

ICTP2017 Industry Workshop 3 Briefing note.

Metal forming and Sustainability

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At first glance, metal forming seems to have only a weak link to the goals of environmental sustainability: the energy used to power metal forming equipment is only a small part of the industrial total, and the fluids used to cool and lubricate processes are generally well controlled. The main environmental impacts of the metals industries clearly rise from the original production of the metal from ore and these metallurgical processes are highly optimised. However, downstream metal forming processes, which have been tuned for maximum throughput, turn out to be highly wasteful: potentially around one half of all the metal made in the world each year is unnecessary. One quarter of all metal production never reaches a product but is cut off for example during blanking or after deep drawing. In addition most products are made with components having a constant cross-section, where optimised components which would be a third lighter, have variable cross-sections. This workshop therefore explored the possibilities for new developments in metal forming to add more value to less metal, and this note summarises the discussion.

The context of the workshop is set by developments in the liquid metals production industries themselves – are there new technologies that will allow a significant reduction in the carbon emissions of producing new liquid metal from ore?

- The EU's ULCOS consortium has explored and promoted a range of technologies focused mainly on the separation of CO₂ from other waste gases from blast furnaces. A range of options exist, but none has been pursued at scale and as yet Carbon Capture and Storage implementations have been restricted to those with Enhanced Oil Recovery, and the total capacity is invisibly small compared with total anthropogenic carbon emissions.
- The Hisarna initiative aims to reduce the steel industry's dependence on high-cost high-grade coking coal, by reducing iron ore directly from coal (instead of coke). The pilot scale process at Ijmuiden in The Netherlands is showing promising results, and at best this may lead to a 10-20% reduction in the total emissions of the primary steel making process.

- A newer development is the integration of Carbon Capture and Use (CCU) technology with steel making. An example of this would be the use of microbes to convert CO and CO₂ into ethanol, for use as a substitute fuel for internal combustion engines. This innovation is at an early stage of development, so may in future scale to be significant, but it is too early to make realistic forecasts of its likely impact.

An alternative approach to promoting sustainability, which could be profitable with a transformation in the business models of the incumbent liquid metal industries, is to pursue developments which would lead to a reduction in the overall requirement for new metal production. This might happen by:

Designing or processing higher strength metals:

- Advanced processing, for example servo-presses and controlled rolling can be used to reduce material losses and produce higher-strength parts.
- Hot-stamping has expanded the applicability of high strength metals to parts with complex geometries formed from sheet, while advanced cold forging has allowed a reduction in material wastage through forming more difficult shapes with better properties and a reduced requirement for machining.
- However, while innovations in composition and thermo-mechanical processing have led to significant increases in metal strength its Young's Modulus is essentially determined by basic chemistry and has changed hardly at all. In future developments, therefore increasing strength will be achieved by continuing developments in processing, while increasing stiffness will arise from improved component design.
- Both developments are important: for example, for car bodies it is important to increase the strength to enhance safety in collision, so high strength sheets are used more and more; meanwhile, to increase stiffness, new designs of component shapes are required, such as hollow and thin stiff shapes with ribs and webs.
- Thus, it is essential for metal forming (manufacturing) engineers aiming to realize components with high stiffness, high strength and low cost to cooperate with component designers to come up with lighter and stronger shapes and structures, and with material scientists to develop stronger and more economical metals.

Reducing yield losses in the sheet metal supply chain:

- Blanking and stamping scrap currently dominate the use of metal in the automotive supply chain: on average around half the sheet material purchased by car manufacturers actually ends up in the car. The industry average yield is 56% but best practice is around 70%.
- Blanking losses could be reduced relatively easily, for example through nesting different shapes along coils, as is already regular practice in the clothing and textiles industry.

- Stamping losses are associated with the requirements for blank-holding in deep drawing, so can't be eliminated (unless the double-action press is replaced by an alternative means to form net shape parts, as is possible with axisymmetric parts made by spinning) but might in future be reduced.
- This saving opportunity has not been fully researched. Advances are required in both stamping technology and product and process design to reduce yield losses.

