A new ultrasonic flow enhancement technology applicable to cold-runner and hot-runner injection moulding to save energy & increase productivity

Figure 1: Complete Soniplas system – ready to install

Summary

Matrix Moulding Systems Ltd (MMS) - and previously their parent company: The Technology Research Centre Ltd (TRC) - have developed a technology (Soniplas) which is applicable to all methods of polymer injection moulding for thin section parts (<6mm thick - which is applicable to around 94% of the market). It is designed to be retrofitted into existing moulding machines and incorporated into new build tools and machines.

The Industrial Energy Efficiency Accelerator (IEEA)

The IEEA programme supports the development of innovative technologies that will help industry reduce energy consumption and cut carbon emissions. It focuses on innovations with large potential cross-sector energy and carbon reduction impact - either new technologies or established technologies applied to new sectors. Over £15 million in public and private funding has been committed to develop solutions through partnerships between technology developers and industrial companies willing to test technologies on-site. The programme is funded by the UK government (BEIS) and managed by the Carbon Trust, with support from Jacobs.

Barkley Plastics have played an integral testing and validation role in the technology’s development to date. In this project we have designed, built and demonstrated in a commercial setting our cold-runner and single-drop hot-runner system, using case-study production-like tools with a range of thermoplastic materials. We have further developed our technology into a validated multi-cavity hot-runner system and demonstrated this in a qualified commercial demonstrator at Barkley Plastics’ site.

Introduction

The principle of introducing ultrasonics into the injection moulding process, with the aim of improving polymer flow and reducing the energy required, was first developed in the early 2000s, and TRC / MMS have continued the development over the last decade.

Support from the IEEA in this project has been instrumental in the specification/design/build and demonstration of three iterations of the system, validating the energy savings and productivity increases to potentially any thin section injection moulding – just as the industry is seeking to drive reductions in its carbon footprint to meet Net

Zero objectives. Without IEEA support, it is highly likely that this would have taken several more years to be realised.

About the innovation

Plastic injection moulding has the inherent challenge of achieving a suitably low viscosity for injection flow into moulds; which is traditionally accomplished through applying heat energy, to melt the polymer, and pressure, to inject molten polymer into the mould cavity. Upon filling the mould cavity, cooling energy is then required to cool the part to allow removal from the mould. This process results in injection moulding being a highly energy-intensive industry. Plastic injection moulding is conducted in three ways, depending on the application for the moulded part: cold-runner, single-gate hot-runner and multi-cavity/multi-gate hot-runner. The three pictures below show examples of the differences (each of the examples formed the basis for the three experimental trials undertaken):

Figure 2: Cold-runner parts (with sprue still attached)

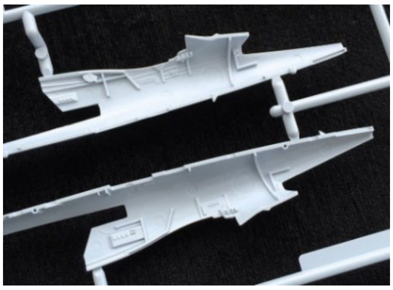


Figure 3: A selection of example hot-runner parts (no sprue)

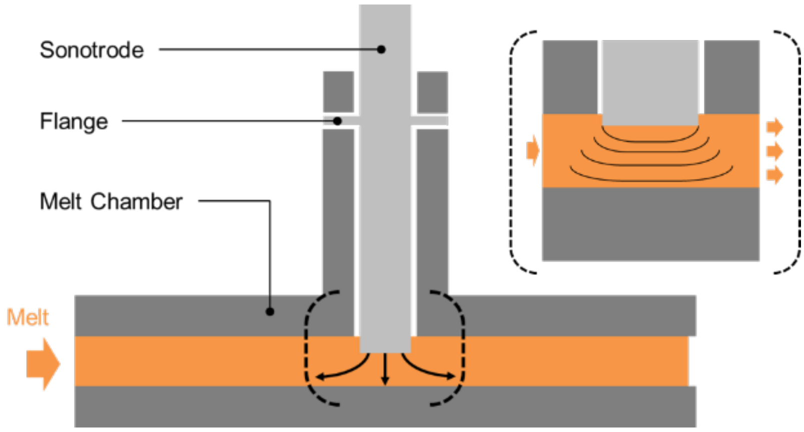
Figure 4: Multi-drop hot-runners can be used to create larger, more complex parts such as car bumpers, or multiple identical parts simultaneously.

Soniplas is applicable to all three methods of polymer injection moulding, and can be retrofitted to existing moulding machines, which will reduce the energy consumption required to create high performance quality moulded parts by as much as 29% (based on project results).

