Outputs from the EPSRC Virtual Manufacturing Workshop

Wednesday 17th November 2010
Copthorne Tara Hotel, London Kensingston

Engineering and Physical Sciences Research Council

Introduction

Virtual manufacturing is a topic that has been raised by some of EPSRC's strategic partners and business contacts as topic of interest. This workshop was convened to bring together a group of people from different academic disciplines and industry sectors to meet each other, and to think about future challenges in the area.

The specific objectives of the workshop were:

1. To provide an opportunity for interested companies and UK academic experts to meet, to discuss the research challenges faced by different companies and sectors and to identify relevant academic research;

2. To investigate whether there are any fundamental research challenges that need to be addressed for the future, and what EPSRC's role should be.

Attendees are listed at the end of the document.

Working definition of Virtual Manufacturing

For the purposes of the workshop, our definition of Virtual Manufacturing was as follows:

'Development of manufacturing products, processes and services which will remove the need for physical prototyping and testing.'

However, attendees were invited to take a broad interpretation of this in order to have a useful discussion.

Industry presentations

All industry attendees present were invited to give a three minute presentation on 'What does Virtual Manufacturing mean to us, why would we use it and what's stopping us'. Key points included:

- The term 'Virtual manufacturing' is not used by everyone, and many have a wider and different perspective to the definition above.
- It can be used to describe:
    - Computer-aided tools merged within a collaborative environment to aid manufacturing processes or maximise benefits
    - Planning systems, execution systems and knowledge and data management
    - Virtual design, assembly and testing of products, processes, buildings, plants/factories, operations, and assessment of human impacts and interactions
    - Services and remote maintenance
    - Business process redesign
- The benefits include:

- Reduced product development time and cost
- Maintenance of consistency in quality
- Ability to test different scenarios
- Harmonisation and collaboration with others
- Improved forecasting and delivery
- Communication with customers
- Reduced environmental impact
- Safety
- Learning support and improved understanding

- The vast majority of products and processes still cannot be designed and tested virtually.

Speed-networking

All academic attendees were given the chance to meet the industrial attendees and vice versa through speed-networking. Attendees found this exercise very useful. Key feedback points from industry at the end of the exercise included:

- Lots of expertise present in complex systems and process design
- Differing levels of 'granularity' being investigated

- Need physical materials modelling expertise
- Need to consider inhomogenity of materials
- Need to model feedback to people in a meaningful manner
- Need to model people realistically (academics looking at this)
- Need simplified user interfaces – number of academics looking at this
- Need to look at digital manufacturing processes related to carbon fibre
- Consider 'legacy products'

- Need effective, affordable knowledge-based systems
- Need systems integration

- Modify use of civil engineering (e.g. in factory of the future) – don't speak the same language as automotive/aerospace etc.
- What about VM beyond 'capital goods' and healthcare?

- How do we put real data in a CAD environment?
- There are synergies in data management across sectors
- Standardisation of design and digital data needed across industry (need help from academia to make it robust)
- Through-life data needs to be fed back into manufacture
- (From academia) Integration of different tools for major suppliers and supply chain is an issue (inter-operability)

- Lot of duplication going on – need to work together
- Need link to PLM suppliers (e.g. Siemens)
- There are gaps between industrial needs and academic research

Research challenges and barriers to Virtual Manufacturing

Attendees were asked to come up with up to 3 fundamental research challenges or knowledge gaps, and any major challenge or barrier that was not research related. The individual responses are given in Annex 2. The ideas put forward were clustered, leading to 5 main over-arching challenges:

- Accurate Predictive and Validated Models that Account for Real World Variability
- "Factory of the future" – but needs a better name!
- Knowledge Capture/Management/Representation
- Through Life Support – Virtual Manufacturing
- Representation of the Problem – EI, Visual, Haptic etc

Each of these areas was discussed in more detail in breakout groups, answering a series of questions. The discussion proformas are reproduced in Annex 1.

Barriers include:

- Lack of standards for hardware, software and data (or reduce reliance on off-the-shelf technologies)
- Management of huge data sets
- Infrastructure/software costs
- Usability/skill levels required
- Needs to be tailored to the product before implementation
- Value of DM/VM not always recognised
- Gaps between industry and academic activities and drivers
- Engagement with PLM suppliers

Workshop feedback

Attendees enjoyed the interaction between academics and industry, and with other industries. They also enjoyed discussion of the challenges and felt the group size was about right, although some commented that it would have been helpful to have other universities with relevant research present, as well as SMEs and PLM suppliers.

