MANUFACTURING FOR A SUSTAINABLE FUTURE

The influence of the ASME MED on environmental sustainability.

BY JOHN W. SUTHERLAND, FORMER MANUFACTURING ENGINEERING DIVISION CHAIR (2000-2001)

From its very beginning 100 years ago, the ASME Manufacturing Engineering Division (MED) was concerned about waste. This was particularly true of the Machine Shop Practice Division, a predecessor of the MED, as revealed by the minutes for the ASME annual meeting in 1921. It is not clear whether time, money, concern for the environment, or some combination of these factors motivated this emphasis on waste.

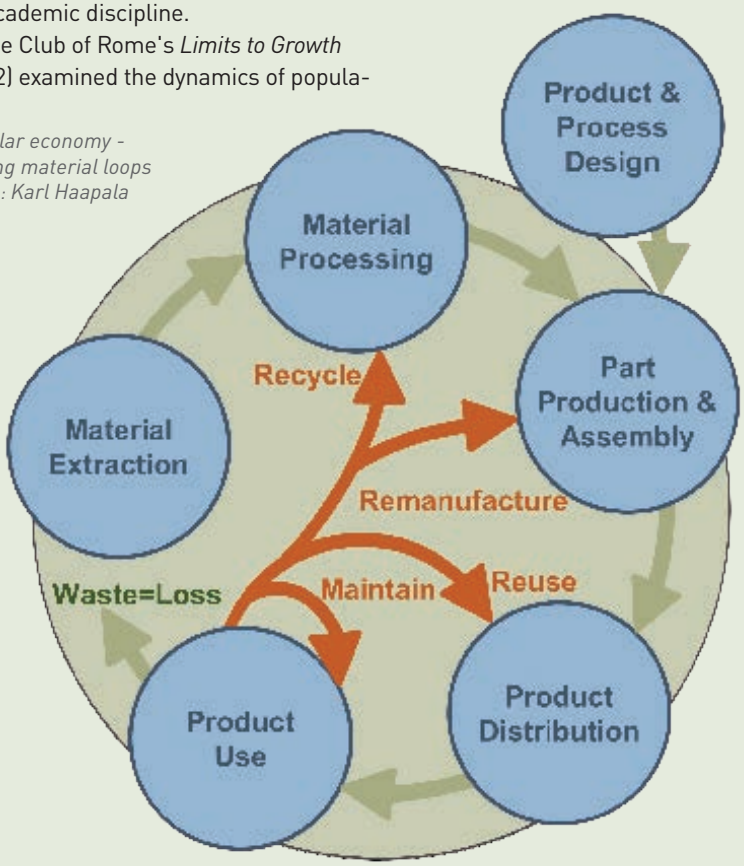
Demands on the environment have changed much over the last century. Globally, the population has increased fourfold and GDP per capita is ten times larger. While 100 years ago we only required about 5 percent of one earth, presently we require about two earths to support ourselves (in terms of materials, energy, and locations to store waste). The issue is will we have enough resources and places for waste in 50-100 years if we stay on the present path?

We are also far more cognizant of the fragility of Earth's ecosystems. Engineers have a responsibility to heed this last point–those engaged in manufacturing are no exception.

With this in mind, I will share my view on how members of the MED have contributed to reducing the environmental burden of manufacturing—and will suggest some directions we should follow to ensure a sustainable future.

While attention to environmental resource limits and conservation have been of interest for hundreds of years, a seminal contribution to the modern environmental movement was Rachel Carson's 1962 book, *Silent Spring*, which cited society's disruption of natural processes, and brought these issues to the attention of the U.S. public. The book sparked landmark environmental legislation, which indirectly promoted the growth of environmental engineering as an academic discipline.

The Club of Rome's *Limits to Growth* (1972) examined the dynamics of population, resources, pollution, and other factors and laid the groundwork for the concept of sustainability. In 1973, the principal outlet for MED research, the ASME Journal of Engineering for Industry (now the *ASME Journal of Manufacturing Science and Engineering* [JMSE]), published several papers that urged caution in pursuing profligate consumption of resources. These papers predated 1987's



Circular economy - closing material loops
Image: Karl Haapala

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Brundtland Report, *Our Common Future*, which formally defined the concept of sustainable development.