To achieve this energy reduction, during the injection phase, the molten polymer moves past a sonotrode placed within the melt chamber and is exposed to vibrational energy at 20kHz and up to 70 microns sonotrode peak amplitude, on its journey to the mould, as shown in Figure 5 below:

Low power vibrational energy has the effect of providing a temporary reduction in viscosity, through thixotropic orientation of the entangled molten polymer molecules in the direction of flow, resulting in enhanced flow characteristics which enable parts to be moulded and cooled in a more energy efficient manner. Associated energy reduction can be primarily taken in the form of reduced melt temperature (as much as 60°C reduction), whilst still achieving a sufficiently low viscosity such that the part can be moulded, or in the form of much reduced clamp & injection hydraulic pressure requirements, facilitating thinner wall sections on future part designs.

Figure 5: illustrative design of ultrasonic application in injection moulding process



The demonstration

Barkley Plastics are a highly experienced thermoplastic injection moulding company (established in 1965) with a range of over 40 injection moulding machines, representative of the whole injection moulding sector range of clamp sizes. They operate across a wide-range of market sectors including automotive, medical, household and construction with an 85,000ft2 facility that produces over 50 million mouldings each year. Their in-house skills cover the entire range of those used within the sector, with in-house design and toolmaking facilities supporting their state-of-the-art injection moulding facility. Having collaborated with MMS during a previous successful prototype scale-up project, Barkley were keen to continue their involvement and help see the technology reach market for mutual benefit.

Key project stages

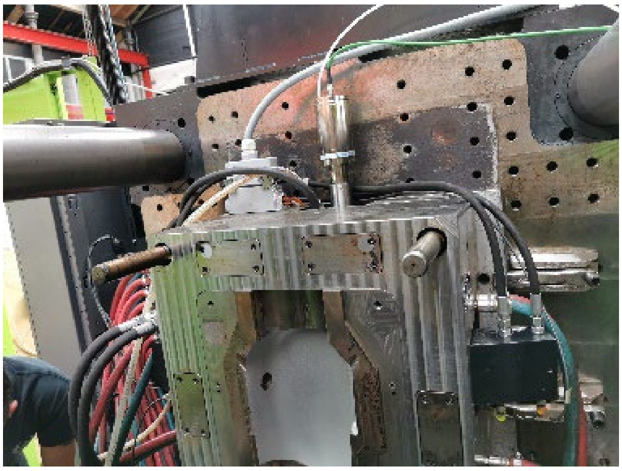
For all three trial & demonstration systems, the development process followed a similar path using Barkley Plastics:

- Select existing, or design new case study parts, for specified moulding machine capabilities.
- Use theses to specify and design the ultrasonic system, mould tool, melt flow chamber, cooling system and control software.
- Purchase equipment, fabricate steelwork, build and commission the three distinct systems – first at MMS and then on site at Barkley Plastics.
- Perform validation trials to ensure full part production and measure energy consumption and cycle time. Soniplas system was calibrated to produce full parts with no shorts, noticeable defects or material burn/degradation.
- Alongside the development work, we carried out testing of parts, moulded using Soniplas, in order to gain more knowledge of the ultrasonic effect and to ensure that the polymer was not degraded during the process.

Trial 1: Cold Runner (Figure 6):

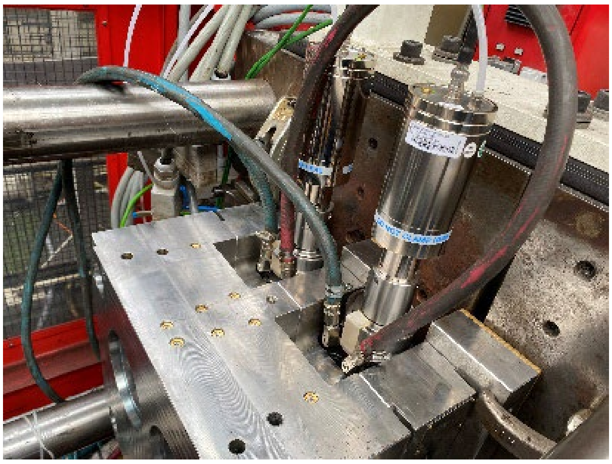
- Standardised cold runner block used (throughout the project) retrofitted between the injection moulders fixed platen and the chosen mould tool.
- Sonotrode fitted to current standard in the melt flow channel.

Trial 2: Single Drop Hot Runner (Figure 7):



- Bespoke hot runner plate design manufactured and attached to a specific single drop hot runner tool.
- Sonotrode included in the plate hot runner channel.
- Sonotrode located at a 90° angle and tip was parallel along the molten material flow.

Trial 3: Multi-Drop Hot Runner (Figure 8):



- Bespoke tool manufactured that included twin sonotrodes in complimenting melt chambers that attach a hot runner to of two cup parts.
- Each sonotrode worked independently in its hot runner channel.
- Sonotrode was located at a 90° angle and parallel along the melt channel.

