BAB 6
KESIMPULAN DAN SARAN

6.1. Kesimpulan

Software analisis CAE *Autodesk Simulation Moldflow Synergy* 2015 memang terbukti sangat baik dalam menganalisis *input paramater* dan pengaruhnya terhadap simulasi proses injeksi. *Software* ini mampu memprediksi setiap permasalahan yang terjadi, termasuk masalah *shrinkage, sink marks dan warpage* yang diteliti.

Berdasarkan hasil dari penelitian, maka dapat ditarik beberapa kesimpulan yaitu:

1. Analisis CAE *Autodesk Simulation Moldflow Synergy 2015* menghasilkan kombinasi *setting* parameter injeksi plastik yang optimal menggunakan material PC pada mesin injeksi plastik berkapasitas 180 ton untuk meminimalkan cacat *shrinkage, sink marks* dan *warpage* pada produk CT103 *Casing* P1-P2. Kombinasi parameter terbaik pada eksperimen delapan (tabel 4.14) yaitu dengan *mold temperature* 80 °C, *melt temperature* 320 °C, *injection pressure* 137 MPa*, injection time* 2,5 detik, *holding time* 14 detik dan *cooling time* 34,5 detik.
2. *Output* dari analisis CAE *Autodesk Simulation Moldflow Synergy* 2015 *dual-domain* lengkap pada produk CT103 *Casing* P1-P2 dapat digunakan sebagai panduan bagi *engineer mold maker* dalam membuat konstruksi *mold* baru atau memodifikasi *mold* yang sudah ada. *CAE Moldflow* mampu memprediksi hasil injeksi dengan konstruksi produk dan parameter yang rumit.

6.2. Saran

Dari proses analisis CAE *Moldflow* pada studi kasus CT103 *Casing* P1-P2 didapatkan beberapa hal yang perlu diperhatikan oleh *mold maker* atau operator *setting* mesin injeksi sebagai berikut:

1. Perlu dilakukan analisis yang lebih optimal pada kombinasi parameter terbaik yang telah dipilih, yaitu dengan menambahkan derajat kebebasan. Analisis bisa dijalankan lagi dengan menambahkan dan mengurangi nilai sebuah parameter, sehingga hasilnya akan lebih optimal. Misal *mold temperature* 80 °C $\pm$ 5 °C, maka analisis bisa dijalankan dengan memasukkan angka *mold temperature* 75 °C dan 85 °C, lalu dianalisis hasil yang terbaik.

2. Untuk memperbaiki cacat *sink marks* dan *warpage*, perlu dilakukan modifikasi pada bagian *cooling system,* karena analisis CAE *moldflow* menunjukkan hasil yang kurang optimal pada analisis *cooling.* Rancangan *cooling system* yang tidak optimal juga membuat *cycle time* proses injeksi lebih lama.
3. Pembuatan *air venting* perlu dilakukan pada *mold* untuk bagian-bagian yang terjadi *air traps,* sehingga cacat *short shot* bisa dihindari.
4. *Weld line* bisa diminimalisir dengan menambah jumlah *gate* atau mengubah ukuran *runner* dan *gate* agar waktu pengisian material plastik semakin cepat dan mengurangi *flow marks*.

Tindak lanjut dari penelitian ini adalah perlunya kerjasama lebih erat antara PUTP dengan unit kerja *Design Engineering* dan *Work Injection* di PT. ATMI-IGI Center Surakarta khususnya, dan juga industri *mold* dan manufaktur plastik yang lain agar proses konvensional yang ada bisa berubah menjadi proses manufaktur plastik yang modern. Kerjasama dengan Universitas maupun Lembaga Pendidikan Tinggi mengenai analisis proses injeksi plastik bisa ditingkatkan dengan adanya penelitian-penelitian yang mendukung industri plastik di Indonesia.

DAFTAR PUSTAKA

Agazzi A., Sobotka V.,, LeGoff R., Jarny Y., (2013) *Optimal Cooling Design in Injection Moulding Process - A New Approach Based on Morphological Surfaces, Applied Thermal Engineering* 52 (2013) 170e178, © Published by Elsevier Ltd.

Autodesk (2010) *Autodesk Moldflow Insight Performance* (*course modul*). Jakarta: Autodesk.

Budiyantoro C., (2007) *Analysis and Optimation of Injection Molded Parts using Fusion and 3D Elements of Moldflow*. Germany: Polymer Technology University of Aalen.