My own "green" epiphany came in 1992, after discussions with environmental engineering faculty. I realized my decisions as a manufacturing engineer could create problems that environmental engineers would be tasked with cleaning up. I decided to pursue manufacturing research that enabled more efficient and effective resource use and avoided waste creation. Others within MED engaged in environmentally responsible design and manufacturing research at that time included Walt Olson and Paul Sheng. In parallel, colleagues in ASME's Design Engineering Division such as Bert Bras, Kos Ishii, and Deborah Thurston were emphasizing green design and life cycle engineering.

One of the first MED-oriented green manufacturing research projects emerged from the Machine Tool Agile Manufacturing Research Institute (MT-AMRI), which was established in 1994 and was led by Richard DeVor and Shiv Kapoor (MED Chair: 1991-92). One MT-AMRI project explored environmental effects associated with resource and waste flows and investigated the reduction of cutting fluid impacts. Other key MED members involved included David Dornfeld (MED Chair 1984-85), K.P. Rajurkar, Sheng, Steven Skerlos, and myself. As a result of this and other foundational activities, several seminal JMSE papers were published. Many focused on recycling, greening, and reducing or eliminating cutting fluids in practice, and were among the first to reveal the advantages of dry and MQL (minimum quantity lubrication) machining.

In the late 1990s through the leadership of MED member Delcie Durham, who was serving at NSF, a World Technology Evaluation Center (WTEC) study was commissioned to benchmark environmentally benign manufacturing (EBM) technologies in Japan and Europe. The study team was David Allen, Diana Bauer, Bras, Tim Gutowski, Cynthia Murphy, Tom Piwonka, Sheng, Thurston, Egon Wolff, and myself. This was perhaps the first organized activity in the U.S. to provide holistic input on a research agenda for green manufacturing (also known as sustainable manufacturing). A report and many papers resulted from this study, one of which appeared in JMSE.

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A follow-up EBM workshop was organized by Jacqueline Isaacs, Michael Overcash, and Bras in 2003. This and other EBM workshops that followed laid out a roadmap for acting on the WTEC study findings. Durham went on to establish several National Science Foundation programs focused on environmental issues related to design/manufacturing.

The MED organized numerous ad hoc symposia related to environmentally responsible design and manufacturing during the 1990s and early 2000s. However, it wasn't until an MED technical committee focused on life cycle engineering was established around 2003 that environmental issues became an ongoing priority. In 2005, ASME's Board on Research and Technology Development (BRTD) launched a research committee on "Sustainable Products and Processes," led by MED member I.S. Jawahir, who conducted several strategic planning workshops and ultimately developed a vision and roadmap.

By the late 2000s, the environment was a well-recognized consideration in the design of products and manufacturing processes and systems. Progress had been made in producing less material waste, using less solvents, and consuming less energy. Material flow analysis and life cycle assessment were commonplace. A cadre of MED members recognized that attention to the environment could stimulate innovation and improve industrial competitiveness.

Over the last decade, numerous sustainable manufacturing papers were published in ASME journals and MSEC (ASME Manufacturing Science and Engineering Conference) symposia and workshops. These were often led by the next generation of MED environmental leaders such as Fazleena Badurdeen, Sara Behdad, Bill Bernstein, Dan Cooper, Nancy Diaz-Elsayed, Karl Haapala, Moneer Helu, Barbara Linke, Jeremy Rickli, Chris Yuan, and Fu Zhao.

So, where should we direct our attention in the years ahead?

The fundamental challenge remains: How do we use resources and manage wastes so future generations have the same opportunities that we do today? I suggest three areas for emphasis: i) products, ii) processes and production systems, and iii) circular economy. In product design, life cycle energy utilization must have a higher priority. Design strategies to reduce demand for virgin materials should be emphasized.

For manufacturing processes and systems, new approaches are needed to avoid waste and reduce energy use. Process planning and production scheduling need to consider environmental metrics, in addition to traditional measures.

Finally, the concept of circular economy—which calls for the recovery of end-of-life (EoL) products and their reintroduction into new products—requires new technologies for recycling and remanufacturing. This would reduce virgin material consumption and avoid EoL waste. The full life cycle, including EoL, must be considered during design; otherwise, pursuing circularity may face insurmountable economic or environmental challenges.

Many exciting manufacturing research and education opportunities are being pursued by the ASME MED community to ensure a sustainable future. Here's hoping that a century from now those that come after us will favorably view our efforts. **ME**

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