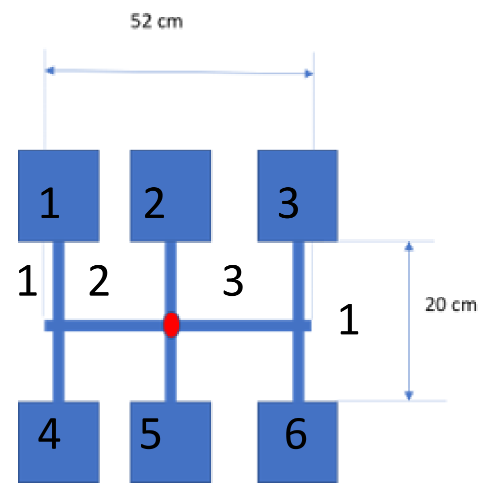
Solution Problem 1

Injection Molding

1. Calculate the pressure required to fill the mold.



- The dimensions (in cm) of each cavity are 10x10x1
- The runners diameter is 1 cm and their length are indicated in the drawing.
- The polymer is a PP with a density of 0.9 g/cm^3
- The viscosity curve for the resins is given in the document called PPVIS 2020:
    - Groups 1 and 3 should work with resin PAR0
    - Groups 2 and 4 should work with resin PAR3
    - Gropu   5 and 6 should work with resin PAR5
- The injection is done at the red dot.

1. Rephrase

- It is wanted to calculate the pressure required to fill a plastic part by injection molding. The part is constituted by rectangular and cylindrical shapes. The viscosity curve clearly indicates a Non-Newtonian behavior.

2.-Information

- Runners dimensions (radius, R=1cm; Length L1=20, L2=52)
- Cavities dimensions (Length, Lc=10; Width, W=10; Heigth, H=1)
- Polymer density; $\rho = 0.9$gr/cc
- Viscosity curve
- Injection zone location

3.- Assumptions

- Several assumptions can be proposed, and this will affect the results.
  - Just to mention some of them we can assume:
    - Isothermal flow
    - Laminar flow
    - Steady state flow
    - Filling time

4. Algorithm

1. Define the pressure drop equation using the momentum equations for a rectangular and cylindrical channels.
2. Determine the volumetric flows to fill each section
3. Determine the shear rate as function of flow rate
4. Determine the viscosity from the curve (or the fitting equation) at the shear rate according to the <u>assumed filling time</u>
5. The total pressure is the summation of the parts ΔP in each section
6. Solve

1.- Determine drop pressure equation from momentum equation for a rectangular and cylindrical channels

