1. Introduction

The market potential for 3D printing technologies (3DP) is estimated to be at 230-55 billion US$ by 2025[1]. If 3DP applications grow rapidly in the next 10 years, research needs to be directed into the sustainability of 3DP before the markets explode. Although 3DP is seeing considerable growth, there are still some high-volume markets where break-even production points shift towards more traditional processes (e.g., injection moulding). This study explores the feasibility of transferring experimentally tested energy consumption models for injection moulding into 3DP processes by defining common sustainability criteria.

2. Method overview

A conjoined model for the estimation of the specific energy consumption, SEC, is used; where SEC is defined as [2]:

\[
SEC = \frac{P}{m} = \frac{E}{m} ; \quad P = \text{input power (kW)} \quad m = \text{Process rate (kg/h)} \quad E = \text{Energy (MJ)} \quad m = \text{Shot size (kg)}
\]  

(1)

The energy of a produced part is hence determined by, \(E_p[3]:\)

\[
E_p = \frac{n}{n} \left( \frac{0.75 + E_m}{\eta_f} + \frac{E_c}{\eta_r} + \frac{0.25 + E_m}{\eta_h} \right) - \frac{n \cdot (1 + \eta + \Delta)}{\eta_{machine}} + P_{on} \cdot t_{total}
\]  

(2)

This model was applied in conjunction to the process information gathered via pressure-temperature (PT) cavity sensors fitted in an injection mould to obtain a single SEC value (fig.1). This was compared against the power data obtained using an Tiny Tag energy logger connected to the condutor cables providing the three-phase electric power of the injection machine as per figure 2.

Three sustainability criteria for 3DP processes are sought [1]:

1. Changes in production processes through additive printing
2. Changes in production time per piece
3. Changes in energy requirements per piece

3. Results and discussion

The PT signals inside the mould were monitored for 4 different settings: a) the optimum parameters (O), b) -30% injection speed (IS), c) -30% injection speed +50% holding pressure (HP), Parameters \(P_{inj}\) and \(T_{ij}\) were used in the calculation of \(E_p\).

Some 3DP technologies (i.e. fuse deposition modelling, FDM) share some similarities with injection moulding, hence some of the concepts hereby mentioned can be extrapolated into energy models for 3DP. In all, physical correlations between; pressure, temperature and material are required to achieve any successful parameter optimisation that can lead to energy and waste reduction.

4. Conclusions

The current energy model validated in injection moulding, can serve to define further models for 3DP, when making the following assumptions:

1) 3DP offers energy savings from traditional net-shape processes in that it saves the production of moulds
2) Production times can be monitored with the use of sensors
3) Energy analysis can help to quantify any changes in energy requirements per piece

5. References

