



Prediction of Creep Behaviour of Plastic Components

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ABSTRACT

Polymers and their composites often exhibit anisotropic properties and this needs to be taken into account when predicting the properties of components. Laboratory experiments have been carried out to measure the centre point deflection of injection moulded anisotropic plates under a line load in flexure. The plates were made from polypropylene and poly(butylene terephthalate) in the unreinforced state and reinforced with glass fibres. Tensile creep data were obtained on strip specimens cut from the plates and modelled to produce creep moduli. MOLDFLOW and PANDA software packages have been used to model the plates using the creep data to predict their time-dependent deformation under a line load. The software predictions have been compared with the laboratory results. The predictions made by MOLDFLOW and PANDA usually agreed to within an average of 5%. Discrepancies of about 15% were found between experiment and theory and are under investigation.

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Approved on behalf of Chief Executive, NPL, by Dr M K Hossain
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1 INTRODUCTION

The work described in this report forms part of the DTI Project AM5. This aims to provide the design engineer with creep data on plastics that allow for the effects of process-induced orientation in moulded components. Anisotropic square plates were injection-moulded from polypropylene (PP) and poly(butylene terephthalate) (PBT) both unreinforced and reinforced with glass fibres. Laboratory creep experiments were performed on the plates to determine the centre point deflection under a three point bend in flexure with a distributed line load for times between 10 and 10^5 seconds. Creep moduli, over the same time range, were obtained from strip specimens cut from the plates. Computer packages MOLDFLOW and PANDA were used to model the plates theoretically and the models were used together with the creep modulus data to predict the time-dependent deformation for different patterns of orientation. The predicted deflections from each of the packages were compared with the experimental creep measurements.

MOLDFLOW is a large sophisticated injection moulding flow and mechanical properties analysis package costing ~ £100k. PANDA is a simple panel design and analysis package which is supplied free to purchasers of the Design Guide for Plastics Panels [1]. Details of the finite element methods used in MOLDFLOW are contained in the MOLDFLOW User Manuals [2] and details of the finite difference methods used in PANDA are contained in [3]. The most important difference between the MOLDFLOW and PANDA packages for this application is that the MOLDFLOW Flow Modelling stage produces a set of moduli for every point in the plate that has been represented in the model, and these moduli can be different both in size and direction at every point in the plate, whereas the simpler PANDA software assumes the moduli to be the same at every point.

MOLDFLOW Flow Modelling software was used to model the molecular or fibre orientation distribution within the plate and MOLDFLOW FEA software was used to perform a stress analysis for the plate model under a line load. A simplified set of plate geometry and loading conditions was prepared to predict the deflection with the PANDA software.

The purpose of this report is to describe the steps involved in preparing the data required for use with the software and to compare the predictions made by each of the packages with the experimental measurements.

2 DATA REQUIRED BY MOLDFLOW AND PANDA

The following data must be provided for both MOLDFLOW and PANDA packages

- Component geometry
- Material stiffness data
- Applied load and boundary conditions

In addition the Flow Modelling stage of MOLDFLOW requires provision of

- Material properties data eg viscosity and structural data
eg fibre volume fraction.
- Processing parameters eg mould temperature, injection time.

2.1 GEOMETRY

The injection moulded plates measured 150 × 150 mm and were produced with a nominal thickness of 2.7 mm for each material. The geometry of the component is shown in Figure 1.

2.2 PROCESSING DATA FOR MOLDFLOW FLOW MODELLING

MOLDFLOW Flow Modelling software was used to predict the flow of plastics into the mould cavity and the resultant fibre orientation/anisotropy and modulus values as a function of time of the plates thus formed. Details of the characterisation and modelling of the coathanger-gated square plate and the injection moulding conditions used have been reported in [4] and [5]. The values of Poisson's ratio used for each of the four materials were obtained from [7]. Summaries of the material structural data, and the processing data used for the flow modelling are given below in Tables 1 and 2 respectively.

Material	ν_{12}	Glass fibre length (mm)	Glass fibre diameter (mm)	% volume glass fibres
PBT/Glass	0.44	0.334	.0090	10.8
PP/Glass	0.46	0.4880	.0125	13.2
PBT	0.45			
PP	0.47			
Glass	0.2			

Table 1 Material structural data used in MOLDFLOW and PANDA(ν_{12} only)

Specimen	FILLING			PACKING		
	Mould temperature (°C)	Melt temperature (°C)	Injection time(s)	Pack pressure (MPa)	Pack time(s)	Cool time(s)
PBT/Glass	58	270	4.36	59	6	30
PP/Glass	60	250	1.01	55	15	30
PBT	58	270	4.03	38	12	30
PP	60	250	3.9	44	25	25

Table 2 Processing data used in MOLDFLOW for the Flow Modelling of filled and unfilled plates

2.3 MODELLING OF MATERIALS CREEP DATA

In order to predict the time-dependent deformation of the plate the following material stiffness data was used with the MOLDFLOW and PANDA packages

Tensile modulus parallel to flow direction $E_0(t)$
 Tensile modulus perpendicular to flow direction $E_{90}(t)$
 Shear modulus $G_{12}(t)$
 Poisson's ratio ν_{12}

This stiffness data must be provided for each time of interest and involves the use of creep moduli data obtained from tensile strip specimens cut from test plates made from each of the four materials [6]. In [6] it has been shown that this data can be accurately modelled by the stretched-exponential function

$$E_\theta(t) = E_\theta(0) \exp \{ -(t/t_o)^\gamma \} \quad (1)$$

where the parameters have the following definition

$E_\theta(0)$ is the creep modulus at angle θ for time $t=0$
 t_o is a mean retardation time
 γ is the creep index
 θ is the angle to the flow direction in the plate at which the strips were cut.

