Power analysis for machine tool states: critical factors towards a more robust machine tool energy model

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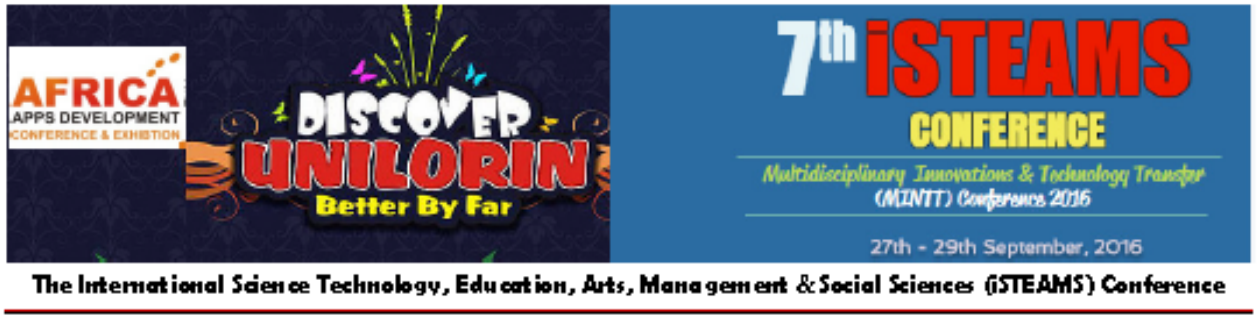

Outline

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- Research Aim
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- Background
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Abstract

Mechanical machining processes are common manufacturing strategies to re-shape materials to desired specification. The mechanistic approach has revealed the mechanics of the machining processes with various parameters determined. The aim of this work is to investigate the impact of swept angle optimisation and their influence on the specific cutting energy in milling AISI 1045 steel alloy. This is achieved by varying the step over at different feed rate values in order to determine the optimisation criterion for machining. It was observed that an optimum swept angle of 31.8o was appropriate in the elimination of ploughing effect and reducing the specific cutting energy to an optimised minimum value. However, higher swept angle of 41.4o increases the specific cutting energy with a higher machine tool power. This is due to the reduction in the cycle time due to shorter toolpath length. The results obtained further elucidate the knowledge base for the determinations of optimum parameters for sustainable machining and resource efficiency of manufactured products.

Research context

a. Higher cost of consumer goods and services have been attributed to higher electrical energy consumption, cost due to value adding improvement of manufactured components [1].

b. These are done in order to improve their functionality and efficiency thereby increasing time-to-market product deliveries [2].

c. This functionality helps to improve product quality and reduce production time by optimising cutting parameters and electrical energy resource.

Swept angle and tool life characteristics

- The tool life is one of the major factors in machining theory that must be given due consideration in order to achieve better surface integrity [9, 10], lower machining and tool changing cost, and economic cost of manufacture for resource efficiency [11, 12].
- The swept angle or the engagement angle has been identified as one of the selection criterion for tool life for minimum cost *tc, tool life for minimum production time tp, and tool life for maximum efficiency tef [13].*

Research aim

To investigate the effect of machine modules and auxiliary units on the power and energy consumption for machine tools at **zero load** and **idle states**.

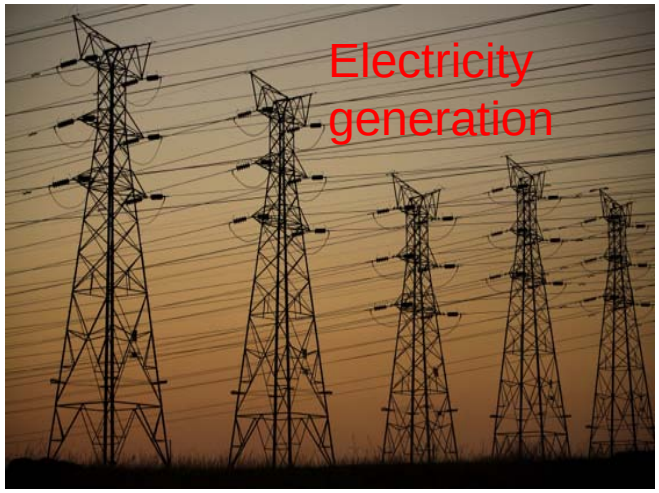
Research objectives

a. To understand how choice of machine tool can alter the energy demanded for machining a given component and quantify the impact of making such decisions.

b. To event stream the total electrical current consumption of machine modules and NC codes.

c. To analyze statistically the power in order to define the significance of machine events on power and energy consumption.