Next steps

1. There is already some work in the current portfolio of EPSRC research that is relevant to some of the research challenges developed in the afternoon. We will circulate details of this to the workshop group. We will also forward details of any relevant new EPSRC Centres of Innovative Manufacturing that are announced in February 2011.
2. We will continue discussion with workshop participants on the fundamental research challenges and ways that EPSRC can help to support knowledge exchange.
3. We will also talk to TSB about mutual support for the area.

Annex 1

Accurate Predictive and Validated Models that Account for Real World Variability

What is the challenge? What are the research challenges/knowledge gaps?

- Coupled microstructure evolution and material properties
- Techniques for measuring behaviour under real processing conditions
- Prediction of range of variable as-manufactured part forms
- Characterisation of resource variability
- Usability
- Integration of models/tools to give combined effect
- Access to real world (industrial) data

Why is it important? What is the potential impact?

- Right first time manufacture
- Predictable performance and life
- Responsive to design change
- Increased customer confidence
- Reduced unit cost
- Reduced NPI cost and lead time
- Increased capacity
- More capable products
- More competitive products

Who needs to be involved? What's the role of the Research Council?

- PLM system suppliers
- Modelling software supplier
- Industrial end users
- Equipment suppliers
- Universities
- EPSRC and TSB

“Factory of the future” – but needs a better name!

What is the challenge? What are the research challenges/knowledge gaps?

- Misconception that virtual factory has been delivered → it has not! All we have is bits of it (some pieces of the jigsaw)
- Current approach is cost prohibitive
  - Lack of knowledge, models and standards → high cost to virtualise. High cost to scale up
- How do we move our focus from this to a “top down” approach → synthesis: transform from analysis to synthesis
- Need to think of “factory of the future” → but needs a better name!

Why is it important? What is the potential impact?

- Globally competitive factories
- Rapid facility start up and production
- Eliminate high level (time) of unproductively
- Forces a more holistic optimisation of MFG capability (not just product driven)
- Make UK attractive for MFG, win orders vs overseas plants
- Drives (UK) supply chain and extended enterprise towards combined capability
- Top-down approach to build capability and expose weak links
- Facilitates individual work packages (research, *R&D etc) which can then be integrated into a single solution. *incl skills development
- Enables real time optimisation, operation and information – regard the factory as a “product”
- Enables mobile factories and distributed production and mass customisation

Who needs to be involved? What’s the role of the Research Council?

- Stakeholders in real world manufacturing inc SME’s (Industry driven)
- IT system/PLM etc providers
- KTNs
- RCs
- TICs

Knowledge Capture/Management/Representation

What is the challenge? What are the research challenges/knowledge gaps?

- Access to data/knowledge is restricted
- Experience (craftsmanship, best practice…) difficult to record in tools – failures, fear!
- How to capture with the right context?
- How to recall/access knowledge? – new tools required
- How to interpolate/extrapolate between data/knowledge points?
- Knowledge repository (KML©) – commercial/IP/
- Issues: what to share/keep private – supply chain?
- Systems becoming more complex and dependant on other systems
- Potentially huge data set (multi dimensional) – massive problem
- Can current/future IT systems cope
- Will IT scale

Why is it important? What is the potential impact?

- Right first time
- Cost saving, risk reduction
- Avoid corporate memory loss – where/how to extract key data
- Speed up innovation
- Drive towards ease of use
- Predictability
- Being able to do the job!

Who needs to be involved? What's the role of the Research Council?

- Industry supply chain
- Industry/academic consortium
- Open source – vendor tools may be too restrictive
- Sponsor of research collaborative research

Through Life Support – Virtual Manufacturing

What is the challenge? What are the research challenges/knowledge gaps?

- To use product knowledge to extend value chain
- To gather product design/manufacture info to re-use in operational environment
- To reduce cost of support/maintenance and availability
- To monitor performance of product in use to improve design/manufacture
- To manage environmental/safety issues of disposal
- To validate the starter model & performance (connect to point above)
- To predict failures/service schedules/maintenance schedules
- To manage the supply chain – contractual/data control – availability

Why is it important? What is the potential impact?

- Information to make good decisions – integrating through life knowledge of product – customer satisfaction
- Ensure UK industry retains capability for future development on long term programmes
- To develop UK industry best practice – perhaps industry has lead in through-life support on non-UK product expert knowledge
- To extend digital thread/virtual manufacture through to support – how? – research

Who needs to be involved? What's the role of the Research Council?

- Construction Industry
- Aerospace
- Car/Truck
- Medical
- Chemical
- Nuclear
- Case Studies
- Research*

Representation of the Problem – EI, Visual, Haptic etc

What is the challenge? What are the research challenges/knowledge gaps?

