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Optimasi Parameter *Plastic Injection Molding* pada *Mold ID Card Holder Landscape* untuk Menurunkan Cacat *Sink Mark*

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Abstrak

Masifnya industri pengolahan plastik mendorong perguruan tinggi vokasi untuk memberikan kompetensi kepada lulusannya menjadi *mold maker*. Sebagai perwujudan kompetensi tersebut, mahasiswa Program Studi Pembuatan Peralatan dan Perkakas Produksi di Politeknik Astra membuat *project mold ID card holder* dengan format *landscape* berbahan *Polypropylene*. Tujuan pembuatan *mold* ini adalah sebagai alat peraga praktikum dan adanya permintaan produk yang dapat dijadikan sebagai souvenir resmi Politeknik Astra. Seiring berjalannya waktu, *ID card holder* yang dihasilkan memiliki cacat *sink mark*, deformasi dan mengalami penyusutan material sehingga *ID card* sangat sulit untuk masuk dan secara visual tidak layak untuk dijadikan souvenir. Penelusuran yang dilakukan menghasilkan temuan adanya kesalahan prosedur berupa *trial dan error* dalam proses cetak dan tidak digunakannya CAE dalam proses pembuatannya. Penelitian ini bertujuan untuk menemukan kembali kombinasi parameter optimal pada *mold ID card holder landscape* dengan menggunakan kombinasi Metode Taguchi dengan pendekatan *GRA-PCA* dan software Autodesk Moldflow Adviser Ultimate 2024 serta mendapatkan perbandingan biaya sebelum menggunakan CAE dan sesudahnya. Parameter *mold temperature*, *melt temperature* dan *injection time* menjadi variabel bebas dalam penelitian ini. Sedangkan *sink mark estimate*, *volumetric shrinkage* dan *warp* menjadi variabel terikatnya. Kombinasi parameter *mold temperature* 30 °C, *melt temperature* 200 °C dan *injection time* 3,5 s memberikan respon optimal sehingga cacat *sink mark* maksimalnya 0,02 mm dan selisih biaya Rp8.250.000,00 lebih rendah dengan memanfaatkan CAE.

Kata kunci: *mold, sink mark, GRA-PCA, CAE, parameter.*

Abstract

The significant growth of the plastic processing industry has driven vocational colleges to equip their graduates with competencies in mold making. As a manifestation of this competency, students in the Production Equipment and Tooling Program at Polytechnic Astra have undertaken a project to create a landscape-format ID card holder made from Polypropylene. The purpose of creating this mold is twofold: as a practical training aid and to fulfil demand for a product that can serve as an official souvenir of Polytechnic Astra. Over time, the produced ID card holders have exhibited defects such as sink marks, deformation, and material shrinkage, making it difficult for ID cards to fit and visually unsuitable as a souvenir. Investigation revealed procedural errors involving trial and error in the molding process and the absence of CAE (Computer-Aided Engineering) utilization during production. This study aims to rediscover the optimal parameter combinations for the ID card holder landscape mold using a Taguchi Method combined with GRA-PCA approach and Autodesk Moldflow Adviser Ultimate 2024 software. Additionally, it seeks to compare process costs before and after CAE implementation. Mold temperature, melt temperature, and injection time are the independent variables in this research. Sink mark estimate, volumetric shrinkage, and warp are the dependent variables. The combination of mold temperature 30 °C, melt temperature 200 °C, and injection time 3,5 s provides optimal responses, minimizing sink marks to a maximum of 0.02 mm and lower cost difference of Rp8.250.000,00 when utilizing CAE.

Keywords: *mold, sink mark, GRA-PCA, CAE, parameter.*

1. Latar belakang

Dunia industri yang berjalan saat ini tidak lepas dari pengolahan plastik di dalamnya, baik itu sebagai bahan baku atau bahan pendukung dalam proses produksinya. Hal ini dikarenakan sifat plastik yang mudah dibentuk atau dicetak,

A Simulation Study on the Optimization of Plastic Injection Molding Parameters in Family Molds as Part of a Project-Based Learning Approach