Budiyantoro C., (2010) Thermoplastik dalam Industri, Teknika Media, Surakarta.

Fish, J., Belytcschk, T., (2007) *A First Course in Finith Elements*. England: Wiley

Gastrow H. (2006) *Injection Molds: 130 proven Designs*. Germany: Hanser Gardner Publication

Georg M., (2001) *How to Make Injection Molds*. Geman: Carl Hanser Verlag.

Goodship V., (2004) *Practical Guide to Injection Molding*. Arburg: Rapra Technology Limited

Guo W., Hua L., Mao J., Meng Z.H., (2012) *Prediction Of Warpage In Plastic Injection Molding Based On Design Of Experiments*, *J. Mech. Sci. Technol.* 26 (4) 1133-1139.

Huszar M., Belblidia F., Helen M.D., Arnold C., Bould D., Sienz J.; (2015) *Sustainable Injection Moulding: The Impact of Materials Selection and Gate Location On Part Warpage and Injection Pressure*; *Sustainable Materials and Technologies* 5 1–8; © 2016 Published by Elsevier Ltd.

Indonesian Mold and Dies Assosiation. (2006) *Mold Dictionary.* Diakses tanggal 16 April 2017 dari http://www.imdia.or.id/indonesian/dictionary/mold.html.

Listiono A., (2011). Penerapan *Value Engineering* Terhadap Struktur Plat dan Balok Pada Proyek Pembangunan Gedung Asrama Putra SMP MTA Gemolong, Skripsi Fakultas Teknik Sipil, Universitas Sebelas Maret, Surakarta.

Liu J., *Application of MoldFlow Technology in the Warp Analysis*, Przegląd Elektrotechniczny, ISSN 0033-2097, R. 89 NR 1b/2013

Moerbani J. (1999) *Plastic Moulding*. Solo: ATMI Press

Moldflow Corporation (2015) *Tutorial Moldflow Plastic Insight* 2015. USA: Autodesk

Oliaei E., Shiroud, H., Behzad, Seyed M.D., Mozhgan B., Saeed D., Hejazi I., Seyfi. J., (2016) *Warpage and Shrinkage Optimization of Injection-Molded Plastic Spoon Parts for Biodegradable Polymers Using Taguchi, ANOVA and Artificial Neural Network Methods, Journal of Materials Science & Technology* http://dx.doi.org/doi: 10.1016/j.jmst.2016.05.010.

Sesaria D. (2016). "Penerapan Rekayasa Nilai (Value Engineering) Pada Proyekpembangunan Gedung II Fakultas Ilmu Sosial dan Ilmu Politik Universitas Brawijaya". Tugas Akhir Jurusan Teknik Sipil Fakultas Teknik Universitas Brawijaya Malang.

Seto A., Anggoro P.W., Budiantoro C.,(2015) "Optimalisasi Proses Injeksi Plastik menggunakan *Moldflow Dual-Domain* Pada Desain Base Plate", Proseding Seminar Nasional IDEC,2015,ISBN : 978-602-70259-3-6

Shoemaker J. (2006) *Moldflow Design Guide; a Resource for Plastic Engineers*. German: Carl Hanser Verlag

Vishnuvarthanan M*.,* Rajesh P., Ilangovan S., Nayak S.K., (2013) *Optimization Of Injection Molding Cycle Time Using Moldflow Analysis*, *International Journal of Current Research Vol. 4, Issue, 01, pp.259-261.*

Wang C., Huang M., Shen C., Zhao Z., (2015) *Warpage Prediction of The Injection-Molded Strip-Like Plastic Parts*, doi: 10.1016/j.cjche.2015.12.012

