**DESIGN PROJECT REVIEW II**

**MEE 321**

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**Process description:**  
Polyol, MDI and 1, 4-Butanediol are the main reactants for the formation of TPU.

**Polyol Reactor:** Adipic acid and 1, 4-Butanediol are made to react to produce polyester Polyol. Water liberated from the reaction is condensed and treated as effluent. Along with the water some amount of organic material also gets produced which needs to be analysed for the presence of monomers and oligomers.

**Polyol Blend Tank:** Prepared polyol is melted to liquid state and is fed to the blend tank with additives in a very negligible amount as per application.

The flowrate of raw materials is calibrated to avoid polymer build up. The calibrated reactants cannot be reused again as it gets exposed to air and gets a colour due to oxygen presence.

**MDI and BDO Charging:** MDI and BDO supplied to the tanks are charged after melting. The flowrate is maintained to maintain the polymer consistency and final quality of the product.

**FettAlkohol Tank:** Fettalkohol C-8 98% is a chain terminating agent which controls the side reaction of a product which is not desired to be formed.

**Extruder:** Co-rotating twin reactive screw extruder is used. Mixer product and BDO are sent to the extruder and are fed one by one, with few minutes gap and the material is collected in waste drums till all raw material are mixed and uniform polymer is formed before sending the polymer to pelletisation process. The technique used for making the pellets from the resin is called *Under water pelletisation*. Resin from the extruder passes through a DIE and then pulled out in the required cross sectional area and is cut by the blades of the pelletiser , then cooled by chilled water. A lot of waste is also removed due to pelletiser upset as a result of improper polymer build up.

**Dryers:** A centrifugal dryer is used. Here the pellets and water gets separated. This water is recycled. The final moisture content present in the pellets after dehumidification ( hot air dryer) is 0.05%.

**Sieving:** The desired shape of pellets is between 3-5mm. Hence the bigger sizes are left on the upper sieves and the required size of pellets are obtained.  
**Packing:** The final product is packed and dispatched to various industries.

The process shows a maximum conversion rate of 96%.

Production of TPU : 350 Kg/hr = 8400 Kg/day = 8.4 tons/day

Composition of the TPU pellets ( excluding water content)

|  |  |
| --- | --- |
| POLYOL | 48.06% |
| BDO | 10.14% |
| MDI | 41.04% |
| Additives | 0.76% |

The additives used are :

|  |  |
| --- | --- |
| Finawax | 0.36% |
| Edenol | 0.25% |
| Irgonax | 0.10% |
| Carbodiimid | 0.05% |

|  |  |  |  |
| --- | --- | --- | --- |
| *stream* | *Temp* | *specific heat, Cp* | *∆Hf* |
|  | ***(K)*** | ***(KJ/kg)*** | ***(KJ/mol)*** |
| *water* | ***298*** | ***4.18*** | ***-242*** |
| *adipic acid* | ***298*** | ***2.43694*** | ***-994.3*** |
| *BDO* | ***298*** | ***2.219263205*** | ***-503.25*** |
| *polyol* | ***363*** | ***1.89*** | ***-1250*** |
| *MDI* | ***338*** | ***1.8*** | ***-360*** |
| *TPU* | ***333*** | ***1.65946*** | ***-1393*** |

|  |  |
| --- | --- |
| ***Temp. of reactor (K)*** | ***493*** |
| ***Temp. of Extruder (K)*** | ***523*** |
| ***Temp. in hot air dyer(K)*** | ***368*** |
| ***Temp of water effluent(K)*** | ***318*** |
| ***Temp of mixer(K)*** | ***373*** |
| ***specific heat of mixer outlet(KJ/kg)*** | ***1.78*** |
| ***enthalpy of mixer outlet stream*** | ***-1483*** |
| ***Temp of chilled water wash (K)*** | ***385.5*** |
| ***temp in centrifugal dryer(K)*** | ***298*** |

**MASS BALANCE**

Mass Balance of reactor:

*Adipic acid 1,4-butanediol butanediol adipate water  
 (polyester polyol)*

Where ***R*** = ***C4H8***

**Adipic acid**   
 84.64 Kg/hr  
(2.0314 tons/day)

28.853% by wt

**Butanediol adipate (Polyol)**  
168.21 Kg/hr  
(4.037 tons/day)

**POLYOL REACTOR**

**1,4-butanediol**  
208.7 Kg/hr  
(5.009 tons/day)

71.142% by wt

**Water effluent**  
41.762 Kg/hr  
1.0022 tons/day

Mass Balance of Mixer:

**Polyol Blend   
(Polyol+ Additives)**  
170.78 Kg/hr  
(4.098 tons/day)

54.32% by wt

**Intermediate product**314.037 Kg/hr  
(7.536 tons/day)

**MIXER**

**MDI  
(Methylene diphenyl diisocyanate)**143.25 Kg/hr  
(3.43 tons/day)

45.67% by wt

Mass Balance of Extruder and Pelletiser:

**Mixer product**314.037 Kg/hr  
(7.536 tons/day)

89.86% by wt

**EXTRUDER  
 &  
PELLETISER**

**TPU Pellets**349.51 Kg/hr  
(8.388 tons/day)

**1,4-butanediol**  
35.47 Kg/hr  
(0.851 tons/day)

10.14% by wt

**Chilled Water**21000 kg/hr  
(504 tons/day)

**Wet TPU pellets**4536.15 Kg/hr  
(108.86 tons/day)

20% water absorption

**TPU Pellets**336.154 Kg/hr  
(8.067 tons/day)

**Water out**16800 Kg/hr   
(403.2 tons/day)

Mass Balance of Centrifugal dryer:

**CENTRIFUGAL  
 DRYER**

**Partially dried pellets**  
2016.154 Kg/hr  
48.387 tons/day

**Wet TPU pellets**4536.15 Kg/hr  
(108.86 tons/day)

**Water removed**  
2520 Kg/hr  
(60.48 tons/day)

Mass Balance of Hot air dryer:

**Water removed**  
1679.82 Kg/hr  
(40.315 tons/day)

**HOT AIR DRYER**

**TPU pellets**  
336.329 Kg/hr  
(8.07 tons/day)

**Partially dried pellets**2016.154 Kg/hr  
48.387 tons/day

Assuming no losses : input= output=**350Kg/hr** = 8.4 tons/day

The conversion is **96%** i.e. 4% loss of material = 14Kg/hr = 0.336 tons/day.

Therefore including all the losses ; production =**336.329 Kg/hr** (96.094 % of 350)

These losses accounts for:

1. **Charging and Metering loss :**  
   Charging Polyol and MDI from drums gives us loss of 0.15% each. , there is 1 to 2 kg of Polyol left out in the drums, as it cannot be pumped out fully. The flow rate of raw material is very critical as it decides the polymer build up and the final property of the product. So always in any grade, before starting the process, Polyol flow is calibrated and material used for the calibration are not reused as it is exposed to air, and subsequent color build up due to oxygen content, This Polyol is disposed as waste and it works out to be 0.10%.
2. **Extruder start up loss:**Systematic feeding sequence is adopted to overcome any material choke in the extruder. So raw material are fed one by one , with few minutes gap and the material is collected in waste drums till all raw material are mixed and formed the uniform polymer before the polymer to pelletisation process. This takes minimum of half an hour to 45 minutes. Material collected during this time is not useful for the regular production. This material is declared as waste and amounts to be 9.0%. This is main area, where maximum waste is generated.
3. **Pelletiser upset loss:**TPU process is very difficult one and stabilization requires few hours. During the startup process or due to slight variation in the flow steams or delay in push up of material in the extruder, improper polymer build up occurs and leads to pelletiser upset. While overcoming the pelletiser upset by way of removing the cutter and cleaning it, polymer passes through the extruder are collected in drums and treated as waste since it cannot be sold to any customer. This is an average, accounts to be 1.6%