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Abstract

The Indonesian government emphasizes the importance of establishing a strong link and match between vocational higher education and industry. Vocational higher education institutions are encouraged to equip their graduates with specific competencies required by the workforce, one of which is mold making. As an implementation of this policy, the Mechanical Engineering Study Program at Polytechnic of A collaborated with SAP Ltd. to duplicate a mold for a microcontroller case as a learning medium through a Project-Based Learning (PjBL) approach. The goal of this PjBL is to assess whether students are capable of producing a product identical to the microcontroller case. In practice, however, many defects occurred, predominantly shrinkage, sink marks, burn marks, and short shots. Additionally, it was found that Computer-Aided Engineering (CAE) technology had not yet been optimally applied, resulting in continued reliance on a trial-and-error method for injecting the microcontroller case. This led to high production costs—USD 2,600 for producing only 20 intact pieces—and a prolonged injection process lasting 120 hours. This research essentially utilizes CAE and inferential statistics from the Taguchi Method, combined with Grey Relational Analysis (GRA), to determine the optimal parameters that can reduce defects in the microcontroller case, thereby also enabling cost reduction. The resulting optimal parameters are: mold temperature at 40 °C, melt temperature at 210 °C, injection time of 10 seconds, injection pressure of 141 MPa, holding time of 7 seconds, holding pressure of 141 MPa, and cooling time of 25 seconds. The significance of each parameter is as follows: melt temperature 63.84%, injection time 17.72%, mold temperature 10.34%, holding time 2%, injection pressure 0.58%, cooling time 0.57%, and holding pressure 0.26%. These optimal settings successfully minimized shrinkage to 2.152%, sink marks to 0.0317 mm with a sink mark index of 1.499%, and optimized the product conformity with warpage reduced to only 0.44 mm. The use of CAE proved to be highly effective as a part of PjBL, as it ultimately reduced the injection process cost to just USD 108 (a 96% reduction) and shortened the processing time from 120 hours to only 5 hours (also a 96% reduction).

Keywords

Project-based learning, mold, simulation, optimization, CAE

Introduction

As part of the effort to address the challenges of Industry 4.0, many countries have increasingly emphasized the importance of establishing a strong link and match between Technical and Vocational Education and Training (TVET) institutions from vocational high schools to universities of applied sciences or polytechnics and industry (Deutscher and Winther, 2016; Ali et al., 2019; Faraco et al., 2019; Basuki et al., 2020). This program is initiated to ensure that students not only acquire theoretical knowledge but also engage directly in industrial processes, thereby developing relevant and practical competencies aligned with the demands of the workforce. As a result, upon graduation, students are expected to become skilled workers who are ready to face industrial challenges and can immediately contribute positively in the workplace (Pilz, 2012; Sagardia et al., 2017).

An effective learning method that serves to bridge this link and match, according to Pulskwik and Hamari (2014), is Project-Based Learning (PjBL). This is due to the shared objective of both education and industry equipping students with skills that are directly based on industrial needs so that the competencies acquired are already aligned with current industry requirements.

Lampiran 3 Log hasil simulasi percobaan verifikasi

Copyright Autodesk, Inc. All rights reserved.
(C)2009 2010 2011 2012 2013 2014 2015 2016
(C)2017 2018 2019 2020 2021 2022 2023 2024
Portions of this software are covered by U.S. Patent Numbers 5,287,408 and 6,096,088.

Flow Analysis

Version: Autodesk Moldflow Insight 2025 (Build 48.0.19)
64-bit build

Analysis commenced at Wed Apr 2 11:18:28 2025

Running on host: VINSENSIUS-PC
Operating System: Windows 11 (Build 26100)
Processor type: GenuineIntel Intel64 Family 6 Model 186 Stepping 3 ~2496 MHz
Number of Physical Processors: 10
Number of Logical Processors: 12
Total Physical Memory: 32400 MBytes

No mesh for the cores was found.
Core shift analysis switched OFF

Attempting to acquire the required solver license at: Wed Apr 2 11:18:31 2025
Solver license acquired successfully at: Wed Apr 2 11:18:40 2025

Fill Analysis

Pack Analysis

Residual Stress Analysis

Allocating memory for analysis...
... finished allocating memory

Analysis has detected outdated thickness information...
... recalculating mesh match and thickness information
Processing Dual Domain mesh...
Computing match using the maximal-sphere algorithm
... finished processing Dual Domain mesh
Reading input data...
File name : casing_gundala_final_2~1
Reading solver parameters...
Reading material data...
Reading process settings...
Reading finite element mesh...

