

Parametric Design



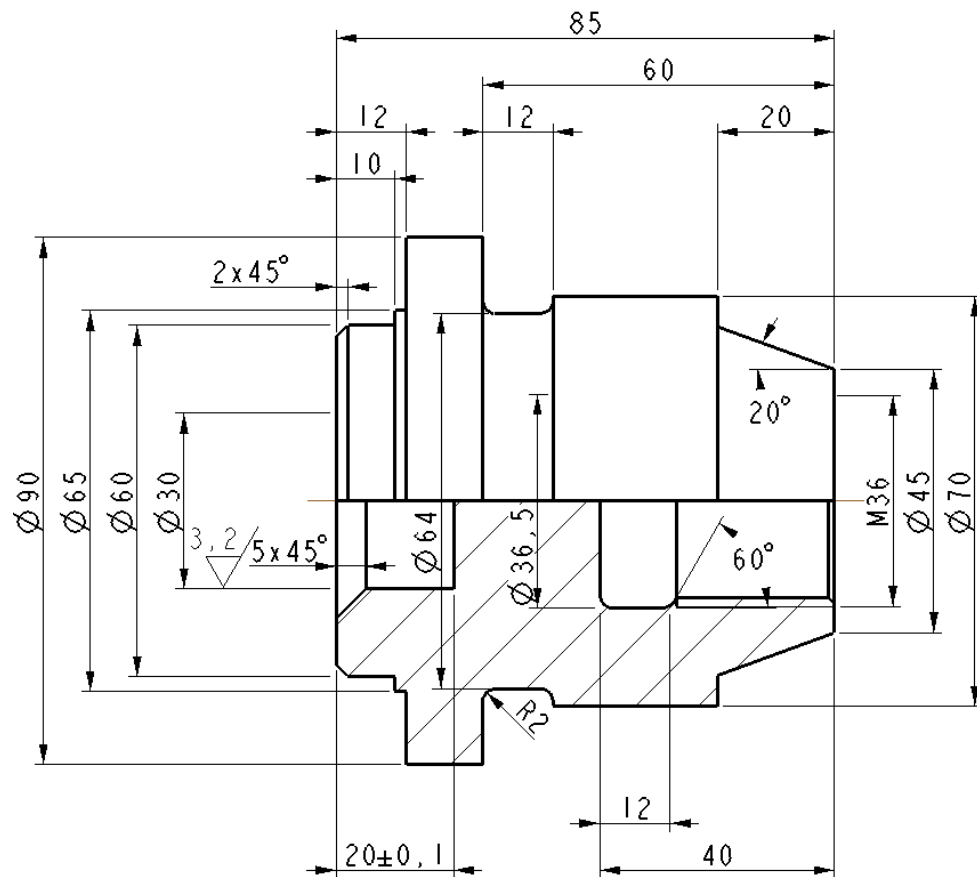
Aalto University
School of Engineering

Kaur Jaakma

16.11.2020

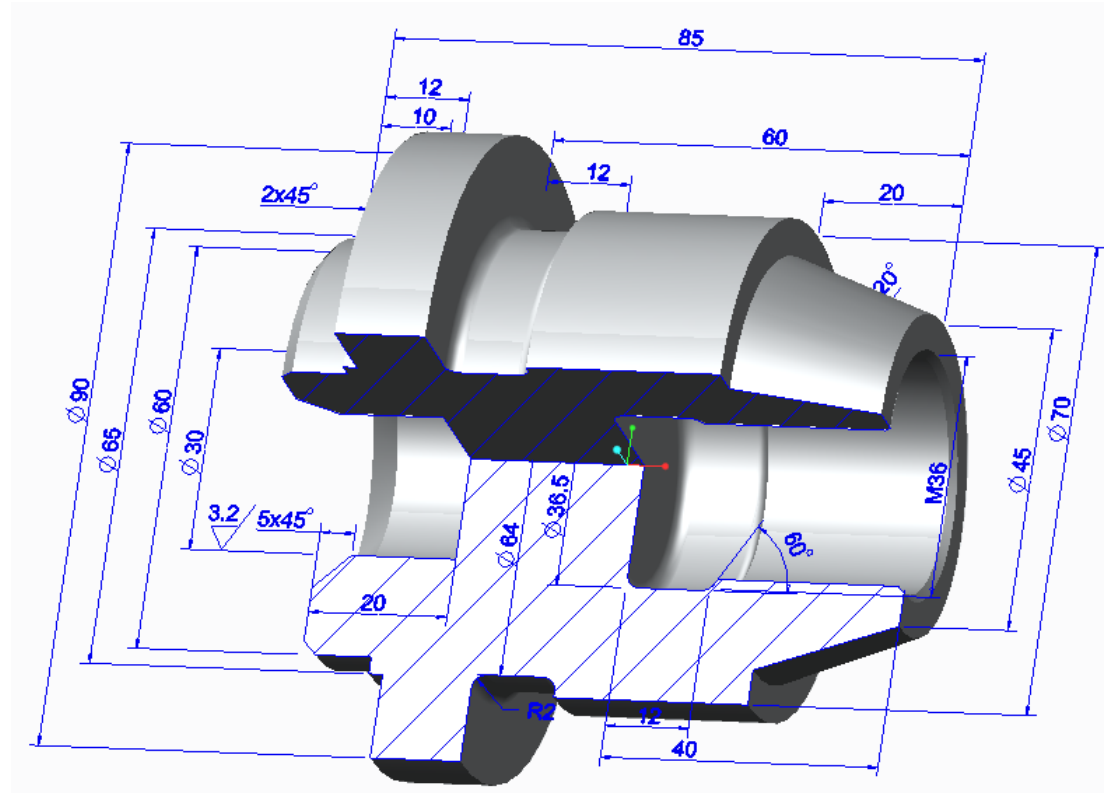
