VIRTUALIZATION OF HIGH VACUUM AND HIGH PERFORMANCE HPDC MACHINE FOR TOP QUALITY CASTING

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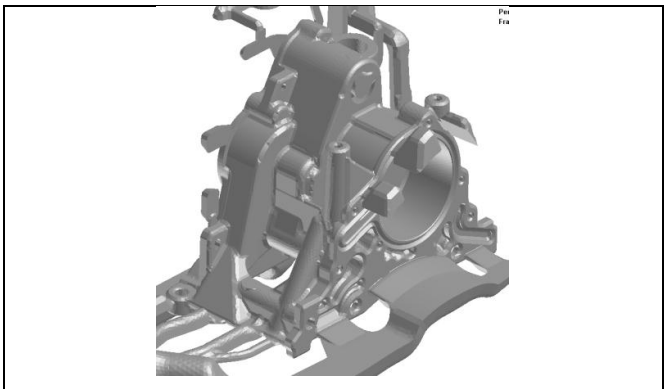
A B S T R A C T

OEM and automotive market is driven foundry suppliers to high performance castings: high structural integrity, high mechanical properties, welding and heat treatment. These requirements are typically obtain with gravity and low pressure die-casting due to HPDC limitations.
HPDC need Heat Treatment T6 and special Al alloy to increase mechanical properties. In case of T6, gas porosity inside the component is forming blisters during solubility heat treatment at 520-530°C for 8-12 hours, decreasing component performances. In case of special alloys, these alloys have high viscosity due to low Si with unfilling problems that decrease component mechanical properties.
First point is that only with HIGH VACUUM technology is possible to cast structural parts and cast components with T6 and special alloy. Vacuum technology has increased its performances in these last years to offer two levels of vacuum: standard vacuum and high vacuum. Today the innovation is HIGH VACUUM.
Second point is the request of high performance HPDC machine (DCM). The integration between machine and Vacuum grants top quality casting. This mean a gas evacuation curve that is in phase with the injection curve with the flow rate control of both aluminum and air.
Third point is the virtualization of HIGH VACUUM and DCM. Virtualization means to do a simulation of HPDC process. Usually simulation is used to define the design of the die with the best gating system and evacuation lay-out. All these conditions are finally used with right process parameters cheeked with the software. For the first time the virtual machine has been simulated with virtual close loop and with finite power.
This paper has the aim to present the last developments in technology of HIGH VACUUM and DCM using a new virtualization approach in casting simulation software. The current state-of-art of application will be presented.
KEYWORDS: HPDC, CASTING SIMULATION SOFTWARE, VACUUM DIE CASTING, DCM, MACHINE

OIL PUMP: FROM 1 TO 2 CAVITIES WITH A DCM FROM 560T to 750T

This paper is showing the application of the new approach of Virtualization of Die Casting Machine, now called V-DCM (Virtual-DieCasting Machine). Virtualization means to do a simulation of HPDC process. Usually simulation is used to define the design of the die with the best gating system and evacuation lay-out. All these conditions are finally used with right process parameters checked with the casting simulation software without considering real DCM hydraulic injection force. For the first time the DCM has been introduced in ProCAST casting simulation software with virtual close loop and with finite power.
This innovation has been applied on the real case: automotive oil pump casted by FAR foundry in Italy.



Automotive oil pump, HPDC, EN AC46100 AlSi11Cu2(Fe)

This new Virtual approach has been mandatory to response to FAR foundry necessity to reduce cost production of this OEM oil pump thanks to the switching from 1 cavity to 2 cavities die.
One cavity die was used on PFO 560. Standard approach using the empirical injection nomogram on Flowrate and Injection Pressure had showed the necessity to use a DCM of 1000t-1200t. Colosio DCM portfolio has PFO560, PFO750, PFO1000 and PFO1200. In the first step FAR has selected a DCM PFO 1000 instead of PFO 1200.

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The challenge of FAR technical and management team has been to develop the project of this new 2 die cavities on DCM PFO 750 and not for PFO 1000.
See energy cost consuming for these 3 DCM:

COLOSIO DieCastingMachine - DCM	PFO 560	PFO 750	PFO 1000
Electric energy consumption	21 kWh	30 kWh	45 kWh
Benchmark on electric energy cost per year 0.14€/h; 16 hours per day 252 working days on year 2016	11'800€/y	16'900€/y +5'100€/y; +43% ---	25'400€/y 13'600€/y; +115% **+50% of PFO 750**
Benchmark on DCM Price	Confidential	Confidential	**+25% of PFO 750**

Moreover FAR has selected PFO 750 Green Line instead standard machine with inverter to minimize cost.
COLOSIO has developed a special line of DCM, called Green Line, to reduce energy cost and increase DCM efficiency.