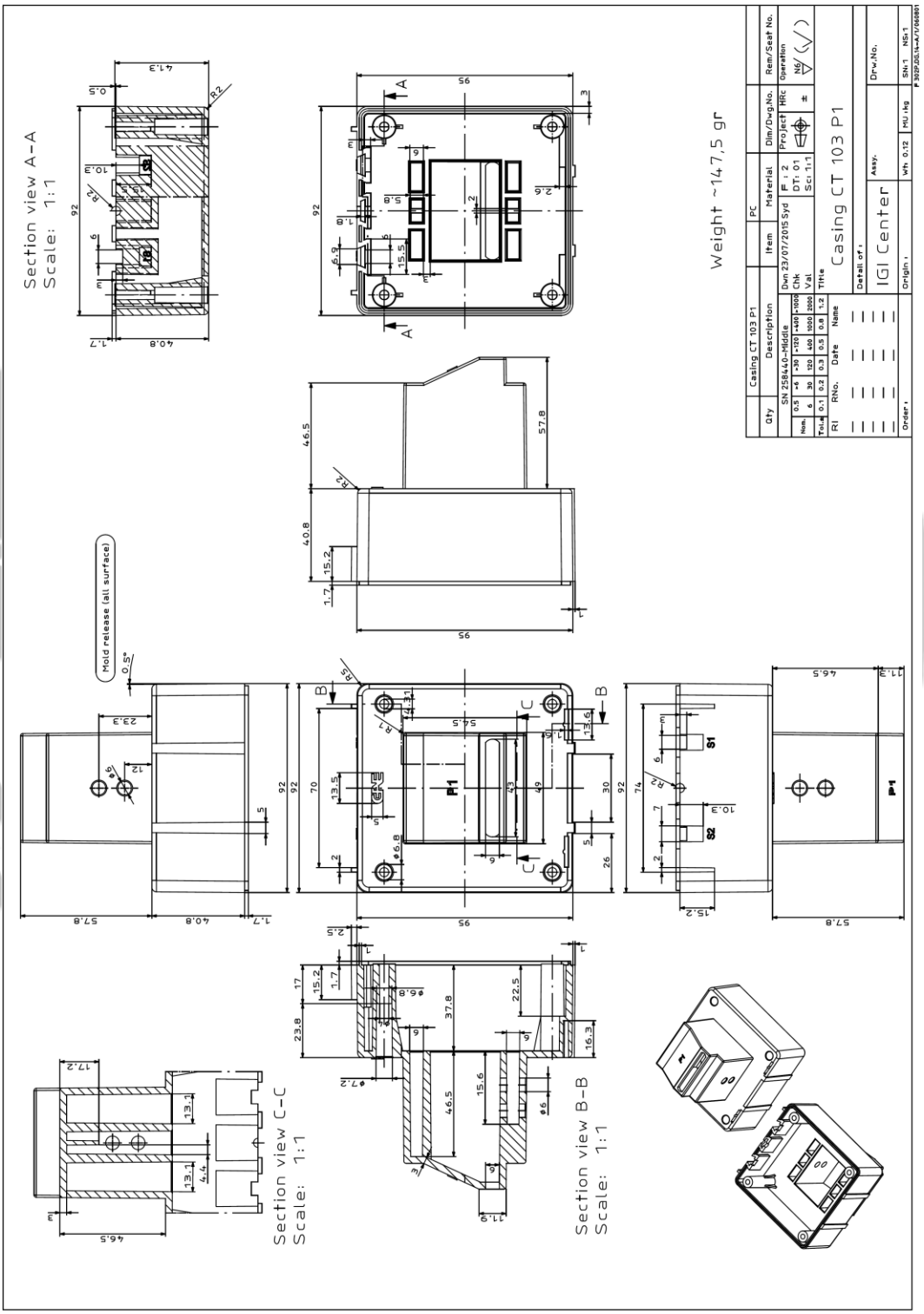
Wavare A., Ubale S., (2016) *Investigation of Shrinkage and Warpage in the Plastic Injection Molding Process of PP MAS1110 by* Autodesk Mold-Flow, *IJSRD - International Journal for Scientific Research & Development*| *Vol. 4, Issue 01, 2016* | *ISSN (online): 2321-0613*

Xiaoxin W., Guoqun Z., Guilong W., (2013) *Research on the Reduction of Sink Mark And Warpage of The Molded Part in Rapid Heat Cycle Molding Process*, *Materials and Design* 47 (2013) 779–792, Published by Elsevier Ltd.