The curse of CAD

Computer Aided Drawing



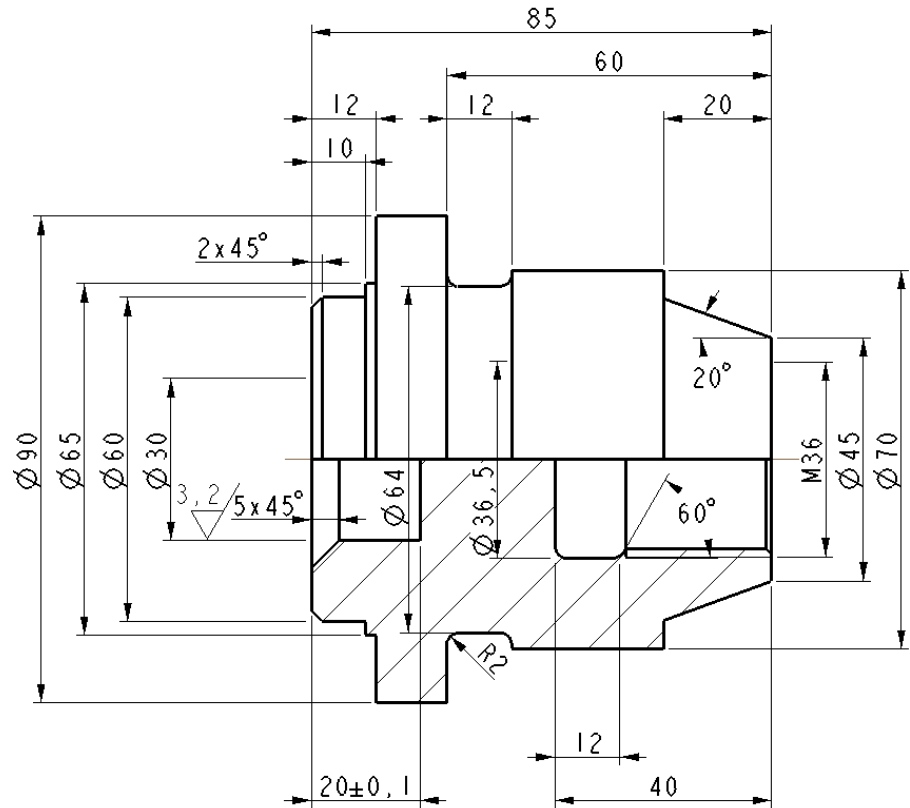
The curse of CAD

Computer Aided Design



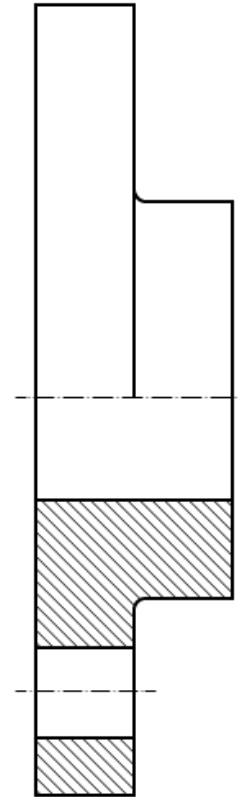
A?

