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Plastic Injection Molding using CAD/CAE Integration

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Abstract

An injection molding process is necessary to model the parts and molds using CAD software. To perform the full filled parts, CAE software has been exploited thoroughly in design the optimize gate and runner systems. The data of models need to transform between CAD and CAE software. This method is extremely time-consuming and prone to error when models are complicated. Coupling CAD/CAE system in plastic injection analysis is one of the ways to save time and cost. This research proposed technique using the CAD/CAE integrated software to design the injection parts and mold based on the full filled condition. The multi core-cavity system was the best choice of design and analysis. The propose technique was validated by creating an injection mold and parts according to the CAD/CAE integrated results. The CAD/CAE integration could reduce the computing cost and was obtained an average error of 5.82 % when compared the dimensions of parts with the CAD model.

Keywords: Plastic, Injection, Molding, CAD/CAE, Integration.

1. Introduction

The injection molding process is carried out in three stages: 1) filling, 2) packing and 3) cooling. A melted polymer fills the part cavity, moving through the sprue, runners and gates during the first stage. The second stage, the additional melted polymer enters the cavity to balance the part shrinkage caused by cooling of the third stage [1]. The quality of injection molded products may be characterized in terms of dimensions and properties. Products are designed by experience and experiment then are not more powerful than a product is designed by numerical simulations. The Computer Aided Design (CAD) software and Computer Aided Engineering (CAE) software are the powerful tool to speed-up the product development cycle, reduce activities links with experimental tests and mold fabrication [2-6]. The CAD and CAE software use different models to describe a design and they run under their own environments. The optimal design of an injection mold is performed by trading solution to adjust design parameters manually. When models are complicated, this method is extremely time-consuming and prone to have the product dimensional errors. The CAD/CAE integration was employed CAD features to CAE analysis for injection molding analysis and design [7-10]. This software compensated for a lack of transfer data between CAD and CAE software. The earlier CAD/CAE integrated software is TopSolid'CAD and TopSolid'PlasticFlow. TopSolid'CAD software includes CAD to model products and TopSolid'PlasticFlow software includes CAE to analysis plastic flow into the part cavities. The iterative analysis is performed to optimize the plastic injection molding conditions to finally produce the plastic parts.

2. Experimental Methodology

This research carried out parts of a company producing plastic products. The functional requirements for the plastic component were related to respecting strict tolerance for the final assembly with the other parts of the complete product.

2.1 CAD/CAD integrated injection molding design and analysis

The part was modeled using TopSolid'CAD and then selected CAD model by TopSolid'PlasticFlow to define a gate location at the surface part (Fig. 1). Definition of the parting plane and mold cavities are pre-requisites to be satisfy before the filling analysis can be carried out. The parting plan was located by the x-y plane at the z-level was zero for equally dividing part cavities. The numbers of cavities was eight for obtaining the highest production for the possible mold dimensions. The feeding system was employed sprue, runner and gate. Fig. 2

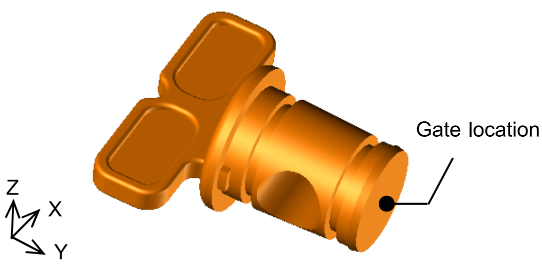

Fig. 1 CAD model of a reference part

shows the parting plan and the feeding system of the injection molding design. The mold components also were design using TopSolid'CAD software. Fig. 3 shows the 3D-model of an injection mold.

