

MAGIT*: Gas injection technology on the road to industrial application in high pressure die casting

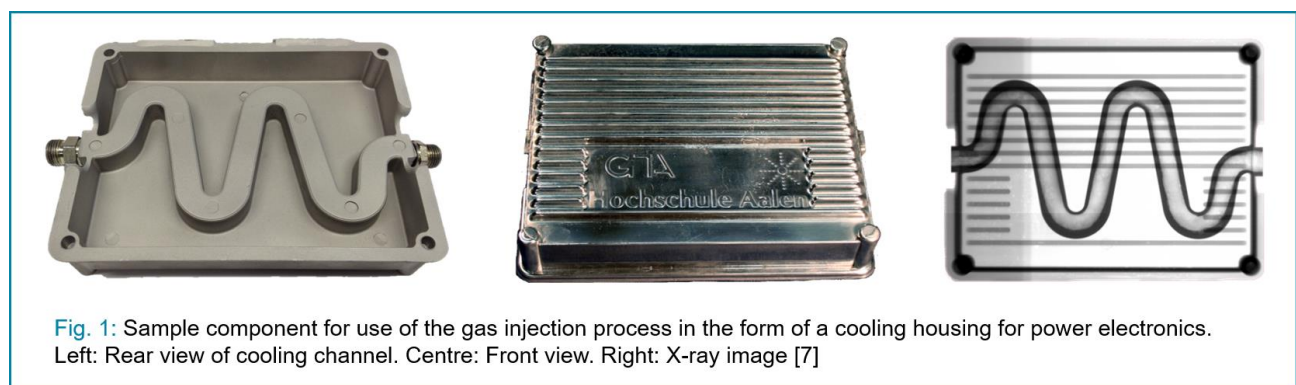
The objective of this research project is the transfer of gas injection process already employed in plastic injection moulding to the series die casting process involving metallic melts. Gas injection technology allows the creation of cavities in the die casting process. In particular, this process is to be developed further for application to aluminium melts and implementation in an industrial manufacturing environment [1, 2, 3].

From Lothar H. Kallien, Wolfgang Kuchar, Aalen, Marcel Op de Laak, Teningen, Michael Haas, Mühlhausen i. T.

1 Introduction

Steadily increasing demands for castings, faster cycle times and lower production costs make gas injection technology a special process with enormous potential. It allows the creation of a cavity in castings without upstream and downstream processes, an option which is not possible where lost cores are used. Furthermore, gas injection technology offers the advantage of a reduction in sink marks and distortion while also providing greater and, indeed, new levels of freedom when designing thick-walled, hollow components with short cycle times [4]. One major challenge posed by the gas injection process is the development of suitable gas injectors with an adequate service life [5, 6]. The sample die that was selected for the gas injection process produced a cooling housing for power

electronics (Fig. 1). A meandering channel created through gas injection acts as the conduit for a cooling medium. A gas injection system that meets the requirements of an industrial production process is being developed in a research project aimed at developing gas injection technology for aluminium die casting applications funded by the German Federal Ministry for Economic Affairs and Energy as part of its Central Innovation Program SME. Essential new developments relating to gas injection technology in die casting and test results for the tested system are presented in this publication. The overall system is being developed in cooperation with TIK – Technologie in Kunststoff GmbH and Haas Metallguss GmbH. The new gas injection system for die casting will be used for the first time in an industrial production environment at Haas Metallguss GmbH following testing at Aalen University.



* MAGIT: Metal and Aluminium Gas Injection Technology

2 Gas injection system

In order to develop a repeatable process and a system that is suitable for an industrial application employing the gas injection process with metallic melts, specifications were defined for just such a system [8, 9]:

- Maximum reaction time of the system is 5 ms
- Provision of process gas directly at the injector
- Hydraulic actuation of the gas injector
- Long service life of gas injection components such as the gas injector and spill-over valve
- Compliance with safety criteria for use of this technology in an industrial production environment
- Gas injection system as supplementary module for die casting machinery

