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Porosities Comparison between Production and Simulation in Motorcycle Fuel Caps of Aluminum High Pressure Die Casting

P. Meethum, C. Suvanjumrat

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***Abstract*—**Many aluminum motorcycle parts produced by a high pressure die casting. Some parts such as fuel caps were a thin and complex shape. This part risked for porosities and blisters on surface if it only depended on an experience of mold makers for mold design. This research attempted to use CAST-DESIGNER software simulated the high pressure die casting process with the same process parameters of a motorcycle fuel cap production. The simulated results were compared with fuel cap products and expressed the same porosity and blister locations on cap surface. An average of absolute difference of simulated results was obtained 0.094 mm when compared the simulated porosity and blister defect sizes on the fuel cap surfaces with the experimental micro photography. This comparison confirmed an accuracy of software and will use the setting parameters to improve fuel cap molds in the further work.

***Keywords*—**Aluminum, die casting, fuel cap, motorcycle.

I. Introduction

A high pressure die casting (HPDC) is a favored methodology which produced aluminum parts for a motorcycle [1]. Some parts have a thin and complex shape therefore these parts may be occurred porosities and blisters on its surface cause of the impracticable mold design [2], [3]. Fuel caps are the motorcycle part which has the thin and complex shape. Production of these parts was required the best surface quality which depended on a good HPDC mold. If the cap's mold is design depending on experiences of mold makers the porosity and blister may occur which not know in advance. Finally, waste of aluminum from the HPDC process will be obtained unavoidably.

Nowadays computer aided engineering (CAE) is an advantage in production technology for the HPDC process. The porosity could assume by the numerical analysis for the gas entrapment defect in HPDC parts [4]–[7]. Reduction of porosities in parts could perform by simulation to improve runner and the gating system design of the HPDC mold before production [8], [9]. The gas entrapment in HPDC parts could simulate to predict porosities in many literatures with the CAE software. However, it could not specify locations and sizes of porosity on the surface of HPDC parts.

P. Meethum is with Department of Mechanical Engineering, Faculty of Engineering, Mahidol University, Salaya, Nakorn Pathom 73170 Thailand (e-mail: wichaman_53@hotmail.com).

C. Suvanjumrat is with Department of Mechanical Engineering, Faculty of Engineering, Mahidol University, Salaya, Nakorn Pathom 73170 Thailand (corresponding author phone: 662-889-2138 ext. 6416; fax: 662-889-2138 ext. 6429; e-mail: chakrit.suv@ mahidol.ac.th).

This research attempted to specify porosities with locations and sizes. CAST-DESIGNER software was used to simulate the HPDC process for the motorcycle fuel cap production. The simulated results were compared with experiments and evaluated the software accuracy. The method which received from simulation of the HPDC process will be used to improve fuel cap parts of motorcycle for better surface quality.

II. Experimental Methodology

Fuel caps are performed using the HPDC process under parameters which are described in Table I. The die casting machine model TOYO-350T was employed to cast parts with melted aluminum. The horizontal cold chamber was a casting machine type. An example of a HPDC part to produce motorcycle fuel caps with the machine is shown in Fig. 1. Some features of the HPDC part such as vent components were broken while removing it from the HPDC mold therefore the HPDC part not had the completely component as same as a die cavity. Small porosities were observed on surface of fuel caps. The quantity of porosities appeared nearly a keyhole were more than another area of a motorcycle fuel cap. Subsequently the interested porosities on a left side cap of a symmetry HPDC part were closed by circles for expansion with the scanning electron microscope (SEM). Micrographs of porosities in circles at A-, B- and C-location are shown in Fig. 2. The defect areas were estimated by multiplying length and width which measured from micrographs. The areas of porosity were 0.022, 0.019, 0.013 mm^2 for A-, B- and C-location, respectively. In the meanwhile a maximum size of porosities was measured and comprised of 0.278, 0.374 and 0.188 mm for A-, B- and C-location, respectively. The biggest size of porosities occurred on B-location but the largest area occurred on A- location. However the cause of porosities in these locations was expected from the air entrapment.