2.2 Injection mold manufacturing and fitting

The CAD model of injection mold was transform to G-code for machining all components

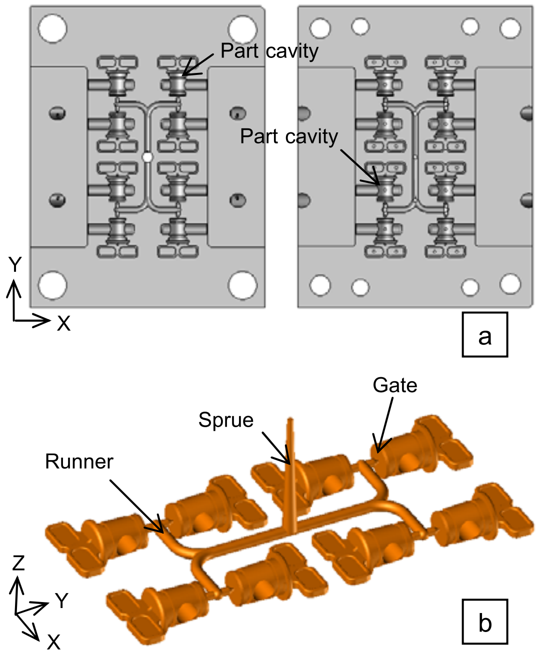

Fig. 2 CAD models of: (a) parting plan with cavities and (b) patterned parts with sprue, gate and runner

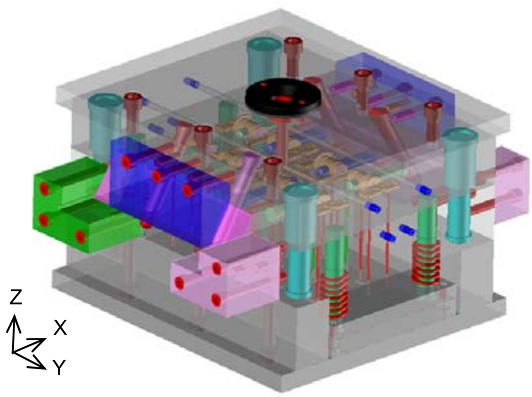

Fig. 3 CAD model of an injection mold

using TopSolid'CAM software. The material utilized for mold components was selected as AISI-P21 steel. Some machines such as CNC milling, EMD machine, drilling and grinding were employed for fabricating the mold components. Subsequently, an injection mold was set up with the plastic injection machine, Model HTF1600; HAITAI; China, as shown in Fig.4. The specifications of injection machine are described in Table. 1.

Table. 1 The technical data of a plastic injection machine (Model HTF1600; HAITAI; China).

INJECTION UNIT		
Screw diameter	mm	35
Screw L/D ratio	L/D	22.8
Shot volume (theoretical)	cm^3	182.4
Injection weight (PS)	g	166
Injection rate	g/s	134
Injection pressure	MPa	292.3
Screw speed	rpm	260
CLAMPING UNIT		
Clamp force	kN	1600
Open stroke	mm	435
Space between tie bars (W*H)	mm	460*460
Max. Mold height	mm	520
Min. Mold height	mm	180
Ejector stroke	mm	135
Ejector force	kN	50
OTHERS		
Max. Pump pressure	MPa	16
Pump motor power	kW	22
Heating Power	kW	13.6
Oil tank Cubage	L	380

2.3 Plastic injection parameters

The material of parts was Polyoxymethylene (POM), grade Derlin 900P NC10, and its properties are shown in Table. 2. In this research, plastic injection process parameters such as the mold temperature, melt temperature, injection pressure, injection time and cooling time were employed both of TopSolid'PlasticFlow software and an injection machine as shown in Table. 3. The filling analysis of CAD/CAE integration was validated by the plastic filling results in the period of injecting time of 2.1, 4.1, 6.1 and 7.5 sec, respectively.

