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Energy and material efficiency metrics in foundries

Emanuele Pagone*, Konstantinos Salonitis, Mark Jolly

Sustainable Manufacturing Systems Centre, School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, MK43 0AL, United Kingdom

Abstract

Most of the current foundry processes are based on well-developed and established practices typical of mature technologies. Contemporary economic, environmental and societal developments have concurrently changed at an unprecedented rate the context where traditional metal casting methodologies have not really developed much over time. Consequently, significant challenges and opportunities arise. This work will present the founding metrics of a novel approach to metal casting with the development of a new philosophy (called “Small is Beautiful”) aimed at tackling the current pressures on the industry with a focus on energy and materials’ efficiencies and flexible production. Traditional and well-established parameters are presented and compared to new metrics defined from first principles and thermodynamic properties. All metrics are validated using industrial and scientific literature data of five sand casting plants melting different ferrous and non-ferrous alloys.

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Keywords: Energy efficiency; Casting; Sustainability.

1. Introduction

Metal shape casting is among the oldest manufacturing processes and its origins can be traced back to the prehistoric period of mankind. Over time its processes have developed in conjunction with new alloys. Well after the flourishing of the scientific revolution, metal casting has been long considered an art [1]. Probably because of its long history, the adoption of a more scientific approach has proceeded slowly and a more systematic analysis of the related complex engineering problems has been completed only a few years ago. For example, John Campbell's “Ten rules for good casting” is one of the most recent and significant achievements of this approach [2].

* Corresponding author. Tel.: +44-1234-754608
E-mail address: e.pagone@cranfield.ac.uk

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However, resource scarcity, environmental pollution and demographic pressure on resources push the mature, energy intensive and highly competitive metal casting industry towards future challenges. “Small is Beautiful” is a new philosophy that intends to respond to these contemporary issues incorporating resource efficiency (both in material and energy terms) and flexible production since the beginning of the design process. Alongside the mentioned characteristics, other critical aspects, such as profitability and responsiveness to market needs are considered. Energy resilience is identified as the first step to address the mentioned challenges considering the energy intensive nature of metal casting. In the longer term, a more comprehensive and holistic approach implementing all aspects of sustainability [3] is envisaged. “Small is Beautiful” intends to support and promote both these future evolutionary steps, as depicted in Figure 1.

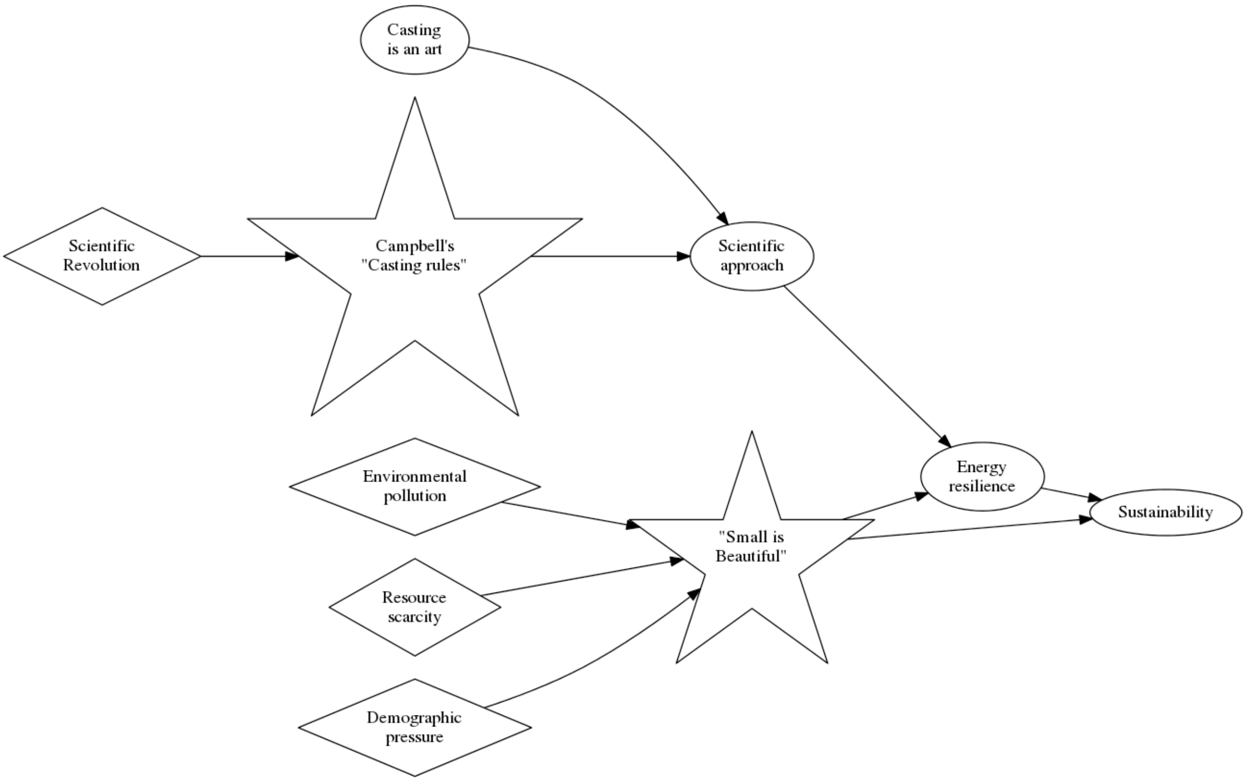

Fig. 1. Examples of historical metal casting development (elliptical elements) with two major (but not exhaustive) intellectual contributions (stars) and the relevant environmental pressures that generated them (diamonds).

2. The “Small is Beautiful” project

The first steps in defining this new philosophy were focussed on capturing practices and comparing energy and resource efficiency studying 80 foundries, contacting 60 and visiting 10 of them. About 100 enterprises and industry experts were interviewed and general energy data were collected. This survey revealed that usually foundries do not consider energy efficiency and emissions a key decision-making factor and thus do not monitor in detail energy consumption. In this area, the greatest interest of the foundry management is on the costs associated with energy bills. As a consequence, there is generally little knowledge on how to monitor energy efficiency and, where identified, major differences in practices between foundries have been recorded [4]. Thus, the need for a structured energy auditing framework [5] and an effective visualisation tool of measurements able to integrate with existing manufacturing systems [6,7] have been identified. An example of Sankey diagrams that can be obtained with the mentioned visualisation tool is shown in Figure 2.