PFO 750		PFO 750 Green Line
An engine controlled by inverter works in a range from 800 to 1'500 rpm.		A pure efficiency system with Brushless engine works in a range from 40 to 1'500rpm
Electric Energy consumption	21 kW/h	10 kW/h
Benchmark on Electric Energy cost per year	16'900€/y	5'600€/y; -11'300€/y **-66% of PFO 750 standard**

The original die with one cavity was with FONDAREX Vacuum to solve gas porosity problems and to reduce injection force requested to DCM thanks to strong reduction of air counter-pressure during filling. FAR decided to use Vacuum also on two cavities die because mandatory to reach final quality.

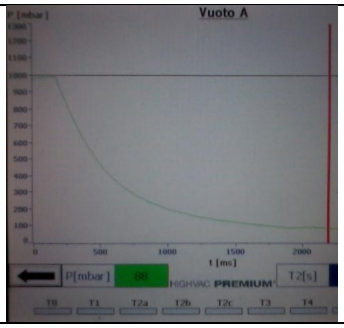
1 cavity die, PFO 560, Fondarex Vacuum

2 cavities die, PFO 750, Fondarex Vacuum

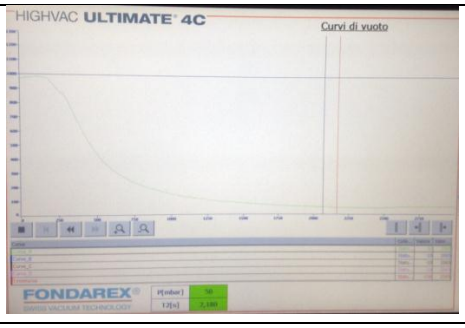
Automotive oil pump casted by FAR Italy

In last 3 years has appeared a new concept of vacuum: High Vacuum.
This mean that vacuum system performances are focus on:

1. High control of evacuation curve
2. Minimum residual pressure inside cavity, around 40-60mbar
3. Maximum quantity of gas and air evacuated by cavity, around 95% of total nominal volume
4. High efficiency of evacuation system design simulated by ProCAST casting simulation software



Vacuum: residual pressure in cavity 88 mbar



High Vacuum: residual pressure in cavity 50 mbar

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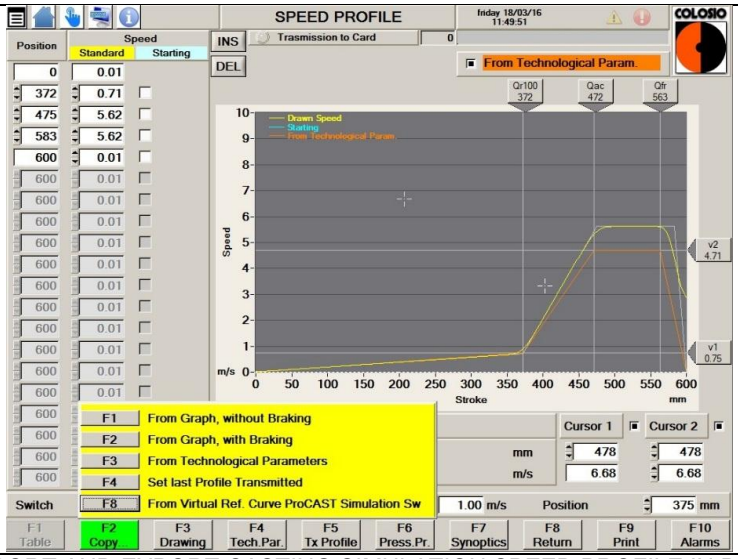
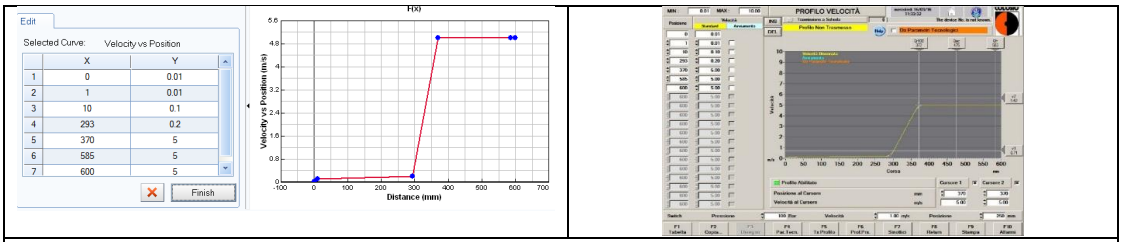
	High Vacuum 8 dm^3 evacuated gas on 8.4 dm^3 nominal Efficiency 96%

