An Innovative Device for Vacuum and Air Venting

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ABSTRACT

Vacuum technology is widely used in the die casting process to evacuate air from the die cavity, thereby reducing air entrapment and porosity in the casting. A major issue for existing technologies is the reliability of the valve function. An innovative 3-dimensional chill vent type of device named CASTvac is introduced, which overcomes the reliability issues associated with conventional valves. It consists of no moving parts and therefore never fails to close off the vacuum path. It provides a large venting area with a low projected area, and has high evacuation efficiency. This device has been trialed in production machines for extended periods, reliably producing thousands of high quality parts.

1. INTRODUCTION

Die casting is an efficient, economical manufacturing process which is capable of producing high quality, near-net-shape components with excellent surface finish. A major shortcoming is air entrapment which occurs during the highly turbulent metal injection. The entrapped air forms gas porosity or blisters in castings, which can degrade casting quality and make it unsuitable for heat treatment. A solution to reduce the entrapped air is the use of a vacuum system. By the use of a vacuum system, air can be extracted before the metal enters the cavity and therefore the amount of gas entrapped in the castings can be substantially reduced.

Die casting as a process began commercial mass production in the early 1900s. However, large scale use of vacuum technology came in the late 1950s. A simple type of vacuum system, which is still used today, consists of a vacuum valve, a pump and a tank, and is controlled with a PLC. The signal used to trigger the closure of the vacuum valve can be a plunger position or the metal front position. In this system, the vacuum valve is the critical component. It opens to apply vacuum to the cavity and later closes to prevent metal entering the vacuum supply system. Since the cavity filling is very fast, for safety reasons the valve is normally shut off before the metal enters the cavity. As the vacuum source is disconnected due to the closure of the vacuum valve, air can be drawn back through gaps between the dies into the evacuated cavity. Badal et al reported that the leak rate could be as high as 230 mbar/s for the tested die. This leak will decrease the level of vacuum in the cavity and the worst thing is that the gas has no chance to be expelled at this stage since the valve is closed. Thus, from the casting quality point of view, it is ideal to shut off the valve as late as possible, so that the vacuum in the cavity can be maintained at a high level when the cavity filling takes place.

Since the early 1980s, development of more advanced vacuum valves such as GF and Fondarex has occurred. This type of valve is mechanically activated by the metal pressure built up during the final stages of cavity filling. It can keep extracting gases from the cavity until the last instance of the cavity fill. Therefore it is much more efficient than the simple vacuum system mentioned above. Die casting is a very efficient and also a very harsh manufacturing process. It requires the process to be consistent and therefore the mechanical valve must be robust. Any failure of the valve will introduce an additional maintenance cost due to the machine downtime. However, the mechanical valves which currently serve in the industry are prone to malfunction and also have a high capital cost.

Conventional chill vents are commonly used in the die casting industry to ventilate air from the die cavity through a corrugated gap. Typically the gap is less than 1 mm in depth and about 100 mm in width. It can also be used as a vacuum valve when it is connected to a vacuum system. However, its small venting area restricts
its evacuation efficiency. To increase its efficiency it would be necessary to increase the venting cross-section area, i.e. the chill vent has to be made wider. This will however accordingly increase the projected area of the die, therefore increasing the risk of die flash.

2. CASTVAC – A ROBUST AND EFFICIENT VENTING DEVICE

The Cooperative Research Centre for Cast Metals Manufacturing (CAST) and its industrial partner Nissan Casting Australia Pty set up a project called “Vacuum Valve” for short in late 2002. This project was initially aimed at understanding the malfunction problem of a commercial valve used in the plant and later on led to inventing and developing a more robust new type of vacuum valve.

The concept behind the invention is to rotate the face of the conventional chill vent by an angle up to 90 degree, so that the main face of the new vent is nearly perpendicular to the die parting face. By doing so, a limited space can have more chill faces, and the advantage is that the size of the chill face is substantially increased without increasing the die projected area because the major faces are nearly perpendicular to the die parting plane in this invention.

This invention is embodied in the design of a new venting device as illustrated in Fig. 1. A series of this innovative device is named CASTvac. It consists of two halves and each half consists of wedge-shaped inserts as shown in Fig. 1a. When two halves are engaged together as shown in Fig. 1b, it forms a vertically corrugated and horizontally wedge-shaped venting gap. When it is used in the die casting machine, molten metal enters the inlet at the bottom as shown in Fig. 1a, and loses heat while it flows in the gap until eventually solidifying and stopping as it does in the conventional chill vent. Vacuum can be applied through the vacuum ports (one on each side) as shown in Fig. 1b.

CASTvac has the following advantages:

- **Robust.** CASTvac has no moving parts. It will never fail to close off the vacuum path. The mechanical type of valves consists of a complex triggering system and a shut-off piston which can fail due to many uncontrollable reasons. For instance, pre-ingress of metal droplets or flimsy flash metal will jam the piston to be shut off. A fragmented metal flow will result in an insufficient pressure difference for the activation of the triggering system. Industry experience indicates that the unpredictability of the machine stops due to the valve failure induces more frustration than the production interruption itself.