The gas injection system developed consists of four main components (Fig. 2), which are linked in a network. The central component is a compressor module which is the core element of the system and contains all components for control, gas and hydraulic pressure. The accumulator module is positioned immediately adjacent to the mould to

shorten routes to the die. The die module, which is mounted on the side of the moving half of the die casting mould, takes charge of the gas supply, hydraulics and cooling water line. According to the specification for the new gas injection system, the compressor module and both the accumulator and die module can be mounted on a conventional die casting machine without any modification (Fig. 3). An injection module has been developed for actuation of the injector and provision of the process gas directly at the injector. This module is mounted directly behind the injector in the die (Fig. 4). Signals from the required die sensors and two inductive proximity sensors are forwarded to the PLC control via appropriate charge amplifiers fitted in the accumulator module. Two metal front contact sensors (MFCS) in the gate area of the die are crucial for the gas injection process. The gas injection process is triggered within the preconfigured delay time on the basis of this signal. The other die sensors are used to monitor and evaluate the gas injection process that has occurred and are also fitted in the stationary mould half (Fig. 5). Control and process monitoring of gas injection and parameter inputting for the gas injection process are realised via a tablet PC which allows the operator to assess the actual gas injection process in real time using the integrated measuring system (Fig. 6).

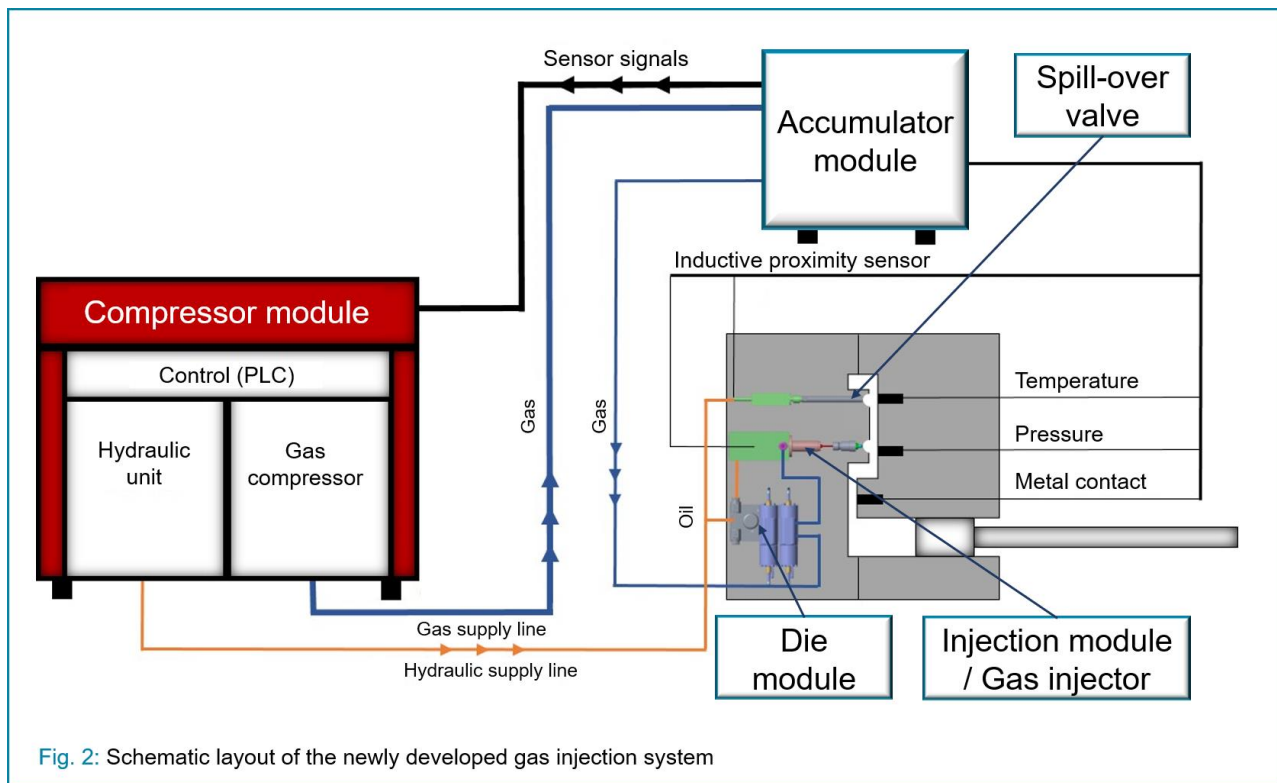


Fig. 2: Schematic layout of the newly developed gas injection system

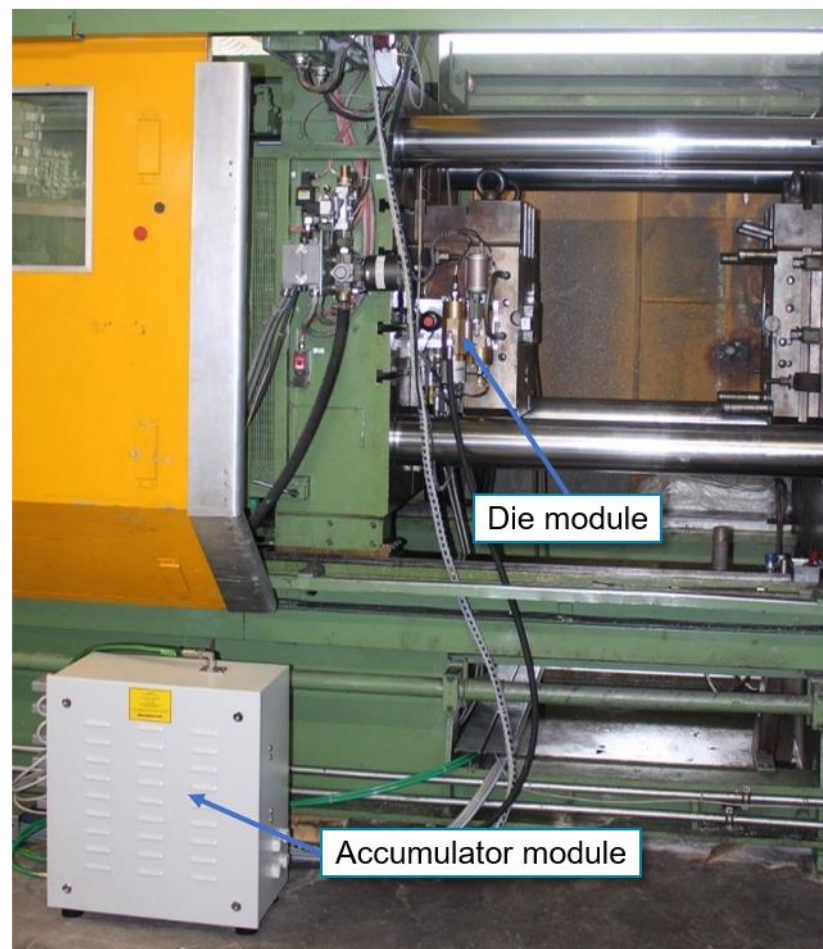
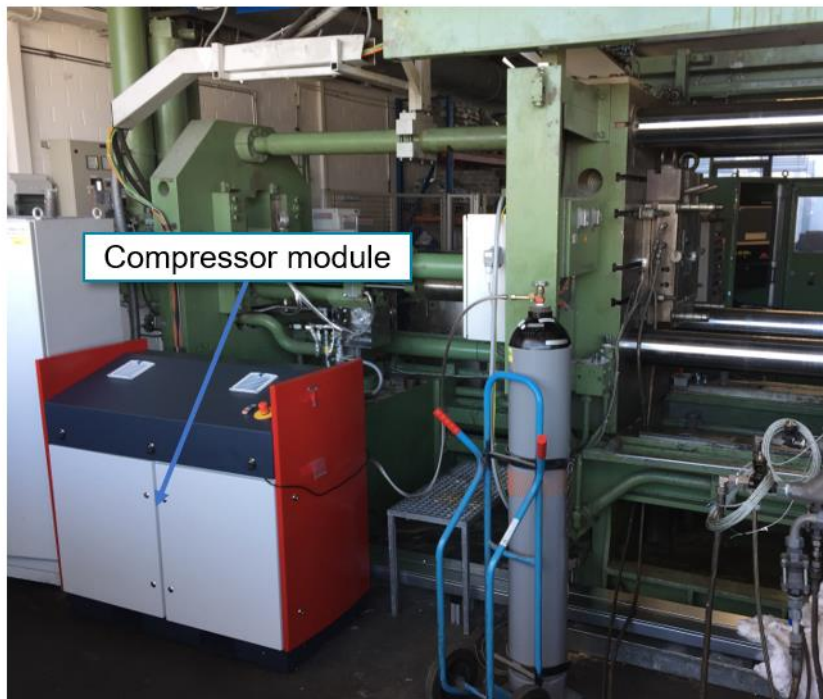


Fig. 3: Real layout of the new gas injection system with a compressor module, accumulator module and die module on a cold chamber die casting machine.