INTRODUCTION



Industrial sector in UK = 7.3% of total energy in 2010

Which way?

http://earthgreen9.com/how-do-we-stop-global-warming/liberty_stop_global_warming/

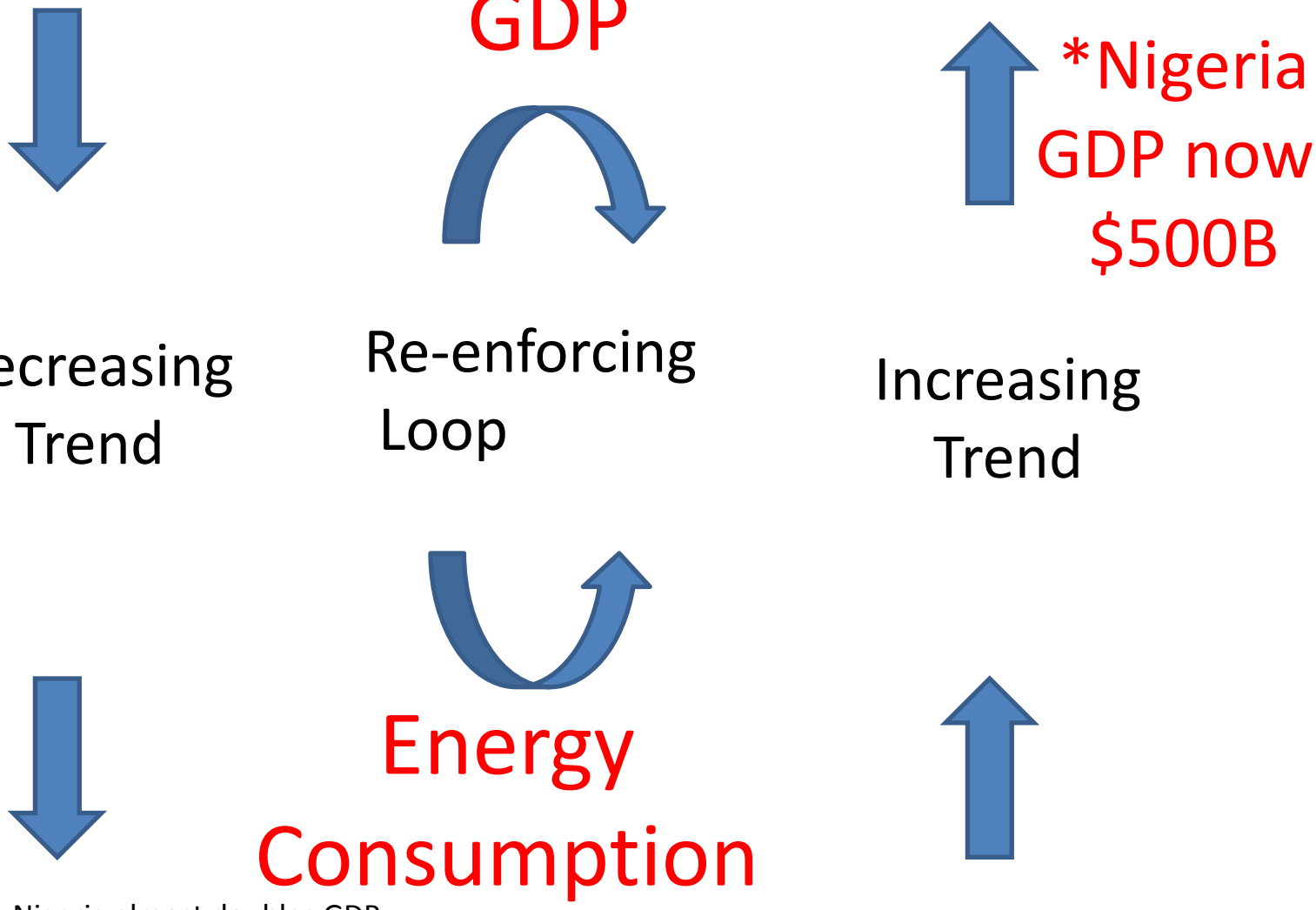
http://lifeboat.com/ex/energy.2020

http://www.aceee.org/sector/industrial

Introduction cont'd

- Manufacturing industries consumes electrical energy during the production processes.
- In Nigeria, manufacturing contributed 6.3% to the GDP between 1996 and 1998 [Anyanwu, 2000]. Also, Corporate Nigeria [2014] reported that manufacturing contributes 4.2% to the GDP in 2009, up from 3.6% in 2008.
- There are an increasing trend of electricity demand in Nigeria and globally.
- Electricity is predominantly generated through the use of fossil fuel.
- It simply implies that the higher the consumption of electricity in manufacturing industries, the higher the carbon footprints left by such processes and end products.
- Global communities, UK government, European Commission and other nation's), through the United Nation Environment Program UNEP [1982],
- An increasing demand for energy efficiency throughout the manufacturing cycle.

INTRODUCTION



*Blas, J. and W. Wallis, Nigeria almost doubles GDP in recalculation. Financial Times, 2014.

Literature review

- Energy demand of machine tools.
  - Actual cutting = 14.8% of total energy demand
  - Idle or auxiliary function = 85.2% [Gutowski et al., 2005]
- Specific cutting energy approach.
  - Tool tip energy demand of a unit process [Balogun et al., 2013]
  - Energy demand to remove of 1cm^3 material from the workpiece
- Online monitoring approach
  - System monitoring and data analysis software e.g. MT Connect, OEEM system [Vijayaraghavan et al., 2010]
- Use Phase energy consumption approach