**Aalto University
School of Engineering**



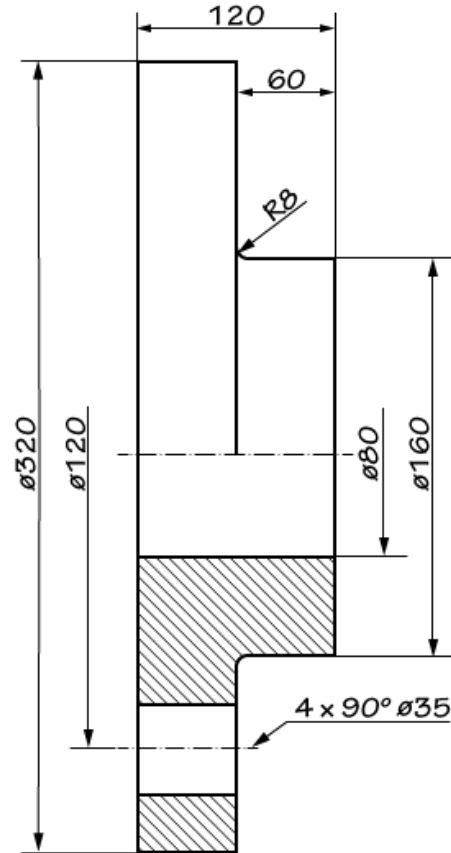
Simple Example 1/2

Traditional method is to first
draw the lines...