Values of these parameters for each of the four materials are given in [6] and have been reproduced in Table 4 overleaf. The first column of the Table gives the plate number according to reference [5]. Note that for the fibre-reinforced materials the parameters depend on the position in the plate - specified by numbers 1,2 and 3 (see diagram Table 4). The values of the parameters used to generate moduli for the software packages were averages over these positions.

For PANDA, where $E1 = E_0(t)$ and $E2 = E_{90}(t)$, averages for PP/Glass and PBT/Glass were taken over positions 1,2 and 3, and over 1 and 3 respectively. For the unfilled polymers it was assumed that the properties were essentially independent of position in the plate and the 0° and 90° values of the parameters for PP and PBT were taken directly from Table 4. These parameters are summarised in Table 3.

Specimen	$E_0(0)$ $E_{90}(0)$ (GPa)	t_o t_{o2} (sec)	γ γ_2
PBT/Glass	6.91 3.91	2.02×10^8 2.31×10^7	.21 .19
PP/Glass	8.42 5.14	3.43×10^7 1.16×10^6	.075 .089
PBT	2.52 2.44	1.13×10^7 6.88×10^6	.28 .30
PP	3.12 2.92	4900 10050	.085 .076

Table 3 Creep parameters taken from Table 4 and used to generate orthotropic moduli $E1, E2$ for PANDA from the model $E_\theta(t) = E_\theta(0) \exp \{ -(t/t_o)^\gamma \}$

Table 4 Parameters obtained from modelling the creep modulus data of strip specimens by a stretched-exponential function
 $E_{\theta}(t) = E_{\theta}(0) \exp \{-(t/t_0)^{\gamma}\}$

Specimen	$E_{\theta}(0)$ (GPa)	t_0 (s)	γ
PP			
0° (BO5-1)	3.12	4.90×10^3	0.085
90° (BO6-1)	2.92	1.01×10^4	0.076
45° (BO7-1)	2.57	5.03×10^3	0.088
PP/Glass			
0° (CO2-1)	8.07	6.95×10^6	0.072
0° (CO2-2)	8.33	2.49×10^7	0.077
0° (CO2-3)	8.86	7.12×10^7	0.078
90° (CO3-1)	5.02	1.03×10^6	0.093
90° (CO3-2)	5.03	1.49×10^6	0.090
90° (CO3-3)	5.35	9.64×10^5	0.084
45° (CO4-1)	5.81	6.02×10^5	0.080
PBT			
0° (HO6-1)	2.52	1.13×10^7	0.28
90° (HO7-1)	2.44	6.88×10^6	0.30
45° (HO8-1)	2.54	8.23×10^6	0.29
PBT/Glass			
0° (F25-1)	7.15	3.13×10^8	0.20
0° (F25-3)	6.66	9.05×10^7	0.23
90° (F30-1)	3.97	1.74×10^7	0.19
90° (F30-3)	3.85	2.83×10^7	0.19

The MOLDFLOW package can be used in two modes - Mode 1 for filled components (defined as the Fibre mode) and Mode 2 for unfilled components (defined as the Thermoplastic mode). The user is required to provide isotropic modulus data for both fibre and matrix for the Fibre mode. For the Thermoplastic mode the material moduli data can be provided as isotropic or orthotropic.

For the MOLDFLOW fibre mode, isotropic matrix data for PP/Glass and PBT/Glass was obtained by using the mean of the 0°, 45° and 90° creep modelling parameters for PP and PBT respectively from Table 4 to generate the matrix moduli. These parameters are summarised in Table 5a.

MATRIX	E(0) GPa	t_o sec	γ
PP	2.87	6660	.083
PBT	2.50	8.81×10^6	.29

Table 5a Creep parameters derived from Table 4 and used to generate isotropic moduli for MOLDFLOW Mode 1 for fibre-filled plates

A value of 72 GPa was provided from the MOLDFLOW database for the modulus of the glass fibre.

In the MOLDFLOW thermoplastic mode the unfilled PBT material was assumed to be isotropic. The same modelling parameters were used as for the matrix of the filled PBT in Table 5a and these are summarised in Table 5b below. The unfilled PP material was assumed to be orthotropic and the same parameters were used as for PANDA in Table 3 and these are summarised in Table 5c below.

Specimen	E(0) (GPa)	t_o (sec)	γ
PBT	2.50	8.81×10^6	.29

Table 5b Creep parameters used to generate isotropic moduli for MOLDFLOW Mode 2 for unfilled plates

Specimen	$E_0(0)$ $E_{90}(0)$ (GPa)	t_o t_{o2} (sec)	γ γ_2
PP	3.12 2.92	4900 10050	.085 .076

Table 5c Creep parameters used to generate orthotropic moduli for MOLDFLOW Mode 2 for unfilled plates

Poisson's ratio was assumed by both packages to be constant and the shear modulus G_{12} was assumed to depend on time according to

$$G_{12}(t) = E_0(t) / 2(1+\nu).$$

2.4 LOADING AND BOUNDARY CONDITIONS

The load used was a three point bend with a distributed line load as illustrated in Figure 2a. In order to examine the effects of anisotropy in the plate two loading cases were analysed. In the first the line of loading was parallel to the flow direction in the plate, and in the second the line of loading was normal to the flow direction. The magnitude of the load was chosen to give a deflection of about 2 mm at the centre of the plate and varied between 50 and 180N. The plate boundary conditions used in the three point bend test are shown in Figure 2b.

2.5 DEFORMATION PREDICTED

The deformation predicted by the packages was the deflection per unit load at the centre of the plate as a function of time between 10^{-10} and 10^5 seconds as measured in the laboratory creep tests on the four plates reported in [7].

