6 University of Applied Sciences Konstanz
HERA enjoys a long-standing research relationship with the Mechanical Engineering Department of the University of Konstanz and the purpose of the visit was to catch up on joint research programs and observe new developments. Its materials department head Prof. Paul Gümpel has been working closely with HERA’s New Zealand Welding Centre in a series of research projects looking into the performance of stainless steel and its welds in respect to corrosion and micro-bacterial attachments as e.g. relevant for food processing.

One of their recent research projects looked at the performance of novel stainless steels (SS) nets for fish farming applications. Standard nylon-based nets have a very limited life and need to be treated with poisonous anti-fouling solutions. The novel SS-solutions were tested across 8 locations in the world and proved not only the concept but also led to novel ways of combating, in a cost effective manner, net fouling. Business is now booming for the Swiss netting manufacturer and as a result of the visit, HERA is now assisting in finding NZ partners for delivering the netting solution to NZ fish farming applications.

2.7 Steel Construction/ Heavy Engineering R&D
- Steel Construction Institute Technical University Aachen

With HERA’s steel construction research hat on, the author felt right at home when visiting this leading steel construction research facility in the home town of the emperor Charlemagne or “Charles the Great” who laid the foundations for modern France and Germany in the early middle ages. However the talk with institute head Prof. Markus Feldman and his colleagues did not focus on German history but the future of steel construction.

While being impressed with the new developments being progressed in steel construction research in Germany and Europe, it was also worthwhile to note what excellent progress steel construction has made in New Zealand as part of the largely HERA driven research actions. We noted that in the area of seismic and fire engineering related design actions we can confidently compare notes in our respective research programs. However, it was noted with a degree of envy
on the German side, how successful New Zealand was in integrating the latest R&D results into our standards and codes as e.g. opposed to the German federal-states-governed fire engineering legislation which had hindered effective steel construction innovation in Germany due to endless hurdles at state level.

As to novel and outstanding steel construction research topics we note the continued shift to the area of composite construction with particularly strong developments in the steel/glass, the steel/other metals and steel/plastic-based composite areas.

In the case of heavy steel columns, a common approach is to use complex stiffeners to allow force transfer which have a significant fabrication cost attached. A different approach is to use heavy section steel cores within concrete filled columns to simplify fabrication and enhance performance in fire. Finding the optimum arrangement is aimed at reducing steel construction cost.

In the case of steel/glass composites seeing how multi-layered glasses with their elastic bonding interfaces stick together as a unit following destructive testing gives the impression that there is no real difference between a composite steel/concrete floor deck and a bonded steel/glass combination. No doubt a space to watch by the steel and glass industry in the same way glued-in glass windows are now an integral part of automotive body design and performance.

In the composite area an interesting program is for life extension of steel-based bridges. Like in New Zealand with the Auckland Harbour Bridge, a large number of steel bridges are getting to the end of their design life. Research aims to find ways to extend their useful life. A particular useful research approach e.g. for orthotropic bridge decks appears to be to add a second decking plate by bonding it with an elastic adhesive layer to the existing steel deck. The research showed that as a result of the dampening effect of the bonded layer, the redistribution of load and the additional strengthening, substantial fatigue life extension is possible.
Like in the HERA/NZTA research project which looks at ways to increase the rating capacity of steel concrete composite bridges to accommodate heavier load spectrums, maybe a worthwhile approach could be to consider a potential joint HERA/TU Aachen/NZTA-project in the above fatigue life extension topic.

Another novel concept tested in the area of composite steel concrete composite floors/bridges is the use of high-strength steel materials and innovative shear connectors. The examples shown are prefabricated bridge girders which facilitate efficient transfer of static and cyclic loads via the composite dowel elements. Advantages are in particular the increased strength, good deformation capacity even within high strength concrete and the simple application in steel sections without upper flange.