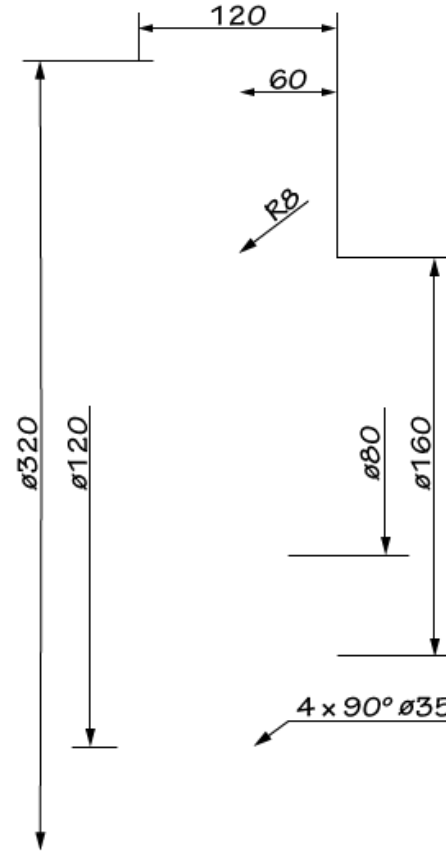
Simple Example 2/2

...and then to add dimensions



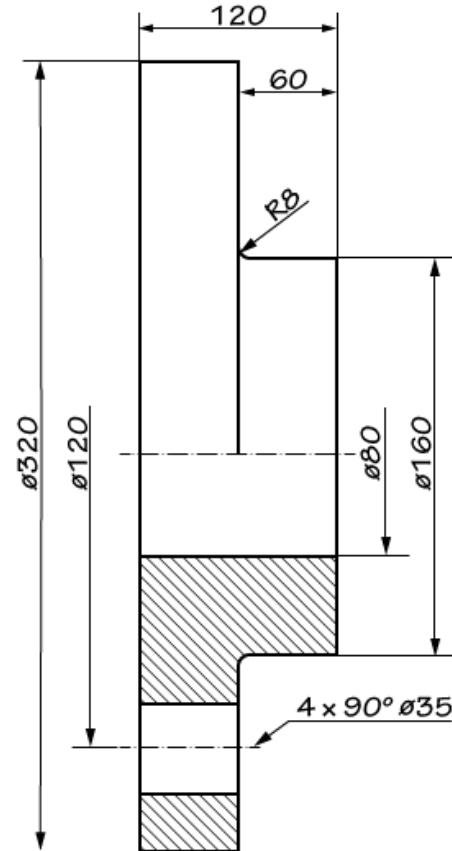
What we should do 1/2

We have a group of demands and requirements



What we should do 2/2

We use those limits to find out a geometry



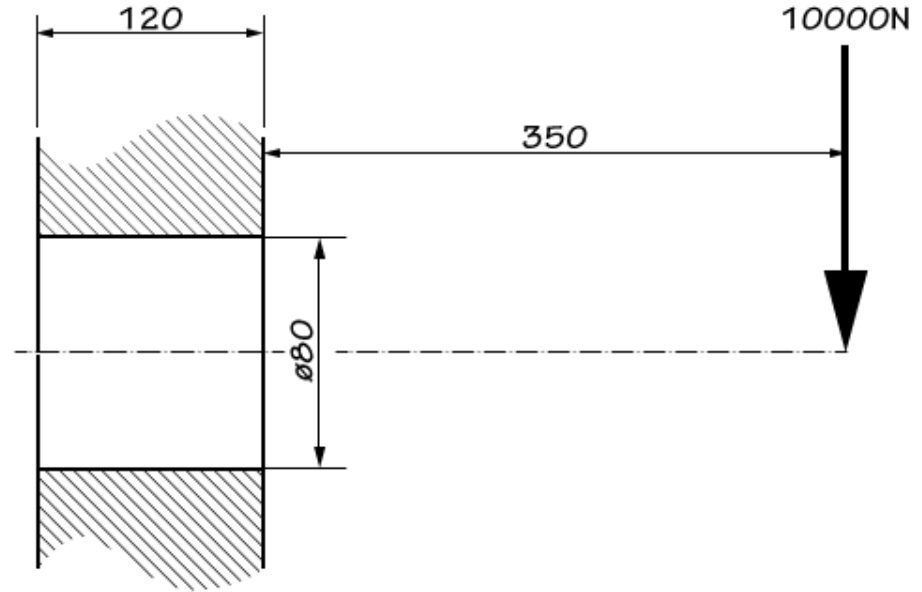
Reality is not that simple

Usually we know something like this

The case can be quite complex

Unknown things

Known things are subject to change



What CAD is?

CAD is not a documentation tool, it is a **design** tool

Use it to streamline your **design process**

Parametric Design

What is parametric design?

Microsoft Word example

Word is parametric text processor

- Computer-aided tool



Two different documents

Main Heading

First Heading

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Phasellus rhoncus augue in nulla venenatis sagittis. Quisque suscipit mauris non neque.

Praesent ac neque quis ipsum vehicula laoreet. In iaculis sodales justo vitae iaculis. Pellentesque habitant morbi tristique senectus et netus.

Second Heading

Proin vehicula, arcu sit amet egestas pretium, dolor felis mattis elit, eget sodales magna urna et massa. Ut feugiat rhoncus.

Maecenas accumsan, arcu quis tincidunt sagittis, velit diam pellentesque nunc, nec ullamcorper augue enim in metus. Sed at libero ante.

Third Heading

Etiam in tortor pulvinar ipsum varius placerat. Pellentesque risus urna, iaculis vel porta vitae, tincidunt sed nunc. Vivamus in dolor.

Main Heading

First Heading

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Phasellus rhoncus augue in nulla venenatis sagittis. Quisque suscipit mauris non neque.

Praesent ac neque quis ipsum vehicula laoreet. In iaculis sodales justo vitae iaculis. Pellentesque habitant morbi tristique senectus et netus.

Second Heading

Proin vehicula, arcu sit amet egestas pretium, dolor felis mattis elit, eget sodales magna urna et massa. Ut feugiat rhoncus.

Maecenas accumsan, arcu quis tincidunt sagittis, velit diam pellentesque nunc, nec ullamcorper augue enim in metus. Sed at libero ante.

