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20 Years Experience

ProVac® Vacuum – System

Die evacuation: Valve or chill vent?

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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. For more than twenty years, VDS has devoted considerable effort to developing high-speed vacuum shut-off valves with very high performance and excellent reliability. In addition VDS produces high quality chill vents that satisfy a certain level of evacuation requirements.

Extensive research and testing has shown that the vacuum valve will always offer a quality advantage in vacuum pressure die-casting. The associated control systems ensure reliable operation while maintaining a high rate of production. Today more than ever VDS is at the cutting edge of technology in this field.

This article describes the advantages of the vacuum exhaust valve over the chill vent, and covers a number of practical points concerning good design and operation of the valves and the process.

INTRODUCTION

Vacuum pressure die-casting makes it possible to produce high-quality thin-walled parts with predictable and repeatable mechanical properties with or without heat treatment or welding. The process requires fast, accurate control of the vacuum and precise timing of its cut-off, which in practice demands an advanced vacuum valve with fast, efficient and reliable behaviour.

Many vacuum die-casters ask themselves if it is possible to use chill vents instead of a vacuum valve without sacrificing too much performance during casting and without detracting from the quality of the product. The aim of this paper is to help the reader resolve this question, and further, to present some advanced die-casting tools for improving the quality of the whole die-casting process and for monitoring the improvement.

For over twenty years, VDS has devoted considerable effort to developing high-speed vacuum shut-off valves with very high performance and reliability, as well as long lifespan chill vents. The control systems used with VDS's ProVac® valves and chill vents already ensure reliable operation and sophisticated process analysis; however, VDS has recently developed the Vacuum Analysing and Monitoring Process (VAMP), a powerful tool towards attaining high integrity in vacuum die-casting. Many years of extensive research, development, and testing have finally resulted in the best system for satisfying the requirements of the most demanding customers.

This article will deal with the question of the choice between vacuum valve and chill vent.

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DIE-EVACUATION VALVE OR CHILL VENT ?

1. FIRST STEP, THE VACUUM LEVEL

The first major step towards a high integrity vacuum die-casting process is to choose an appropriate vacuum system. There are three essential requirements:

- A vacuum tank with a large volume relative to that of the die cavity. This is necessary for 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: it should be at the most one millibar.
- Good sealing throughout to reduce air leaks to a minimum.

2. A CORNELIAN CHOICE*, OR ON THE HORNS OF A DILEMMA

What is the best choice between a high-speed die-evacuation valve and a chill vent ? In making this decision it is important to keep in mind that it is desired to cast high-quality products and to be able to monitor the consistency and performance of the process (for repeatability, safety, Statistical Process Control and so on).
To resolve this dilemma, three aspects need to be considered: the technical criterion for the choice, monitoring this criterion, and practical considerations such as reliability and ease of maintenance. These are dealt with respectively in the following sections 3, 4 and 5.

3. TECHNICAL 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 one or two seconds after the piston begins to move). The best way to determine this is to measure it directly, comparing evacuation devices of a comparable size well suited to the casting weight. The appropriate size of the high-speed valve or of the chill vent will be affected by its 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 a valve and a chill vent having the same critical evacuation section, with a machine set up for high vacuum tightness.

VDS has a continuously operable laboratory test bench, which was built to optimise the design of its ProVac® valves and chill vents. The equipment permits the evacuation of gas volumes from 0.1 to 40 litres, and directly measures the pressure in the die cavity as well as that at the valve or chill vent. 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 were used to measure and record the pressures.

In a typical case the tests were made for a 4 kg shot-weight part (evacuation volume of 3 litres), comparing the ProVac® Plus 2000 vacuum valve and the ProVac® chill vent Cv2000, each one having the same critical evacuation section of 60 mm^2. Figure 1 shows the evolution of the measured pressures in this example. The two similar steep curves correspond to the pressures at the vacuum valve and the chill vent, while the less steep curves show the pressure in the die cavity. The pressure in the die cavity is the critical one because it is the determining factor for the quality of the casting.