Equally noteworthy is the research in the area of energy efficiency of the different metals-based construction components. Continuous improvement allows optimisation of the steel based penetration options which improve via composite material approaches the minimisation of heat transfer. Again this is something where HERA, through its FEA modelling capabilities, is up with the game and we could gain by co-operating and using thermal testing capabilities from our overseas partners.
The Research Association for Steel Applications (FOSTA) has its headquarters in Düsseldorf and is under the roof of the German Stahl Zentrum. It co-ordinates the research efforts relating to the application of steel and organises the funding of this research from public national, European and industry sources. It also provides support for research consortia formation, manages the progress of projects in co-operation with the different research centres, and contributes to the dissemination of the results. The author discussed the FOSTA's research program with Dr Gregor Nuesse who is responsible for research co-ordination.

Part of the discussion was the funding framework and some of the 130 steel construction related research projects covered by the FOSTA research management. Worldwide steel making is under considerable commercial pressure and the ability for industry to spend money on application R&D is stretched. Particularly the threatened new carbon contribution requested from the steel makers by the European Union most likely will lead to an exodus of steel makers from Europe to less restrictive countries and the American Economic Minister has already asked European Steel makers to consider America as the new base for high value steel making.

The more remarkable it seems to see the broad based program of steel application research administered by FOSTA and some of the projects described above at the TU of Aachen were part of this research portfolio. It is good to see that continued support of the government and the European Union in the value added aspect of steel applications in manufacturing even though it appears that steel making is not in favour as a continued economic activity for Europe.
Just to highlight one co-ordinated project example with potential impact on NZ steel construction. Germany has currently over 10,000 bridges which cannot be repaired and need to be renewed. Many of them are constructed from concrete which mainly suffered cracking and reinforcing bar corrosion induced failure while steel bridges have been effected by general corrosion. Steel bridges are generally protected by organic coatings which deliver a service live of 25 years plus.

In comparison to this, hot-dip galvanised construction has a durability record of 80 years or more of surface and is well accepted in general heavy engineering. However, the method of corrosion protection has not been accepted in bridge fabrication as insufficient knowledge on the fatigue performance of hot dip galvanised bridges was available. The research shows, while recognising that there is a reducing influence on fatigue live of hot –dip galvanised components, that by adequate fatigue category classification of welded hot dip galvanised components, service life of bridge and coating for a theoretical bridge service life of 100 years could be demonstrated.

Therefore, taking a whole-life costing approach the use of hot-dip galvanising technology as the most economic long-term coating solutions has been highlighted. Therefore investigating feasibility of a project may be worthwhile, which in Germany looks at the sustainability focused assessment of steel and composite bridges with an intended service life of 100 plus years.

As a result of our information exchange, HERA/FOSTA have agreed to intensify our research information exchange and to seek increased co-ordination and cooperation.

• **FhG Centre for Large Structures, Rostock**

The Fraunhofer Anwendungszentrum Grossstrukturen in der Produktionstechnik is part of the FhG IPA family and is linked in traditional FhG fashion with the
Institutes of Manufacturing and Joining Technology of the University of Rostock. The institutes’ combination has 68 employees and its director is Prof. Martin-Christoph Wanner, a former colleague of the author from his time at the FhG IPA in Stuttgart.

The impressive array of applied research performed has almost always had a direct application impact for the local ship and offshore industry but also the more general heavy fabrication industry. As previously noted, the main aim for achieving productivity increases is strongly driven also in this research by the application of IT to existing technologies, but it is also extended by exploring manufacturing process enhancements such as in welding with the productivity related outcomes affecting in the short to medium term our New Zealand operations.

No doubt the most impressive R&D item is the development of the world’s most likely largest robot. Primarily for applications around the manufacture of large structures, it is based on unique kinematic components derived from large-arm lifting devices and incorporates several novel features such as use of relatively large laser sintered components, novel gear and bearing solutions. But probably most importantly it contains location sensing solutions which are able to accurately position the robot-arm working device in the large operation area.