** WARNING 98780 ** No cooling channel is specified.
Reading cooling data...

NOTE: In the analysis sequence for this study, a Cool analysis has not been run before Flow. Flow will use the constant mold temperature setting in the Process Settings Wizard.
Running a Cool analysis before Flow provides more detailed information about mold temperatures and heat fluxes.

Reading restart data...
Note: No restart data was found.
Finished reading input data
Checking input data...
... finished checking input data
Optimizing memory usage...
... finished optimizing memory usage
Initializing variables...

... finished initializing variables

Summary of analysis inputs :

Solver parameters :

No. of laminae across thickness = 12
Intermediate output options for filling phase
 No. of results at constant intervals = 20
 No. of profiled results at constant intervals = 20
Intermediate output options for packing phase
 No. of results at constant intervals = 20
 No. of profiled results at constant intervals = 20
Flow rate convergence tolerance = 0.5000 %
Melt temperature convergence tolerance = 0.0200 C
Number of threads for parallelization = Automatic
Initial number of threads used in the analysis = 7
Mold-melt heat transfer coefficient
 Filling = 5000.0000 W/m²-C
 Packing = 2500.0000 W/m²-C
 Detached, cavity side = 1250.0000 W/m²-C
 Detached, core side = 1250.0000 W/m²-C
Maximum no. of flow rate iterations = 125
Maximum no. of melt temperature iterations = 200
Nodal growth mechanism = Multiple
Pressure trace sample frequency = 0 Hz
 Total number of pressure trace nodes = 1
 Node 1 = 4
 Juncture loss option = 1

Material data :

Polymer : ABS HI-121 : LG Chemical

pvT Model:

2-domain modified Tait

coefficients: b5 = 383.3000 K

b6 = 2.3350E-07 K/Pa

Liquid phase Solid phase

b1m = 0.0010 b1s = 0.0010 m³/kg

b2m = 6.4700E-07 b2s = 3.2210E-07 m³/kg-K

b3m = 1.8346E+08 b3s = 2.2132E+08 Pa

b4m = 0.0049 b4s = 0.0041 1/K

b7 = 0.0000 m³/kg

b8 = 0.0000 1/K

b9 = 0.0000 1/Pa

Specific heat:

Tabulated data:

Temperature T (K)	Specific Heat Cp (J/kg-K)
324.1500	1481.0000
338.1500	1571.0000
353.1500	1670.0000
358.1500	1756.0000
363.1500	1882.0000
368.1500	2011.0000
373.1500	2013.0000
378.1500	2082.0000
413.1500	2212.0000
453.1500	2330.0000
488.1500	2419.0000
508.1500	2449.0000

Thermal conductivity: Tabulated data:

Temperature T (K)	Thermal Conductivity K (W/m-K)
303.1500	0.1240
318.1500	0.1240
339.1500	0.1300
360.1500	0.1320
380.1500	0.1530
400.1500	0.1830
420.1500	0.1810
440.1500	0.1810
459.1500	0.1880
479.1500	0.1850
498.1500	0.1900
518.1500	0.1960

Viscosity model:

Cross-WLF

coefficients: n = 0.3806
 TAUS = 1.8090E+04 Pa
 D1 = 1.6900E+12 Pa-s
 D2 = 373.1500 K
 D3 = 0.0000 K/Pa
 A1 = 27.0500
 A2T = 51.6000 K

Transition temperature

= 90.0000 C

Juncture loss equation :

DPe = c1 * TAUW^c2
 where c1 = 4.8240 Pa^(1-c2)
 c2 = 1.1200

Mechanical properties data:

E1 = 2240.0000 MPa
 E2 = 2240.0000 MPa
 v12 = 0.3920
 v23 = 0.3920
 G12 = 804.6000 MPa

Transversely isotropic coefficient of
 thermal expansion (CTE) data:

Alpha1 = 0.0000800 1/C
 Alpha2 = 0.0000800 1/C

Residual stress model with CRIMS

coefficients: A1 = 0.5303
 A2 = -0.0316
 A3 = 0.0031
 A4 = 0.6635
 A5 = -0.1432
 A6 = 0.0035

Process settings :

Machine parameters :

Maximum machine clamp force = 1.5000E+02 tonne
 Maximum injection pressure = 1.8000E+02 MPa
 Maximum machine injection rate = 1.2600E+02 cm³/s
 Machine hydraulic response time = 2.0000E-01 s