3 Test results

During the series of trials conducted with the new gas injection system on the GDK750 cold chamber die casting machine at the Aalen University foundry laboratory, the focus was on testing the complete system and suitability testing of various special materials selected in advance for gas injector components in contact with melt (Fig. 7). These materials were to ensure a long injector service life and proper functioning of the gas injector. Two materials were identified in this respect which could withstand the die casting process with aluminium melts. A ceramic material helped achieve quantities akin to small series levels before the injector broke under the casting forces. Up to this failure, no undermining attack on the aluminium could be determined on the injector which could have limited the function of the gas injector. The second special material in the form of coated steel allowed the generation of far higher quantities without any injector failure being detected. Fig. 8 illustrates typical shot curves associated with gas injection.

The shot curve can be used to analyse whether the gas injection process creates a channel which has been blown hollow. Indications come from the signals emitted by the inductive proximity sensors mounted on the injector and spill-over valve. The movement here should be a rapid and continuous opening to 100 % on the injector and 0 % on the spill-over valve, as indicated on the shot curve illustrated (Fig. 8). Another indication of a successful gas injection process is the curve progressions of the die sensors recording the die temperature and internal die pressure. It is evident from the graph that the internal die pressure and die temperature fall abruptly and rise again subsequently after the

side cavity is released by pulling the spill-over valve. The escape of residual molten metal on opening the side cavity causes the casting to shrink initially from the die surface before being pressed against the die wall again by the

increase in gas pressure inside the component. In the absence of a fluid connection between the casting plunger and side cavity, the latter is not filled by the casting plunger and the gas injection process has been realised.

