BIOE 435
Parametric Design
Parametric design allows you to analytically test features of your design early in the design process.

What is parametric Design?

Example from Previous Project

Apply it to your Context
Parametric design allows you to analytically test features of your design early in the design process.

What is parametric Design?

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Apply it to your Context
Parametric Design is part of the design process and helps you define outputs.
Parametric Design is an emphasis on design variables (which the designer sets) and setting values for these variables combined with modeling.

Heart Defibrillator Medical Device Model

200 to 1,700 volts

https://poserworld.com/3d-heart-defibrillator-medical-device-model
The parametric Design Process Model involves several parameters which allow you to ‘tune’ your product.

Inputs
- User specifications
- Design Standards

Intermediate variables: determined as ‘tuning knobs’ from initial parameters

Outputs
- User specs
- Design Standards
Parametric Design helps you determine what you really need to design and how to document decisions

- Dimension: specific sizes, lengths, radii, diameters, material types, and manufacturing process requirements
- Feasible designs: performance satisfies all the design constraints
- Compare to competitors: predicting performance of alternative candidate designs using analytical methods and/or experimental methods, determine which is the best
You will create 3D models of your designs and be able to test them but not everything has to be complex...
Parametric design allows you to analytically test features of your design early in the design process.

What is parametric Design?

Example from Previous Project

Apply it to your Context
PleurX Pro’s mission is to develop a HIPAA-compliant, user-friendly mobile application incorporating a data logging function for users of the PleurX catheter system to input drainage data and instructions on conducting drainage for patients and placement of the catheter for physicians. This application will be used by patients undergoing self-treatment with the PleurX catheter system, nurses, hospice caretakers, and physicians.
One of the most important aspect to quality of life is ease and pain during draining

Draining of ascites from the abdomen can cause pain in some patients if done too quickly. As pain management was important to both clinicians involved and CareFusion, we chose to focus on a way to model the flow during drainage as that can lead to pain in certain cases.
Steps in Parametric Design

Step 1: Formulate the parametric design problem.

Step 2: Generate alternative designs.

Step 3: Analyze/predict the performance of the alternatives.

Step 4: Evaluate the performance of each alternative.

Step 5: Refine/optimize.
Step 1: Formulate Problem

Step 1. Familiarize yourself with the problem parameters and plan ways complete the design

– *Performance Parameters/Solution Evaluation Parameters*

  • Reviewing engineering design specifications – reaffirm what functions the customer wants the product to perform

  • Select engineering characteristics to measure the predicted performance of the functions.

  • Solution evaluation parameters: the engineering characteristics that are selected to evaluate how well a candidate design "solves" the problem
Step 1: Formulate Problem
Solution Evaluation Parameters

- Solution evaluation parameters depend upon the product and part being designed:
  - cost, weight, speed, efficiency, safety, and reliability
    - Denote parameter symbols, & units of measurement
    - Any lower and or upper limits of the parameter
    - Agree on analytical or experimental methods to determine their values
Step 1: Formulate Problem
Denver Shunt Example

• Customer wants the less pain, so slower drainage from the device
  – Solution evaluation parameter: optimize diameter for slow drainage
    • The time is not infinite, most patients want to be draining for no more than 10 minutes
      – Lower limit – 0 minutes
      – Upper limit – 10 minutes
Step 1: Formulate Problem
Design Variables (DV$s$)

- Parameters under the control of the designer, which influence the candidate's performance
  - Design variables usually relate to part dimensions, tolerances, and/or material properties.

- Establish design variable names, appropriate symbols, units, and upper and/or lower limits or bounds

- Diameter will be predicted using an analytical formula (experimental tests could have been used)
The PleurX Drainage System contains the following components:

1. Vacuum bottle
   Active vacuum technology drains quickly and comfortably without the need for gravity. Bottles available in 500 ml and 1000 ml sizes.

2. Patented safety valve
   Helps prevent inadvertent passage of air or fluid through the catheter.

3. Polyester cuff
   Promotes tissue ingrowth to help reduce infection risk and hold the catheter securely in place.

4. 15.5 Fr silicone catheter
   Soft and flexible, conforms to the pleural space and minimizes insertion site discomfort.

5. Beveled fenestrations
   Large, smooth fenestrations with beveled edges promote drainage and help avoid occlusions.
Step 1: Formulate Problem
Problem Definition Parameters (PDPs)

- PDPs - Parameters that describe specific conditions of use, such as operating conditions
  - Establish appropriate symbols, units, and values.

- PleurX example:
  - Vacuum canister pressure
  - Patient abdomen pressure
  - Tubing length
Step 1: Formulate Problem
Problem Definition Parameters (PDPs)

- PDPs - Parameters that describe specific conditions of use, such as operating conditions
  - Constraint: want to use a known French diameter to keep compatible with other devices

\[ Fr = D \text{ (mm)} \times 3 \]
We first need to identify the variables for the problem.