This positioning requirement is a real challenge when you consider that the robot operation is likely supporting manufacturing of large components and additionally using quite large and heavy work tools. Due to the large workspace and the required long reach of the robot arm, compensation for elastic movement in the system is required. Here the IPA researchers could build on previous research work from the automation of ship building where their IP based position recognition solutions allow exact location of the robot tool relative to the structures to be build.
Large structures do include structures made from large pipes such as for offshore structures. This requires welding of complex pipe intersections where due to the all positional welding requirements manual welders are stretched to the limits. A novel approach via a robotic welding system hooked up on a crane system has been designed and is currently being realised. Again the fact that the size makes automatic positioning difficult led to a solution which attaches itself to the large component and creates a defined workspace around itself.

In the energy sector, Germany’s biggest challenge is getting its “Energiewende” program of getting out of non-renewable and nuclear energy implemented. The Rostock Institute is right in the middle of it and a real example for HERA. Multiple programs are performed in the area ranging from further development of welding processes for heavy thickness steels to the evaluating of bolted connections for the demanding offshore applications.
Organised by the IPA Institute, the specialist large pipe structures manufacturer EEW Group was also visited. The 500 plus employees facility has its own dock and can manufacture pipe up to 12m diameter, 80m long and weighing up to 1500 tonnes. Impressive to see the operation based on sound welding engineering principles, principles which are now also followed in New Zealand by the HERA administered Steel Fabricator Certification (SFC) scheme to AS/NZS/ISO 3834. A solid basis for NZ fabricators to consider expanding into tailored larger structural pipe manufacture.

Currently the Rostock EWE plant is run in 3 shift operation manufacturing monopiles for the offshore wind farms established largely in the Baltic Sea. Monopiles manufacturing as well as their shipping out to sea could be observed.

No doubt the “Energiewende” politic of the German government has a big imprint on the innovation and growth of companies operating in the renewable energy sector allowing them to be amongst the world leaders with a very strong export focus as demonstrated by EWE’s manufacturing locations outside Europe in Korea and Malaysia.
Monopiles In Transport to their Windfarm Location in the Baltic Sea

Specialist Offshore Windfarm Maintenance Ship
3. Conclusions and Recommendations

- **IT Driven Metals Engineering Technologies**

The main learning in respect to future changes in our metals-based engineering environment is the influence of IT creating the 4th industrial revolution and described in the German Economic Development politics as Industry 4.0. The consistent message from government, research providers and industry that this is the most important item the German industry must focus on to remain competitive cannot be overemphasised. To the author this demonstrates how powerful it can be if a common strategic approach is taken to motivate everyone involved.

As described in the report, every one of the places visited demonstrated the way IT was shaping more productive, user- and environmentally friendly manufacturing technologies with an overabundance of future development opportunities.

The German R&D investments exhibited are massive and at first glance might frighten visitors from small countries such as New Zealand as it might give the impression that small countries with limited funds cannot compete with the size and quality of leading industry countries’ investments. However, what a visit to several competing R&D institutions in a high tech country such as Germany, also demonstrates there is a lot of redundancy leading to healthy competition but the effectiveness of the investment can suffer due to a lack of co-ordinated co-operation and many different funding pots.

A consistent observation during the visit of particularly FhG research institutes has to be industry integration into the research projects in the form of funding and active participation. Feedback given indicates that to obtain public R&D basically mandates industry participation and industry funding contributions. In the author’s view this high industry participation is not only because FhG research proposals leverage government co-funding, the main driver for industry participation is the existing R&D culture within the German corporate world, largely also because company top management is spiked with former FhG researchers who have come through the FhG research environment and, following the completion of their generally very applied PhD’s, are generally ending up in industry.

As shown by the UoA/FhG IPA bio-engineering research co-operation and also by some of the HERA research efforts where there is international connection, New Zealand is in those isolated areas on par with international development, however in the author’s mind it is not possible for a 4 million people country to be up with the game in all areas and it is important that NZ is able to effectively
prioritise its resources into developing long term sustainable business opportunities.