The total loss of 336 kgs of material per hour (8.064 tons/day):

|  |  |  |  |
| --- | --- | --- | --- |
| **LOSSES** | **%age** | **Kg/hr** | **Tons/day** |
| Polyol loss | 2.25% | 7.728 | 0.1854 |
| MDI loss | 2.25% | 7.728 | 0.1854 |
| Extruder loss | 81% | 272.16 | 6.532 |
| Pelletiser loss | 14.4% | 48.384 | 1.1612 |
| **TOTAL** | **100%** | **336** | **8.064** |

**Calculations:**

Since the mass flow rate is 350 kg/hr for TPU pellets. It has 0.05% of moisture and 99.95% of solids and the percentage composition of BDO is 10.14% of the solids. Therefore, the mass flow rate of **stream 9** = 10.14% x 99.95% x 350  
 = 0.1014 x 0.9995 x 350   
 = **35.47 Kg/hr = 0.851 tons/day**.

The percentage composition of polyol is 48.06% of solids. Therefore, the mass flow rate of **stream 4** = 48.04% x 99.95% x 350 = 0.4806 x 0.9995 x 350  
 = **168.125 kg/hr = 4.035 tons/day.**

Now according to the reaction:

*Adipic acid 1,4-butanediol butanediol adipate water  
 (polyester polyol)*

Where ***R*** = ***C4H8***

1 mole Adipic acid—2 moles BDO—1 mole polyol—2 moles water

Therefore, mass flow rate of Adipic acid i.e **stream 1** = (168.125/290) x (1x146)  
 = **84.642 kg/hr =2.031 tons/day.**

Mass flow rate of BDO i.e **stream 2** = [ (168.125/290) x 2 ] x (2 x 90)  
 = **208.7 kg/hr = 5.009 tons/day.**

Similarly, mass flow rate of water effluent i.e **stream 3** =(168.125/290)x2 x (2x18)  
 = **41.74 kg/hr = 1.0017 tons/day.**

The percentage composition of MDI is 41.04% of solids. Therefore, the mass flow rate of **stream 6** = 41.04% x 99.95% x350 = 0.4104 x 0.9995 x 350 =143.568 kg/hr.

we know that there is a loss of 2.25% of 4% of 350 i.e 0.315 kg/hr. Therefore (143.568 - 0.315) = **143.25 kg/hr = 3.43 tons/day.**

Stream 5is a blend of polyol and additives. The percentage composition of additives is 0.76% of solids.   
Therefore mass flow rate of **stream 5** = (0.76% x 99.95% x 350) + 168.125  
 = (0.0076 x 0.9995 x 350) + 168.125  
 = **170.78 kg/hr = 4.098 tons/day.**

Therefore, now mass flow rate of **stream 7=stream 8** = 170.78 + 143.25  
 = **314.037 kg/hr = 7.536 tons/day.**

The mass flow rate of **stream 10** = 314.037+35.47= **349.51kg/hr =8.388 tons/day.**

Since the extruder startup loss and pelletiser upset loss contribute to a total loss of 10.1% of 4% of 350 = 11.34 +2.016 =13.356 kg/hr.

Therefore, mass flow rate of **stream 11** = 349.51 – 13.356  
 = **336.154kg/hr = 8.067 tons/day.**Now with 21000 kg/hr of chilled water for wash of pellets from extruder and 20% absorption of water by the pellets.  
 Therefore mass flow rate of **stream 12** = **21000 kg/hr = 504 tons/day**   
and that of **stream 13** = 80% of 210 00kg/hr = **16800 kg/hr = 403.2 tons/day.**  
Mass flow rate of **stream 14 = stream 15** = 336.154 + (20% of 21000kg/hr )   
 = 336.154 + 4200   
 = **4536.154 kg/hr = 108.86 tons/day.**

Since the centrifugal dryer is efficient in removing 60% of the moisture content , therefore mass flow rate of **stream 16** = 60% of 4200   
 = **2520** **kg/hr = 60.4 tons/day.**

After removing 60% moisture, the mass flow rate of **stream 17 = stream 18** = (4536.154 - 2520) = **2016.154 kg/hr = 48.387 tons/day.**