- Optimisation of value of the solution eg sound represented by sound!
- Technology to represent senses
- Holograms
- Representation of error and quality
- Selling benefits to end user
- Recreating phenomenon
- Communication of issue
- Combination of stimuli

Why is it important? What is the potential impact?

- Decision making support
- Impact: better product, cheaper, quicker
- Recognising that human is in loop
- Can't get rid of prototypes in design verification until all can be done virtually, including subjective

Who needs to be involved? What's the role of the Research Council?

- Multidiscipline – human factors, technology, senses, end users, customers
- Focus for this area → integration of all senses
- What's out there? Where is it? (trl)
- Filling gaps and bringing together

Annex 2 – Individual challenges and barriers

Real World Integration - (Real World Viability)

- Design synthesis going beyond robustness
    - Design for unsuitability avoid lock-in issues
    - Embedding error into CAD/PLM
- Fidelity of solutions
    - Accuracy – viz of error
    - Verification
    - Validation
- To develop models of manufacturing processes and resources
- To enable both nominal and actual capability's of the resources
    - Thus providing an actual accurate representation of the resource through out its life
    - Requires interfacing of machine sensors and software to represent "health" of resource and resource capability
- Reliably reproducing and measuring realistic process conditions in controlled (LAB) empirical experimentation
- Step changes
    - Transition of CAD technologies within PLM tools, to use of more realistic part forms ie move away from 'as designed' towards 'as manufactured' geometries for truly virtual manufacturing
- Materials process modelling in a 'connected and predictive' ways
- Challenges
    - Evaluate accuracy of results predicted/obtained through simulation with results obtained from physical/real world
    - Use physical laws to build simulator models
- Prediction of fundamental material microstructure/state evolution under manufacturing processing conditions, and hence prediction of as-manufactured state and properties
- Integration of real world into digital environment
    - Modelling of 'real world' material properties
    - Tolerance management that reflects reality
    - Data flow upstream and downstream to enable KBE in production with verified lpk
    - Manipulation of equipment/revised operator instructions
    - Intelligence CAD build into digital solution based on KBE

Real World Representation

- Applying all your senses to the "virtual" problem
    - Visualisation
    - Touch
    - Audio
    - Smell/taste?
- Research Challenges:
    - How do we bring the virtual world out here?
        - We can do this now with geometry (3d universe)
        - But what about everything else?
        - Humans are in the loop in all real systems but rarely in virtual representation
        - Although modelling of physical phenomena in specific problems may be seen as incremental actually solving this one app at a time will add up to a significant step forward
        - Design synthesis – going beyond robustness (→ diagnosibility)
            - design for uncertainty to avoid lock-in
        - Work systems modelling and simulation for white collars (stripped collar)
            - Currently it works for : well specified output, repeatable tasks, highly prescribed workflow
        - Virtually simulated work environment
        - Closed-loop lifecycle beyond PLM → harmonisation → to interactive optimisation
- Quality of data and its visualisation

Knowledge Capture and Management

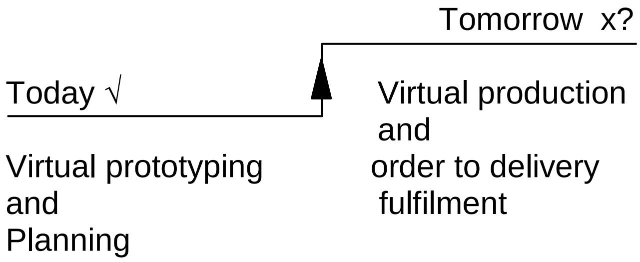
- Characterisation of existing products and integration into models in operational env.
- To enable legacy products designs to be interpreted with state of art PLM/CAX systems and be manufactured and assembled with current manufacturing facilities for "right first time manufacturing"
- Knowledge capture and management re-use
- Although this has been a challenge for a while, we have not realised the potential for this in terms of industrial productivity
    - Why?
    - What can be done?
    - What is the research?
- Research Challenge 1 – reconciling transparency (Interpretability) with significance (accuracy) of a digital system directly applicable to manufacturing
- Need research to inform and support standardisation of data and knowledge descriptors for virtual manufacturing
- Challenges – using performance data in design
- Stepped change in:
    - Synergise the UK manufacturing knowledge across sectors to deliver best practice across UK industry
    - Simplify the data management of various source information – need affordable by high quality/configuration of our digital data
    - Improve the excitement to accomplishment ratio for digital systems by adding improved engineering capability to the "management" systems which are currently available ie better integration of engineering disciplines that inform process design
- A modelling language that encapsulates system attributes, behaviours and operational contexts in an unambiguous way that supports collaboration across disciplines