It is great to see that New Zealand’s metal’s engineering industry is fully engaged in some of these developments as demonstrated by the export success example of Achema2015 exhibitor Cuddon’s from Blenheim with their freeze drying technology which fits in our world leading food processing equipment technology sector. Having just processed the many entries for the 2015 HERA Exporter and Innovator of the Year awards, it is obvious that these export oriented companies have products with strong own IP, however most significantly have also very strong IT componentry which make the products desirable in export markets. Adding Industry 4.0 thinking to those products may create further opportunities

**Recommendations:**

- That the NZ metals-based engineering industry is encouraged to take advantage of the opportunities offered by the IT based 4th Industrial Revolution. NZ industry is up with the international play when it comes to IT-savviness and engineering-related creativity and there are endless opportunities out there.
- That HERA and the manufacturing industry specifically advocate that IT applied in conjunction with high value manufactured products is likely having a higher return to the country than IT based software product developments on their own. Maybe MBIE starting a NZ Industry 4.0 initiative is a worthwhile consideration.
- That HERA research puts increased focus on the IT integration aspects and sponsors and supports more research in the IT interface to metals based manufacturing e.g. in mechatronic projects, use of smart (e.g. phase changing) metals, metals based additive manufacturing.
- That the universities and research providers use the new and renewed contacts made to increase research co-operation with the German research providers and companies visited. In particular, the Industry 4.0 research opportunities with the FhG institutes are an ideal opportunity to follow up. Organising the Heavy Engineering Educational and Research Foundation (HEERF) or other bodies to support visiting scholars for technology transfer and inspiration are an easy target to achieve from the contacts made. For HERA specifically the fish-farming technology improvement with SS netting in conjunction with Konstanz University and the ORC co-operation with the Karlsruhe Institute of Technology are to be followed up.
- In German and European applied research projects it is basically mandated that strong industry participation is required for a project to be funded and in NZ public funded projects putting more emphasis on industry participation may be a worth-while consideration.
- It is positively noted that the NZ governments (CI) R&D funding programs put more emphasis on funding researchers from within companies and for specific company project’s, however it may be worth-while to even stronger promote the researcher to a future industry manager pathway as applied in the FhG system.
- Noting the strong public sector funding support for applied industry research in Germany and its effectiveness on innovation, the author wishes to use this
report opportunity to point out that in New Zealand sector-specific collective industry-levy based R&D funds are in general excluded from attracting government R&D co-funding and this also applies for HERA funding. This exclusion applies for both Callaghan Innovation R&D Growth Grants and the Independent Research Association Capability Fund and it is recommended that MBIE addresses this anomaly.

**Steel Construction Research**

The visits to German steel construction research facilities and funding agencies confirmed a continued level of activity and exciting new opportunities particularly in composite construction. However it was also noted that the mood of the European steel makers supporting steel application research efforts was not very confident as to their future steel making in the EU. This was due to carbon charges expected to be pushed onto them increasing the cost of European steel making up in the range of being uncompetitive. Also the ongoing steel oversupply situation with uneconomic steel pushed into the market is of great concern.

It was also noted that German steel construction opportunities for steel in the multi-storey building market cannot be realised fully due to many roadblocks on the complex legislative side of fire engineering. A fact which positively highlights what can be done in construction innovation in a small, and by comparison, responsive New Zealand building regulation environment. Equally the fact that NZ steel construction research funding operates via an industry wide levy which is relatively independent of direct steel manufacturer support shows its value especially at times of difficult economic situation as the funds continue to flow.

As to steel construction innovation, New Zealand can confidently compare notes what concerns seismic and fire engineering design. The extension of our knowledge as to the reliability of structures during and for repair assessment after earthquakes are offering potential for making structures cost- effectively safer and easier to repair. For new products inspiration can be gained particularly from the steel composite material research area which includes steel/glass and steel/steel adhesive bonded elements with excellent deformation capabilities and increased fatigue life. Especially research pathways into glass steel composites and steel bridge life extension also supported by the established co-operative links appear to be very worth-while targets for New Zealand research.