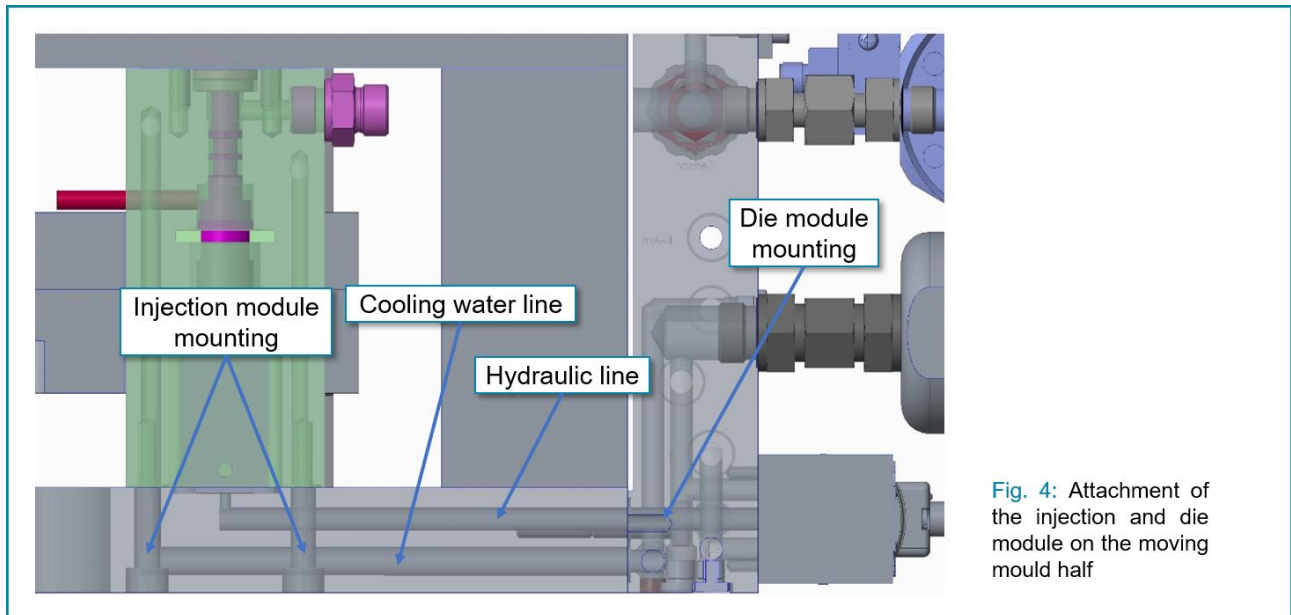


Fig. 4: Attachment of the injection and die module on the moving mould half

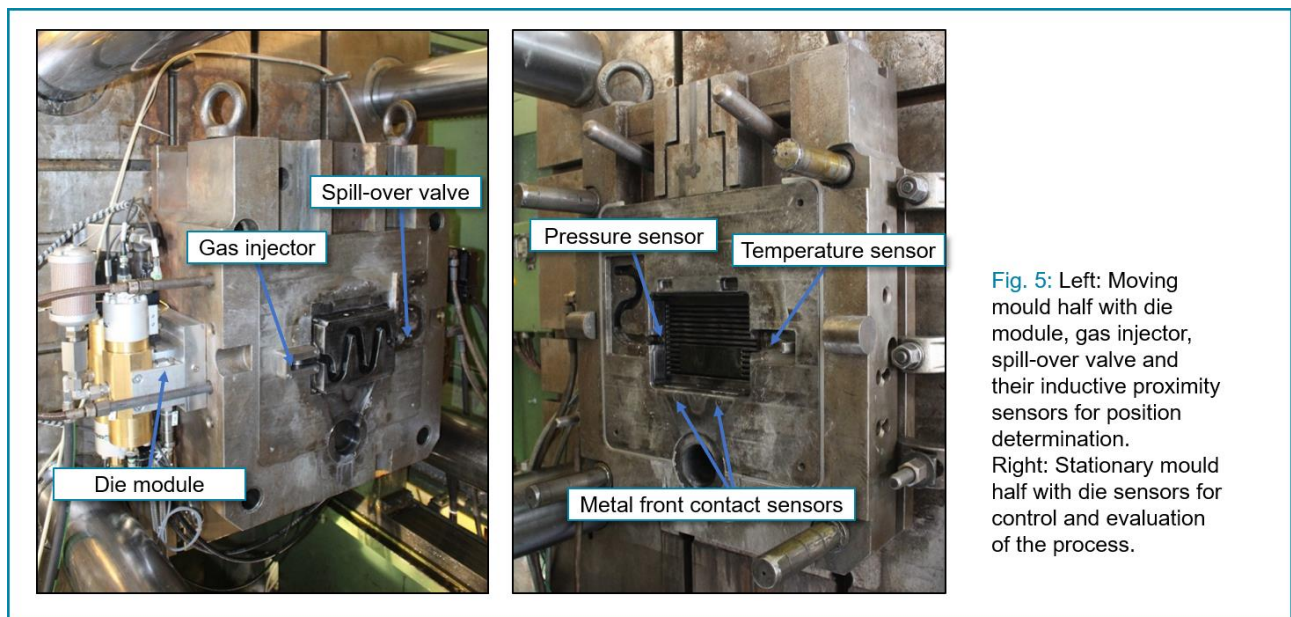


Fig. 5: Left: Moving mould half with die module, gas injector, spill-over valve and their inductive proximity sensors for position determination. Right: Stationary mould half with die sensors for control and evaluation of the process.

4 Reproducibility

The process repeatability required for a serial application was not achieved, due to the very narrow process window available with gas injection systems from previous projects [10]. One of the most important criteria to be achieved is the repeatable control of the gas injector and its correct opening. The system reaction time is shown in Fig. 9 as a function of the setpoint entered for the delay time of the injector and spill-over valve components. The value illustrated therefore represents the deviation from the setpoint. As a process criterion, the repeatable release of the side cavity is as important as the deviation of the gas

injector actuation. The high number of outliers meant that only a standard deviation of 5 ms was achieved. Why these outliers occurred to this extent was not apparent from the corresponding shot curves. Further trials will need to be conducted to investigate whether errors occurred here during recording of measurement values or if these are the actual values to be expected. When compared to the setpoint deviation of the gas injector, it is noticeable that the mean spill-over valve value is almost 3 ms higher than in the case of the gas injector. This can be explained by the fact that, when actuating the spill-over valve, a larger volume of hydraulic oil needs to be set in motion before a movement of the spill-over valve

occurs. The outliers are interesting during this comparison, as these are exactly the same shots at which they occurred. This is also evident when comparing the standard deviation and the number of cycles within 10 ms. The

actual effect in the process which lies behind this has not yet been explained. However, it is most probable that a systematic error occurred during recording of the measurement values.

