**TEAM 5**

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**FINAL - Plastics and Composites Engineering**

Due any time before 22:00 hrs on August 1st, 2020

**Instructions**

**Solve the problems following the next steps:**

1. Rephrase the problem indicating very clearly what you have been asked to do.
2. List all the data provided.
3. Make a list of the assumptions, justifying each of them.
4. Write down an algorithm for the solution you are proposing (no calculations are needed at this stage)
5. Solve the problem.
6. Ask yourself if the result is reasonable and, if needed check in the web for technical papers to support your answer.
7. List the references used in the solution of the problem.

This procedure is a must for this part of the exam to be considered for grading.

1. Work by yourself from A to D, afterwards you will work E to G with your team.
2. Upload your individual proposal in the Google Drive in the folder 10 Final Assessment in your personal folder, as: MY NAME. FINAL EXAMINATION PART ABCD.
3. Upload your team´s solution with the Subject: TEAM NUMBER FINAL EXAMINATION PART EFG

**Problems (60 points)**

## Q1: The manufacturing plant where you work, The Mexico Supply Chain, has been requested, by the China Car Company, to inject a flat piece with the following dimensions (W=10 cm, L=20 cm y H= 0.5 cm) **{20 pts}**

W

L

y

z

x

The injection can be done in a multicavity die and the plant manager wants to produce 10 specimens per minute, considering two different type of resins, but before he accepts the request of the China Car Company, he asks you

1. To determine the pressure required to produce those pieces using the resin that requires the lowest pressure drop.
2. To propose he best multicavity configuration (justify your answer)

Consider that the injection happens at 200oC and that the density of the material at that temperature is 0.75; the viscosity can be represented by a power law and their respective parameters are given below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Resin | MFI | ηo (poises) | Critical shear rate (s-1) | Power law index |
| **1** | 1.5 | 54000 | 1.5 | 0.48 |
| **2** | 2.5 | 29000 | 2.5 | 0.48 |

A. INSTRUCTIONS

Given a injection mould process, a) determine the pressure required to produce ten flat pieces using the resin that requires the lowest pressure drop; and b) propose the best multicavity configuration.

We have to inject a flat piece of dimensions W=10 cm, L=20 cm y H= 0.5 cm. It can be done in multicavity die, we need 10 pieces per minute and we have 2 resins. We need to determine the pressure required for producing them, with the resin that needs the lowest pressure drop and we have to design the best multicavity configuration.

We have been requested to produce flat pieces, by injection molding, using 2 different type of resins. But before doing that, the plant manager ask us to determine the pressure required to produce those pieces using the resin that requires the lowest pressure drop and also, to propose the best multi cavity configuration for that pression.

B. AVAILABLE DATA

* Dimensions of the flat piece (W=10 cm, L=20 cm y H= 0.5 cm)
* Process: injection molding
* Mold: Multicavity
* 10 pieces per minute needed
* Polymer: 2 resins
* Injection temperature
* Densities, MFI, Viscosities, critical shear rates, power law indexes
* Number of cavities: to determine
* Arrangement of cavities: to determine
* Pressure required: to be determined from resin with less pressure drop

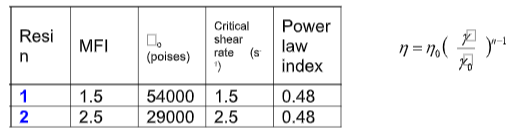
.- The following dimensions for the flat pieces: (W=10 cm, L=20 cm y H= 0.5 cm)

.- We want to produce 10 specimens per minute.

.- The injection happens at 200 °C.

.- The density of the material at that temperature is 0.75.

.- The viscosity can be represented by a power law and their respective parameters are given below.



