**Phase III (MASS)– Nathan’s Scope and Unit Process**

Scope: Mixer and Capsule Filler Machine

PFD for this process section:

Mixer

Capsule Filler

Powder Flow Pump

Empty Capsules

Formulation

Dried Cells

Filled Capsules

Formulation

Excipients

**Capsule Filler:**

Our defined hourly rate of production will be 100,000 filled capsules per hour. It is nice to think of these discretely rather than as a bulk-flow. We can achieve conventional bulk-flow analysis, however, when we know the exact mass of formulation inside each capsule. The team has defined that to be 1 gram. Thus,

For the capsule filler, we have 100 kg/hr of formulation flowing into the capsule filler per hour. One can see very quickly that there will be a required 100,000 empty capsules per hour to flow to the capsule filling machine as well. Lets look at the mixer.

**Mixer:**

The mixer has two streams in and one stream out. In this unit operation, we are mixing the dried cell mass together with the excipients. In the formulation, 20% of the mass is due to the dried cells, and the other 80% comes from the excipients. The excipients are comprised of the following ingredients:

* Maltodextrin
* Inulin
* Talc
* Magnesium Stearate
* Colorants (Titanium Dioxide and Iron Oxide).

Per one capsule that contains 1 gram of formulation, the following recipe applies:

|  |  |  |
| --- | --- | --- |
| **Ingredient** | **Mass** | **Mass Fraction** |
| *Bacteria Blend* | 200 mg | 0.2 |
| *Maltodextrin* | 400 mg | 0.4 |
| *Inulin* | 200 mg | 0.2 |
| *Talc* | 50 mg | 0.05 |
| *Magnesium Stearate* | 50 mg | 0.05 |
| *Colorant* | 100 mg | 0.1 |

Note the following mass fractions in the formulation out-stream above.

We can use this to get the mass flowrates of the inlet streams:

We know then by doing a total mass balance around all mass in the mixer system, that the excipient stream must equate to 80 kg/hr of mass flow. We can readjust the mass fractions and calculate the composition of the excipient stream:

|  |  |  |
| --- | --- | --- |
| **Ingredient** | **Mass** | **Mass Fraction** |
| *Maltodextrin* | 400 mg | 0.5 |
| *Inulin* | 200 mg | 0.25 |
| *Talc* | 50 mg | 0.0625 |
| *Magnesium Stearate* | 50 mg | 0.0625 |
| *Colorant* | 100 mg | 0.125 |

We can then multiply the total mass flow rate by the mass fraction to achieve the component mass flow rate inside that stream:

Similar calculations can be made and the following data on all streams entering and leaving the mixer can be summarized into the following tables:

SUMMARY TABLES:

|  |  |  |
| --- | --- | --- |
| **Dried Cell Mass Stream IN** | | |
| **Component** | **Mass Flow** | **Component %** |
| *Dried Cells* | 20 kg/hr | 100 |
| *Total Flow Rate* | 20 kg/hr | 100% |

|  |  |  |
| --- | --- | --- |
| **Excipient Stream IN** | | |
| **Component** | **Mass Flow** | **Component %** |
| *Maltodextrin* | 40 kg/hr | 50% |
| *Inulin* | 20 kg/hr | 25% |
| *Talc* | 5 kg/hr | 6.25% |
| *Magnesium Stearate* | 5 kg/hr | 6.25% |
| *Colorant* | 10 kg/hr | 12.5% |
| *Total Flow Rate* | 80 kg/hr | 100% |

|  |  |  |
| --- | --- | --- |
| **Formulation Stream OUT** | | |
| **Component** | **Mass Flow** | **Component %** |
| *Dried Cells* | 20 kg/hr | 20% |
| *Maltodextrin* | 40 kg/hr | 40% |
| *Inulin* | 20 kg/hr | 20% |
| *Talc* | 5 kg/hr | 5% |
| *Magnesium Stearate* | 5 kg/hr | 5% |
| *Colorant* | 10 kg/hr | 10% |
| *Total Flow Rate* | 100 kg/hr | 100% |

**Phase IV (Energy)– Nathan’s Scope and Unit Process**

Scope: Mixer and Capsule Filler Machine

PFD for this process section:

(same PFD as before)

I identified three main areas of energy consumption:

1. The mixer (paddles/screws)
2. The powder flow pump/manifold
3. Capsule machine

**The Mixer:**

I found a study that related many paramteres related to the powder flow and mixer to the power requirmnet of the mixer:

Gijón-Arreortúa, I., & Tecante, A. (2015). Mixing time and power consumption during blending of cohesive food powders with a horizontal helical double-ribbon impeller. *Journal of Food Engineering*, *149*, 144–152. <https://doi.org/10.1016/j.jfoodeng.2014.10.013>

The parameters were as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Symbol** | **Units** | **Our Values** |
| Bulk Density | ρb | Kg/m3 | 100 |
| Friction Coefficient | µi | Unitless | 0.20 |
| Impeller Volume | VI | m3 | 10 |
| Impeller Length | LI | m | 5 |
| Rotational Speed | N | rpm | 30 |
| Power | P | Watts | ? |
| Friction factor | f | Unitless | 0.71 |
| Gravitational Speed | g | m/s2 | 9.81 |

The power required for a helical impeller mixer can be calculated with the following equation:

**Powder Flow Pump/Mainfold:**

Finding equations to calculate the power requirements for powder flow is posing to be extremely difficult. To give a rough estimate, I will simply model the powder as a highly viscous liquid:

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Symbol** | **Units** | **Our Values** |
| Power | P | Watts | ? |
| Flow Rate | Q | m3/s |  |
| Efficiency | η | unitless | 0.85 |
| Pressure Drop | ΔP | Pa | 101,300 |

To calculate the flow rate, we can use our mass balance calculations:

Thus,

Our powder flow manifold requires about one order of magnitude greater power than our mixer.