TABLE I
High Pressure Die Casting Process Parameters

Description	Quantity	Unit
Accumulator	12.00	MPa
Instant's Accumulator	10.50	MPa
Injection Low Speed	0.36	m/s
Injection High Speed	2.30	m/s
Cast Press	90.00	MPa
Injection High Speed Stroke	40.00	mm
Biscuit Thickness	15.00	mm
Cooling Time	<15	sec
Aluminum Temperature	670	°C

Fig. 1 A HPDC part for motorcycle fuel caps

III. THE HPDC SIMULATION

A cavity of a HPDC part for producing motorcycle fuel caps in the previous section was modeled using computer aided design (CAD) software which was SolidWorks version 2011. The 3D-model of the fuel cap cavity comprises of a sprue, runners, gates, ingates, overflows, and vents as shown in Fig. 3. Subsequently, the cavity model was exported for the standard file to use in the computer aided engineering (CAE) software–CAST-DESIGNER software. Therefore the standard file which was a .stp file imported into the CAST-DESIGNER software to create elements. The 392,140 hexahedral elements are used to divide the cavity model and the generated result of finite element model (FEM) is shown in Fig. 4. The maximum size of elements was 1.0 mm. The fine element or mesh which had size about 0.7 mm was controlled to locate around the keyhole of the motorcycle fuel cap.

The numbers of hexahedral elements which used in this research were tested with the mesh divergence. The material property of melted aluminum was defined into the FEM as same as the experiment. Boundary conditions such as the injection high speed and the aluminum temperature were specified on the FEM according to the HPDC process parameters (Table I). Thermal properties of the HPDC mold and melted aluminum are described in Tables II and III, respectively [10]. The personal computer with Core-i5 CPU and 4 GB of RAM memory was used to perform the HPDC simulation.

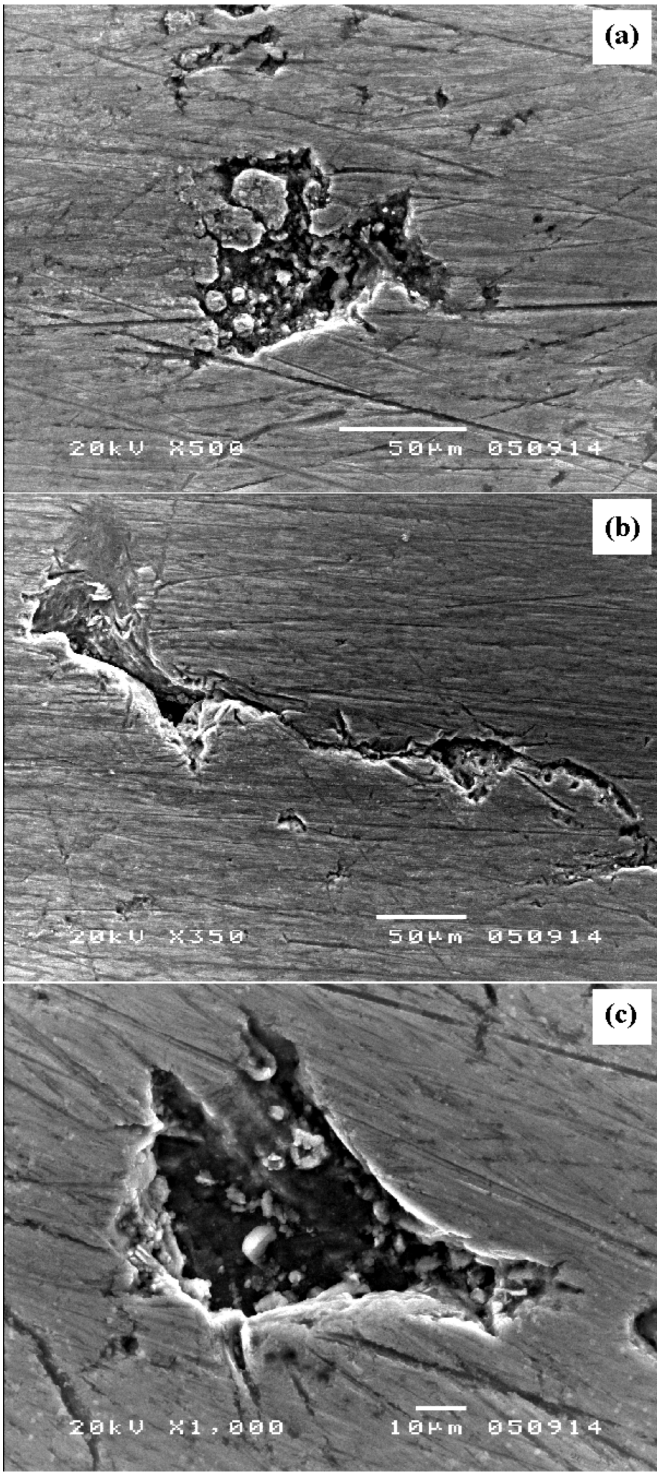

Fig. 2 Micrographs of porosities on: (a) A-location (b) B-location and (c) C-location of a motorcycle fuel cap