Process parameters :

Fill time = 10.0000 s
 Stroke volume determination = Automatic
 Cooling time = 25.0000 s

Velocity/pressure switch-over by injection pressure= 141.0000 MPa
Packing/holding time = 7.0000 s
Ram speed profile (rel):
% shot volume % ram speed

0.0000 100.0000
100.0000 100.0000
Pack/hold pressure profile (abs):
duration pressure

7.0000 s 141.0000 MPa
25.0000 s 0.0000 MPa
Ambient temperature = 25.0000 C
Melt temperature = 210.0000 C
Ideal cavity-side mold temperature = 40.0000 C
Ideal core-side mold temperature = 40.0000 C

NOTE: Mold wall temperature data from Cool analysis not available

Model details :

Mesh Type = Dual Domain
Mesh match percentage = 93.2 %
Reciprocal mesh match percentage = 94.1 %
Total number of nodes = 42111
Total number of injection location nodes = 1
The injection location node labels are:
4
Total number of elements = 84228
Number of part elements = 84200
Number of sprue/runner/gate elements = 28
Number of channel elements = 0
Number of connector elements = 0
Parting plane normal (dx) = 0.0000
(dy) = 0.0000
(dz) = 1.0000
Average aspect ratio of triangle elements = 1.6006
Maximum aspect ratio of triangle elements = 12.4299
Element number with maximum aspect ratio = 98681
Minimum aspect ratio of triangle elements = 1.1548
Element number with minimum aspect ratio = 131981
Total volume = 55.3362 cm³
Volume filled initially = 0.0000 cm³
Volume to be filled = 55.3362 cm³
Part volume to be filled = 54.1578 cm³
Sprue/runner/gate volume to be filled = 1.1785 cm³
Total projected area = 122.7034 cm²

Fill Analysis

Pack Analysis

Residual Stress Analysis
analysis is beginning

Filling phase: Status: V = Velocity control
P = Pressure control
V/P= Velocity/pressure switch-over

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm ³ /s)	Status

0.500	2.04	33.75	0.24	1.28	V
1.004	5.39	63.73	0.50	5.57	V
1.501	9.98	64.96	0.57	5.43	V
2.000	14.56	66.80	0.67	5.47	V
2.513	19.26	68.01	0.80	5.50	V
3.010	23.80	69.21	0.95	5.51	V
3.506	28.35	69.88	1.12	5.51	V
4.008	32.94	70.64	1.34	5.51	V
4.512	37.50	71.42	1.60	5.51	V
5.015	42.07	72.22	1.89	5.51	V
5.513	46.59	73.08	2.24	5.51	V
6.021	51.18	74.04	2.65	5.51	V
6.523	55.66	74.97	3.07	5.52	V
7.012	60.08	75.86	3.52	5.52	V
7.511	64.60	76.89	4.05	5.52	V
8.014	69.00	78.29	4.72	5.51	V
8.513	73.34	82.48	6.38	5.50	V
9.004	77.59	87.70	8.88	5.51	V
9.503	81.94	91.55	11.58	5.54	V
10.000	86.52	87.68	10.91	5.53	V
10.511	91.05	89.58	12.53	5.53	V
11.011	93.92	126.69	49.49	5.53	V
11.508	98.24	108.81	51.34	5.53	V
11.600	99.02	109.74	52.14	5.51	V/P

Execution time in Filling Phase = 7583.72 s

Packing phase:

Time (s)	Packing (%)	Pressure (MPa)	Clamp force (tonne)	Status
11.721	0.38	110.28	60.97	P
12.380	2.44	113.23	78.37	P
14.130	7.91	121.04	69.28	P
15.630	12.59	127.74	57.63	P
17.130	17.28	134.44	47.30	P
17.880	19.62	137.78	42.85	P
18.600	21.88	140.93	38.96	P
18.600				Pressure released
18.805	22.51	0.00	37.98	P
21.509	30.97	0.00	27.31	P
25.009	41.90	0.00	18.66	P
28.509	52.84	0.00	13.88	P
32.009	63.78	0.00	11.28	P
35.759	75.50	0.00	9.59	P
39.259	86.44	0.00	8.52	P
42.759	97.37	0.00	7.79	P
43.600	100.00	0.00	7.70	P

Filling phase results summary :