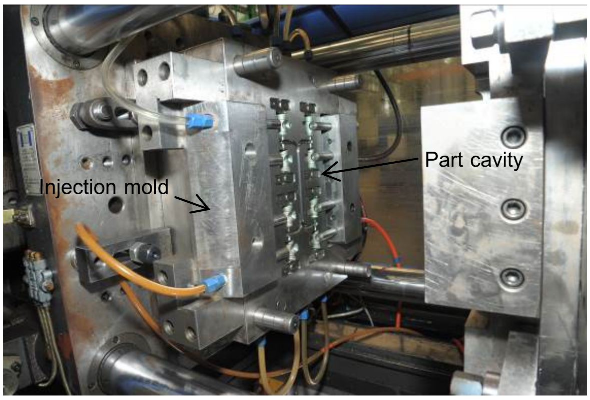

Fig. 4 Mold installation with the HTF1600 HAITAI injection machine

Table. 2 Properties of Polyoxymethylene grade Derlin 900P NC10

PHYSICAL PROPERTIES		
Density (Solid)	g/cm^3	1.42
Density (Melt)	g/cm^3	1.16
Water absorption		
- Equilibrium 50%RH	%	0.26
- Immersion 24 hr	%	0.56
- Saturation, immersed	%	1.4
Linear mold shrinkage	%	1.9
Max. shear stress	MPa	71
Melt flow	g/min	21
THERMAL PROPERTIES		
Melting point	^{o}C	210
Specific Heat	$J/Kg/^{o}C$	3,020
Thermal Conductivity	$W/m/^{o}C$	0.15

Table. 3 Injection parameters

Heater setup	°C	175-215
Position screw setup	g/min	10-115
Max. pressure	bar	300
Filling time	sec	7.5
Packing time	sec	3.5
Cooling time	sec	30-45

3. Results and Discussions

3.1 Plastic filling results

The validation of model with the experiments was needed to confirm the simulated results. The filling process were stopped at four differ step in time and obtain flow fronts were compared. Fig. 5 illustrates the simulated results obtain for filling times of 2.1, 4.1, 6.1 and 7.5 sec, respectively. These results show the flow path of plastic through the cavities by plotting contours. These contours were displayed in a range of colors from red, to indicate the first region of fill, through to blue to indicate the last region to fill. The part cavities that not filled would be displayed as translucent. The plastic injection results of experiments accorded to the filling simulations are shown in Fig. 6. The volume of plastic in cavities of model was in agreement with the experimental test results.

3.2 Dimensions of parts

The measurements of dimensions of plastic part were performed to check the temperature effect from the injecting process. The filling time of injection process of 7.5 sec induced the shrinkage occurring on part surfaces caused of the temperature on the part surface was cooled down. TopSolid'PlasticFlow was used to determine the temperature on the surface of model. The red color indicated the hot surface of plastic parts as shown in Fig. 7. The sections x-x and y-y of model had diameters of 23.00 and 21.50 mm, respectively (Fig. 8). The plastic parts