C. ASSUMPTIONS

* The Power Law model fits well the viscosity modulus of the resins
* The plant manager is interested in spending the least amount of energy in the production of the flats.
* there is a constant velocity at a given pressure
* .- The temperature remains constant through
* .- The material density remains constant through the process
* .- The melt flow remains constant at a given pressure

D. ALGORITHM

1. Plot the given data of each resin into the Power Law model
2. Graph the viscosity curves of each resin
3. Select the resin with the lowest zero-shear viscosity
   1. As it will require the least pressure drop
4. Decide the design of a single cavity to minimize injection defects (flashes, warpages, jetting, sink marks, short shots, etc.)
5. Scale the mould into a multicavity configuration
6. Calculate the strain and stress of the melt
7. Calculate the pressure needed to produce the flats.

Use the power law model to analyze the data -> Define the shape of the system cavities needed to transport the polymer into the flat pieces -> Define the boundaries -> Calculate the shear stress from the movement -> Calculate the shear strain -> Calculate the flow velocity -> Calculate the flow rate -> Calculate the pressure

E. SOLUTION

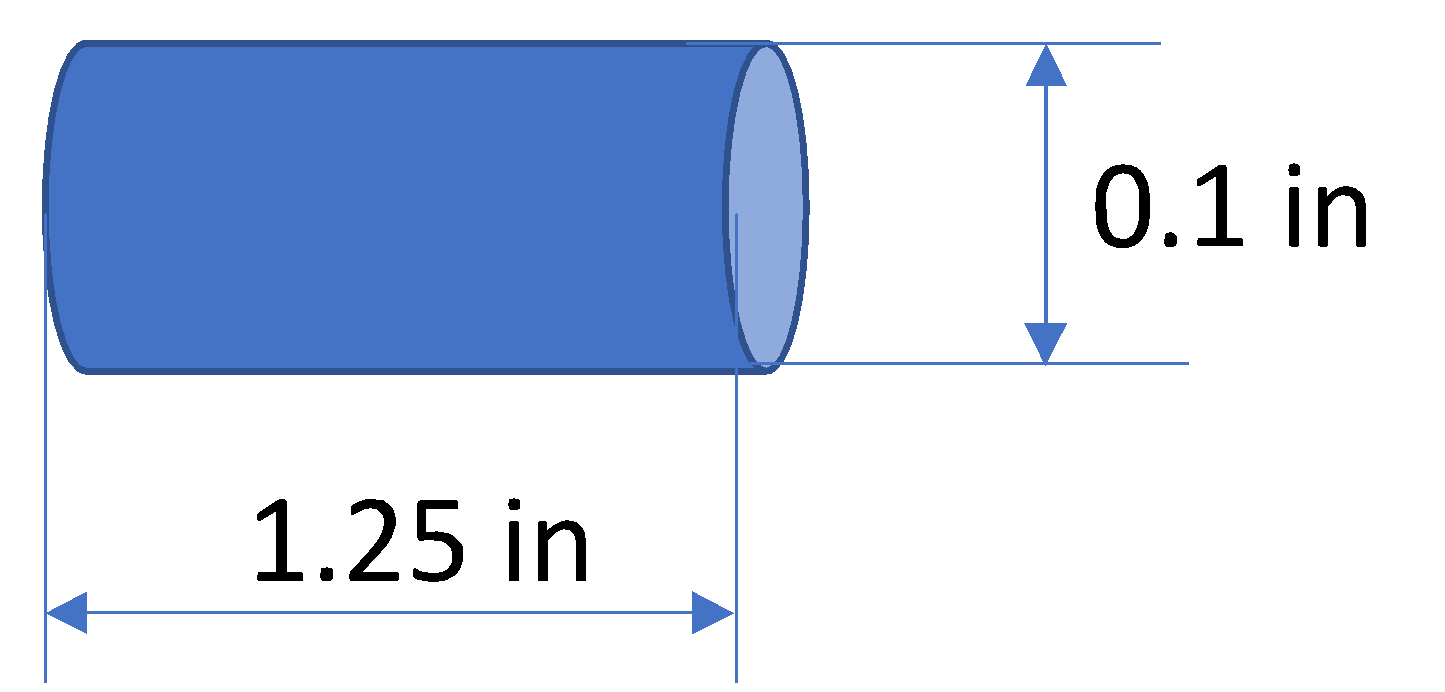
F. VALIDATION

G. REFERENCES

## Q2: You have decided to start a plastic recycling company and Mr. Good Die is selling you an extruder with a 500 holes die, each of them has a length of 1.25 inches and an radius of 0.05 inches **{20 pts}**