Avoiding over-design:

- Commercial buildings constructed with steel frames typically over-use steel by up to 100%: the cost of steel is low while the cost of labour is high, so the cheapest way to build a building is often to use extra steel to avoid the design and construction costs of using only what's required.
- For many construction projects, we don't know the loads that will be applied to a building over its life span – so take an extremely conservative view, and design them against the highest imaginable loadings, even if there is not possibility that these will occur in practice. Engineering education in future could provide more training on tolerances and dimensioning to help reduce over-use.
- Pressure vessels intended to cope with loads of around 400 bar are typically manufactured assuming a maximum load of 1000 bar to cover uncertainty about the properties of the metal in use. Better knowledge about component properties arising from manufacturing would help avoid such over-use.
- Powder based processes (sintering, hot isostatic pressing or three dimensional printing) are typically inefficient in their use of energy and material if used to make whole parts. However, combining conventional metal forming processes with powder processes for local detailing may create new opportunities for overall energy and material efficiency. Combined polymer and metal powder injection moulding may have some efficiencies.
- An initiative to hot roll tailored variable-depth I-beams that could save around a third of the metal required to support floors in steel-framed construction showed technical promise but failed to raise commercial interest: the construction industry weren't interested in the innovation, as constant section I-beams are already so cheap, clients were un-interested as they would see little cost difference, and potentially more tailored beams were less viable for re-use.

Keeping products in service for longer before replacing them:

- Most products (all except those associated with infrastructure) are replaced before they are 'broken' so could be used for longer. Creating the motivation for this to happen depends on new business models, in which the ownership of valuable metal is maintained by companies focused on optimising material life.

Improving the recycling of end-of-life metals:

- Conventional recycling by melting is dependent on the control of composition: copper contamination in steel recycling, or the mixture of cast and wrought alloys in aluminium recycling, degrades the value of metal made from scrap. New approaches to identifying, separating and sorting different metal scrap streams could add considerable value over existing practice.
- Aluminium (and potentially some other non-ferrous metals) may also be recycled without melting by solid bonding. Clean extruded aluminium scrap may have the properties equivalent to virgin material and solid state recycling looks to be highly efficient: perhaps 5-6 GJ/tonne of recycled aluminium compared to around 16-19GJ/tonne for recycling by melting. At present, processing beyond extrusion may lead to problems with surface cracking, but this could be addressed in future process developments.
- The scrap market currently gives little acknowledgement to the exact composition of scrap, and instead values it by source. Future recycling markets could improve the energy saving effect of recycling by creating higher value for more segregated waste streams.

In considering any of these options, there are some common concerns:

- How does the emissions impact of making new material (the embodied emissions) contrast with the effect of using a product made in different ways (the use-phase emissions)?
- Combining the development of manufacturing technologies with those of product design may facilitate more efficient use and re-use of materials.

The fact that 25% of annual metal production never enters a product but is scrapped through the supply chain demonstrates that there is significant potential for metal forming technologies to contribute to reducing metals waste. Similarly, the habit of over-design could be countered by novel flexible processes. However, the commercial incentive to implement materials saving processes is currently weak: without a globally agreed mechanism to pass through the impact of the upstream, lower-value but high-emissions processes, to the downstream higher-value low-emitting processes, it is hard to create a business case to realise the efficiency improvements that have been identified in the workshop. Under current incentives, materials suppliers will aim at maximising sales volumes and the supply chain of manufacturing principally aims to reduce labour costs rather than material costs; high asset costs in metal processing lead to long periods of lock-in to established practices; clients and end-users have little motivation to promote material saving, unless it creates a substantial cost-saving. Nevertheless, as the imperative to reduce global CO₂ emissions grows, there will be increasing pressure on the metals industry to add more value to less new material, and the workshop has demonstrated a significant potential for innovation in this area.