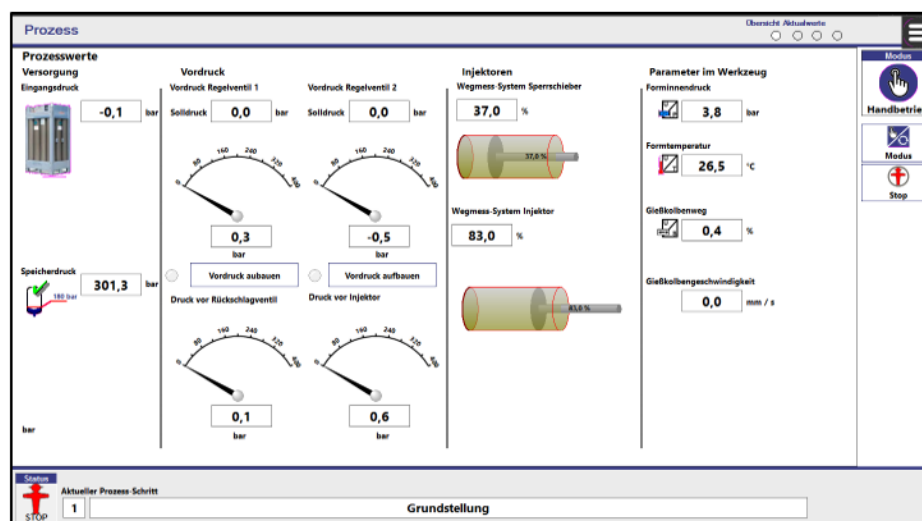
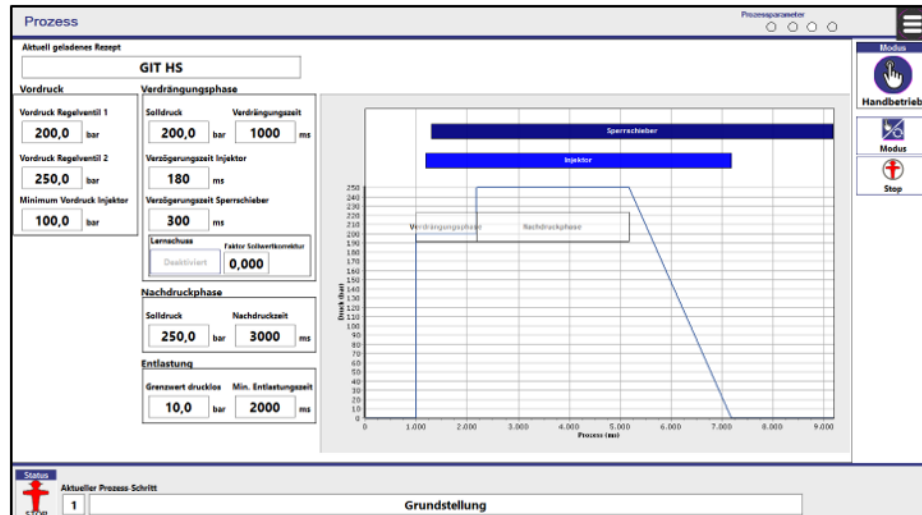


Fig. 6: Tablet PC user interface for control of the new gas injection system. Top: Inputting of process parameters relevant to gas injection. Bottom: Real-time system monitoring with different gas pressure levels, the gas injector and spill-over valve position and the sensor signals

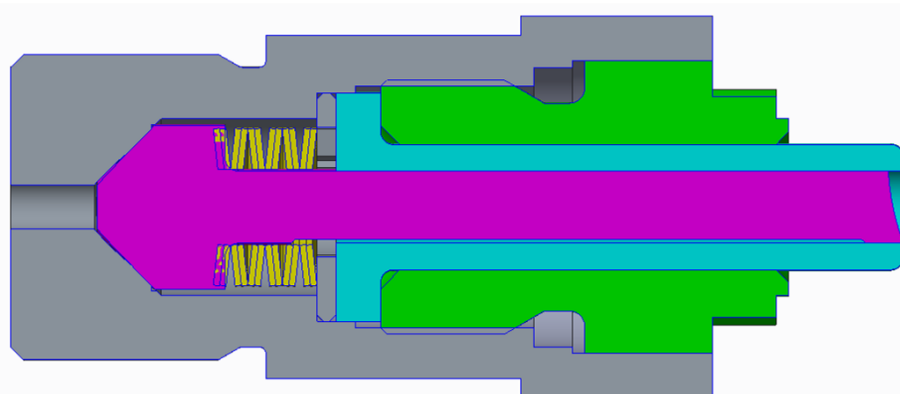


Fig. 7: Newly developed gas injector with special materials in the vicinity of areas in contact with molten metal: sleeve (blue) and needle (magenta)