You need to *estimate the pressure drop* across the die since that information is needed to determine how much energy/ton of recycled plastic you have to pay. You will use that information together with other data (energy for platicizing the plastic, extruder maintenance, etc.) to estimate the investment and the ROI. You want to make sure that can get recycled pellets at 1,000 kgs/hour. The viscosity curve is that given in the first problem for resin 2.

A. INSTRUCTIONS

Calculate the pressure drop across the extruder die.

We will recycle plastics (resin 2 from problem 1). For the process we will use an extruder with a 500 hole die. The length and radius of the holes is 1.25 and 0.05 in respectively. We have to obtain the pressure drop across de die and then determine the energy/ton of the recycled plastic we need to pay. With that and other information we will obtain the investment and the ROI. We need to recycle 1,000 kg of pellets per hr.

We need to estimate the pressure drop across an specific extruder die, to estimate if it’s worth to do an investment for a plastic recycling company. The pressure drop is needed to determine how much energy/ton we have to pay and it would be necessary to estimate some other things for the investment. We want to make sure that we can get recycled pellets at 1,000 kgs/hour with a good ROI balance.

B. AVAILABLE DATA

* Extruder with a 500-holes die
* Dimensions of a single hole (length of 1.25 in and an radius of 0.05 in)
* 1,000 kgs of material shall be recycled per hour
* Viscosity curve of resin 2
* Process: extrusion
* Polymer: Recycled material (resin 2)
* Die with 500 holes
* Hole dimensions: 1.25 in length and 0.05 in radius
* Recycle pellets at 1,000 kgs/hour
* Viscosity curve from resin 2 in problem 1
* Pressure drop across die: to be determined
* energy/ton of recycled plastic to pay: to be determined
* Investment: to be determined
* ROI: to be determined

.- A extruder with 500 holes die, each of them has a length of 1.25 inches and an radius of

0.05 inches

.- We want to make, at least, 1,000 kgs of recycled pellets per hour.

.- The viscosity curve for the polymer used is given for the resin 2.

C. ASSUMPTIONS

* The applied pressure is constant
* The resin density remains constant
* Constant temperature at 200C
* The energy increases with the shear stress into the polymer
* viscous heating at the wall and entrance effects as the flow changes are neglected
* We will use plasticizers and other elements
* We will take the energy costs of Mexico
* We will sell the pellets at a selected price
* The flow in the extruder is at constant velocity, constant pressure is being applied
* .- We assume that we have all the money needed to do the investment.
* .- Making less than 1,000 kgs of recycled pellets per hour its not worth for the company.
* .- We can’t choose for either other extruder nor companies.
* *.-* We don't have enough information to estimate the ROI. We only only want to measure the pressure and then, estimate if it would be worth or not somehow.

D. ALGORITHM

1. Determine the viscosity vs. shear rate curve at 200C
2. Use the Navier-Stokes equation to approximate the basic shapes (cylinders) as the pressure is increased with hole length but decreases with the radius.
3. Calculate the stress at the wall, which depends on the pressure drop
4. Solve the pressure drop from the previous step

E. SOLUTION

F. VALIDATION

G. REFERENCES

## Q3: You are requested to get the TTS curve of a PP-HDPE Copolymer (MFI of 2 g/10 min) and its composite loaded with 3% of CNT to get their complex viscosity curves at 195oC. Also, using the master curve of the G” (ω) you are requested to get the First normal stress difference at steady state. Make any comments/observations you consider important. **(20 pts)**

A. INSTRUCTIONS

Describe the TTS and modelling procedure to get the first normal stress difference at steady state from complex viscosity curves.