Through Life Support

- Setting up (Stage 1) and implementing (Stage 2) a truly generic end-to-end case study
- To develop a spectrum of connected tools
- Case studies of best practice
- Stepped changed in:
    - re-use of data utilising digital knowledge throughout the product life cycle
    - for use to determine design to manufacturing/maintainability
    - Information data management
    - For improvement in design definition and responding to manufacturing/maintainability capabilities
    - Support predictable availability contracts to improve performance of the through life processes
- Use of simulations to predict “real world” results
- Step changes:
    - Extension of digital methods beyond design and manufacture into broader lifecycle incorporating environmental and end of life issues at all stages of product development
- Research Challenge 2
    - Development of ‘generic’ digital systems which may be self learning requiring little outside intervention/maintenance
- Into service and support – past design and manufacture

Factory of the Future

- Research Challenges “Factory of Future” (RW)



- Factory that ‘works’ in the virtual environment
- All systems proven
- Selected from modular KBE database
- Fully commissioned
- Plug and play in real shop floor environment
- Adapt to product variation, production quantity changes, movement of modular factory globally
- Real-time factories
    - Real time information
    - Real time optimisation

Disruptive

- Transformative
- Design-manufacture
- Connection
- Stepped change in:
    - Adaptability in design/manufacture to allow (under design constraint)
    - To manufacture best fit to reduce cost and improve repeatability
- Research Challenges:
    - Investigation of more disruptive technologies

Co-ordination Products and Processes

- **Research Challenges:**
    - Accessibility:
        - Data,
        - Information
        - Resources
    - To provide universal manufacturing platform for enabling “plug and produce” manufacturing. For use across the supply chains and stakeholders in the business
    - Integrating and co-ordinating work across global teams

Barriers

- **Barriers to Research:**
  - Vendors have no advantage to use standard and interface as they make business advantage by lack of total integration
  - Lack of standards for hardware and software integration
  - Need manufacturing data management not just product focus "we need to design factories as we design products"
- **Non-Research related barrier:**
  - Digital manufacturing research will not be tolerated if it is not focussed on a "product"
  - Value of DM is not recognised in business
  - Skills level too high to be effective in required timescales
  - Industry sector requirements are unique per sector eg micro machining vs bridge constructing??
  - Engagement with PLM suppliers!
- **Long time-scales involved in full life-cycle**
- **Integration of C.O.T.S. Softwares/Systems**
  - Management of huge data sets
  - Usability
  - Infrastructure costs
- **Barriers – Non-Research**
  - Digital manufacturing simulation software quite complex and expensive but needed to keep relevance of DM research
  - Gap between TRL 123 and 678
- **Non-Research Issues**
  - Cost of change control in digital world
  - Ability to automated process – measurement NPT
- **Key challenges:**
  - Making sense of data
  - Data sharing
  - More synergetic interactions between acad./industry
- **Barriers → non-research**
  - IT(web) infrastructure to support broader application of digital technologies through single enterprise and broader supply chain
  - Cost of next gen PKLM systems must come down!

  Or
  - Reduce reliance on off the shelf technologies
- Education of next generation engineering professionals for ability to be efficient in the 'Digital;' era
- Low user skill level but fully optimised output to enable reduced time to market, accurate product life cycle costing, optimised manufacturing solution
  - Skills ability target – "like using Microsoft office"!
- Balancing the needs of academic work with industry needs (more towards consultancy). (It is not realistic to share star models from industry)
- How do we get the virtual tools and PLM suppliers working with academia?
- Developing a structure in which industry and academia can collaborate effectively to mutual benefit

Annex 3

Attendees

Paul	Brown	Rolls-Royce
Joe	Butterfield	Queens University
Darek	Ceglarek	Warwick University
Julian	Faraway	University of Bath
Tony	Harper	Jaguar Cars
Nigel	John	Bangor University
Barry	Jones	BAE Systems
Roy	Kalawsky	Loughborough University
Mahdi	Mahfouf	University of Sheffield
Hugo	Maruri-Aguilar	QMUL
Stephen	Newman	University of Bath
Ivana	Partridge	Cranfield University
Mark	Summers	Airbus
Jennifer	Whyte	University of Reading
Robin	Wilson	TSB
Victor	Winrow	BAE Systems
EPSRC		
Richard	Bailey	
Anne	Farrow	
Emma	Feltham	
Derek	Gillespie	
Claire	Tansley	