- **Low cost.** Machine time is very costly to the die casting industry. Any machine stoppage will add more cost to the product. The cost is a very crucial issue to die casters in such a competitive environment. Machine stoppage due to failure of a mechanical valve is unavoidable. Furthermore, the moving parts used in the mechanical valve need to be precisely made and very well maintained, leading to high manufacturing and maintenance costs. CASTvac costs are lower because stoppages are rare and maintenance in the tool room negligible.

- **Efficient.** In principle, the evacuation channel of CASTvac is open until the last instance of cavity fill so that a high level of vacuum can be maintained during cavity fill. The cross-sectional area of the venting path is almost 4 times that of a conventional chill vent. As will be discussed later in this paper, CASTvac has been proven to have the same efficiency as the advanced mechanical shut-off valves and is much more efficient than the conventional chill vent.
- **Simple.** A mechanical valve requires a special runner to control the metal flow to avoid a direct impact to the mechanical triggering system of the valve. Fig. 2 lists two examples of the runner design. The problem is that no common rule exists for the design of this kind of runner for different part shapes. In some cases, the shape of the runner is critical to avoid a malfunction of the valve. For a new part, it takes time to get the runner design right. This could make the die casters frustrated for the commitment of the delivery of a new contract. The use of CASTvac can be as simple as the conventional chill vent. No special runner is required.
- **Easy to adapt.** CASTvac is designed as such to fit the same envelop in the die as for the commercial mechanical shut-off valves. Little extra effort is required to substitute the existing commercial valve with CASTvac.
- **Flexible.** CASTvac is made in a modular structure. When one insert is worn out or damaged, only that piece needs to be replaced.

![Fig. 2: Two examples of vacuum runner design for a commercial vacuum valve.](image)

A PCT application has been lodged for this innovation. The patent is held by CAST.

### 3. INDUSTRIAL TRIAL AND BENCH TEST

CASTvac has been trialed in the plant for two types of parts on an 800t machine. Fig. 3 shows CASTvac installed in the die for the first trial. In one trial, CASTvac was continuously run for 1800 shots. The trial was stopped when a sufficient number of sample castings had been produced for quality assessment, and not due to any failure of CASTvac.

![Fig. 3: CASTvac installed in an industrial die for the first trial.](image)

Pressure sensors were installed in the vacuum line to monitor gas pressure in different locations both for the trials of CASTvac and for the normal production using a commercial mechanical valve. Typical pressure changes in the downstream adjacent to the vacuum valves are plotted in Fig. 4. As can be seen in the figure, both valves could quickly achieve a high level of vacuum (0.3 sec in this case) at the measured spot (in principle a high level of vacuum in the cavity as well) and CASTvac performed as well as the mechanical valve.
During the trial, the casting quality was monitored using an in-house X-ray machine. Also all the castings from the trial were sent to the customer for the final quality assessment. The results both from the in-house X-ray inspection and from the customer indicated that in general the casting quality from the trial was the same as that from the normal production using the commercial mechanical valve.

A bench test was conducted to compare CASTvac with a conventional chill vent. Since CASTvac was designed not to fit the same die envelope as the conventional chill vent, the comparison with the chill vent was unable to be carried out in the die as was the case for the commercial vacuum valve. An experimental apparatus was specially built up for this test. It consisted of a vacuum tank (110 liters), a vacuum pump and a vacuum vessel (3 liters) which simulated the die cavity. The conventional chill vent used in this test had a gap dimension of 100 mm in width and 0.6 mm in depth. Fig. 5 shows the pressure changes in the vacuum vessel soon after introducing the vacuum source from the vacuum tank. The result indicates that CASTvac is much more efficient than a conventional chill vent.
It should be emphasized that the objectives for developing CASTvac were not to achieve better casting quality than the commercial mechanical valves, but rather to have a reliable vacuum valve and at the same time produce castings of similar quality. In principle, it shares the same robustness of the conventional chill vent, but it has a more efficient venting capability and consequently could produce better quality of castings.

4. CONCLUSION

An innovative venting device, named as CASTvac, is described in this paper. It consists of no moving parts and is therefore more robust than the mechanical shut-off vacuum valves currently used in the die casting industry. It substantially increases the venting area compared with the conventional chill vent without increasing the projected area of the die. It is simple and easy to adapt to an existing vacuum system, and is flexible for various sizes of parts and machines. It has been trialed in production machines for extended periods, reliably producing thousands of high quality parts. CAST is currently seeking an appropriate commercialization company to take CASTvac to market.

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REFERENCES

1. NADCA: http://www.diecasting.org/faq/
7. InterGuss: http://www.optivent-online.de/