Turbine Life Cycle Engineering

Andrew Kusiak
Intelligent Systems Laboratory
2139 Seamans Center
The University of Iowa
Iowa City, Iowa 52242 - 1527
andrew-kusiak@uiowa.edu
Tel: 319-335-5934  Fax: 319-335-5669
http://www.icaen.uiowa.edu/~ankusiak

Life Cycle Engineering

- Where it all begins?
- All resources are limited, including ability of the earth and atmosphere to clean itself
- Major water and atmosphere pollutants, e.g., CO₂, NOₓ, and SOₓ
- CO₂ emissions in the energy production process (in particular the wind energy equipment production)
- Water contamination by industry, e.g., waste disposal, etc.
- Waste and disposal of contaminants and resources, e.g., electronics, mercury, cellulose (paper)

Sustainable Development

Main goal
- Meeting our needs without negative impact on the ability of future generations to meet their needs

- Most disputes evolve around who is going to pay for making the world clean and healthy
- Is it natural to be sustainable (responsible, no debt, …)

Sustainability Chain in Wind Energy

Energy usage and environmental impact perspective

- Extraction of natural resources, e.g., iron ore, chemicals, cellulose
- Transportation of natural resources
- Production of raw materials, e.g., iron, fiber glass
- Fabrication and machining – material processing
- Assembly of subsystems
- Transportation
- Final assembly
- Service (operations and maintenance)
- Product end of life
Sustainable Manufacturing

- Sustainability is of paramount importance in wind energy industry due to high material (energy) content, e.g., gearbox, tower, cables.
- Sustainability has not been sufficiently addressed at this time by the wind energy industry due to the wind energy “rush.”
- Now is the very last opportunity (somewhat late) to address turbine life-cycle engineering issues in wind industry.

The Four-Criteria Dilemma

- Maximization of turbine performance
- Maximization of turbine life-cycle
- Minimization of energy used to build a turbine
- Minimization of environmental impacts

Emerging solution: Predictive engineering

Source of Decreased Wind Turbine Life Time?

- Problem: Variable loads
- Key issue: Torque management is a viable solution to reduction of extreme stresses
- Solution: Anticipation of the extreme loads (wind conditions)
- Implementation: Predictive engineering

What to Do With an Old Wind Farm Equipment?

- Reuse (most preferred)
- Remanufacture
- Recycle
- Disposal (should disappear)

Life cycle engineering
Life Cycle Engineering

Best industrial practices
✓ Fuji-Xerox
✓ Caterpillar
✓ Appliance industry, e.g., washers

UI’s “Wind Turbine Corporation”

Design, process, and mfg engineers:
✓ Kevin Langan
✓ Robbie Levstuen
✓ Dan Rogge
✓ Matt Zanker

UI engineering students

Turbine Components

Hub
Generator components designed for reuse and remanufacturing

Coil manufacturing

Rated power: 750 W
Total cost: $354

Vane

Rated power: 750 W
Total cost: $354

Yaw mechanism
Life Cycle Engineering covers issues ranging from product (component) conceptual design to its retirement.

Basic ways of assembly (component) retirement:
- Reuse (most preferred)
- Remanufacture
- Recycle
- Disposal (should disappear)

Why reuse?
How long does it take to decompose when disposed in a landfill?
- Paper: 2 – 5 months
- Orange peels: 6 months
- Milk cartons: 5 years
- Plastic bags: 10 – 20 years
- Leather shoes: 24 – 40 years
- Plastic containers: 50 – 80 years
- Disposable diapers: 75 years
- Tin cans: 100 years
- Aluminum cans: 200 – 500 years
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Assembly (component) reuse
- Products involve components and assemblies with different useful life time
- Estimating (predicting) residual life time of components and assemblies is of importance to their reuse
- A component (assembly) designed for sustainability may be reused a number of times and serve different product generations

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Assembly (component) remanufacture
- Components (assemblies) that cannot be reused in "as is" form could be remanufactured and then used in the current or next product generations

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Assembly (component) recycle
- Components (assemblies) that cannot be reused and remanufactured should be recycled in most environmentally conscious way
- Components (assemblies) disposal should meet the highest standards of the societal scrutiny
- The long-term goal should be elimination of the product disposal as the life cycle alternative

Benign Manufacturing and Transportation

- The turbine manufacturing process itself and transportation should not adversely impact the natural environment
- Manufacturing processes with minimal adverse impact on the environment should be developed
- Supply chain logistics should focus on minimizing transportation energy during the wind farm construction as well as operations and maintenance
**Ubiquitous** Manufacturing and Wind Farm Operations

- A ubiquitous system involves many sensors, including RFIDs.
- Comprehensive integration of information among physical objects (e.g., machine tools, components) and people for the best outcomes in productivity, quality, and energy use.
- The concept of ubiquitous systems could apply to turbine manufacturing, transportation, and wind farm operations.

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**Summary**

- Wind energy industry needs to embrace the principles of life cycle engineering.
- Energy needed to build, transport, and maintain a wind turbine needs attention.
- Design of components (assemblies) for reuse should become a standard practice.