Third Heading

Etiam in tortor pulvinar ipsum varius placerat. Pellentesque risus urna, iaculis vel porta vitae, tincidunt sed nunc. Vivamus in dolor.

Let's look under the hood



Two different documents?

Main Heading¶

First Heading¶

¶
Lorem ipsum dolor sit amet, consectetur adipiscing elit.
Phasellus rhoncus augue in nulla venenatis sagittis. Quisque
suscipit mauris non neque.¶

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Praesent ac neque quis ipsum vehicula laoreet. In iaculis
sodales justo vitae iaculis. Pellentesque habitant morbi tristique
senectus et netus.¶

Second Heading¶

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Proin vehicula, arcu sit amet egestas pretium, dolor felis mattis
elit, eget sodales magna urna et massa. Ut feugiat rhoncus.¶

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Maecenas accumsan, arcu quis tincidunt sagittis, velit diam
pellentesque nunc, nec ullamcorper augue enim in metus. Sed
at libero ante.¶

Third Heading¶

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risus urna, iaculis vel porta vitae, tincidunt sed nunc. Vivamus
in dolor.¶

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• Main Heading¶

• First Heading¶

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Lorem ipsum dolor sit amet, consectetur adipiscing elit.
Phasellus rhoncus augue in nulla venenatis sagittis. Quisque
suscipit mauris non neque.¶

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Praesent ac neque quis ipsum vehicula laoreet. In iaculis
sodales justo vitae iaculis. Pellentesque habitant morbi tristique
senectus et netus.¶

• Second Heading¶

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Proin vehicula, arcu sit amet egestas pretium, dolor felis mattis
elit, eget sodales magna urna et massa. Ut feugiat rhoncus.¶

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Maecenas accumsan, arcu quis tincidunt sagittis, velit diam
pellentesque nunc, nec ullamcorper augue enim in metus. Sed
at libero ante.¶

• Third Heading¶

¶
Etiam in tortor pulvinar ipsum varius placerat. Pellentesque
risus urna, iaculis vel porta vitae, tincidunt sed nunc. Vivamus
in dolor.¶

Real differences

Smart use of styles

- Headlines
 - Distance from previous paragraph
 - Distance to next paragraph
- Main text paragraphs
 - Empty line after paragraph

• Main Heading¶

• First Heading¶

Lorem ipsum dolor sit amet, consectetur adipiscing elit.
Phasellus rhoncus augue in nulla venenatis sagittis. Quisque
suscipit mauris non neque.¶

Praesent ac neque quis ipsum vehicula laoreet. In iaculis
sodales justo vitae iaculis. Pellentesque habitant morbi tristique
senectus et netus.¶

• Second Heading¶

Proin vehicula, arcu sit amet egestas pretium, dolor felis mattis
elit, eget sodales magna urna et massa. Ut feugiat rhoncus.¶

Maecenas accumsan, arcu quis tincidunt sagittis, velit diam
pellentesque nunc, nec ullamcorper augue enim in metus. Sed
at libero ante.¶

• Third Heading¶

Etiam in tortor pulvinar ipsum varius placerat. Pellentesque
risus urna, iaculis vel porta vitae, tincidunt sed nunc. Vivamus
in dolor.¶

Real differences

No styles

- Manually changed colors and font sizes
- Empty paragraphs

Imagine how easy is to change this document...

No **reusability** value



¶
Main Heading¶

¶
First Heading¶

¶
Lorem ipsum dolor sit amet, consectetur adipiscing elit.
Phasellus rhoncus augue in nulla venenatis sagittis. Quisque
suscipit mauris non neque.¶

¶
Praesent ac neque quis ipsum vehicula laoreet. In iaculis
sodales justo vitae iaculis. Pellentesque habitant morbi tristique
senectus et netus.¶

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Second Heading¶

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Proin vehicula, arcu sit amet egestas pretium, dolor felis mattis
elit, eget sodales magna urna et massa. Ut feugiat rhoncus.¶

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Maecenas accumsan, arcu quis tincidunt sagittis, velit diam
pellentesque nunc, nec ullamcorper augue enim in metus. Sed
at libero ante.¶

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Third Heading¶

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Etiam in tortor pulvinar ipsum varius placerat. Pellentesque
risus urna, iaculis vel porta vitae, tincidunt sed nunc. Vivamus
in dolor.¶

¶

Know your tools

CAD programs can do many things

- But you must know that those things exists

Knowing *one* CAD well will help you to learn how *other* CAD programs work

Almost all mechanical CADs have same principles

- Main difference is what the *user* is allowed to do

What is parametric design?