Maximum injection pressure (at 11.0107 s) = 126.6886 MPa

End of filling phase results summary :

Time at the end of filling = 11.7206 s
Total weight (part + runners) = 54.3391 g
Maximum Clamp force - during filling = 52.1442 tonne

Filling phase results summary for the part :

Bulk temperature - maximum (at 11.011 s) = 224.3324 C
Bulk temperature - 95th percentile (at 11.011 s) = 219.4781 C

Bulk temperature - 5th percentile	(at 11.600 s)	=	88.9513 C
Bulk temperature - minimum	(at 11.600 s)	=	40.0064 C
Wall shear stress - maximum	(at 11.011 s)	=	35.9447 MPa
Wall shear stress - 95th percentile	(at 11.011 s)	=	2.3926 MPa
Shear rate - maximum	(at 11.508 s)	=	5580.6655 1/s
Shear rate - 95th percentile	(at 1.004 s)	=	2402.9067 1/s

End of filling phase results summary for the part :

Total part weight (excluding runners)	=	53.1696 g
Bulk temperature - maximum	=	223.7843 C
Bulk temperature - 95th percentile	=	218.7479 C
Bulk temperature - 5th percentile	=	88.9513 C
Bulk temperature - minimum	=	40.0064 C
Bulk temperature - average	=	170.7165 C
Bulk temperature - root-mean-square deviation	=	42.7918 C
Wall shear stress - maximum	=	27.2996 MPa
Wall shear stress - 95th percentile	=	1.8690 MPa
Wall shear stress - average	=	0.4757 MPa
Wall shear stress - root-mean-square deviation	=	1.5522 MPa
Frozen layer fraction - maximum	=	1.0000
Frozen layer fraction - 95th percentile	=	0.6626
Frozen layer fraction - 5th percentile	=	0.0967
Frozen layer fraction - minimum	=	0.0000
Frozen layer fraction - average	=	0.2608
Frozen layer fraction - root-mean-square deviation	=	0.1958
Shear rate - maximum	=	5530.2764 1/s
Shear rate - 95th percentile	=	135.4005 1/s
Shear rate - average	=	23.3977 1/s
Shear rate - root-mean-square deviation	=	105.5335 1/s

Filling phase results summary for the runner system :

Bulk temperature - maximum	(at 11.600 s)	=	223.3916 C
Bulk temperature - 95th percentile	(at 11.011 s)	=	223.1392 C
Bulk temperature - 5th percentile	(at 0.500 s)	=	213.4290 C
Bulk temperature - minimum	(at 11.508 s)	=	211.1573 C
Wall shear stress - maximum	(at 11.011 s)	=	1.7497 MPa
Wall shear stress - 95th percentile	(at 1.004 s)	=	0.3796 MPa
Shear rate - maximum	(at 11.508 s)	=	5.6166E+04 1/s
Shear rate - 95th percentile	(at 1.004 s)	=	1810.6218 1/s

End of filling phase results summary for the runner system :

Total sprue/runner/gate weight	=	1.1695 g
Bulk temperature - maximum	=	223.3916 C
Bulk temperature - 95th percentile	=	222.3039 C
Bulk temperature - 5th percentile	=	217.1807 C
Bulk temperature - minimum	=	211.8634 C
Bulk temperature - average	=	220.8352 C
Bulk temperature - root-mean-square deviation	=	1.7786 C
Wall shear stress - maximum	=	1.3587 MPa
Wall shear stress - 95th percentile	=	0.3543 MPa
Wall shear stress - average	=	0.2557 MPa
Wall shear stress - root-mean-square deviation	=	0.1128 MPa
Frozen layer fraction - maximum	=	0.2518
Frozen layer fraction - 95th percentile	=	0.1702
Frozen layer fraction - 5th percentile	=	0.0604

Frozen layer fraction - minimum	=	0.0441
Frozen layer fraction - average	=	0.1237
Frozen layer fraction - root-mean-square deviation	=	0.0343
Shear rate - maximum	=	5.5822E+04 1/s
Shear rate - 95th percentile	=	1788.9945 1/s
Shear rate - average	=	974.1346 1/s
Shear rate - root-mean-square deviation	=	2073.7710 1/s

Packing phase results summary :

Peak pressure		
- minimum among cavity nodes	(at 0.000 s) =	0.0000 MPa
Clamp force - maximum	(at 12.380 s) =	78.3709 tonne
Total weight - maximum	(at 43.600 s) =	55.2391 g