TABLE II
THERMAL PROPERTIES OF THE HPDC MOLD

Description	Quantity	Unit
Density	8.03	kg/m^3
Specific Heat Capacity	502	J.kg/°K
Heat Conductivity	15.10	W/(m°K)
Initial Temperature	225	°C

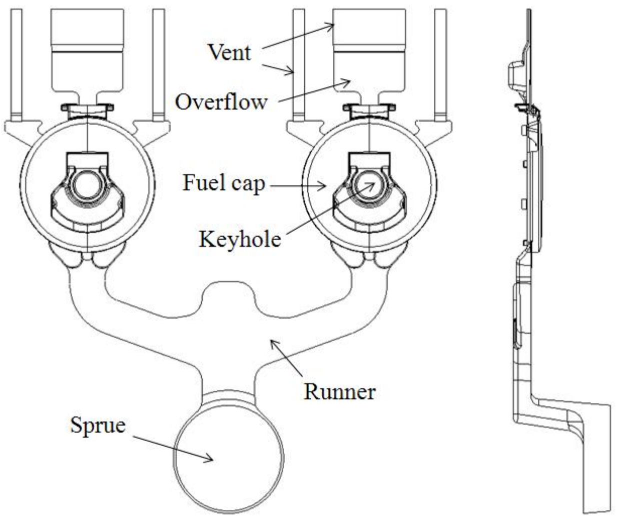

Fig. 3 Components of cavity of a HPDC part for two motorcycle fuel caps

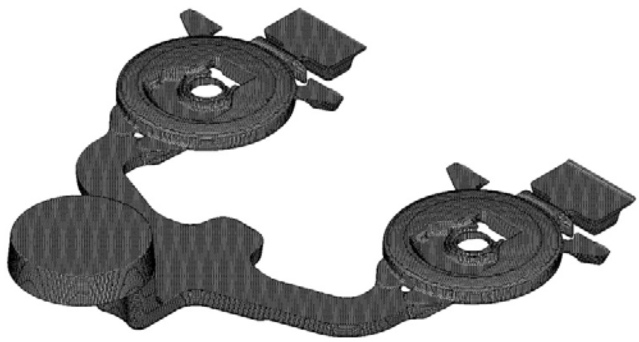

Fig. 4 Finite element model of a HPDC part cavity for two motorcycle fuel caps

TABLE III
THERMAL PROPERTIES OF MELTED ALUMINUM

Description	Quantity	Unit
Density	12.00	kg/m^3
Specific Heat Capacity	10.50	J.kg/°K
Liquidus	613	°C
Solidus	427	°C
Heat Conductivity	121	W/(m°K)
Latent Heat	390	kJ/kg
Aluminum Temperature	660	°C

IV. RESULTS AND DISCUSSION

The simulation results of mold filling are shown in Fig. 5. Pattern of the melted aluminum flowing into the mold cavity could be observed by the sequence images. The melted aluminum flow from sprue and separated into each runner which flow into the motorcycle fuel cap and passing through overflows and vents, respectively. Velocities of melted aluminum flow were depicted by the color contour. The maximum velocity was depicted by red. In converse manner the minimum velocity was signified by blue. The melted aluminum flow with the velocity about 20.24 m/s inside runners and crushed with the keyhole surface. The space of fuel cap cavity which the melted aluminum could not fill occurred at the injected time of 0.024 sec nearly the keyhole. The circular surface of the keyhole obstructed flowing path of the melted aluminum. Therefore the back of circular obstacle often was an unfilled position. This phenomenon was known as the air entrapment which induced the porosity in motorcycle fuel caps.

The porosity defects can simulate and illustrate with a result after the HPDC part is fully filled as shown in Fig. 6. Points of the final porosity were indicated by black color. The simulated locations of porosity had a good agreement with experiments. The A-, B- and C-location had the maximum size of 0.430, 0.327 and 0.270 mm, respectively. Note that the porosity must occur inside the overflow which was an important effect for releasing gas out from motorcycle fuel caps and for the good quality of fuel cap surface. The maximum size of porosities was compared between experiments and simulated results which described in Table IV. Sizes of the simulated porosity were close to the experiments.