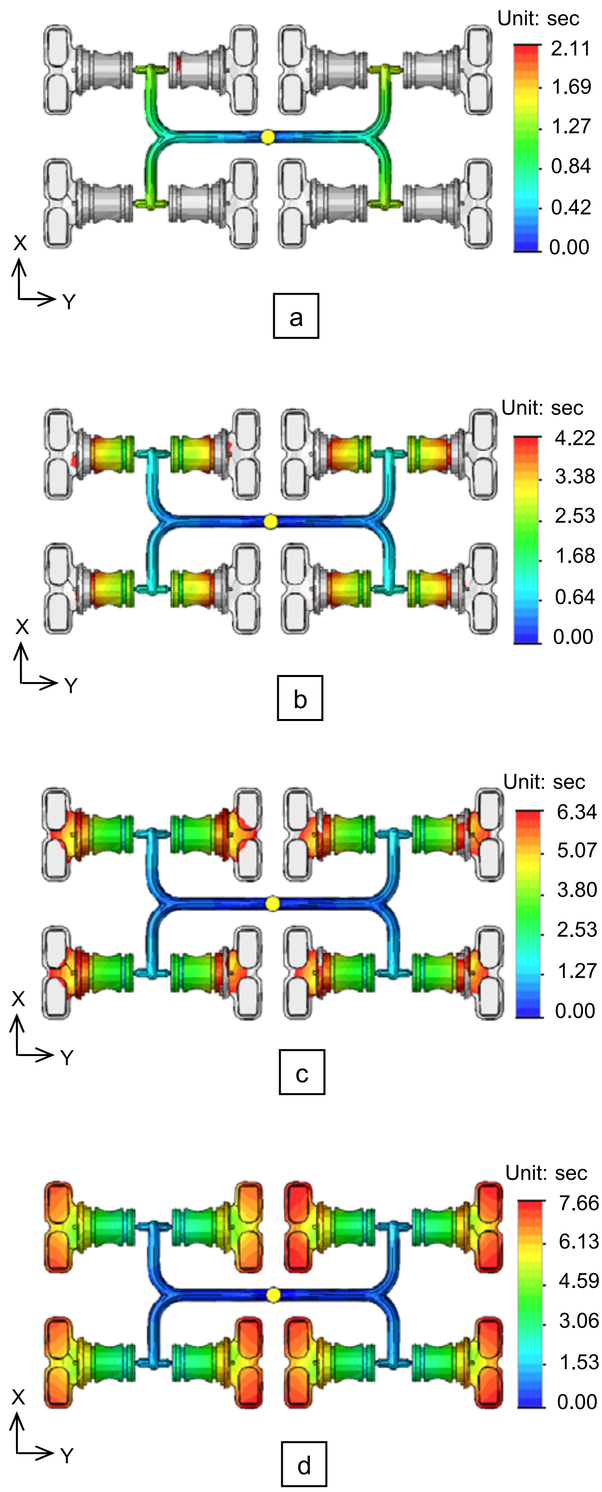

Fig. 5 The filling results of simulation at times of: (a) 2.1 sec, (b) 4.1 sec, (c) 6.1 sec and (d) 7.5 sec

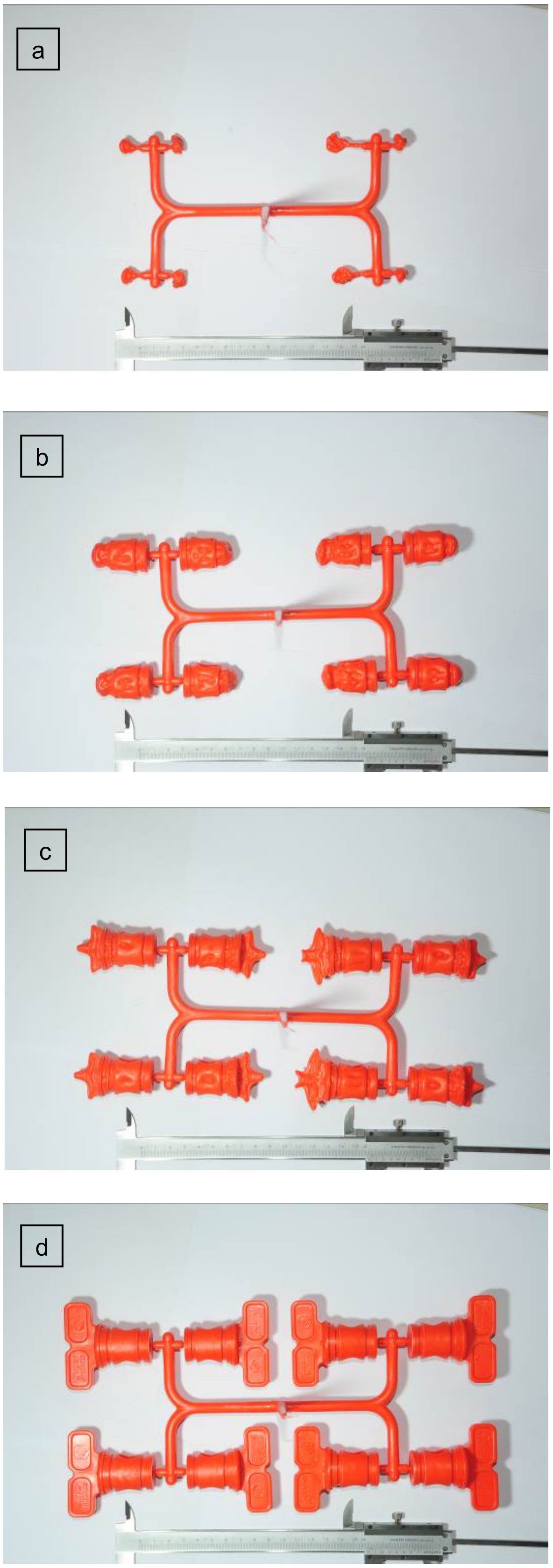

Fig. 6 The filling results of experiments at times of: (a) 2.1 sec, (b) 4.1 sec, (c) 6.1 sec and (d) 7.5 sec