3 MODIFICATIONS TO PANDA

The application of PANDA to the creep of plastics panels has been outlined in the Panel Design Guide [1,8]. It was found (see [6]), that the creep model defined in [1,8] could not be used to model the data satisfactorily, so the stretched-exponential model in equation (1) was included as an option in the PANDA creep module.

The use of PANDA for the creep prediction of plate deflection is illustrated in Appendix 14-17 of the User Notes for PANDA[8], based on worked examples 8.1 and 8.2 from the Design Guide. PANDA results are presented in terms of the maximum plate deflection, and in the case of a line load the maximum plate deflection occurs at the edge of the plate. The output from the creep module was modified for the current work to display the deflection at the centre of the plate instead of the maximum deflection. An example of the output from PANDA for the line loading of the PP/Glass plate along and normal to the flow direction is given in the Appendix.

4 RESULTS AND DISCUSSION

Comparison of the predictions by MOLDFLOW and PANDA with the experimental measurements is presented for the filled plates in Figures 3 and 4 and for the unfilled plates in Figures 5 and 6. The experimental measurements as presented in [7] have been normalised to give the deflection per unit load and are shown as continuous lines in the figures. These results were part of a larger "scouting" exercise in which many different materials, thicknesses and gate conditions were initially tested.

For the filled plates, predicted deflections per unit load normal to the flow direction exceed those parallel to the flow direction at all times, their ratio reflecting the level of anisotropy in the plate. This ratio is close to unity for the unfilled plates in Figure 6 (PBT) consistent with low levels of anisotropy for this material.

The deflections predicted by MOLDFLOW and PANDA agree to within 5% of each other except for the fibre-filled plates loaded normal to the flow direction where they differ by 13-19%. This effect could be due to an overestimate by MOLDFLOW of the transverse fibre orientation in plate regions furthest from the gate. This suggestion is supported by the fact that experimental moduli of the transverse strips 3 (see diagrams Table 4) were considerably lower than recent values predicted by MOLDFLOW.

MOLDFLOW and PANDA over-predict the deflection as measured by anything between 13% and 30% except for PP unfilled where they under-predict the deflection by 10%. One possibility is that the deflection could be sensitive to variations in Poisson's ratio which could increase with time. However for all materials a 5% increase in Poisson's ratio produces less than 2% decrease in the predicted deflection at 10^5 seconds for loading both along and parallel to the flow direction. This is far less than the difference between measured and predicted values. The possibility that restraints on anticlastic curvature could affect the results have also been examined through a few FE calculations. However the results indicated that these effects are insignificant with regard to the centre point deflection.

The relatively large overprediction by PANDA of the deflection of the 0° fibre-reinforced plate (see Figs 3 and 4) could partly arise from the fact that the relevant flexural moduli determined for 0° strips are larger than the tensile moduli[7]. This result was most marked for PP/Glass and is consistent with a skin-core structure in which the skin layer is highly oriented in the flow direction. However this explanation could not explain the overpredictions by PANDA for the 90° fibre-reinforced plate since the measured strip moduli at 90° to the flow were marginally higher in tension than in flexure[7]. Also it could not explain the discrepancies between the observed plate deflections and the MOLDFLOW predictions, since the MOLDFLOW calculations account for through-thickness variations in material properties and hence for differences in tensile and flexural stiffness. As mentioned above, however, the MOLDFLOW predictions for the fibre-reinforced plates could show inaccuracies associated with errors in the predicted fibre orientation distribution. Some discrepancies could also arise from variations of moduli across the plates such that the strip data were not accurately representative of values for the plate (despite the averaging of strip moduli over the location within the plate for the fibre-reinforced materials). Further work is required to check the accuracy of the observed plate deflections and the possible sources of error in the predictive methods.

5 CONCLUSIONS

Software packages such as PANDA and MOLDFLOW can be used for the prediction of the creep behaviour of plastic components.

PANDA, and the similar COMPBEAM software, are quick and easy to use and deal with idealised plate and beam geometries which can be used as building blocks in modelling many components.

MOLDFLOW, or equivalent, needs to be used for complex components but requires familiarity with the software and suitable hardware to run the package.

Discrepancies of about 15% have been obtained between the theoretical and experimental results. Further work is suggested to study the origins of these discrepancies.

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7 REFERENCES

- 1 Johnson A.F. and Sims G.D. Design Procedures for Plastics Panels. NPL Publication, Teddington 1987.
2. MOLDFLOW User Manuals MF/FLOW Release 9 and MF/STRESS Release 3. Moldflow (Europe) Ltd, Orpington, Kent, BR6 0JA. September 1994.
3. Woolf, A and Johnson, A.F. The solution of plate deflection problems by finite difference methods. NPL Report DMA(A)14, July 1980.
4. Chakravorty, S., Rides, M. and Brown, C.S. Characterisation and modelling of injection moulded plates. Part 1, Characterisation. NPL Report DMM(C)28, November 1994.
5. Rides, M., Chakravorty, S., McDermott, J.R. and Read, B.E. Characterisation and modelling of injection moulded plates. Part 2, Modelling and comparison of measurements. NPL Report DMM(C)29, November 1994.
6. Read, BE Generation of tensile creep data on thermoplastic specimens cut from injection-moulded anisotropic plates. NPL Report DMM(C)32, November 1994.
7. Pearce A. and Sims G.D. Short term flexural creep data of oriented, injection-moulded thermoplastic plates, Part 1: edge gated, unfilled and glass-fibre reinforced polypropylene and poly(butylene terephthalate). NPL Report DMM(C)30 November 1994.
8. Woolf A. and Johnson A.F. User Notes for Panel Design Analysis Software. NPL Report DMA(A)170 December 1991.

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6. Graph of plate deflection as a function of time for unfilled PBT.