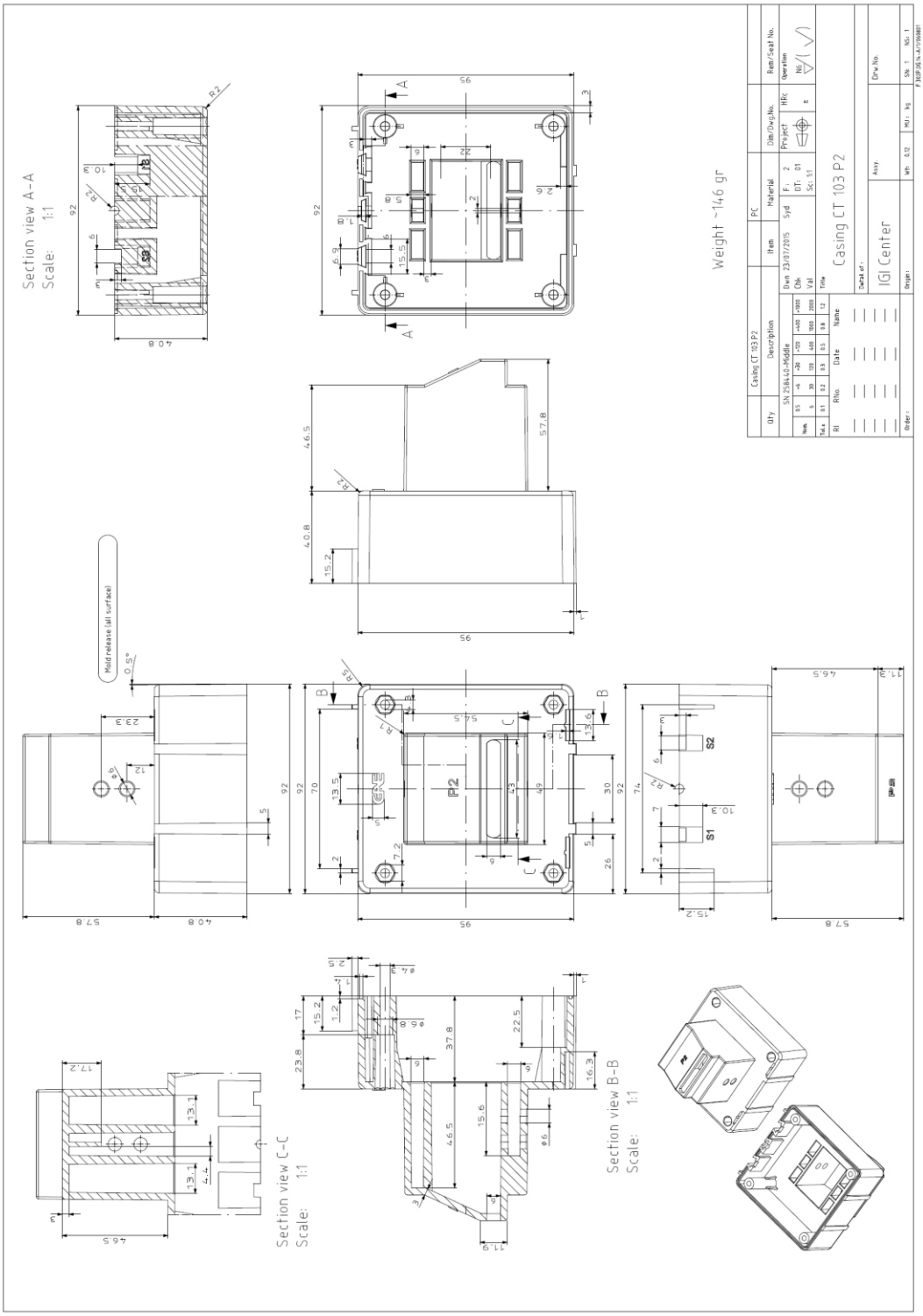
Yi-qi W., Jae-gyu K., Jung-il S., (2013) *Optimization of Plastic Injection Molding Process Parameters for Manufacturing a Brake Booster Valve Body; Materials and Design* 56 (2014) 313–317, Published by Elsevier Ltd.