Monitoring

The trials have followed a measurement and verification plan designed at the start of the project:

- Mould using the standard process.
- Record the power output of the injection moulder over 1 hour, taking data points every second. This duration allowed suitable recording of the load required for a specific run. The power output was measured per part as decreasing cycle times using the Soniplas system meant more parts could be produced in the hour than the control.
- Reduce the melt temperature and cycle time until short shots were produced. Short shots are when the mould cavity did not fill completely and so could be identified easily compared to the control full part.
- Mould using Soniplas and validate that full parts are again fully moulded.
- Reduce the temperature and cycle time further to establish the minimum melt temperature to fill the part when Soniplas is operational.
- Monitor the machine pressure, power usage and ultrasonic amplitude required.
- Record power usage for the reduced Soniplas settings for 1 hour. Record the power per part and compare to the control settings to provide an energy efficiency increase.

Results

The energy and carbon savings results are presented below for the Cold, and Single Drop Hot Runner systems. Parts were moulded with and without using Soniplas, and energy usage recorded. The carbon savings figures are calculated using the Government conversion factor (2021) of 0.212kg Carbon per kWh of electricity. The multi-drop hot runner system needs more development in order to optimise the process and provide consistent results.

The electrical energy savings (up to 29%) shown would result in a return on investment for Soniplas users of around 2-3 years. However, when a cycle time reduction of up to 39% is included, this payback time reduces to under 6 months, if the extra capacity created is utilised.

Figure 9: Monitoring results - based on operating 365days / year

		Cold Runner (ABS)		Single Drop Hot Runner	
		No Soniplas	Soniplas	No Soniplas	Soniplas
Number of parts made for comparison		157	157	61	61
Energy – kWh	Per Part	0.07	0.05	0.21	0.18
	Day	270.75	192.43	307.44	263.52
	Year	98823.24	70236.49	112215.60	96184.80
Energy – MWh	Per Part	0.00007	0.00005	0.00021	0.00018
	Day	0.27	0.19	0.31	0.26
	Year	98.82	70.24	112.2	96.18
Energy Saving %			28.9%		14.3%
Energy Saving MWh	Year		28.59		16.03
tCO_2e	Year	21.0	14.9	23.8	20.4
CO_2 Saving - tCO_2e	Year		6.06		3.40

Future impact

The primary target market sector for our technology is thermoplastic injection moulders producing parts across a range of sectors, including; single use/ food packaging, domestic & electrical goods, medical products, automotive components and the construction sector. The core injection moulding industrial process is common across all sectors. As our technology targets the fundamental aspect of temporarily reducing the molten polymer viscosity during injection, and hence reducing the energy required to inject a part, it will benefit all sectors, and all tooling configurations: cold-runner, single-drop hot-runner and multi-cavity multi-drop hot-runner.

Within the UK this market has a turnover of £3.5bn. There are around 950 moulding sites, with an average of around 10 machines per site, giving industry estimates of a UK machinery population of around 10,000 injection moulding machines. There are also over 13,500 moulding sites across the EU, providing significant future export opportunity. We anticipate a conservative market take up of 4,150 units over the first 10 years, with more than half of these within the UK. If we assume the UK population of machines is 10,000, this enables up to 20% of the UK machines to benefit from the technology.

Innovation lessons

1. Technical:

Maintaining material properties – These are crucial for gaining buy-in from customers and the reason we devoted a long period of time to characterisation tests of the materials.

Importance of thermal management – We have been careful in our system designs so as to avoid transmission of heat from the sonotrode in the melt flow, to the system stack. This had resulted in failures in earlier designs, prior to this project.

Sonotrode design requirements – We gained awareness that for larger & faster parts, we may have to devise new sonotrode designs in order to increase the surface area in contact with the molten polymer, therefore increasing the time exposure to the ultrasonic excitation.

Scale up requirements for high mass-flow rate – We identified the need to re-imagine some aspects of ultrasonic delivery to the melt flow, for parts which are very large or moulded very quickly. Work has commenced on this as part of our new BEIS EEF8 funded project, which commenced on 1 October 2021.

Flow simulation – It can be beneficial to model the effect of Soniplas when designing new mould tools. We have engaged with Moldflow (via Autodesk) in order to have a Soniplas plug-in to their normal simulation package. This work is outside of the IEEA project and is ongoing

2. Commercial drivers for customers:

RoI energy vs productivity – Clients may or may not be able to include productivity increases due to cycle time reduction into their RoI calculation. Creating extra moulding capacity is good but companies can be reluctant to use this, if there is a risk that the new capacity could remain unsold. This has particularly been the case for plc companies (Berry and Polypipe) – and why the IETF grant funding has been crucial for them to adopting the technology. Also:

- Melt temp reduction leads to a cooling time reduction.
- Reduction in clamp force can allow a down gauge in press size – providing the opportunity to mould the same parts on a smaller/cheaper/more efficient machine.
- Pressure reduction can give reduced warp, reduced scrap and increased quality for the customer.
- Wall thickness reduction may be possible, leading to a cooling time reduction and light-weighting / material saving benefits.

Contact information

Who to contact for more information

+44 (0) 1949 842244

andy.watts@matrixms.co

www.matrixms.co

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