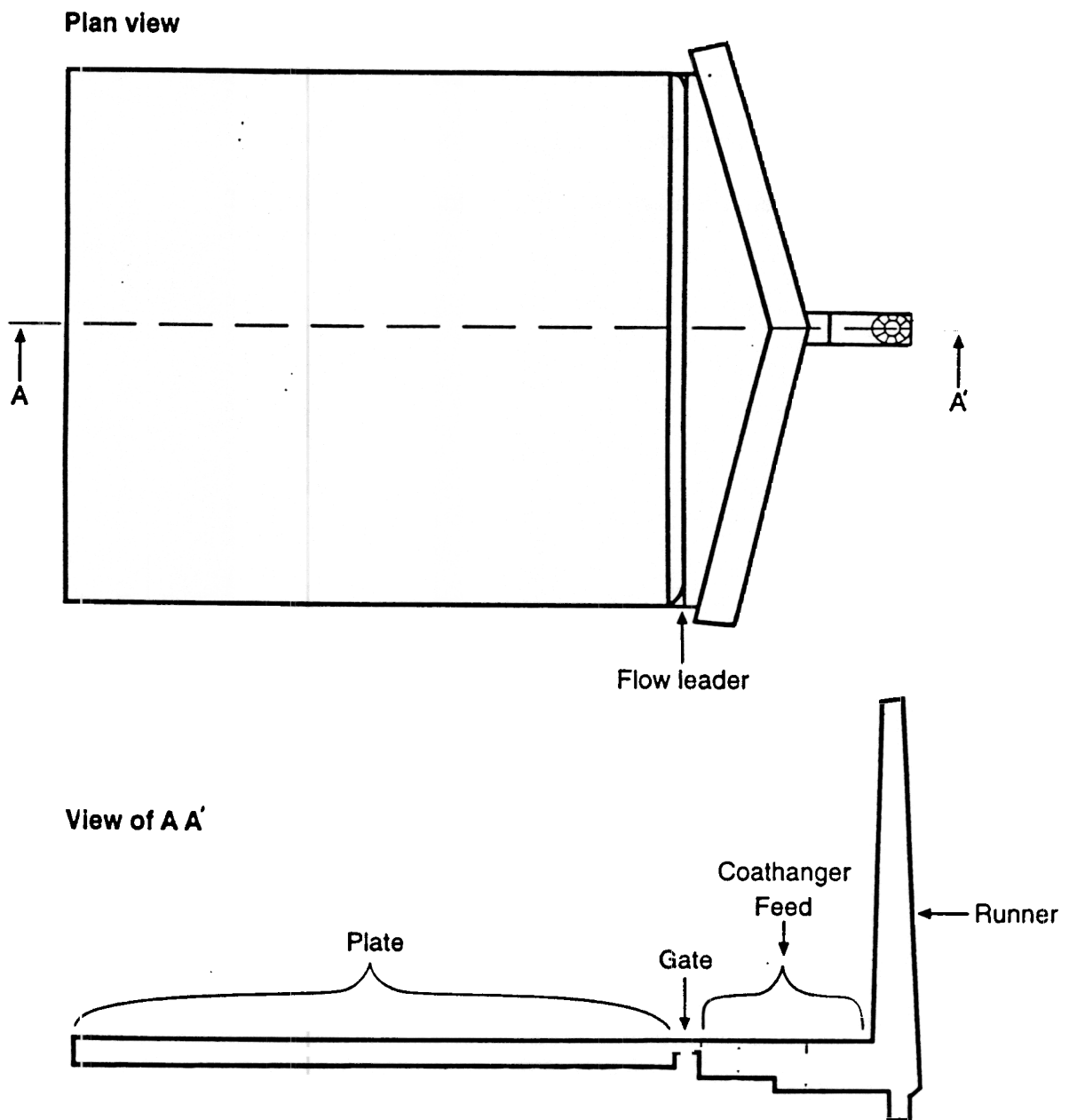


Figure 1 Plate geometry plan and cross-sectional view.

Figure 2a Two distributed line loading conditions used in PANDA and MOLDFLOW

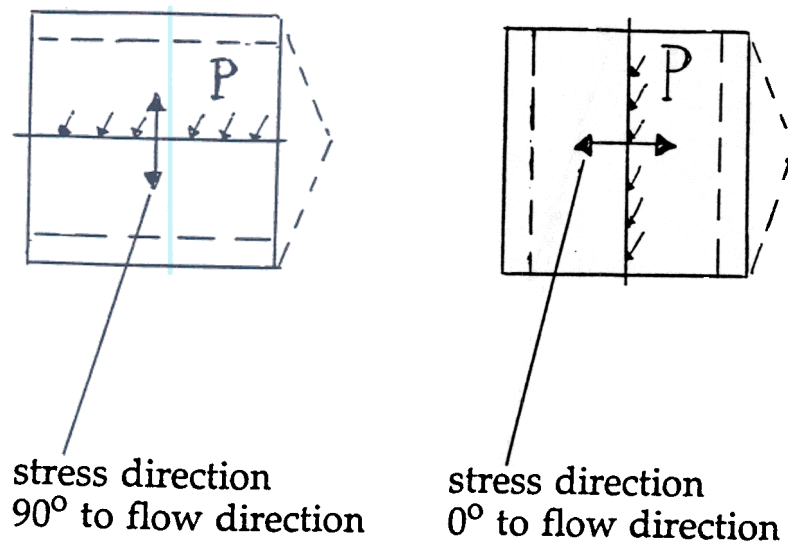
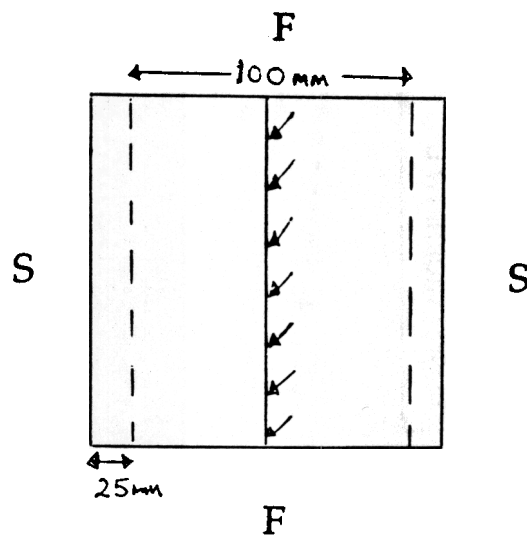