LAMPIRAN

Lampiran 1. Gambar *2D CT103 Casing P1*



Lampiran 2. Gambar *2D CT103 Casing P2*



Lampiran 3. ***Control Values for Processing***

Table 8.2 Control values for processing						
Material	Nozzle-side cylinder temperature[1, 2] (°C)	Mould temperature (°C)	Injection pressure (Bar)	Holding pressure (Bar)	Back pressure (Bar)	Remarks, see footnotes
PS	160-230	20-80	650-1550	350-900	40-80	
SB	160-250	50-80	650-1550	350-900	40-80	
SAN	200-260	40-80	650-1550	350-900	40-80	
ABS	180-260	50-85	650-1550	350-900	40-80	
PPO mod.	245-290	75-95	1000-1600	600-1250	60-90	
PVC - hard	160-180	20-60	1000-1550	400-900	40-80	3, 5, 8
PVC - soft	150-170	20-60	400-1550	300-600	40-80	3, 5, 8
CA	165-225	60-80	650-1350	400-1000	40-80	3, 4, 8
CAB	160-190	60-80	650-1350	400-1000	40-80	3, 4, 8
CP	160-190	60-80	650-1350	400-1000	40-80	3, 4, 8
PMMA	220-250	20-90	1000-1400	500-1150	80-120	4
PC	290-320	85-120	1000-1600	600-1300	80-120	4
PES	320-390	100-160	900-1400	500-1100	80-120	4
PE - soft	210-250	20-40	600-1350	300-800	40-80	
PS - hard	250-300	20- 60	600-1350	300-800	60-90	
PP	220-290	20-60	800-1400	500-1000	60-90	
PA 6,6	270-295[9]	20-120	450-1550	350-1050	40-80	4, 8
PA 6	230-260[9]	40-120	450-1550	350-1050	40-80	4, 8
PA 6,10	220-230[9]	20-100	450-1550	350-1050	40-80	4, 8
PA 11	200-250[9]	20-100	450-1550	350-1050	40-80	8
PA 12	200-250[9]	20-100	450-1550	350-1050	60-90	
PA amorph.	260-300	70-100	900-1300	300-600	60-90	
POM	185-215	80-120	700-2000	500-1200	40-80	3, 8
PET	260-280	20-140	800-1500	500-1200	80-120	
PBT	230-270	20-60	800-1500	500-1200	80-120	
PPS	300-360	20-200	750-1500	350-750	40-80	
FEP	340-370	150				5
ETFE	315-365	80-120				5

1. If no other empirical values are available: nozzle temperature = set nozzle-side cylinder temperature. Cylinder temperatures falling in direction of material throat, drop of 5-10 °C for each heating zone; max. temperature difference between nozzle-side and throat 20 °C. For more than 2 heating zones, set nozzle-side heating zone and the following to same temperature.
2. For heat-sensitive compounds set higher temperatures only for short cycle times (shorter dwell time in cylinder).
3. Heat-sensitive.
4. Process only dry granules.
5. Do not use shut-off nozzles, only open nozzles.
6. Injection without non-return valve recommended.
7. Work only without non-return valve.
8. Work only with low back pressure.
9. To improve material feed behaviour: set temperature at same level or slightly rising towards throat.