Research focus on large and heavy structures outside steel construction leads back to the observations made under Industry 4.0. The opportunities offered via adding IT based elements to otherwise traditional manufacturing are indeed revolutionary with practical examples being demonstrated. in the field of Quality Assurance the use of WIFI solutions for recording applied torque in bolted connections, welding process related weld quality monitoring or material conformance via IT based material tracing.
### Recommendations:

- For HERA and structural steel research parties focus to continue on reliability assessment of welded joints under seismic load conditions and strengthen international cooperation.
- Use IT opportunities to cost effectively improve product quality and conformity assessment e.g. QA with WIFI torque sensing, or welding process related weld quality monitoring.
- HERA to develop with composite material partners steel/composite material research road maps e.g. steel/glass.
- Explore with NZTA and industry partners the establishment of a steel bridge life extension project covering for example bonded steel deck options and hot dip galvanised solutions.

### Hydrogen Based Technologies

Hydrogen as a cornerstone of renewable energy strategies continues to be a main interest of German research and development. The recognition that the two dominate renewable energy generators photovoltaic and wind and to a lesser extend also hydro are weather-dependent and hence intermittent makes production of hydrogen from renewable electricity, its storage and conversion back into electricity or other uses such as for methan or fertiliser production very attractive technology options.

Due to the extensive build up of new renewable generation capacity across the world, the electrical energy storage question is increasingly tackled and this includes the hydrogen options. The commercial electrolysers options are on the market now and the limiting factors to get the clean energy technologies options ready and running on the market are the still relatively high technology costs and the continued low price for fossil fuels which, with the advance of renewable energy options, appears to be more and more unlikely to again dramatically increase. The disruptive driver will be the political will of the leading nations to be serious with carbon emission reductions and via prescriptive incentive based means will lead to the break through. Despite the German car industry dragging the chain on hydrogen vehicle technology and first wanting to create more shareholder benefits from more emission-friendly plug in hybrid solution, Germany will be a leading player in this and the Audi’s methane gas plant based on the hydrolysis and a “methanisation” process are a good example of this.

However even more serious in respect to the hydrogen economy is Japan, which led by its car manufacturer Toyota, has in a big way committed to hydrogen as car fuel. This includes also the use of fuel cells in the home market where it is predicted that by 2030 one in ten residential homes will have a hydrogen fuel cell installed. The prediction is that Japan will likely become a hydrogen importer and so will likely more large economies. The muted idea to transform the uneconomic NZ aluminium smelter into a large scale hydrogen producing facility using demand driven excess hydropower and produce hydrogen and sell it via its deep
water port to Japan and the world justifies a look at, as does other options of using hydrogen locally to improve our carbon balance and make money.

For New Zealand already with a very high proportion of renewable energy and still massive potential to produce cost effective energy particularly from wind, photovoltaic and marine resources, the question is when is the right time to get hydrogen technology going? Hydrogen has serious potential to make a major dent into New Zealand’s petroleum import dependency. It could offer serious investment options for local investors with a commitment to a low carbon economy but also provide and exit options for those having invested in the current petroleum based infrastructure.

One thing appears to be sure is that in a hydrogen economy there are many opportunities for our metal’s based and particularly heavy manufacturing industry to get involved. Any of the steps from large scale hydrogen production, storage and distribution requires fabricated metals products on a big scale and justifies the involvement of HERA in its exploration and development.

**Recommendations:**

- That NZ government and interested parties have a renewed look at the NZ business case for entering into a hydrogen economy
- That HERA (and other NZ research facilities) performs research supporting the development of such a NZ Inc. business case

**Summarising Conclusion**

As a result of a consistent innovations-flow in metallic materials, manufacturing and associated information technology, the author’s overall conclusion is that there is a bright future for competitive metals-based manufactured products. This should give New Zealand fabricators and manufacturers the confidence to look forward to a sustainable future and actively forward-plan their business activities including investing in R&D in their respective fields of work.