Figure 2b Plate boundary conditions used in PANDA and MOLDFLOW



S denotes edge simply supported

F denotes edge free

Single Edge Gate / coathanger / PP / Glass

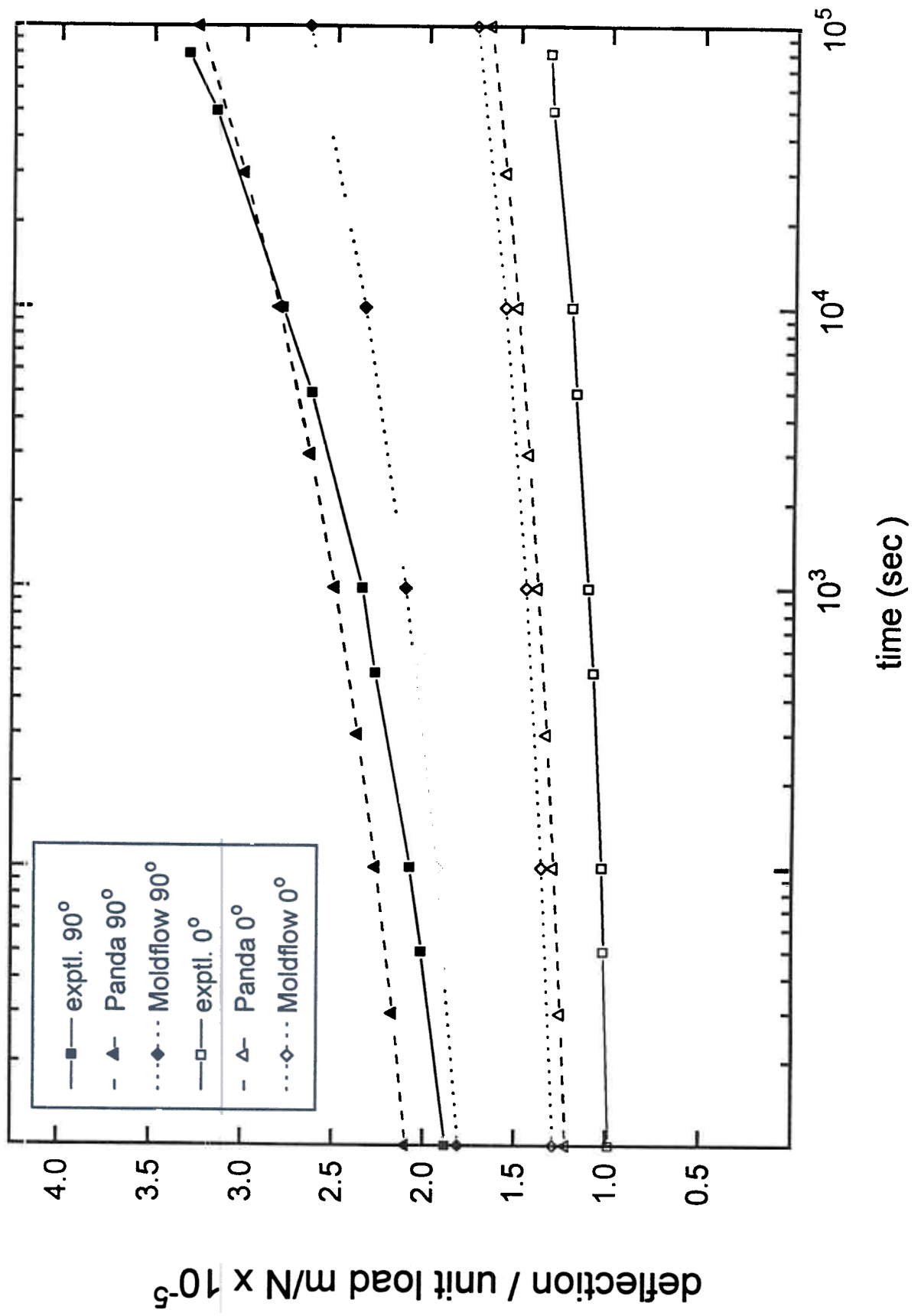


Figure 3

Single Edge Gate / coathanger / PBT / Glass