End of packing phase results summary :

Time at the end of packing	=	43.6002 s
Total weight (part + runners)	=	55.2391 g

Packing phase results summary for the part :

Bulk temperature - maximum	(at 11.721 s) =	223.3260 C
Bulk temperature - 95th percentile	(at 11.721 s) =	218.6984 C
Bulk temperature - 5th percentile	(at 43.600 s) =	40.0402 C
Bulk temperature - minimum	(at 18.600 s) =	39.9999 C
Wall shear stress - maximum	(at 12.380 s) =	32.0374 MPa
Wall shear stress - 95th percentile	(at 12.380 s) =	3.8854 MPa
Volumetric shrinkage - maximum	(at 11.721 s) =	6.3764 %
Volumetric shrinkage - 95th %ile	(at 11.721 s) =	4.1168 %
Volumetric shrinkage - 5th %ile	(at 15.630 s) =	-0.3190 %
Volumetric shrinkage - minimum	(at 12.380 s) =	-1.4521 %
Total part weight - maximum	(at 43.600 s) =	54.0309 g

End of packing phase results summary for the part :

Total part weight (excluding runners)	=	54.0309 g
Bulk temperature - maximum	=	120.7353 C
Bulk temperature - 95th percentile	=	99.6724 C
Bulk temperature - 5th percentile	=	40.0402 C
Bulk temperature - minimum	=	39.9999 C
Bulk temperature - average	=	54.6456 C
Bulk temperature - root-mean-square deviation	=	22.7013 C
Frozen layer fraction - maximum	=	1.0000
Frozen layer fraction - 95th percentile	=	1.0000
Frozen layer fraction - 5th percentile	=	0.3609
Frozen layer fraction - minimum	=	0.2464
Frozen layer fraction - average	=	0.8739
Frozen layer fraction - root-mean-square deviation	=	0.2435
Volumetric shrinkage - maximum	=	3.8060 %
Volumetric shrinkage - 95th percentile	=	2.6425 %
Volumetric shrinkage - 5th percentile	=	-0.2659 %
Volumetric shrinkage - minimum	=	-1.1057 %
Volumetric shrinkage - average	=	0.9440 %
Volumetric shrinkage - root-mean-square deviation	=	0.9471 %
Sink index - maximum	=	1.4989 %
Sink index - 95th percentile	=	0.4635 %
Sink index - minimum	=	-8.9640E-06 %
Sink index - root-mean-square deviation	=	0.1707 %

Packing phase results summary for the runner system :

Bulk temperature - maximum	(at 11.721 s) =	223.0842 C
Bulk temperature - 95th percentile	(at 11.721 s) =	222.0858 C
Bulk temperature - 5th percentile	(at 43.600 s) =	40.3543 C
Bulk temperature - minimum	(at 25.009 s) =	40.0000 C
Wall shear stress - maximum	(at 18.805 s) =	4.9617 MPa
Wall shear stress - 95th percentile	(at 18.805 s) =	1.0352 MPa
Volumetric shrinkage - maximum	(at 11.721 s) =	4.2862 %
Volumetric shrinkage - 95th %ile	(at 11.721 s) =	2.5074 %
Volumetric shrinkage - 5th %ile	(at 18.600 s) =	-1.6182 %
Volumetric shrinkage - minimum	(at 18.600 s) =	-2.0724 %
Sprue/runner/gate weight - max.	(at 18.600 s) =	1.2087 g

End of packing phase results summary for the runner system :

Total sprue/runner/gate weight	=	1.2082 g
Bulk temperature - maximum	=	43.1065 C
Bulk temperature - 95th percentile	=	43.1065 C
Bulk temperature - 5th percentile	=	40.3543 C
Bulk temperature - minimum	=	40.0000 C
Bulk temperature - average	=	41.9578 C
Bulk temperature - root-mean-square deviation	=	0.9045 C
Frozen layer fraction - maximum	=	1.0000
Frozen layer fraction - 95th percentile	=	1.0000
Frozen layer fraction - 5th percentile	=	1.0000
Frozen layer fraction - minimum	=	1.0000
Frozen layer fraction - average	=	1.0000
Frozen layer fraction - root-mean-square deviation	=	0.0000
Volumetric shrinkage - maximum	=	-0.0167 %
Volumetric shrinkage - 95th percentile	=	-0.5069 %
Volumetric shrinkage - 5th percentile	=	-1.3149 %
Volumetric shrinkage - minimum	=	-1.5628 %
Volumetric shrinkage - average	=	-0.7425 %
Volumetric shrinkage - root-mean-square deviation	=	0.2847 %
Sink index - maximum	=	0.0000 %
Sink index - 95th percentile	=	0.0000 %
Sink index - minimum	=	0.0000 %
Sink index - root-mean-square deviation	=	0.0000 %

Preparing interface data...