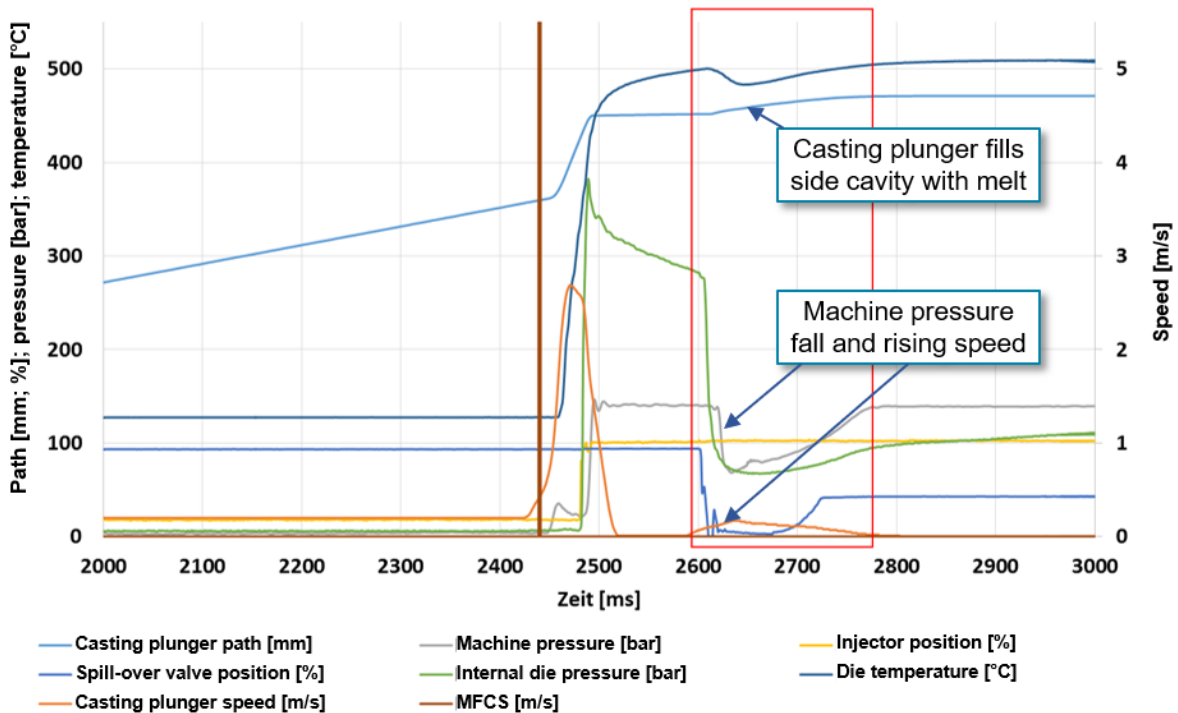
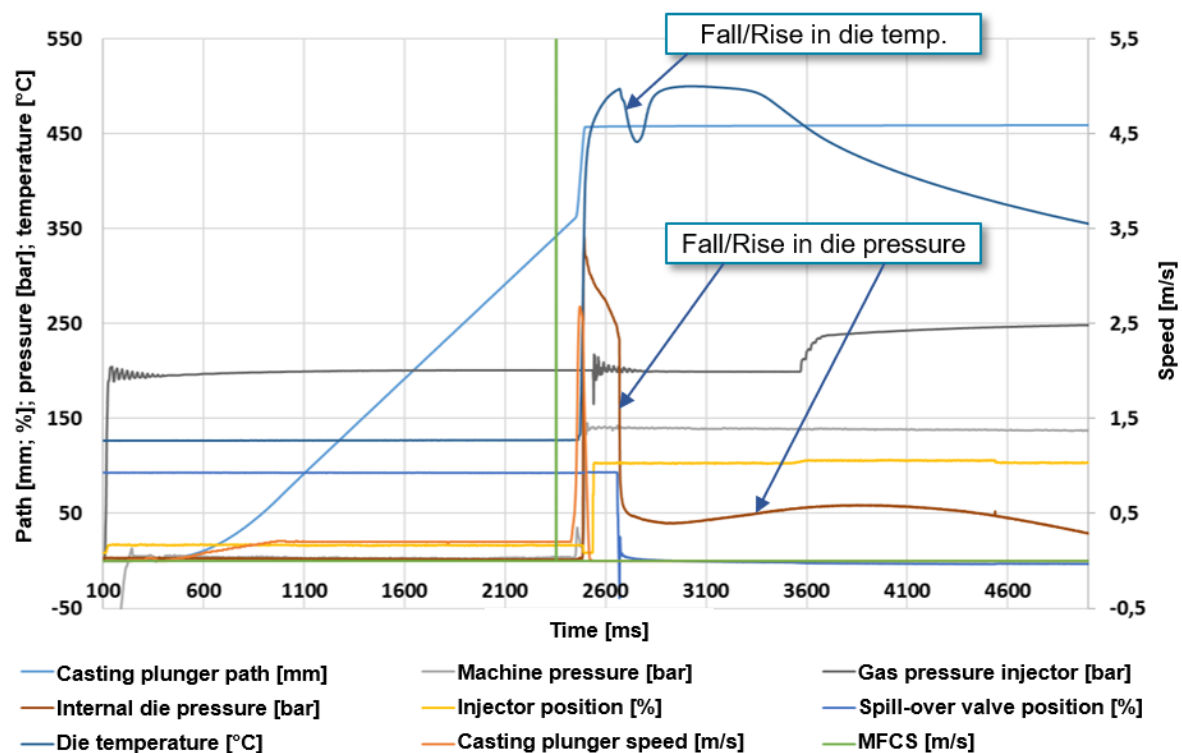