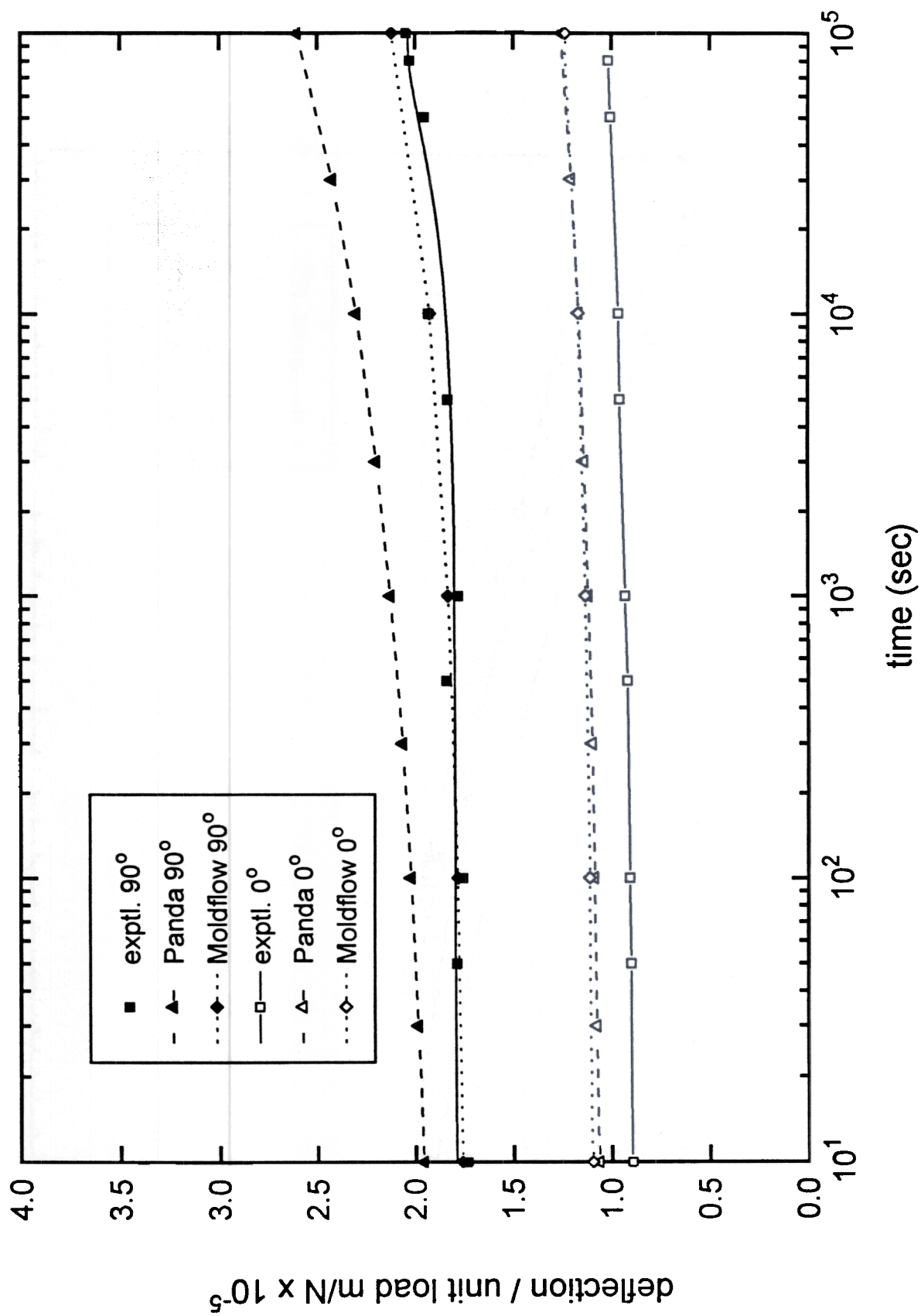
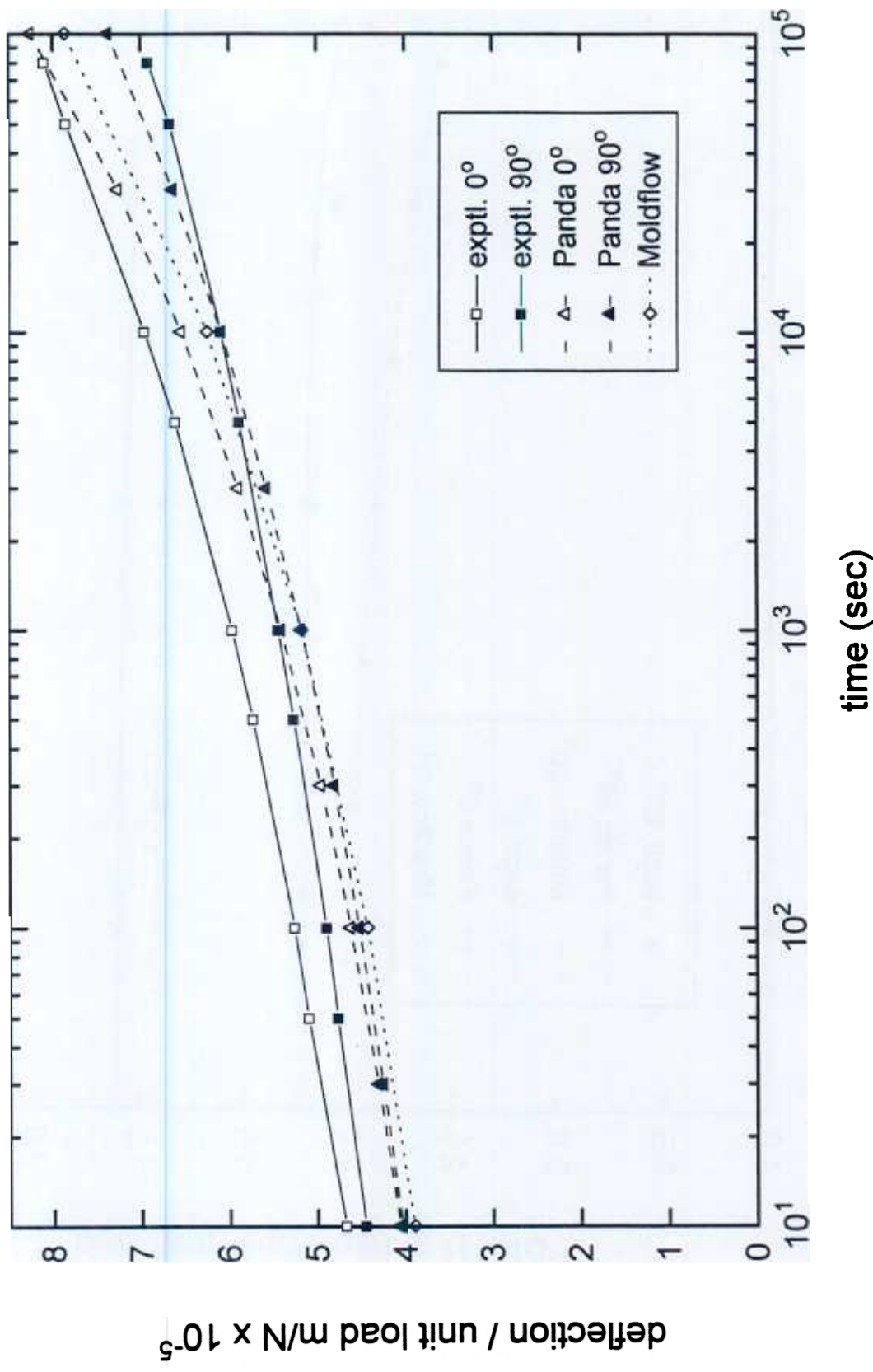
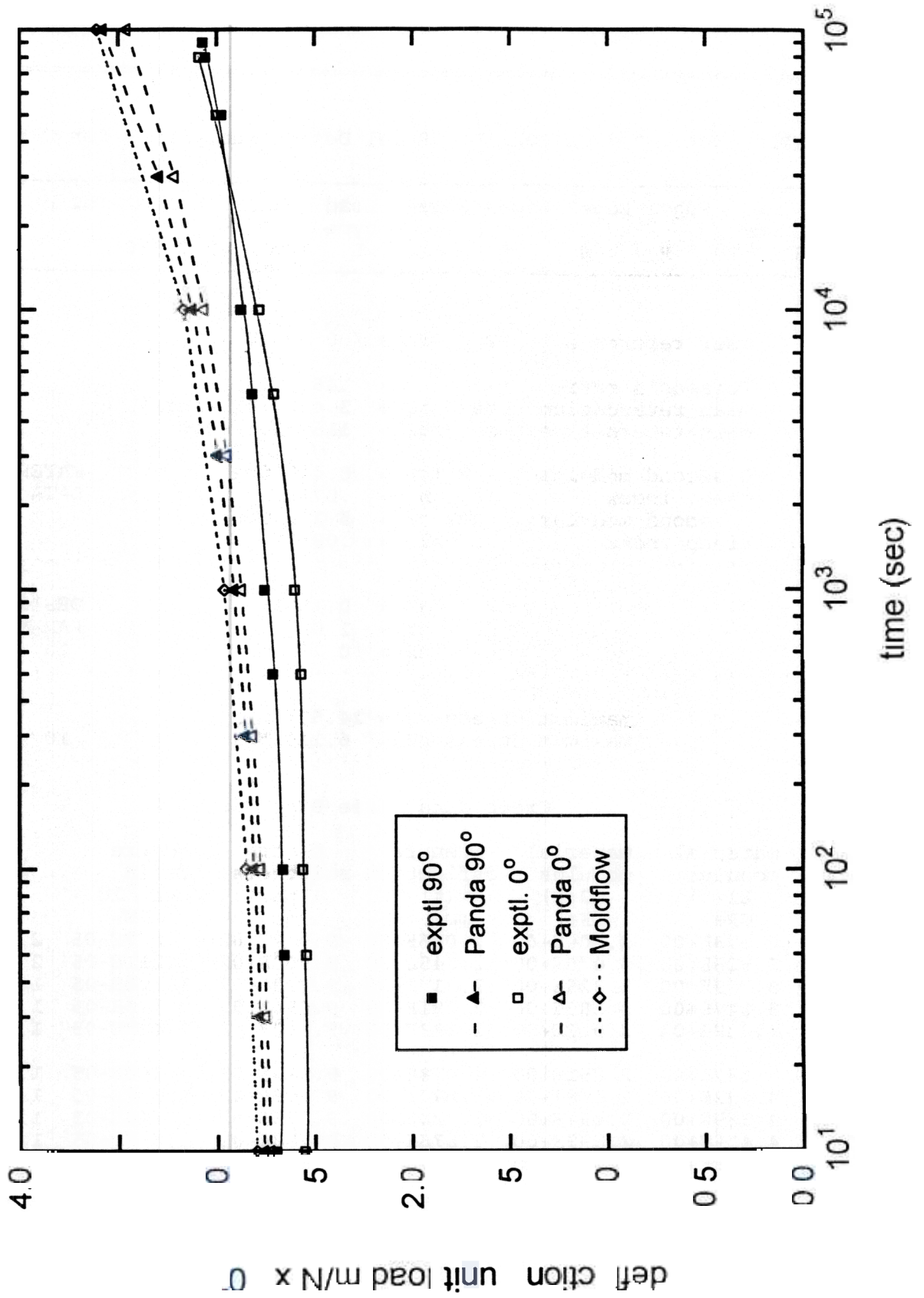