Preparing PPC file for Cool analysis...

Preparing LSP file for Warp analysis...

Finished preparing the interface data

Fill Analysis

Pack Analysis

Residual Stress Analysis
has completed successfully.

Sink Mark Analysis
Sink Mark Analysis completed

Analysis has detected outdated thickness information...
... recalculating mesh match and thickness information
Processing Dual Domain mesh...
Computing match using the maximal-sphere algorithm
... finished processing Dual Domain mesh

Beginning weld line/air trap analysis...

Preparing output data...

Finished preparing output data

Weld line/air trap analysis completed

Execution time

Analysis commenced at Wed Apr 2 11:18:28 2025

Analysis completed at Wed Apr 2 13:10:29 2025

CPU time used 12290.20 s

equivalent to 3 hr, 24 min

Elapsed wall clock time 6721.00 s

equivalent to 1 hr, 52 min

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Portions of this software are covered by U.S. Patent Numbers 5,287,408 and 6,096,088.

Warp Analysis

Version: Autodesk Moldflow Insight 2025 (Build 48.0.19)

64-bit build

Running on host: VINSENSIUS-PC

Operating System: Windows 11 (Build 26100)

Processor type: GenuineIntel Intel64 Family 6 Model 186 Stepping 3

~2496 MHz

Number of Physical Processors: 10

Number of Logical Processors: 12

Total Physical Memory: 32400 MBytes

Analysis commenced at Wed Apr 2 13:12:13 2025

Attempting to acquire the required solver license at: Wed Apr 2 13:12:18 2025

Solver license acquired successfully at: Wed Apr 2 13:12:24 2025

Model file name: casing_gundala_final_2.sdy

Reading solver parameters...

Corner effect is OFF

Analysis has detected outdated thickness information...

... recalculating mesh match and thickness information

Processing Dual Domain mesh...

Computing match using the maximal-sphere algorithm

... finished processing Dual Domain mesh

Dual Domain mesh statistics:

Mesh match percentage = 93.2 %

Reciprocal mesh match percentage = 94.1 %

Reading mechanical property and residual stress data...

Analysis model: Residual stress with crims.

Defining anchor plane...

Number of separate cavities = 2

Writing input file for structural analysis program...

Launching structural analysis program...

Reading structural analysis input file...
...finished reading structural analysis input file.

Matrix solver used = AMG
Number of threads for parallelization = Automatic
Initial number of threads used in the analysis = 9

Beginning load incrementation loop...

Setting structure information...

Assembling stiffness matrix...

Solving finite element static equilibrium equations...

Kstep	Kstra	Nref	Nite	Node	Ipos	Rfac	Displacement
1	1	1	0	652	1	1.000e+00	1.090e+11

Elapsed wall clock time in structural analysis: 4527.96 secs.

Writing result file...

Analysis has detected outdated thickness information...
... recalculating mesh match and thickness information
Processing Dual Domain mesh...
Computing match using the maximal-sphere algorithm
... finished processing Dual Domain mesh

Best-fit transformation will be used to display warpage deflections
if no anchor plane is defined.

Minimum/maximum displacements at last step (unit: mm):

	Node	Min.	Node	Max.
Trans-X	142180	-1.7890e+02	9292	4.3735e+01
Trans-Y	142177	-2.1999e+02	142180	3.9905e+01
Trans-Z	142177	-3.1755e+01	142180	5.5630e+01

Execution time

Analysis commenced at	Wed Apr 2 13:12:13 2025
Analysis completed at	Wed Apr 2 14:30:23 2025
CPU time used	14590.36 s
equivalent to	4 hr, 3 min
Elapsed wall clock time	4690.00 s
equivalent to	1 hr, 18 min

Warp analysis has completed successfully.

Lampiran 4 Customer review dari PT ABC