Fig. 8: Top: Shot curve of a successful gas injection process with parameters relevant to gas injection used to evaluate the completed process. Bottom: Falling machine pressure (grey), rising casting plunger speed (orange) and a rising casting plunger path (light blue) when opening the spill-over valve indicate filling of the side cavity by the casting plunger

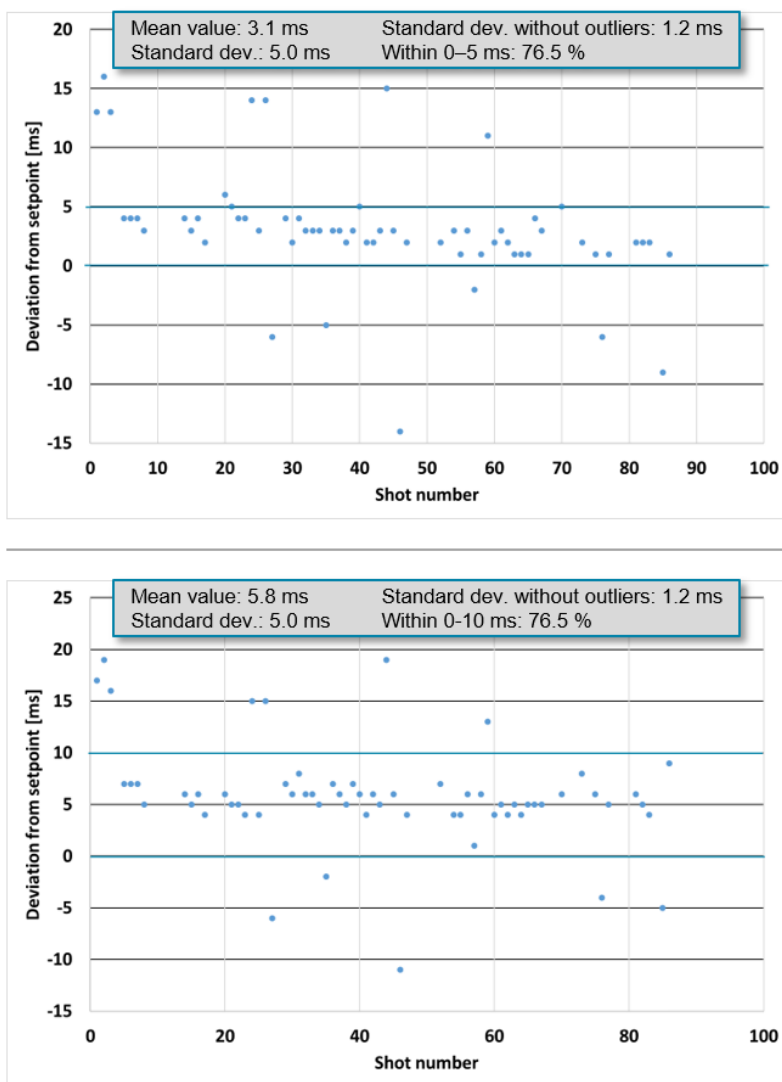


Fig. 9: Evaluation of the deviation from the setpoint entered to actuate the gas injector (top) and spill-over valve (bottom)

5 Discussion

With the aid of our industrial partner, we have taken an essential step towards achieving series-production readiness of gas injection technology in aluminium die casting. In particular, further development of the gas injector in terms of service life is very promising. The gas injection system provides the reproducibility required for use in aluminium die casting, especially with regard to switching times. In the further course of the project, this system will be used to produce a die that will be used in die casting outside laboratory conditions at Haas Metallguss GmbH for the first time.

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