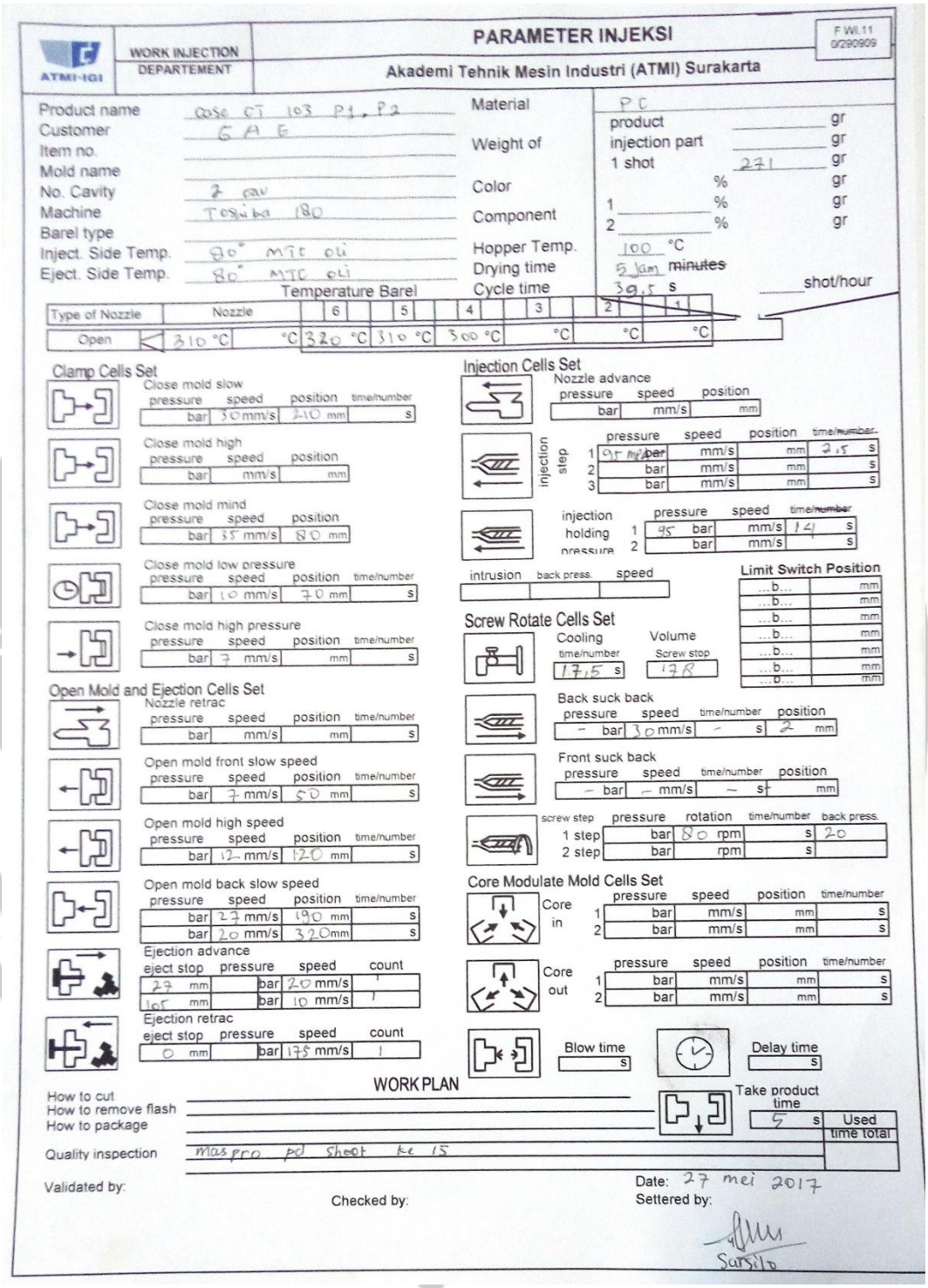
Lampiran 4. ***Temperatures for Cylinder and Mould***

Table 8.5 Temperatures for cylinder and mould: amorphous thermoplastics					
Injection material	**Nozzle-side cylinder temperature (°C) [1,2]**	**Feed yoke temperature (°C) [1,2]**	**Mould temperature (°C)**	**Transition temperature (°C ca.)**	**Remarks, see footnotes**
PS	160-230	30-35	20-60	90	
SB	160-250	30-35	20-60	85	4
SAN	200-260	30-35	40-80	100	4
ABS	180-260	30-35	40-85	105	4
PVC rigid	160-180	30-35	20-60	80	3, 5, 6, 7, 8, 10
PVC soft	150-170	30-35	20-40	55-75	3, 5, 8, 10
CA	185-225	30-35	30-60	100	3, 4, 8
CAB	160-190	30-35	30-60	125	3, 4, 8
CP	160-190	30-35	30-60	125	3, 4, 8
PMMA	220-250	35-45	60-110	105	4
PPE (PPO) mod.	240-290	35-45	70-120	120-130	3, 4, 11
PC	290-320	35-45	60-120	150	4, 11
PAR	350-390	45-65	120-150	190	4, 11
PSU	320-390	45-65	100-160	200	4, 11
PES	340-390	45-65	120-200	260	4, 11
PEI	340-425	45-65	100-175	220-230	4, 11
PAI	340-360	45-65	160-210	275	4, 11
PA amorph.	260-300	35-45	70-100	150-160	4

If no other practical values are available: Set nozzle temperature – nozzle-side cylinder temperature. Cylinder temperature reduction approaching the feed zone by max 5-10 °C per heating zone; max. temperature difference between nozzle and feed side of 20 °C. Set the nozzle-side heater band and the following one to the same temperature with more than 2 heater zones.