CAD models are made for to be changed

- Engineering design is an iterative process
- Within limits

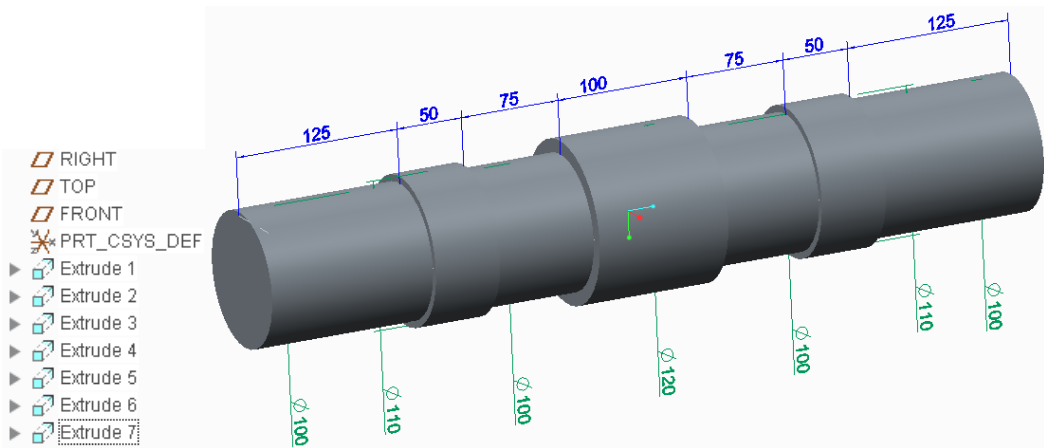
Dimensioning matters

- Main design parameters as model drivers
- Dimensions matter, not their values

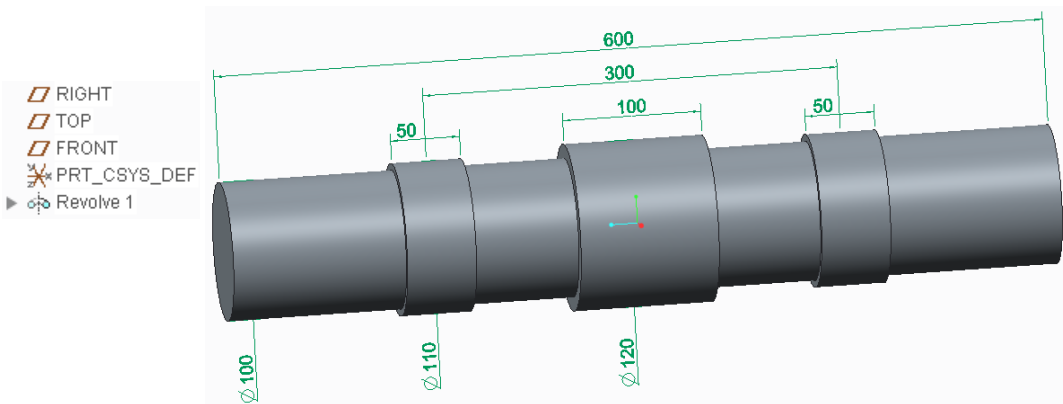
Thing before you do

Meaningful dimensioning

Is this you design?



Or does this make more sense?