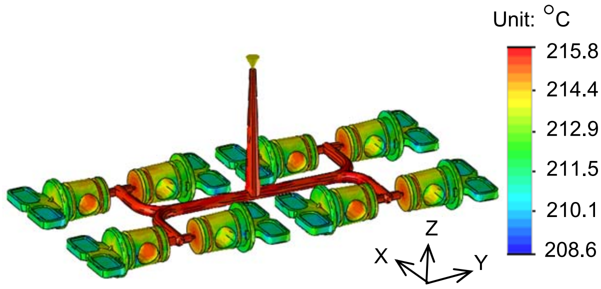

Fig. 7 The temperature result on the part surface

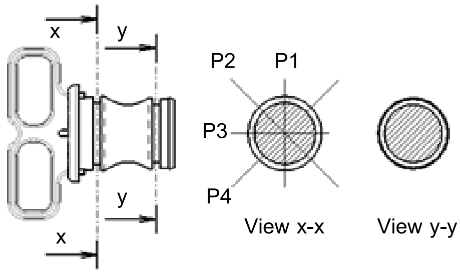

Fig. 8 Points of measurement on the part surface

might be deformed because the temperature reducing occurred on these areas, then the diameter of these sections had to measure. Every 45° around circumference of sections x-x and y-y were specified point P1, P2, P3 and P4 for measuring. The device as MicroScribe G2X was used to perform the measurements. The measurement results are shown in Tables 4 and 5 for section x-x and y-y, respectively. The average errors of section x-x and y-y diameter were found to be 6.34% and 5.30%, respectively.

4. Conclusions

In this study, the injection molding process was started by creating a 3D-model of plastic part. The filling analysis based on CAD/CAE integration was used to determine the optimal injection system without lack of model data. The multi core-cavity system was the best choice of design and analysis. Particularly, the cost of time for transforming CAD model to CAE analysis was

Table. 4 Diameters of section x-x

NO.	Diameter of section x-x				
	P1	P2	P3	P4	Avg.
1	22.12	21.26	22.14	21.93	21.86
2	22.21	22.10	22.15	21.95	22.10
3	22.21	22.09	22.18	22.13	22.15
4	22.02	22.03	21.96	21.78	21.95
5	21.54	21.35	21.81	21.54	21.56
6	21.95	22.09	22.04	22.21	22.07
7	21.71	21.56	21.78	22.03	21.77
8	21.94	21.96	21.91	21.94	21.94
9	22.01	22.39	22.23	22.15	22.20
10	21.82	21.57	21.48	22.05	21.73
11	21.65	21.38	22.26	22.22	21.88
12	21.59	21.48	21.52	21.45	21.51
13	22.11	22.06	22.15	22.05	22.09
14	21.47	21.60	21.27	21.68	21.51
15	22.01	21.53	22.07	22.17	21.95
16	21.58	21.58	21.89	21.63	21.67
17	20.85	20.96	20.85	20.84	20.88
18	20.96	20.85	21.20	20.94	20.99
19	20.79	20.83	20.74	20.64	20.75
20	20.85	20.76	20.82	20.78	20.80
21	20.95	20.84	20.79	20.90	20.87
22	21.20	21.36	21.05	21.45	21.27
23	20.94	20.86	20.79	20.73	20.83
24	20.76	20.65	20.59	20.49	20.62
			Average		21.54

