Die Evacuation: Fast, Efficient and Reliable

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ABSTRACT

No one would deny that the use of vacuum in high-pressure die-casting has brought about crucial improvements in quality. Castool and VDS have devoted considerable effort to developing reliable high-speed vacuum shut-off valves with very high performance.

For high integrity casting**,** where high quality castings with low porosity are required, a high-speed secure vacuum valve is the best solution.

INTRODUCTION

Vacuum pressure die-casting makes it possible to produce high-quality thin-walled parts with predictable and repeatable mechanical properties. The successful use of vacuum requires fast and accurate control of the vacuum valve, and precise timing of its cut-off.

The vacuum valve must be fast, efficient and reliable.

THE VACUUM LEVEL

There are three essential requirements for an appropriate vacuum system.

• Vacuum tank with a large volume relative to that of the die cavity to ensure rapid evacuation, a high level of vacuum in the die, and effective elimination of impurities, dirt and so on after the shot.

• High vacuum in the tank should be at least one millibar.

• Good sealing throughout the system (die and shot end system) to keep air leaks to a minimum.

CRITERION FOR THE CHOICE

The criterion is the level of vacuum in the die cavity just as the metal enters, at the end of the slow movement of the shot piston (just over a second after the piston begins to move). The best way to determine this is to measure it directly, comparing evacuation devices of a comparable size for the casting weight. The size of the high-speed valve is dependant on the critical evacuation section. This is the smallest section that the exhausting gas passes through. The smaller the evacuation section, the longer is the evacuation time. For a valid comparison, the measurement has to be made with valves having the same critical evacuation section, with a machine set up for high vacuum tightness.

VDS has a laboratory test bench, which was built to optimize the design of its valves. The equipment permits the evacuation of gas volumes from 0.1 to 40 liters, and directly measures the pressure in the die cavity as well as that at the valve. The measurements have been performed for a large number of casting shot-weights, performing the evacuation in an extremely tight die and shot sleeve. Precise absolute pressure transducers and a high-speed data acquisition system are used to measure and record the pressures.

CHILL VENT VERSUS *ProVac* VACUUM VAVLE

A chill vent is a device made of two half blocks designed to allow very fast heat removal, to force the molten metal to freeze quickly. The cavity between the two half blocks is narrow (at most 1 mm) and wide. It is also wavy, to increase the surface area and the heat transfer. The structure itself of the chill vent therefore prevents the easy passing through of the gas.

This is not the same for a high-speed vacuum valve.

In a typical case, the tests were made for a 4 kg shot-weight part (evacuation volume of 3 liters), comparing the ProVac® Plus 2000 vacuum valve and a chill vent, each one having the same critical evacuation section of 60 mm2.

Comparing their performances, the VDS valve can evacuate 3 liters of gas to achieve a cavity pressure of 100 mbar in just 1.3 seconds, whereas the chill vent did not attain this level of vacuum even after the unacceptably long time of 2.5 seconds. This result is highly significant in relation to casting quality. The die cavity pressure with the valve also fell to 50 mbar after 1.8 seconds.

In a further test, a bigger chill vent was used, with twice the evacuation section of 120 mm2. It took 1.55 seconds to reach 100 mbar, 20% longer than the valve. Of course using so large a chill vent for such a small shot weight would be quite impractical in reality, (large vacuum channels and loss of metal, very high projected surface, higher price, poor process repeatability and so on).

It is difficult to predict what is happening in the die during the evacuation, since the pressure is normally only measured at the vacuum valve or chill vent, and therefore the measurement of the evacuation will show approximately the same behavior for both evacuation devices in spite of huge differences in evacuation performance.

Generally speaking, a chill vent takes two to three times longer to evacuate the die than a high-speed valve. This remarkable difference in evacuation capability is the result of the higher airflow resistance of the chill vent compared to that of the vacuum valve.

<u>Vacuum measurement in a valve – a valid measurement</u>

When the aspiration piston closes the aspiration hole, the hole for the measurement of vacuum is closed at the same time. The last pressure before the closure is the measured level of the vacuum, and this value is recorded and stored.

<u>Vacuum measurement in a chill vent - an invalid measurement</u>

At the moment when the die cavity is sealed off from the vacuum by the solidified aluminum between the two chill vents half blocks, the manometer remains directly coupled to the vacuum tank. The recorded measurement of the pressure therefore bears no relation to the vacuum in the die.

PRACTICAL CONSIDERATIONS

Design and use

i. For easy and quick maintenance, the VDS valve mechanism is made of a small number of large components

ii. The VDS mechanism is designed for low friction, with suitable low-wear materials.

iii. VDS uses a valve with a reliable mechanism. Mechanisms and their reliability differ greatly from one valve to the other. A careful risk analysis of the closure mechanism makes it possible to determine what the failure potentials are, and if the valve is reliable.

iv. Adequate vacuum runners must be cut into the die from the casting parts or overflows to the vacuum valve. To ensure the best evacuation, the runner sections should be dimensioned adequately. The main runner section, the sum of the side runner section and the total gate section should all be similar to or slightly bigger than the critical evacuation section.