Meaningful dimensioning

Select dimensions that support engineering design

- i.e. main shaft length, distance between bearings

Avoid unnecessary mental arithmetic

- i.e. main length is sum of several shape's lengths

Minimize change workflow

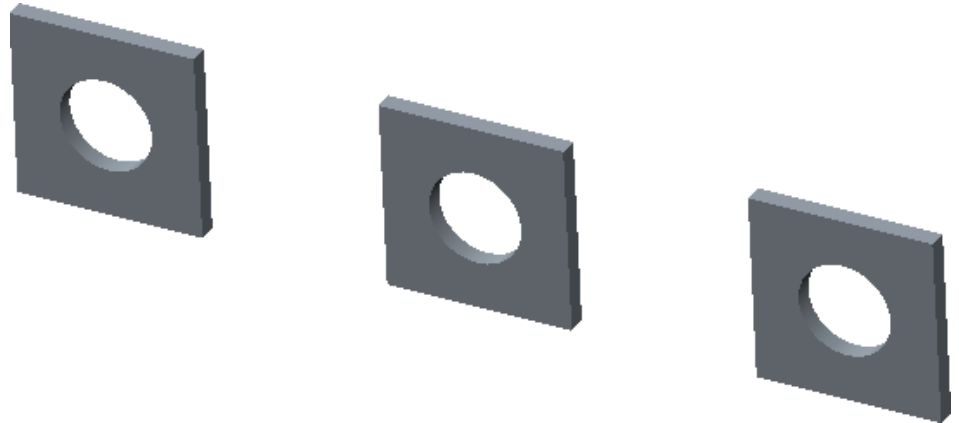
- Four times more changes is four times more mistakes

Design Intent

In CAD, it matters **how** the model is created

Models may look same, but how they response to changes?

Even with same dimensioning, **the model creation process** matters

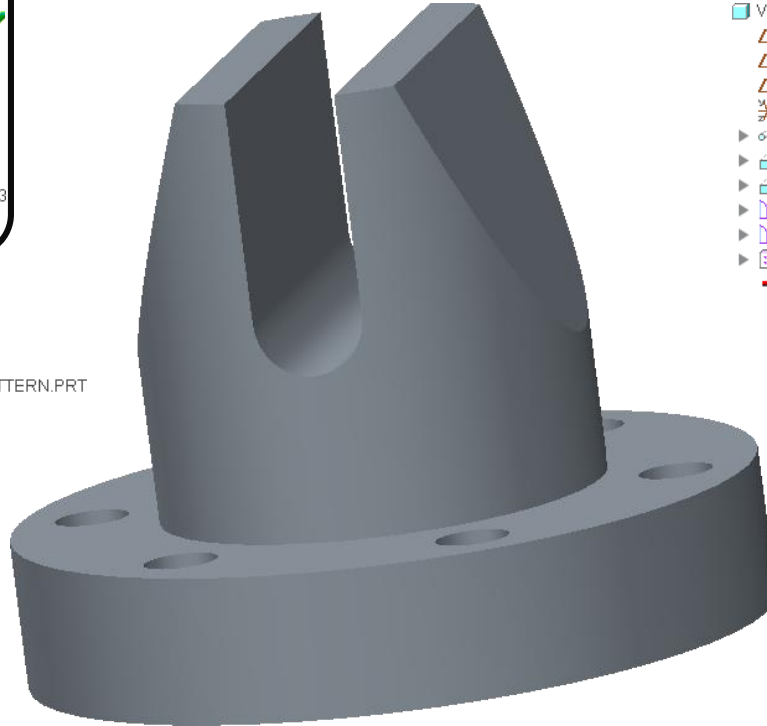


Many ways to create the shape

- VK_VARIABLE.PRT
 - ▢ RIGHT
 - ▢ TOP
 - ▢ FRONT
 - ✗ PRT_CSYS_DEF
 - ▶ Sketch 1
 - ▶ Sweep 1
 - ✗ Datum Point id 153
 - ~ Curve id 156
 - ▶ Sweep 2
 - ▶ Sweep 3
 - ▢ A_1
 - ▢ Sketch 3
 - ▢ Sketch 2
 - ▶ Pattern 1 of Sweep 4
 - ➔ Insert Here

- MID_TERM_EXAM.PRT
 - ▢ RIGHT
 - ▢ TOP
 - ▢ FRONT
 - ✗ PRT_CSYS_DEF
 - ▶ Revolve 1
 - ▶ Extrude 1
 - ▶ Extrude 2
 - ▶ Mirror 1
 - ▶ Pattern 1 of Extrude 3
 - ➔ Insert Here

- VK_UPPERCUT_NOPATTERN.PRT
 - ▢ RIGHT
 - ▢ TOP
 - ▢ FRONT
 - ✗ PRT_CSYS_DEF
 - ▶ Extrude 1
 - ▶ Extrude 2
 - ▶ Extrude 3
 - ▶ Extrude 4
 - ▶ Extrude 5
 - ▶ Extrude 6
 - ➔ Insert Here