* In the French language a cornelian choice is a dilemma, a very difficult choice between valid alternatives

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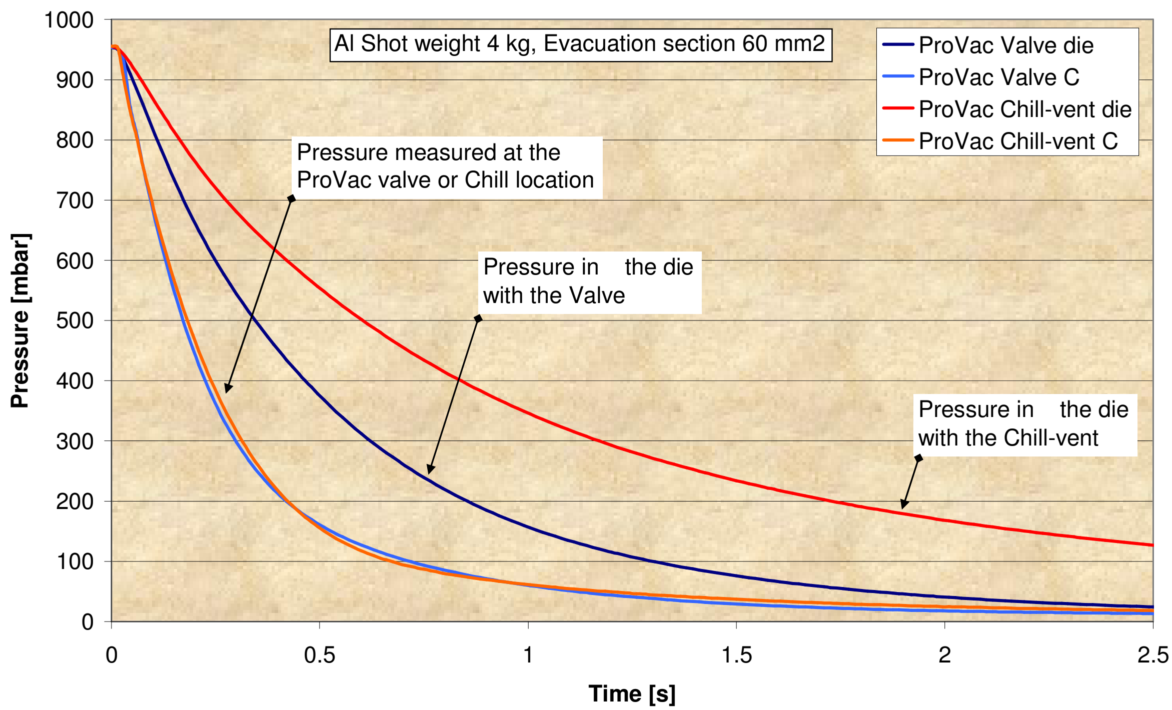

Fig. 1. Pressure with respect to time at entry to the valve and the die for the ProVac® Standard Plus 2000 valve and the ProVac® Cv2000 chill vent, both using the ProVac® PLC-250 vacuum system.

A surprising result

Comparing the performance of the valve and the chill vent, Figure 1 shows that valve evacuates the three litres of gas to achieve a cavity pressure of 100 mbar in just 1.3 seconds, whereas the chill vent has not attained this level of vacuum even after the unacceptably long time over 2.5 seconds. This result is highly significant in relation to casting quality. Notice also that with the valve the die cavity pressure has fallen to 50 mbar after 1.8 seconds.

It is unsurprising that the measurements at the vacuum valve or chill vent (the most usual measurement used to monitor the degree of evacuation for critical parts!) are almost identical.

In a further test, a bigger chill vent was used, the ProVac® Cv3000, with twice the evacuation section of 120 mm^2, and even this took about 1.5 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).

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.

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 (Fig. 2). The clearance between the two half-blocks is narrow (0.5 - 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.

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Fig. 2. The ProVac® Cv1000, Cv2000 and Cv3000 chill vents.

4. PRACTICAL MEASUREMENT OF THE VACUUM

As Figure 1 has shown, it is difficult to predict what is happening into 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 shows approximately the same behaviour for both evacuation devices in spite of huge differences in evacuation performance. So is any measurement possible in practice?

Vacuum measurement in a valve – a valid measurement

The Figure 3 illustrates the method used for pressure measurement at the ProVac® high-speed valve. 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.