http://web.mit.edu/ebm/www/Publications/CIRP_2006.pdf

Research methodology

Non-Cutting Experiment

Standardized NC toolpath

```
N1 G90 G21 G40 ...H00 G59
N2 T11 H11 E26
N3 G00 Y0.0 X00
N4 .....
……..
……..
.... M30
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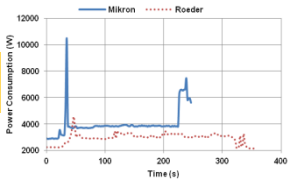
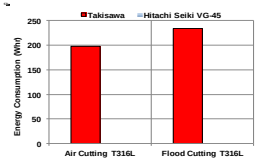
Turning process

Recording power

Power Consumption Profile

Power

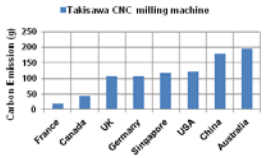




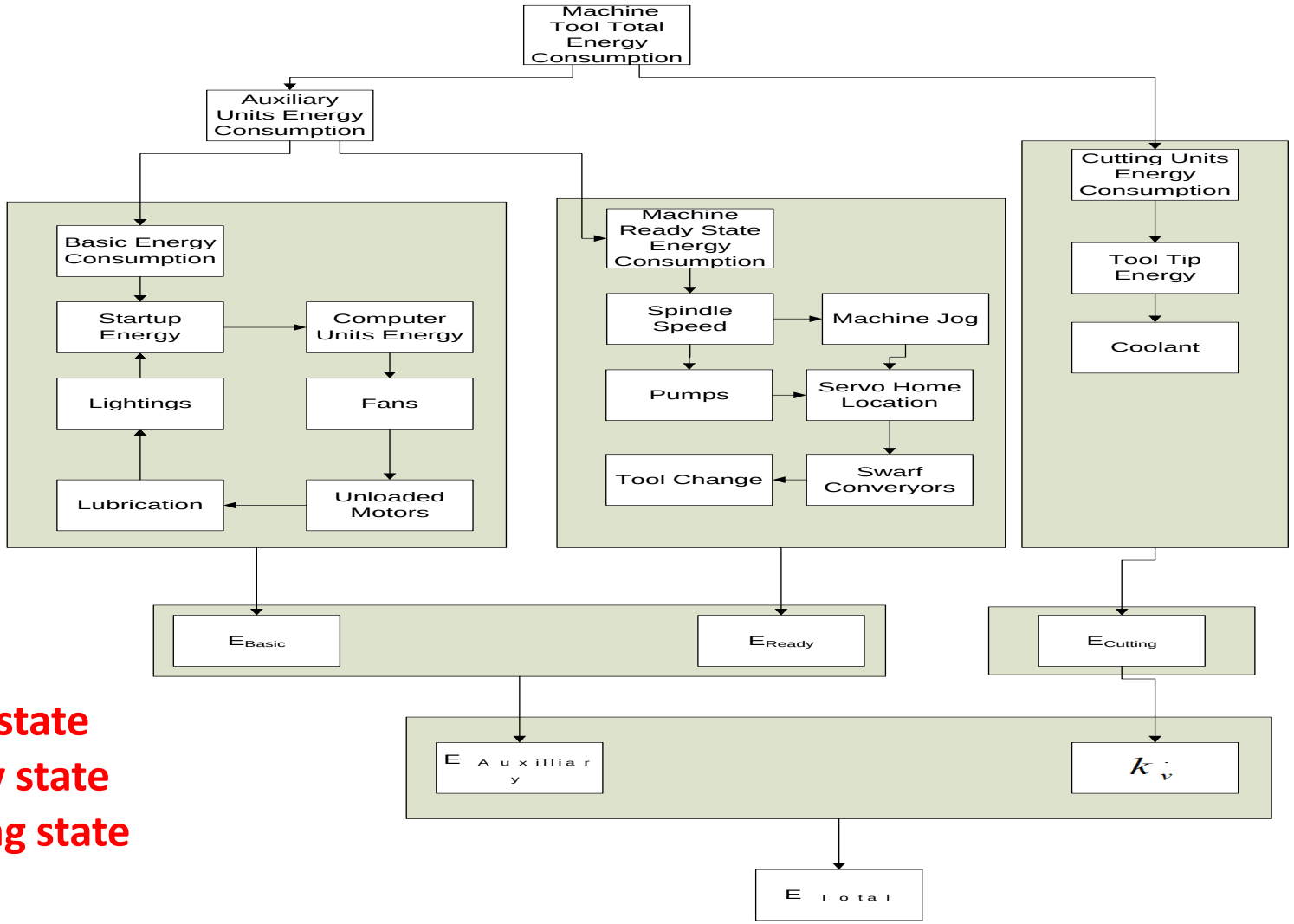
Energy consumption

Power State Classification

Carbon emission of machined part

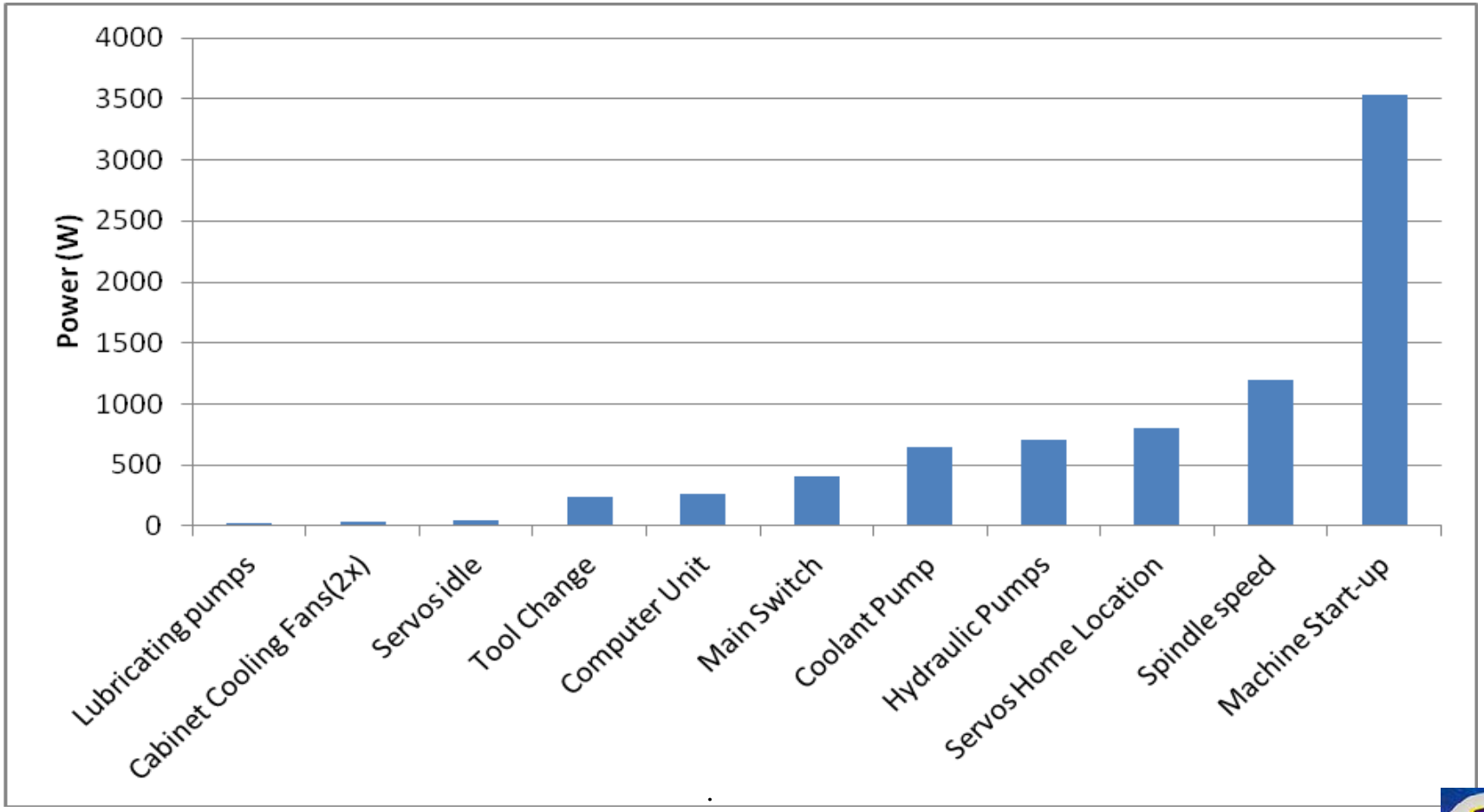


Machine tool energy model

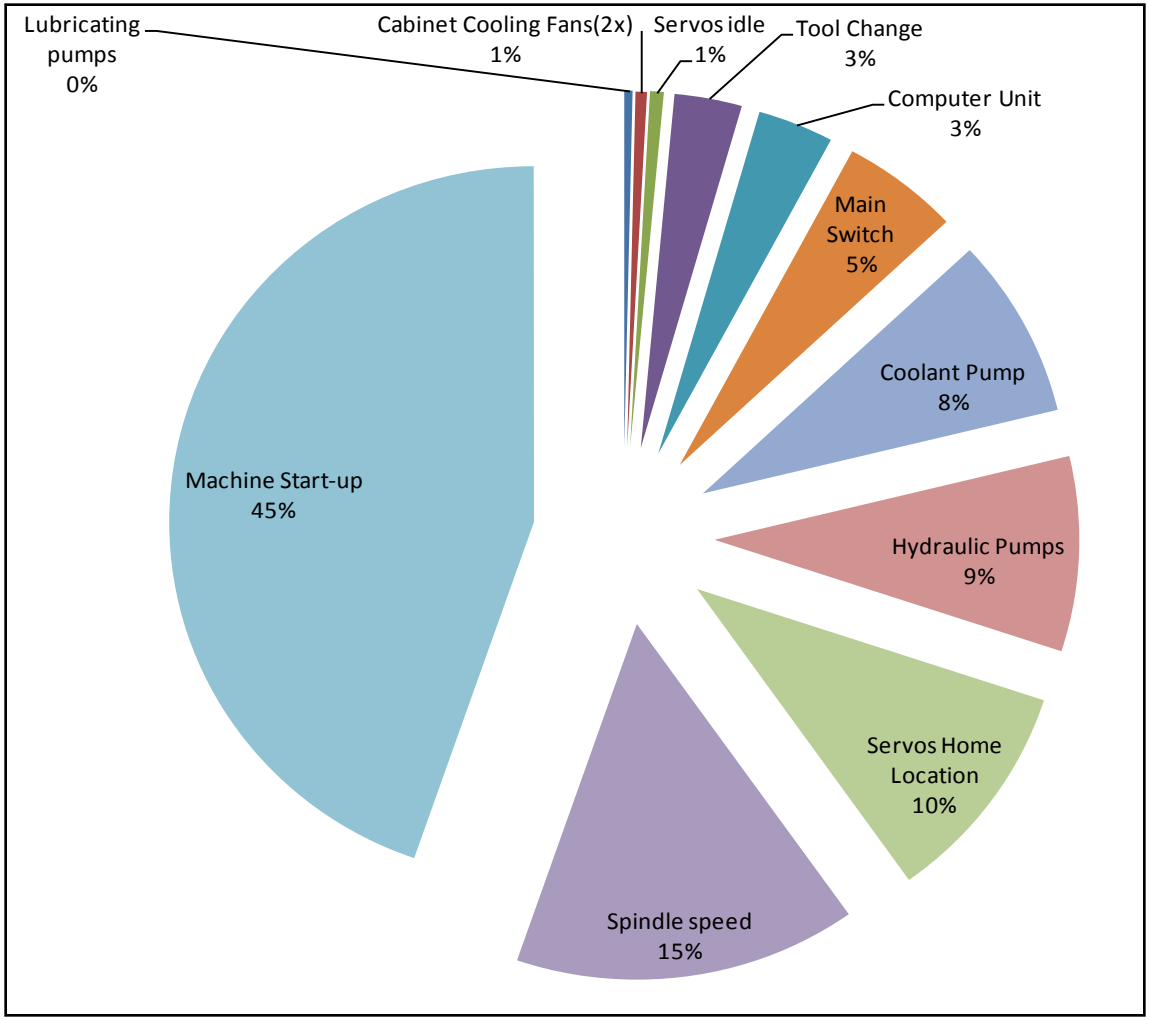


- **Basic state**
- **Ready state**
- **Cutting state**

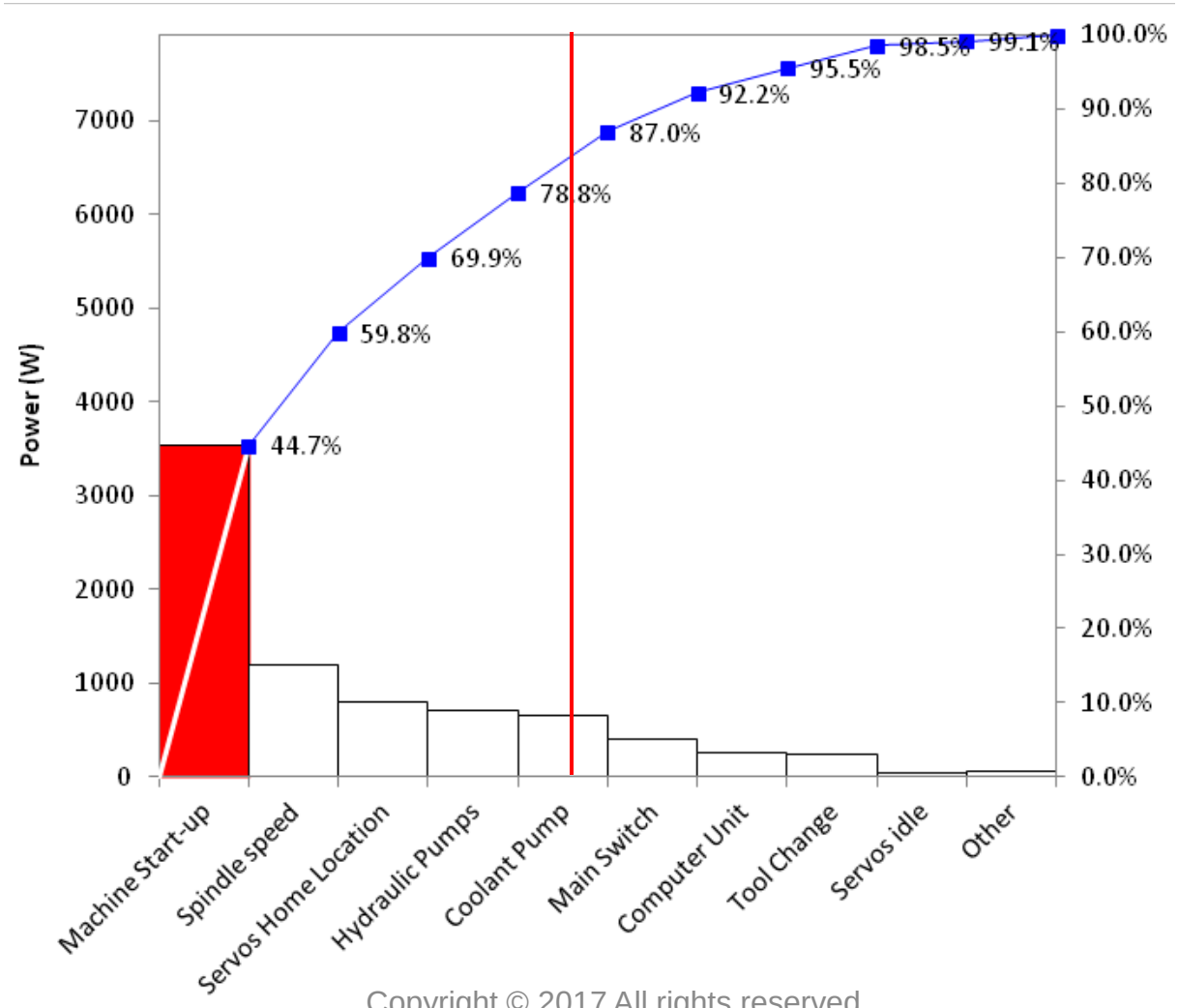
MDSI Open CNC Lathe Power consumption profile



Auxiliary Units Power consumption in percentage.



Pareto 80-20 Rule: Analysis of the Auxiliary Units.



Conclusion

❖This research investigated the power consumption of machine tool states using the MDSI Open CNC Lathe machine as a case study in order to provide data for energy demand modelling of machining processes and to track the source of carbon footprint during mechanical machining processes for optimum performance.

❖The basic machine state of the MDSI Open CNC Lathe machine consumes 63% of the total power during a zero cutting operation.

❖Bulk of the power demand was for the machine start-up (45%), spindle power (15%), servo home location (10%), hydraulic pumps (8.9%) and coolant pumps (8.2%).

Conclusion cont'd

❖Fluid pumping is a major power consumer as it required 17.1% of the total power at zero load. The design of more energy efficient pumps should be a target.

❖Machine tool designers can improve on the technology development to reducing power consumption of the preparatory units and avoid idle states.

❖The re-design of machine tools to target a lower energy footprint resource

Global warming is too serious for the World any longer to ignore its danger or split into opposing factions on it- Tony Blair (former Prime Minister UK)

THANK YOU.

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