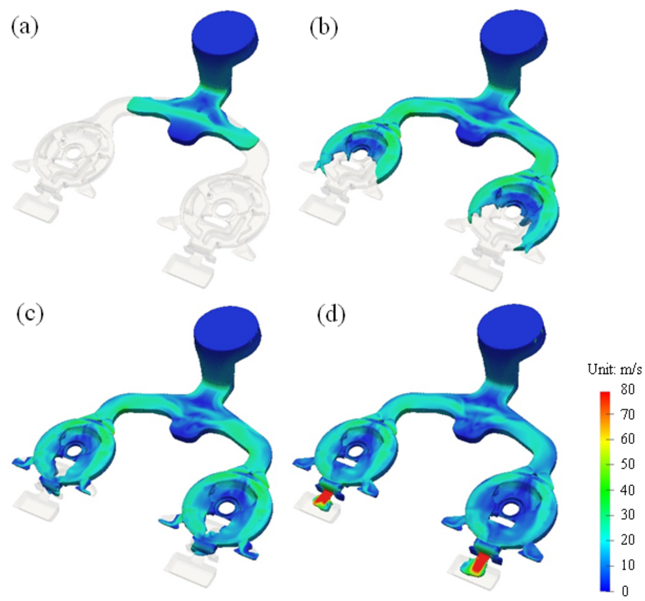

Fig. 5 Sequential images of melted aluminum flowing into the mold cavity at (a) t = 0.015 sec, (b) t = 0.021 sec, (c) t = 0.024 sec and (d) t = 0.025 sec

TABLE IV
COMPARISON OF POROSITIES

Location	Porosity size (mm)		
	Experiment	Simulation	Difference
A	0.278	0.430	-0.152
B	0.374	0.327	0.047
C	0.188	0.270	-0.082

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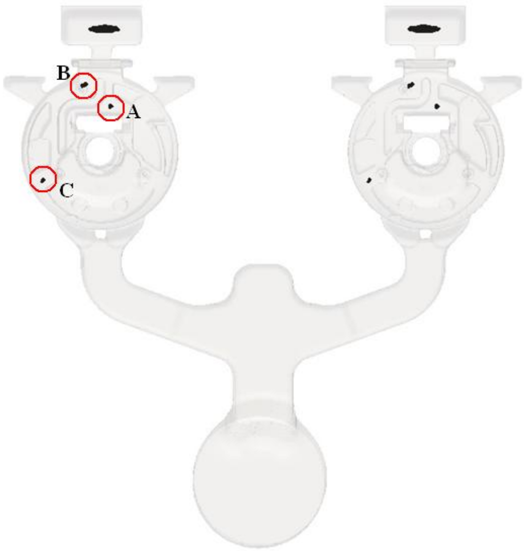

Fig. 6 Locations of porosity in the HPDC model

V. CONCLUSION

The high pressure die casting (HPDC) process was performed to produce the aluminum fuel caps which were the motorcycle part. Fuel caps had a thin and complex shape therefore these parts were risk to occur porosities and blisters on surface cause of the impracticable mold design. Small porosities were observed on surface of fuel caps nearly the keyhole. The defect areas and sizes were measured in the micrographs which obtained from the scanning electron microscope (SEM).

CAST-DESIGNER software which is the computer aided engineering (CAE) software was used to simulate the HPDC process. The material property of melted aluminum was defined into the finite element model (FEM) as same as the experiment. Boundary conditions of FEM were also defined according to the HPDC process parameters. The simulation results of mold filling could investigate by illustration of melted aluminum flowing. The circular surface of the keyhole of fuel cap obstructed flowing path of the melted aluminum. Therefore it induced the porosity occurring in motorcycle fuel caps.

The porosity defects could simulate and express by simulated results. Locations of porosity had a good agreement with experiments. The maximum size of simulated porosities was compared with experiments which had the average of absolute difference of 0.094 mm. The comparison confirmed an accuracy of software therefore the setting parameters of the HPDC simulation will be used to improve fuel cap molds in further works.

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Piyanut Meethum received the B.Eng. degree in mechanical engineering from Mahidol University, Nakorn Pathom, Thailand in 2012. She is currently working for toward the M.Eng. degree in mechanical engineering at Mahidol University. Her research interests in CAD/CAE for the high pressure die casting process.

Dr. Chakrit Suvanjumrat received the B.Eng. degree in mechanical engineering from Price of Songkla University, Songkhla, Thailand, in 1995. He received the M.Eng. and D.Eng. degree in mechanical engineering from Kasetsart University, Bangkok, Thailand, in 2003 and 2009, respectively. He is currently an Assistant Professor at Department of Mechanical Engineering, Mahidol University, Nakorn Pathom, Thailand. The laboratory of computer mechanics for design (LCMD) is his research laboratory. His research interests include finite element analysis, computational fluid dynamics, fluid structure interaction, product design and machine design.