Table. 5 Diameters of section y-y

NO.	Diameter of section y-y				
	P1	P2	P3	P4	Avg.
1	20.11	20.19	20.05	20.22	20.14
2	20.04	20.10	20.88	20.65	20.42
3	20.28	20.31	20.33	20.17	20.27
4	20.19	20.22	20.24	20.15	20.20
5	20.13	20.26	20.03	20.1	20.13
6	20.06	20.12	20.15	20.13	20.12
7	20.14	20.09	20.12	20.07	20.11
8	20.47	20.23	20.06	20.80	20.39
9	20.15	20.20	20.05	20.03	20.11
10	20.33	20.39	20.45	20.60	20.44
11	20.15	20.14	20.08	20.11	20.12
12	20.21	20.19	20.14	20.08	20.16
13	20.45	20.50	20.47	20.42	20.46
14	20.65	20.70	20.82	20.76	20.73
15	20.75	20.82	20.68	20.67	20.73
16	20.39	20.34	20.67	20.80	20.55
17	20.76	20.72	20.67	20.75	20.73
18	20.76	20.84	20.74	20.89	20.81
19	20.78	20.88	20.89	20.76	20.83
20	20.56	20.75	20.72	20.51	20.64
21	20.14	20.22	20.14	20.09	20.15
22	20.09	20.02	20.13	20.11	20.09
23	20.13	20.17	20.14	20.15	20.15
24	20.21	20.15	20.04	20.06	20.12
			Average		20.36

saved too much. The 3D-model of injection mold was created and transferred to G-code for milling the part cavities. The injection mold components were fabricated and fitted with a machine to produce the plastic parts. The products of injection molding process were checked the dimensions and surface for the completion. The average error of dimensions of the final products had less than 5.82%.

5. Acknowledgement

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6. References

[1] Dominick,V.R, Donald, V.R. and Marlene, G.R. (2000). Injection molding handbook, 3rd edition, Springer Science+Business Media, New York.

[2] Oktem, H. (2011). Modeling and analysis of process parameters for evaluating shrinkage problems during plastic injection molding of a DVD-ROM cover, *Journal of Materials Engineering*

and Performance, vol.21(1), January 2011, pp. 25 – 32.

[3] Saman, A.M., Abdullah, A.H. and Mohd Nor, M.A. (2009). Computer simulation opportunity in plastic injection mold development for automotive part, paper presented in *2009 International Conference on Computer Technology and Development*, Kuala Lumpur, Malaysia.

[4] Shien, J.Y.., Wang, L.K. and Ke, S.Y. (2010).A feasible injection molding technique for the manufacturing of large diameter asphearic plastic lenses, *Optical Review*, vol.17(4), pp. 399 – 403.

[5] Chan, I.W.M., Pinfold, M., Kwong, C.K. and Szeto, W.H. (2011). A review of research, commercial software packages and patent on family mould layout design automation and optimisation, *Int. J. Adv. Manuf. Technol.*, vol.57, pp. 23 – 47.

[6] Vietri, U., Sorrentino, A. and Pantani, R. (2011). Improving the predictions of injection molding simulation software, *Polymer Engineer and Science*, vol.51(12), pp. 2542 – 2551.

[7] Deng, Y.M., Lam, Y.C., Tor, S.B. and Britton, G.A. (2002). A CAD/CAE integrated injection molding design system, *Engineering with Computers*, vol.18, pp. 80 – 92.

[8] Galantucci, L.M. and Spina, R. (2003). Evaluation of filling condition of injection moulding by integrating numerical simulations and experimental tests, *Journal of Materials Processing Technolody*, vol.141, February 2003, pp. 266 – 175.

[9] Kong, L., Fuh, J.Y.H., Lee, K.S., Liu, X.L., Ling, L.S., Zhang, Y.F. and Nee, A.Y.C. (2003). A Windows-native 3D plastic injection mold design system, *Journal of Materials Processing Technology*, vol.139, pp. 81 – 89.

[10] Matin, I., Hadzistevic, M., Hodolic, J., Vukelic, D. and Lukic, D. (2012). A CAD/CAE-integrated injection molding design system for plastic products, *Int. J. Adv. Manuf. Technol.*, vol.63, pp. 595 – 607.