The hot air dryer removes moisture upto 0.05% of 350 i.e. the moisture content in stream 20 is 0.05% x 350 = 0.175 and moisture content in stream 18 = (4200 -2520) =1680.  
This implies mass flow rate of **stream 19** = (1680 - 0.175) = **1679.82 kg/hr   
 = 40.315tons/day.**

Mass flow rate of **stream 20** = (2016.154 – 1679.82) = **336.329 kg/hr  
 = 8.07 tons/day.**Therefore % conversion = 336.329 / 350 x 100 = 96.09%

**ENERGY BALANCE**

**Energy Balance on Reactor:**

**For Adipic Acid**

= (-994.3) + (84.685)(2.4369)(493-298) = 39228.19656 KJ/hr

**For 1,4 Butandiol**

= -503.25+ (208.812)( 2.219 ) (493- 298) = 89816.482 KJ/hr

**For Water**

= (-242) + (41.74)( 4.18 ) (493- 318) = 30291.98912 KJ/hr

**For Polyol**

= (-1250 ) + (168.12)(1.89 ) (363- 493) = - 42558.542 KJ/hr

**Heat Loss In Reactor**

Q1  = - 141311.23 KJ/hr

**Energy Balance On Blending Tank**

A blending action is observed. The polyol released from the polyol reactor is mixed with additives like Iragnox and Carbodiimid with the help of an agitator which results in a 10% loss in energy.

Q2 =  Q1 – 0.1\*Q1 = - 126951 KJ/hr

**Energy Balance On Mixer**

**For Polyol**

= (-1250 ) + (170.78)(1.89 ) (373- 353) **= 5205.658 KJ/hr**

**For Methylene Diamine Isocyanate**

= (-360) + (143.25)(1.8) (373-338) = **8664.952593 KJ/hr**

**For Stream 7**

= (-1483) + (314.03)(1.78) (371-373) **= -2600.9746 KJ/hr**

**Heat Loss In Mixer**

Q3 = **-16471.585 KJ/hr**

**Energy Balance On Extruder**

**For Stream 8**

= (-1483) + (314.03)(1.78 ) (523-371) **= 83483.07348 KJ/hr**

**For 1,4 Butandiol**

= (-503.25) + (35.47)(2.219 ) (523- 298) = **17209.26523 KJ/hr**

**For Stream 10**

= (-1393 ) + (349.51)(1.659 ) (483- 523) = **-24592.9 KJ/hr**

**Heat Loss In Extruder**

Q4 = **-125285.26 KJ/hr**

**Energy Balance of Water Wash**

**For Extruder Pellet**

= (336.154)(1.659 ) (385.5- 473) **= -54388.84049 KJ/hr**

**For Inlet Chilled Water**

= (21000)(4.18 ) (385.5- 288) **= 8558550 KJ/hr**

**For Outlet Water**

= (16800)(4.18 ) (304.62-385.5) = **-5679717.12 KJ/hr**

**For Wet TPU Pellets**

= (4536.154)(1.69 ) (308- 385.5) **= -583386.3853 KJ/hr**

**Heat Loss In Water Wash**

Q5 = **-14767265**

**Energy Balance On Centrifugal Dryer**

**For Wet TPU Pellets**

= (4536.15)(1.69) (298- 308) **= -75275.66261 KJ/hr**

**For Outlet Water**

= (2520)(4.18) (305- 298) **= 73735.2 KJ/hr**

**For Dry TPU**

= (2016.154)(1.69) (303- 298) = **16728.6 KJ/hr**

**Heat Loss In Centrifugal Dryer**

Q6 = 165739.498 KJ/hr

**Energy Balance On Hot Air Dryer**

**For Dry TPU Pellets**

= (2016.15)(1.69) (368- 303) = **217472.259KJ/hr**

**For Hot Water Exit**

= (1679)(4.18) (353- 368) = **-105325.022KJ/hr**

**For Dried TPU**

= (336.329)(1.69) (333- 368) = **-19534.36843KJ/hr**

**Heat Loss In Hot Air Dryer**

Q20 **= -342331.65 KJ/hr**