1. Only set the upper temperature with a high shot count with a thermally sensitive material (shorter dwell time in the cylinder).
2. Thermally sensitive!
3. The granulate must be dried before processing!
4. Do not use shut-off nozzles, only open nozzles!
5. Injection without check valve recommended!
6. Only operate with screw tips without check valves!
7. Only operate with low back pressure!
8. To improve the feed performance, set the same or a slightly higher cylinder temperature approaching the feed side.
9. A corrosion protected cylinder unit (Arbid) is recommended.
10. An abrasion proofed cylinder unit (Arbid) is recommended for processing of reinforced materials (e.g., fibre glass).
11. With thermostat cooling water valves:
    30...35 °C 2...3 scale markings
    35...45 °C 3...4 scale markings
    45...65 °C 4...5 scale markings

Lampiran 5. ***Injection Parameters***



WORK INJECTION DEPARTEMENT

PARAMETER INJEKSI

F WI.11 0/290909

Akademi Tehnik Mesin Industri (ATMI) Surakarta

Product name: case CT 103 P1, P2
Customer: GAE
Item no.:
Mold name:
No. Cavity: 2 cav
Machine: Toshiba 180
Barel type:
Inject. Side Temp.: 80° MTC oli
Eject. Side Temp.: 80° MTC oli

Material: PC
Weight of: product ____ gr; injection part ____ gr; 1 shot 271 gr
Color: ____ %
Component: 1 ____ %; 2 ____ %
Hopper Temp.: 100 °C
Drying time: 5 jam ~~minutes~~
Cycle time: 30,5 s ____ shot/hour

Temperature Barel

Type of Nozzle	Nozzle	6	5	4	3	2	1
Open	310 °C	°C	320 °C	310 °C	300 °C	°C	°C	°C

Clamp Cells Set

Close mold slow: pressure bar 30 mm/s; speed 210 mm; position ____ s; time/number
Close mold high: pressure bar ____ mm/s; speed ____ mm; position
Close mold mind: pressure bar 35 mm/s; speed 80 mm; position
Close mold low pressure: pressure bar 10 mm/s; speed 70 mm; position ____ s; time/number
Close mold high pressure: pressure bar 7 mm/s; speed ____ mm; position ____ s; time/number

Open Mold and Ejection Cells Set

Nozzle retrac: pressure bar ____ mm/s; speed ____ mm; position ____ s; time/number
Open mold front slow speed: pressure bar 7 mm/s; speed 50 mm; position ____ s; time/number
Open mold high speed: pressure bar 12 mm/s; speed 120 mm; position ____ s; time/number
Open mold back slow speed: pressure bar 27 mm/s; speed 190 mm; position ____ s; time/number
bar 20 mm/s; 320 mm; ____ s; time/number
Ejection advance: eject stop 27 mm; pressure ____ bar; speed 20 mm/s; count 1
105 mm; ____ bar; 10 mm/s; 1
Ejection retrac: eject stop 0 mm; pressure ____ bar; speed 175 mm/s; count 1

Injection Cells Set

Nozzle advance: pressure bar; speed mm/s; position mm
Injection step: 1 pressure 95 ~~mpa~~ bar; speed mm/s; position mm; time/~~number~~ 2,5 s
2 pressure bar; speed mm/s; position mm; time/number s
3 pressure bar; speed mm/s; position mm; time/number s
Injection holding pressure: 1 pressure 95 bar; speed mm/s; time/~~number~~ 14 s
2 pressure bar; speed mm/s; time/number s
intrusion; back press.; speed

Screw Rotate Cells Set

Cooling time/number 17,5 s; Volume Screw stop 178
Back suck back: pressure – bar; speed 30 mm/s; time/number – s; position 2 mm
Front suck back: pressure – bar; speed – mm/s; time/number – s; position mm
screw step: 1 step pressure bar; rotation 80 rpm; time/number s; back press. 20
2 step pressure bar; rotation rpm; time/number s

Limit Switch Position

…b…	mm
…b…	mm
…b…	mm
…b…	mm
…b…	mm
…b…	mm
…b…	mm
…b…	mm

Core Modulate Mold Cells Set

Core in: 1 pressure bar; speed mm/s; position mm; time/number s
2 pressure bar; speed mm/s; position mm; time/number s
Core out: 1 pressure bar; speed mm/s; position mm; time/number s
2 pressure bar; speed mm/s; position mm; time/number s

Blow time ____ s; Delay time ____ s
Take product time 5 s; Used time total

WORK PLAN

How to cut
How to remove flash
How to package
Quality inspection: Maspro pd shoot ke 15

Validated by:
Checked by:
Date: 27 mei 2017
Settered by: Sarsito