$$\Delta P = \frac{12QL\,k\gamma^{n}}{h^3 w}$$

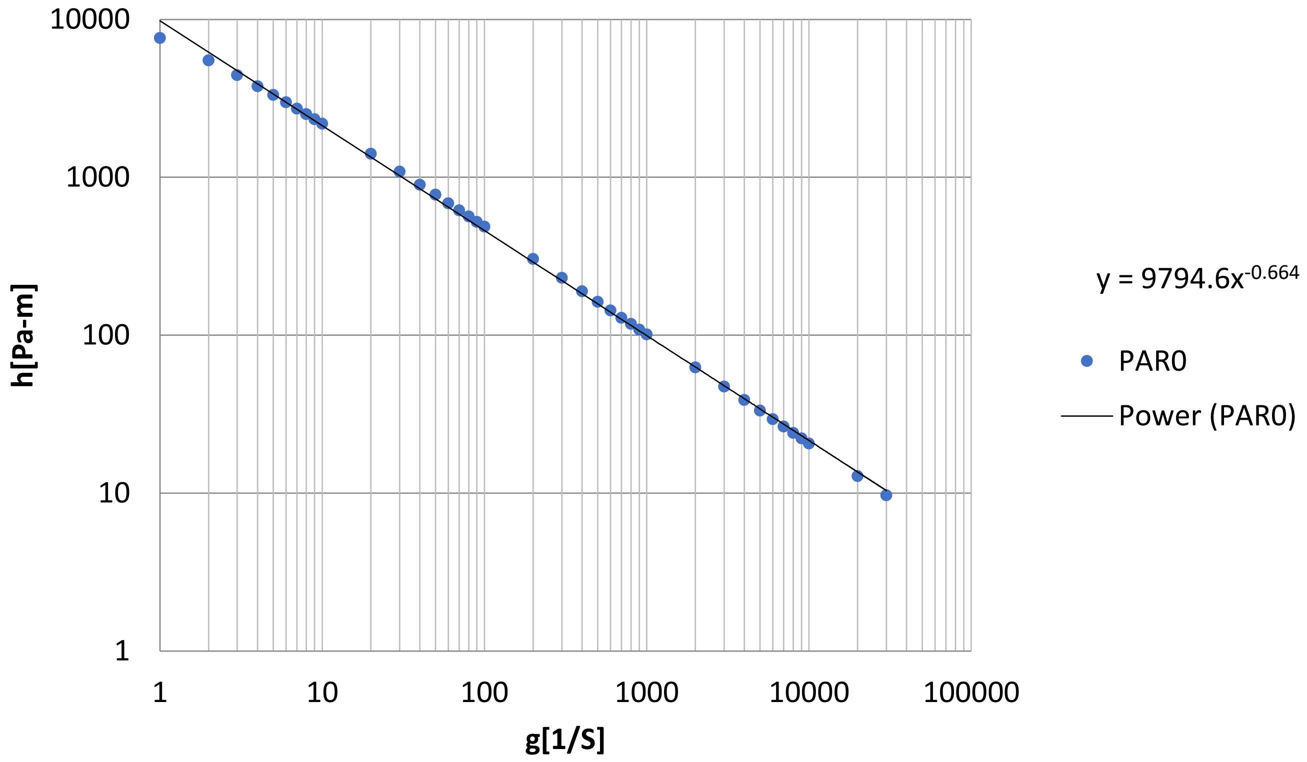
Rectangular prism geometry

$$\Delta P = \frac{8k\gamma^n}{\pi R^4} Q$$

Cynlindrical geometry

Where $k\gamma^n$ is the viscosity as a function of shear rate

2. Determine the viscosity equation as a function of shear rate PAR0 example



$$\eta = K\dot{\gamma}^{n-1}$$

$$\eta = 9794.6\dot{\gamma}^{-0.664}$$

3. Shear rate as function of flow rate

$$\dot{\gamma} = \frac{6Q}{WH^2}$$

Rectangular prism geometry

$$\dot{\gamma} = \frac{4Q}{\pi R^3}$$

Cynlindrical geometry

4. Determine the volumetric flows to fill each section

- Volume of sections:

$$V = \pi r^2 L$$

- Volume of rectangular section

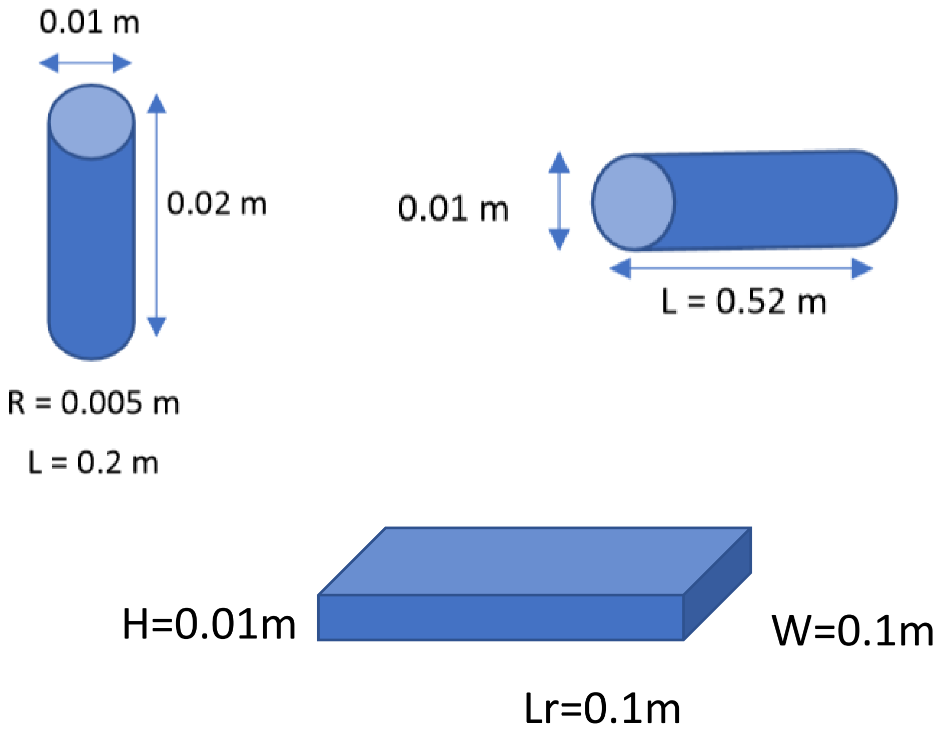
$$V_r = WHL$$

- Flow rate

$$\dot{Q} = \frac{V}{t}$$

Volume

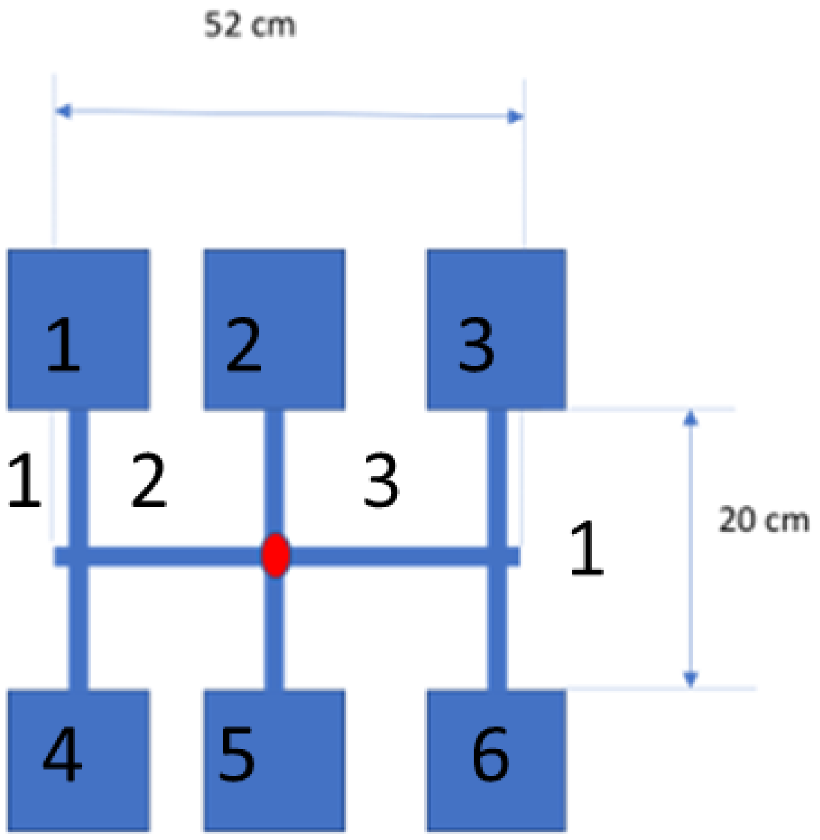
Time (filling)



Filling time t=1sec (use references)

Subscript *r* stands for rectangular shape

5. The total pressure is the summation of the parts ΔP in each section



Solution

t	1	sec

Cylindrical part 1

r	0.005	m
L	0.02	m
V	1.5708E-06	m3
Q	1.5708E-06	m3/s

Cylindrical part 2

r	0.005	m
L	0.52	m
V	4.08407E-05	m3
Q	4.08407E-05	m3/s

$$\dot{\gamma} = \frac{4Q}{\pi R^3}$$

γ	16	1/s

γ	416	1/s

Rectangular part

W	0.1	m
H	0.1	m
L	0.01	m
V	0.0001	m3
Q	0.0001	m3/s

$$\dot{\gamma} = \frac{6Q}{WH^2}$$

γ	0.6	1/s

$$\eta = 9794.6\dot{\gamma}^{-0.664}$$

η	1554	Pa-m

η	178.61	Pa-m

η	13750	Pa-m

$$\Delta P = \frac{8k\gamma^n}{\pi R^4} Q$$

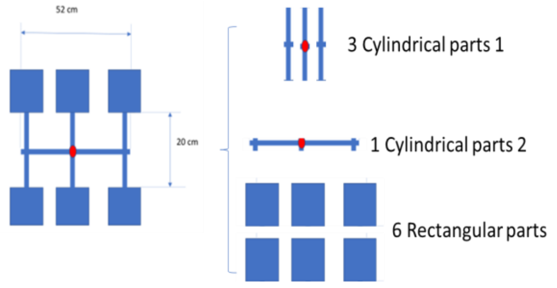
9945600.5	Pa
9.95	MPa

29720907	Pa
29.72	MPa

$$\Delta P = \frac{12QL\,k\gamma^n}{h^3 w}$$

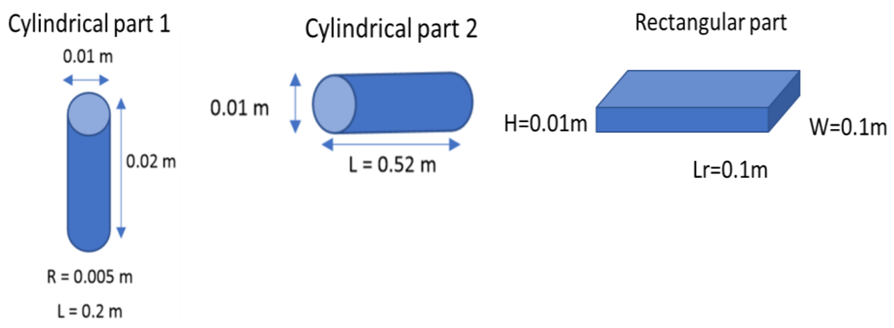
35013.408	Pa
0.04	MPa

Total P	59.76779	Mpa



Notes

Input
Output



Calculations dP=f(t)