Using TTS we need to obtain the master curve G\* and G’’ at 195oC from a PP-HDPE Copolymer with an MFI of 2 g/10 min and from its composite which is loaded with 3% CNT. From G’’ we need to obtain N1, the first normal stress difference at steady state (time infinite).

We need to get a TTS curve for PP-HDPE copolymer and its composite loaded with 3% of CNT to get their complex viscosity. Also, using the master curve of the G”(w), we need to get the first normal stress difference at the steady state.

B. AVAILABLE DATA

* Description of a PP-HDPE copolymer
* Description of a CNT composite
* Process: TTS
* Polymer: PP-HDPE copolymer and composite
* MFI: 2g/10min
* Composite: 3% CNT
* Reference temperature: 195°
* Time: infinite
* Complex viscosity curves: obtain G\* and G’’
* N1: obtain
* PP-HDPE Copolymer (MFI of 2 g/10 min) loaded with 3% of CNT
* Get the master curve and the complex viscosity at 195 °C

C. ASSUMPTIONS

* The complex viscosity experimental data is available
* I have the elastic (G´(w)) and the loss (G´´(w)) moduli for different temperatures.
* All the specimens were run at the same % strain and using the same geometry and gap between the plates.
* The polymer was protected with antioxidants, so decomposition is not present.
* Assume that the lowest temparture is greater than Tg+100 so I can use the Arrhenius equation for the calculation of the shift factors.
* We will be given data from the copolymer and the composite.
* We only need to apply a horizontal shift factor, Ev=0

D. ALGORITHM

1. Decide the reference temperature (1C)
2. Calculate tan delta
3. Plot tan delta vs. frequency to get the horizontal shift factors
4. Plot tan delta vs. G\* to get the vertical shift factors
5. Apply the shift to the data at each temperature
6. Fit the Wagner model to the master curve
7. From the Wagner fit, obtain the as, lambdas, ns and fs fitting parameters
8. With the fitting parameters, calculate N1 at the steady state.

1.Decide the reference temperature

a)Get the tan d vs. frequency using the data at each T to get aT

1.Do the calculations of tan del and G\* where:

a)Tan del = G´´(w)/G´(w)

b)G\*(w) = [(G´´(w))2 +(G´(w))2] ^0.5

1.Plot tan del vs. w for all temperatures in the same graph.

a)Multiply all te frequecies of a given temperature by a factor aT until it coincides with the reference plotted data.

b)Do that for each temperature

c)Once you have all the plots together you have the Master Curve

* Obtain the G’’ and G’ vs frequency curves at different temperatures for both the copolymer and the composite
* Calculate tan del and plot for each temperature
* Obtain the shift factor aT manually by superimposing the curves
* Plot log(aT) vs (1/T-1/T0) obtain the Eh/R
* Use the Arrhenius equation to obtain aT
* Reference the data of each temperature to that aT
* Translate tan del into G’’ and to G\*
* Plot -> TTS master curves for G’’ and to G\*
* For N1 we obtain n1, n2, and f1, lambdai and ai
* Subsitute in this equations and obtain the summation to obtain N1 at the different shear rates.

E. SOLUTION

F. VALIDATION

G. REFERENCES

## Q4: What type of melt distortions can be observed in polymers, give some examples on different polymer extrusión processeses and how can be avoided. **{10 pts} BONUS**

|  |  |
| --- | --- |
| Defect | Solution |
| Bubbles | Bubbles are cause by humidity; therefore, it would be necessary to dry the material |
| Shrinkage | The cause is due to excessive stress in the material. Slower cooling, lower speeds and a die with lower drag may solve this issue |
| pimples | The decrease of extrusion speed sorts out this problem, which is caused by the use of gels |
| Shark skin | Due to melt overheating, solution would be to increase the die temperature and decrease the extrusion speed |
| Surging | The puller may be at irregular speeds; the screw rotation would be at inconsistent velocities; or due to uneven polymer feed |
| Lumpiness | Due to low temperature. Rising the temperature would solve the problem. |