v. The valve runners should guarantee reliable closure. The shape of the vacuum channels strongly affects reliability. Incoming metal at very high speed shows an atomized metal front. The front should be directed towards a “security zone” where it is imprisoned, and then should be conducted as late as possible near the evacuation piston. Such an arrangement can much reduce the incidence of failures.

vi. The vacuum channels should be cut on the ejector-side of the die according to a special shape for high security. VDS strongly recommends cutting the vacuum channels on the side opposite to that carrying the closure mechanism. This ensures that the heat removed from the liquid metal will mainly escape without disturbing the high precision mechanism.

vii. VDS uses a long and powerful blow out procedure. The blow out serves two purposes, the first being to cool the valve’s internal mechanism and the second to clean it. Therefore it is recommended to use a strong flow of air during blow out, and to maintain it throughout the whole die lubrication operation.

viii. The valve should be thermally cycled as is done for the die. It is recommended to spray the valve during the die release agent spraying phase. At each production cycle the amount of heat carried into the valve has to be removed just as it is for the die, in order to ensure steady state casting operations.

viiii. The shot sleeve should be thermally and dimensionally stable to provide a reliable seal, and an absolute minimum amount of lubrication applied in all vacuum installations.

Maintenance

Since not only gas but also dirt, die release agent, and ash have to be evacuated through the evacuation device a certain amount of maintenance is needed. A high-speed valve has high precision moving parts, and VDS recommends carrying out maintenance after 5000 shots to prolong valve life and ensure product consistency (but there have been many instances of customers’ successfully putting off maintenance until more than 20,000 shots).

THE VAMP - PROCESS MONITORING ENSURES GOOD AND REPEATABLE QUALITY

Measuring the pressure in the die is normally extremely difficult, and it may significantly increase the costs of the process, so that in practice it is hardly ever done. VDS has solved this problem with a new advanced analysis system called the Vacuum Analyzing and Monitoring Processor (VAMP).

The VAMP is a microprocessor-supported deep level analysis and control tool for monitoring and optimizing cavity evacuation. In addition it is a tool to help in diagnosing some general characteristics of the die-casting process.

The embedded computerized system is permanently connected to pressure sensors for high precision measurements and to a complete database consisting of laboratory-measured pressure curves.

The VAMP uses either a Siemens or Allen Bradley CPU for advanced analysis of vacuum-curves, suction capacity and pollution control, monitoring and determination of leaks in the die and in the shot sleeve.

The results of the VAMP analysis are stored both in forms of characteristic values giving a summary of the main characteristics for the shot, and also in the form of complete evacuation curves. The user can log more than 20 years of operating results on the hard disk. Results can be reviewed easily to highlight improvements in quality or changes in the die-casting process**.**

THE VAMP - DETERMINING PRESSURE IN THE DIE WITHOUT AN EMBEDDED SENSOR

The VAMP does more than analyzing and monitoring. In the heart of its main program there is a consistent database of laboratory-measured vacuum curves. This database was built up by making a comprehensive series of tests similar to the one which make it possible to predict the die cavity pressure from that measured at the valve or the chill vent. The tests were carried out for all sizes of ProVac® valves with or without vacuum channels, and for a variety of shot weights, and the relation between measured pressure and in-die pressure described mathematically with respect to each one of these parameters. The VAMP uses the database to predict the variation through time of the die cavity pressure from that of the measured pressure at the valve or the chill vent. The procedure is as follows:

• VAMP assumes that the vacuum runners have been cut into the die according to VDS recommendations, which means among other things that the critical evacuation section will be located not in the runners, but in the valve. If this is not so, then the evacuation speed will be lower by an indeterminate amount than that predicted from the database.

• The program calculates the prediction using the database and the mathematical relations.

• The validity of the prediction is verified by checking if the first derivative with respect to time of the measured pressure is plausible. This slope is related to the volume of gas to evacuate and to the leaks of the die and shot-sleeve. Were the vacuum runners for example to be closed by a jam, then this slope would be very much steeper than it could possibly be in relation to the shot-weight.

The VAMP first shot-pattern shows among other things the predicted pressure in the die cavity, which is a vital indicator of quality in vacuum pressure die-casting.

THE VAMP - MANY OTHER HELPFUL TOOLS

The VAMP - Vacuum Analyzing and Monitoring Processor can be very helpful for improving quality in die-casting. They are for example zooming on curves, overview of minima and history, determination of characteristic values (slopes etc.), alarms adjustable on different levels for optimal production monitoring, users' "ideal curves" for comparison and alarms, monitoring of the leaks in the die and shot-sleeve, advanced checks of the evacuation capacity, distribution of the VAMP-windows on the Local Area Network…

CONCLUSION

Castool and VDS's advanced high security high-speed valves help the die-caster on his way towards high quality and a secure and repeatable die-casting process.

For high integrity casting**,** where high quality casting with low porosity as well as repeatability in the process and evidence of the optimal fabrication are required, a high-speed secure vacuum valve is the best solution.

For advanced evacuation in high quality die-casting, the use of the Vacuum Analyzing and Monitoring Processor (VAMP) is a major advantage. This computer-assisted system with its embedded sensors, used in conjunction with a complete database built up from laboratory-measured vacuum curves, offers a totally new perspective for improving the pressure die-casting process.