<table>
<thead>
<tr>
<th>Known Variables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubing Length</td>
<td>66 cm</td>
</tr>
<tr>
<td>Tubing Diameter</td>
<td>15.5 Fr – 5.167 mm</td>
</tr>
<tr>
<td>Fluid Viscosity (assume homogeneous)</td>
<td>0.93 mPa/s</td>
</tr>
<tr>
<td>Vacuum pressure</td>
<td>-29.422 mmHg</td>
</tr>
<tr>
<td>Pleural pressure</td>
<td>755 mmHg</td>
</tr>
<tr>
<td>Average drainage volume</td>
<td>500 mL</td>
</tr>
</tbody>
</table>
Step 1: Formulate Problem
Preliminary Plan for Solving Problem

Small design problems,
   – Jump right in and start calculating things

1. Do we have analytical models/formulas for our problem?
2. Are the assumptions used in our models the same as our problem?
3. Will we need to perform pilot scale or bench-top experiments to validate our analytical formulas?
4. How much time and money do we have to solve the problem?
5. Are "ballpark" computations required, or do we need more thorough and precise calculations?
Step 1: Formulate Problem
Preliminary Plan for Solving Problem

Larger design problems, more involved problems

– Make a preliminary plan based on considerations including previous attempts

6. Do we have knowledge about acceptable industry standards?

7. Do we understand the customers' function requirements versus satisfaction well enough?
Parametric Design
Denver Shunt Example

- Hagen-Poiseuille law which relates pressure difference with flow rate

\[ \Delta P = \frac{128 \mu LQ}{\pi d^4} \]

- Design problem:
  - Know average volume and time for drainage, optimize diameter of tube to allow slower drainage
## Variables and Equations

<table>
<thead>
<tr>
<th>Known Variables</th>
<th>Value</th>
</tr>
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<td>66 cm</td>
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</tr>
</tbody>
</table>

\[
\Delta P = \frac{128 \mu LQ}{\pi d^4}
\]
Need to solve for flowrate using known parameters

Ideal Q for 5 minutes of drainage time:
\[
\frac{500\text{mL}}{60 \times 5 \text{ min}} = 1.667 \frac{\text{mL}}{s} = 1.667 \times 10^{-6} \frac{m^3}{s}
\]

Ideal Q for 10 minutes of drainage time:
\[
\frac{500\text{mL}}{60 \times 10 \text{ min}} = 0.833 \frac{\text{mL}}{s} = 0.833 \times 10^{-6} \frac{m^3}{s}
\]
Solving for $d$

$$\Delta P = P_2 - P_1 = 755 \text{ mmHg} + 29.422 \text{ mmHg} = 784.422 \text{ mmHg} = 104580 \text{ Pa}$$

For a 5 minute drainage time

$$104580 \frac{P}{\pi d^4} = \frac{128(0.00093)(0.66m)(1.667e-6)}{\pi d^4}$$

$$d = 0.000794 \text{ m} = 0.7 \text{ mm}$$
We can generalize our empirical model to use in the future

General equation for finding $d$ for a desired flow rate $Q$:

$$d = \sqrt[4]{\frac{128(0.00093)(0.66m)Q}{\pi \times 104580}}$$
Step 2: Generate Alternative Designs

• Alternative designs - select different values for the design variables to generate different candidate designs
  – Values can come from our own experience, from our company's experience, or from industry standards.
  – Constraint: want to use a known French diameter to keep compatible with other devices

\[ Fr = D \text{ (mm)} \times 3 \]
Step 3: Analyze Alternative Designs

Feasible Designs

- Performance of each design candidate is checked so that every performance constraint is satisfied. → feasible designs
  - Violated constraints - reiterate back to generating another alternative and then analyzing it
- All feasible designs are evaluated
  - One or more criteria identified in the formulation phase used to determine the "best" feasible design alternative
Step 3: Analyze Alternative Designs

Feasible Designs

<table>
<thead>
<tr>
<th>French Gauge</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1.333</td>
</tr>
<tr>
<td>5</td>
<td>1.667</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>2.333</td>
</tr>
<tr>
<td>8</td>
<td>2.667</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
</tr>
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</tr>
<tr>
<td>15</td>
<td>5</td>
</tr>
</tbody>
</table>

Our calculated values can be converted into French Gauges and we can see if they are feasible.

\[
Fr = D \text{ (mm)} * 3 = 0.7 \text{ (mm)} * 3 = 2.1 \text{ Fr}
\]

\[
Fr = D \text{ (mm)} * 3 = 0.6 \text{ (mm)} * 3 = 1.8 \text{ Fr}
\]
After testing, this solution was implemented in the product.
Step 5: Refine/Optimize

- If no feasible design candidates exist - select new values for the design variables, and generate new design candidates
  - Analyze and evaluate for feasibility and optimality.

- After considerable effort cannot find any feasible candidates - design specifications too restrictively? Relax one or more constraints →"respecify"-ing the problem
Parametric design allows you to analytically test features of your design early in the design process.

- **What is parametric Design?**
- **Example from Previous Project**
- **Apply it to your Context**
Here is a list of Fusion 360 Learning Resources

- **Fusion 360 Foundational Concepts**
- **Getting Started with Fusion 360 Tutorials**
- **List of Top Fusion 360 Learning Resources** on Autodesk's Design Academy site
- **Fusion How to Videos**
- **Introduction to CAD and CAE using Autodesk Fusion 360 course**
  - *Instructor curriculum*
  - *Self-paced course*
Your Turn!

• Determine:
  – Solution Evaluation Parameters (SEP)
  – Design Variables
  – Problem Definition Parameters

• Develop a plan for solving the design problem
  – In developing the plan discuss and give the formulas that would be needed