VIRTUALIZATION OF HIGH VACUUM AND DCM

HPDC market have the right devices and technologies to produce high performance parts, but there was a missing for casting simulation software to take into account real DCM performance.
ECOTRE and ESI join to develop a new tool in ProCAST casting simulation software: the V-DCM, Virtual-DieCastingMachine, to check if DCM has enough hydraulic injection force to fill die cavity maintaining the second phase velocity imposed to grant the right filling time. The hydraulic injection force calculated by ProCAST takes into account geometrical and gas counter-pressure inside the chamber and cavity, that oppose high resistance to part filling. A fully integrated simulation with hydraulic power machine virtualization and with vacuum machine virtualization has been done.
All real DCM technical datasheet has been introduced in casting simulation software ProCAST: Hydraulic Injection Force, Hydraulic Cylinder Diameter, Hydraulic Inline pressure…
Speed and pressure profile have been virtualized and now is possible to import the best injection profiles from casting simulation software into DCM PLC system.



IMPORT AND EXPORT CASTING SIMULATION SPEED PROFILE IN DCM
F8 allows to import ProCAST simulation profile



SPEED PROFILE INTEGRATION BEETWEEN VIRTUAL ProCAST AND REAL COLOSIO
Profile is define with plunger position [mm] and speed [m/s] (see first and second column on left)

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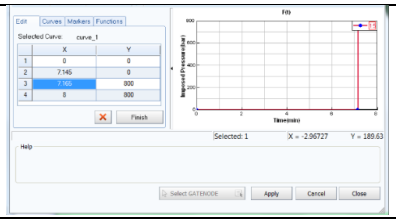
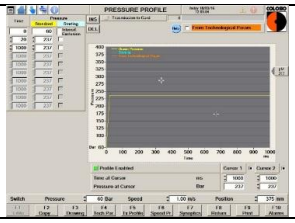
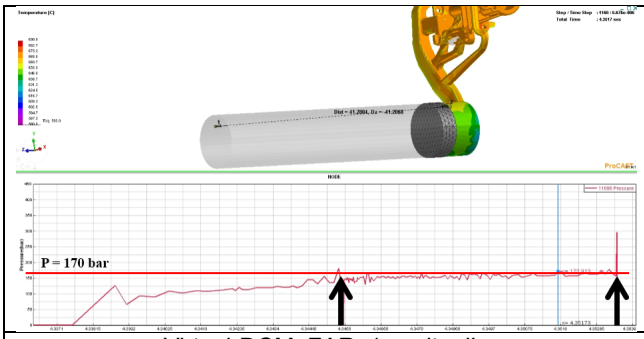




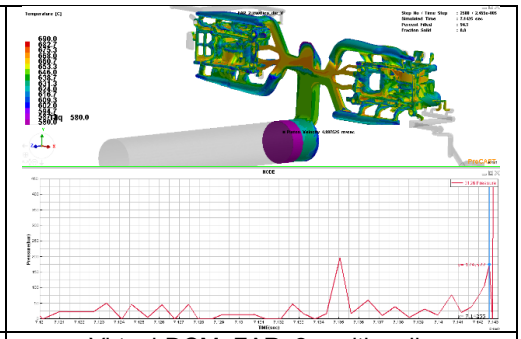
PRESSURE PROFILE INTEGRATION BEETWEEN VIRTUAL ProCAST AND REAL COLOSIO
Velocity profile switch into pressure profile at a reached pressure; after pressure is function of time

Casting Simulation Software calculate real time pressure and injection force requested to DCM to maintain the imposed plunger velocity. This calculated value is compared with the power limit of DCM.

Next pictures are showing the virtualization of DCM in ProCAST. It is interesting to see that at 412mm plunger stroke the requested pressure is 172bar, bigger than limit of 170bar. This mean that plunger velocity decrease for some milliseconds of filling.



Virtual-DCM. FAR, 1 cavity die
Blue line 4.351s: Plunger stroke 412 mm, requested pressure 172 Bar, max pressure available 170 Bar
ATTENTION: DCM hasn't enough power
plunger velocity decrease



Virtual-DCM. FAR, 2 cavities die
Blue line 7.142s: Plunger stroke 537 mm, requested pressure 177 Bar

CONCLUSION

The real and virtual pressure graphs are showing that requested pressure by DCM and V-DCM is changing real time as the plunger advance.

All empirical evaluations of discharge coefficient without simulation that are done to choose the size of DCM are far to satisfy foundry request on cost reduction and casting quality, like shown for this FAR foundry case.

Thanks to this new tool it is possible to optimize gating and evacuation system to use less hydraulic injection force.

Usage of vacuum system reduces requested hydraulic injection force.

Casting Simulation software is the best way to check which is the right DCM to produce casting. After 30 years of casting simulation software without take into account the DCM power, now DCM has been virtualize.

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