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Developing a start-stop production system concept

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Abstract

Our cars have known energy efficiency. We take for granted they are efficient at different speeds, some are able to reuse energy and many have start-stop engine functionality. Critically they do not consume energy when they are not moving. This paper explores the challenges of working towards a start-stop production system concept. The base load energy and other resource consumption (whether during breaks or at night) are known to be a significant proportion of total consumption and attempts to reduce consumption span behavioural aspects through to technology limitations. The impact on switching off machines and supporting utilities has a major impact on the response time to starting full production as well as confidence in the quality that can be achieved. The situation is further compounded by the fact that most production systems are configured with technology that means running at less than full production rate has a serious impact on energy efficiency; there are rarely alternative energy efficient operating speeds.

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Keywords: start-stop production system; energy efficiency; energy value-add

1. Introduction

The need for industrial energy efficiency is well understood and many companies have made significant reductions in their resource use [1, 2]. It is not uncommon for companies engaging in energy efficiency initiatives to achieve double digit savings year on year [3]. Practices that companies have implemented include upgrading drives, upgrading lighting and managing compressed air systems better as well as switching off equipment when not needed and implementing more resource efficient production schedules [4]. Such changes can be technologically or organisationally driven. Often these eco-efficiency changes are within the boundaries of the current production system and factory system design and ultimately the improvements will be limiting.

More radical changes to production systems are required to make significant improvements. Changes could come from reusing energy within the factory or changing production technologies (e.g. moving from steam to direct gas and water in paint plants). Critically there is the need to challenge the fixed cost of production in which companies typically do not see a dramatic reduction in energy at end of production. The significant fixed component of energy consumption of factories affects not just the reduction at end of shift but also within shift whereby there is typically a loose relationship between energy consumed and product produced. The significant fixed energy use means the energy value-add varies according to production volume. Most factories become more efficient as production rises and lower production rates seriously impact on energy efficiency [5].

Research into resource efficiency has resulted in the development of the waste hierarchy [6], tools [7], technologies [8] and methodologies [9] to support industrial improvement. Examples include the use of monitoring [10] to guide operational improvements as well as modelling and simulation tools for examining the production system, the utilities and the surrounding factory building [11, 12]. The latter work at factory scale recognises the independencies and the multi-scale nature of the energy efficiency challenge. It has been observed that the energy spent on production processes is small compared to total energy spent [13]. All these developments enable energy efficiency to be tackled from both technical and organisational standpoints.

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Energy use in production will vary at different production rates [14, 15] and it is notable that the consumption is only weakly related to production with a significant amount of base load, fixed consumption. Whilst there has been some work to align consumption with output on specific technologies [16] and overall system performance [17] work is still needed to understand how whole factories can dramatically reduce energy consumption when production stops. Additionally, many of the barriers to energy reduction relate to organisational issues rather than technology alone [18]. Additionally, greater understanding of the correlation between energy efficiency and production volume is needed to work towards energy efficient production flexibility. Such developments would enable a move from eco-efficient to eco-effective factories.

The paper takes work from reviews from literature in the area of production systems and energy efficiency to assess key constraints that prevent us approaching the concept of the start-stop production system by categorising these constraints according to technology, organisation/people behaviours and overall system operation. Additionally, the work shows examples of industrial practice that could form building blocks of a fuller production system design. The paper concludes with an agenda for future research to address challenges to work towards significant factory energy reduction.

2. Methodology

This work seeks to uncover the technological and structural design features of production systems that enable point resource efficiency and global resource efficiency within a factory, in particular, the features relating to energy. Whilst the focus on energy could be seen as limiting, its relationship with all other resource flows such as use of water, use of compressed air, processing of materials, etc. means that the reduction in use of power will reduce other resource consumption (or identifying the use of power will challenge the use of other resources). Additionally, energy unlike many other resources it is difficult to store.

The work drew on peer reviewed and other literature on sustainable manufacturing, eco-efficiency, eco-factory and energy efficiency. The literature provided both the principles for the concept development as well as practices, good or otherwise. Through review, analogy and argument the beneficial features of eco-efficient factories are used to challenge current design and operational thinking. A set of requirements is developed around a start-stop production system concept. The requirements are grouped around technology, organisation/people and systems. As a result of the development of requirements a number of challenges arise are reviewed.

3. Concept development

Factory energy reduction is driven by multiple factors, especially cost and CO_2 reduction. Factories can often have a weak link between energy consumption and production output due to the fixed overhead of supporting utilities, ancillary equipment, heating, lighting, etc. Additionally production systems have either not being designed with energy efficiency in mind or have been optimised at full output. By analogy, this contrasts with cars that have start-stop engine control so energy is not consumed at idle as well as gearing for efficiency at multiple speeds. The ability of production systems to ramp-up and ramp-down quickly as well as operate efficiently according to the actual production rate would mean that the energy consumption would be proportional to output rather than having a significant fixed element linked to factory opening hours.

There are subtle qualifiers to the analogy to be made here. Cars do need to be warm to take advantage of start-stop and there are distinct speeds for best efficiency so there is not a linear continuum. Hence factories would need both 'start-stop' and 'gearing' as thermal stability is required to achieve quality and production areas need to produce according to the customer demand efficiently.

This section has taken examples of industrial practice as components for extracting principles. Using theory, principles and practices from the literature for the components of technology and people consideration was made of how to achieve efficiency at factory system level. Using the themes of technology, people and systems identified earlier, the components were collated and these are presented in table 1. Each theme is now briefly described and then the following section then discusses the challenges to progress.

Table 1. Themes, principles and remarks for the concept of start-stop production system

Theme	Principle	Remark
Technology	Variable not fixed energy consumption	Additionally equipment must be efficient
	Sized for task	Avoiding over specification
	Fast ramp-up/down	IT as well as tooling
	Ramp-down phased	Recognises next start time due
	Thermal stability	Achieve quickly
	Point efficiency	At multiple rate/takt
	Maintenance simplicity	Includes cleaning
	Longevity	May limit frequent start-stop
	Quality	Not impacted by start-stop
People	Actively conserve energy	Core organisation values
	Incentivised to minimise consumption	Visual metrics
	Organised to minimise consumption	No intra-department barriers
	Comfort and safety	Cannot compromise safety
System	Consumption aligned to value add	Variable not fixed
	Low overall system interdependence	Production, despatch, office, etc weakly linked
	Low production area interdependence	Technology/cells weakly linked
	System efficiency at multiple rate/takt	Balances with technology & people

The technology theme is the basic building block of components on which to build wider system functionality. Technology is the consumer of the power and other resources, whether it is the production tooling or the supporting utilities. Aside from the need for energy efficient equipment, it is important the equipment is sized for the task and not over-specified. Sizing would be either as a fixed resource or an array of resources that can be gradually brought in according to demand.