	Q[m3/s]			γ[1/s]			η[Pa-m]			dP[MPa]			Total dP
t[s]	**CP1**	**CP2**	**RP**	**CP1**	**CP2**	**RP**	**CP1**	**CP2**	**RP**	**CP1**	**CP2**	**RP**	**[MPa]**
0.01	0.00157	0.00408	0.01000	16000.00	41600.00	6000.00	15.83	8.39	30.36	101.31	139.66	3.6431	465
0.02	0.00079	0.00204	0.00500	8000.00	20800.00	3000.00	25.08	13.30	48.10	80.26	110.64	2.8862	369
0.03	0.00052	0.00136	0.00333	5333.33	13866.67	2000.00	32.83	17.41	62.97	70.04	96.55	2.5186	322
0.04	0.00039	0.00102	0.00250	4000.00	10400.00	1500.00	39.74	21.07	76.22	63.58	87.65	2.2866	292
0.05	0.00031	0.00082	0.00200	3200.00	8320.00	1200.00	46.09	24.44	88.39	58.99	81.32	2.1214	271
0.06	0.00026	0.00068	0.00167	2666.67	6933.33	1000.00	52.02	27.58	99.77	55.48	76.49	1.9953	255
0.07	0.00022	0.00058	0.00143	2285.71	5942.86	857.14	57.62	30.55	110.52	52.68	72.63	1.8946	242
0.08	0.00020	0.00051	0.00125	2000.00	5200.00	750.00	62.97	33.39	120.77	50.37	69.44	1.8115	231
0.09	0.00017	0.00045	0.00111	1777.78	4622.22	666.67	68.09	36.10	130.59	48.42	66.75	1.7412	222
0.1	0.00016	0.00041	0.00100	1600.00	4160.00	600.00	73.02	38.72	140.05	46.73	64.43	1.6806	215
0.2	0.00008	0.00020	0.00050	800.00	2080.00	300.00	115.70	61.35	221.91	37.02	51.04	1.3315	170
0.3	0.00005	0.00014	0.00033	533.33	1386.67	200.00	151.45	80.30	290.47	32.31	44.54	1.1619	148
0.4	0.00004	0.00010	0.00025	400.00	1040.00	150.00	183.32	97.20	351.61	29.33	40.44	1.0548	135
0.5	0.00003	0.00008	0.00020	320.00	832.00	120.00	212.60	112.73	407.77	27.21	37.52	0.9786	125
0.6	0.00003	0.00007	0.00017	266.67	693.33	100.00	239.96	127.23	460.24	25.60	35.29	0.9205	118
0.7	0.00002	0.00006	0.00014	228.57	594.29	85.71	265.83	140.95	509.85	24.30	33.50	0.8740	112
0.8	0.00002	0.00005	0.00013	200.00	520.00	75.00	290.47	154.01	557.12	23.24	32.03	0.8357	107
0.9	0.00002	0.00005	0.00011	177.78	462.22	66.67	314.10	166.54	602.44	22.34	30.79	0.8032	103
1	0.00002	0.00004	0.00010	160.00	416.00	60.00	336.86	178.61	646.09	21.56	29.72	0.7753	99
2	0.00001	0.00002	0.00005	80.00	208.00	30.00	533.75	283.00	1023.71	17.08	23.55	0.6142	78
3	0.00001	0.00001	0.00003	53.33	138.67	20.00	698.65	370.44	1339.99	14.90	20.55	0.5360	68
4	0.00000	0.00001	0.00003	40.00	104.00	15.00	845.70	448.41	1622.04	13.53	18.65	0.4866	62
5	0.00000	0.00001	0.00002	32.00	83.20	12.00	980.77	520.03	1881.09	12.55	17.31	0.4515	58
6	0.00000	0.00001	0.00002	26.67	69.33	10.00	1106.99	586.95	2123.18	11.81	16.28	0.4246	54
7	0.00000	0.00001	0.00001	22.86	59.43	8.57	1226.30	650.21	2352.01	11.21	15.46	0.4032	52
8	0.00000	0.00001	0.00001	20.00	52.00	7.50	1339.99	710.49	2570.08	10.72	14.78	0.3855	49
9	0.00000	0.00000	0.00001	17.78	46.22	6.67	1449.00	768.29	2779.15	10.30	14.20	0.3706	47
10	0.00000	0.00000	0.00001	16.00	41.60	6.00	1554.00	823.96	2980.54	9.95	13.71	0.3577	46

Pressure as function of filling time