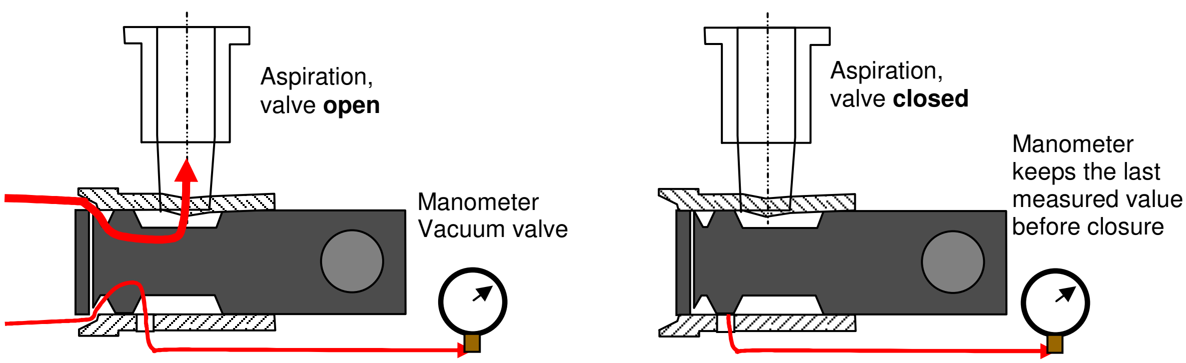

Fig. 3. Pressure measurement for a ProVac® high-speed valve. The aspiration valve is open (left) and closed (right)

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Vacuum measurement in a chill vent - an invalid measurement

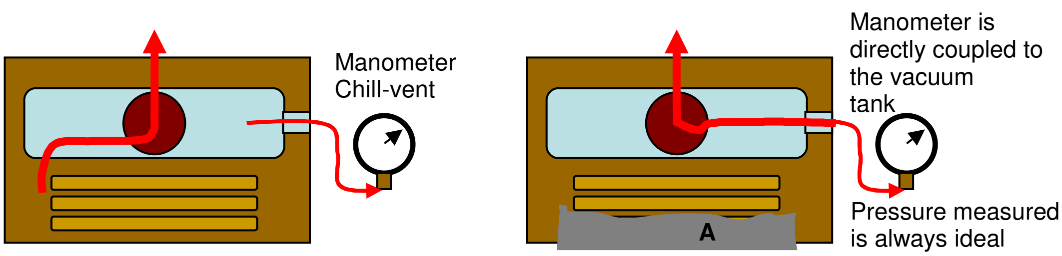

Fig. 4. Pressure measurement for a chill vent. The gap towards the aspiration hole is open (left) and closed by solidified aluminium A (right)

Figure 4 illustrates the method normally used for the pressure measurement at a chill vent. At the moment when the die cavity is sealed off from the vacuum by the solidified aluminium between the two chill vent 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.

5. PRACTICAL CONSIDERATIONS

Cutting the vacuum runners into the die

Adequate vacuum runners must be cut into the die from the casting parts or overflows to the vacuum valve or chill vent. 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 described in Section 3.

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). Acting on the following points will keep long-term maintenance costs low.

Design for low maintenance

i. For easy and quick maintenance, the valve mechanism should be made of a small number of large components
First the parts won't break so easily and second, cleaning will be easier and quicker.

ii. The mechanism should be designed for low friction, with suitable low-wear materials.
Each failure or broken part will increase maintenance costs while also stopping production.

iii. Choose 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.

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iv. Choose valve runners that 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.

Figure 5 show the two half blocks of a vacuum valve. The vacuum channels have been 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.

Fig. 5. The ProVac® Standard Plus 2000 vacuum valve, with the Typhoon vacuum runners

Use operating practices that reduce maintenance

iii. Use 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.

iv. Manage the thermal cycling of the valve as you do 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.

6. SUMMARY OF THE DIFFERENCES

Table 1: This table recapitulates many differences between high-speed valve and chill vent

High-speed vacuum valve	advant -age	Chill vent	advant -age
High evacuation capacity	yes	Reduced evacuation capacity	
Feedback by vacuum measurement	yes	Wrong feedback	
Security excellent if a high security valve is used	yes	Security excellent if process well under control	
"Low" maintenance		"No" maintenance	yes
Low projected surface	yes	High projected surface	
Aspiration check and readiness for the next shot	yes	No readiness check	
Not sensitive to casting parameter increase	yes	Sensitive to high speed increase or other casting parameter increase	
Affordable cost		Low cost	yes
Satisfies all advanced requirements	yes	Does not satisfy all advanced requirements	
Good process repeatability	yes	Limited process repeatability	
High technology		Old technology	

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CONCLUSION

Advanced high security high-speed valve and chill vents are not competing but complementary evacuation devices for helping the die-caster on his way towards high quality and a secure and repeatable die-casting process. With the full knowledge of the facts, particularly giving attention to the drawbacks/advantages listed in Table 1, a chill vent can be used to economic advantage provided that the quality requirements are not very high.

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 only solution.