Figure 4

Singe Edge Gate / coathanger / PP / unfilled



Single Edge Gate coathanger PBT unfilled



figure

APPENDIX Example of output from PANDA

Table A1: Polypropylene/glass 0° to the flow direction

NPL PANDA 1.7 (CONTROLLED) - Panel Design Analysis - for CREEP											RECTNGR DESIGN DATA
a	b	h	Edge1	Edge2	Edge3	Edge4	Load	Load	a1/a	b1/b	
mm	mm	mm					type	N			
100	148	2.70	F	S	F	S	L	1.70E+02	0.500		

user reference : PP / Glass / 0 / d16

Poisson's ratio = .46
mean retardation time to = 3.435E+07 secs
mean retardation time to2 = 1160000 secs

0 second modulus E1(o) = 8.420 GPa MATERIAL
creep index n = .075 DATA
0 second modulus E2(o) = 5.136 GPa
creep index n2 = .089
.....

α = 0.1201 DESIGN
c1 = 1.057 PARAMETERS
c2 = 0.263 10 sec
.....

maximum stress σ_1 = 24.655 MPa
maximum stress σ_2 = 6.140 MPa 10 sec
.....

Creep data (see BER (8.5))

time	material	material	centre	centre	centre	shear
t	modulus	modulus	deflection	stiffness	defln	modulus
secs	E1(t)	E2(t)	w(t)	ptr.	/unit ld	G12
	GPa	GPa	mm	αc	m/N	GPa
1.000E+01	6.093E+00	3.604E+00	2.086E+00	9.994E-02	1.227E-05	2.087E+00
3.000E+01	5.926E+00	3.475E+00	2.145E+00	9.908E-02	1.261E-05	2.030E+00
1.000E+02	5.733E+00	3.325E+00	2.217E+00	9.798E-02	1.304E-05	1.963E+00
3.000E+02	5.547E+00	3.180E+00	2.291E+00	9.684E-02	1.348E-05	1.899E+00
1.000E+03	5.332E+00	3.012E+00	2.383E+00	9.542E-02	1.402E-05	1.826E+00
3.000E+03	5.127E+00	2.851E+00	2.478E+00	9.393E-02	1.458E-05	1.756E+00
1.000E+04	4.892E+00	2.668E+00	2.597E+00	9.209E-02	1.527E-05	1.675E+00
3.000E+04	4.669E+00	2.494E+00	2.720E+00	9.020E-02	1.600E-05	1.599E+00
1.000E+05	4.416E+00	2.299E+00	2.876E+00	8.788E-02	1.692E-05	1.512E+00
3.000E+05	4.178E+00	2.116E+00	3.040E+00	8.552E-02	1.788E-05	1.431E+00
1.000E+06	3.910E+00	1.914E+00	3.247E+00	8.265E-02	1.910E-05	1.339E+00
3.000E+06	3.661E+00	1.730E+00	3.468E+00	7.976E-02	2.040E-05	1.254E+00
1.000E+07	3.384E+00	1.530E+00	3.753E+00	7.630E-02	2.207E-05	1.159E+00
3.000E+07	3.129E+00	1.351E+00	4.058E+00	7.287E-02	2.387E-05	1.072E+00
1.000E+08	2.850E+00	1.161E+00	4.457E+00	6.880E-02	2.622E-05	9.759E-01
3.000E+08	2.596E+00	9.967E-01	4.892E+00	6.483E-02	2.878E-05	8.892E-01

Table A2: Polypropylene/glass 90° to the flow direction

NPL PANDA 1.7 (CONTROLLED)- Panel Design Analysis - for CREEP

a	b	h	Edge1	Edge2	Edge3	Edge4	Load	Load	a1/a	b1/b	RECTNGR
mm	mm	mm					type	N			DESIGN
148	100	2.69	S	F	S	F	L	9.00E+01		0.500	DATA

user reference : PP / Glass / 90 / D10

Poisson's ratio = .46
mean retardation time to = 3.435E+07 secs
mean retardation time to2 = 1160000 secs

0 second modulus E1(o) = 8.420 GPa MATERIAL
creep index n = .075 DATA
0 second modulus E2(o) = 5.136 GPa
creep index n2 = .089

α = 0.0927 DESIGN
c1 = 0.018 PARAMETERS
c2 = 1.058 10 sec
.....

maximum stress σ_1 = 5.196 MPa
maximum stress σ_2 = 13.155 MPa 10 sec

Creep data (see BER (8.5))

time	material	material	centre	centre	centre	shear
t	modulus	modulus	deflection	stiffness	defln	modulus
secs	E1(t)	E2(t)	w(t)	ptr.	/unit ld	G12
	GPa	GPa	mm	αc	m/N	GPa
1.000E+01	6.093E+00	3.604E+00	1.907E+00	7.791E-02	2.119E-05	2.087E+00
3.000E+01	5.926E+00	3.475E+00	1.977E+00	7.791E-02	2.197E-05	2.030E+00
1.000E+02	5.733E+00	3.325E+00	2.067E+00	7.792E-02	2.297E-05	1.963E+00
3.000E+02	5.547E+00	3.180E+00	2.161E+00	7.792E-02	2.402E-05	1.899E+00
1.000E+03	5.332E+00	3.012E+00	2.282E+00	7.794E-02	2.536E-05	1.826E+00
3.000E+03	5.127E+00	2.851E+00	2.411E+00	7.794E-02	2.679E-05	1.756E+00
1.000E+04	4.892E+00	2.668E+00	2.578E+00	7.796E-02	2.864E-05	1.675E+00
3.000E+04	4.669E+00	2.494E+00	2.758E+00	7.798E-02	3.064E-05	1.599E+00
1.000E+05	4.416E+00	2.299E+00	2.994E+00	7.801E-02	3.326E-05	1.512E+00
3.000E+05	4.178E+00	2.116E+00	3.253E+00	7.804E-02	3.614E-05	1.431E+00
1.000E+06	3.910E+00	1.914E+00	3.599E+00	7.810E-02	3.998E-05	1.339E+00
3.000E+06	3.661E+00	1.730E+00	3.986E+00	7.818E-02	4.429E-05	1.254E+00
1.000E+07	3.384E+00	1.530E+00	4.515E+00	7.830E-02	5.017E-05	1.159E+00
3.000E+07	3.129E+00	1.351E+00	5.123E+00	7.845E-02	5.693E-05	1.072E+00
1.000E+08	2.850E+00	1.161E+00	5.935E+00	7.813E-02	6.595E-05	9.759E-01
3.000E+08	2.596E+00	9.967E-01	6.905E+00	7.803E-02	7.673E-05	8.892E-01