- VK_MIRRORS.PRT
 - ▢ RIGHT
 - ▢ TOP
 - ▢ FRONT
 - ✗ PRT_CSYS_DEF
 - ▶ Revolve 1
 - ▶ Extrude 1
 - ▶ Extrude 2
 - ▶ DTM1
 - ▶ DTM2
 - ▶ Mirror 1
 - ▶ Mirror 2
 - ▶ Pattern 1 of Extrude 3
 - ➔ Insert Here

- VK_BOUNDARY_BLEND_ONE_EXTRUSION.PRT
 - ▢ RIGHT
 - ▢ TOP
 - ▢ FRONT
 - ✗ PRT_CSYS_DEF
 - ▶ Sketch 1
 - ▶ Sketch 2
 - ✗ PNT1
 - ▢ DTM1
 - ✗ PNT2
 - ▶ DTM2
 - ▶ Sketch 3
 - ▶ Sketch 4
 - ▢ DTM4
 - ▶ Sketch 6
 - ▢ DTM5
 - ▶ Sketch 7
 - ▶ Boundary Blend 1
 - ▶ Boundary Blend 4
 - ▶ Boundary Blend 5
 - ▶ Merge 1
 - ▶ Boundary Blend 2
 - ▶ Boundary Blend 3
 - ▶ Merge 2
 - ▶ Boundary Blend 6
 - ▶ Merge 3
 - ▶ Merge 4
 - ▶ Merge 5
 - ▶ Sketch 8
 - ▶ Sketch 9
 - ▶ Pattern 1 of Boundary Blend 7
 - ▶ Pattern 2 of Merge 6
 - ▶ Extrude 1
 - ➔ Insert Here

Making Design Intent clear

Plan ahead

- Just doing may seem fast, but changeability will suffer
- Save time in the end, not in the beginning

Use test models

- Test different approaches
- Throw bad models away

Model needs to have a purpose

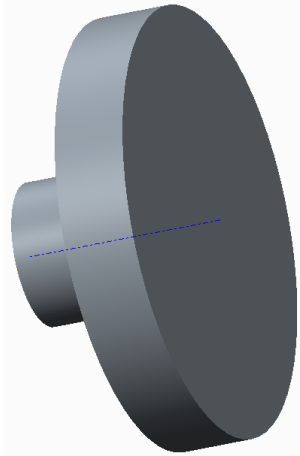
- Model for communication is not a good engineering design model



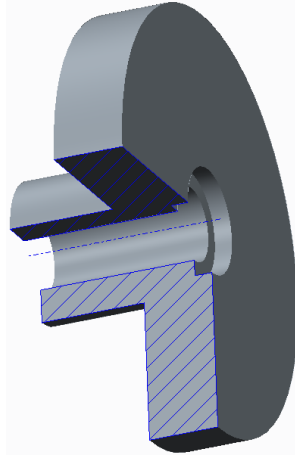
Feature per function

Makes understanding model easier

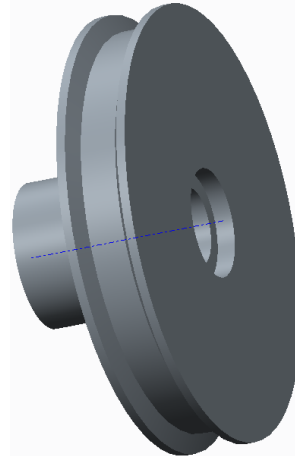
- You don't need to save in the amount of features



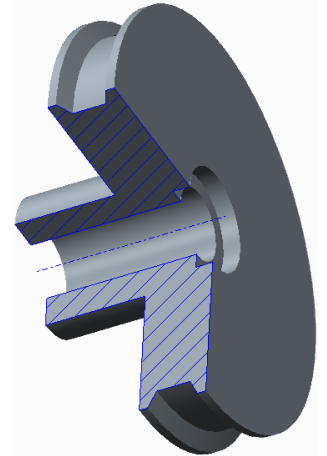
Raw material



Hole for shaft



Groove for
belt wheel



Ready belt wheel

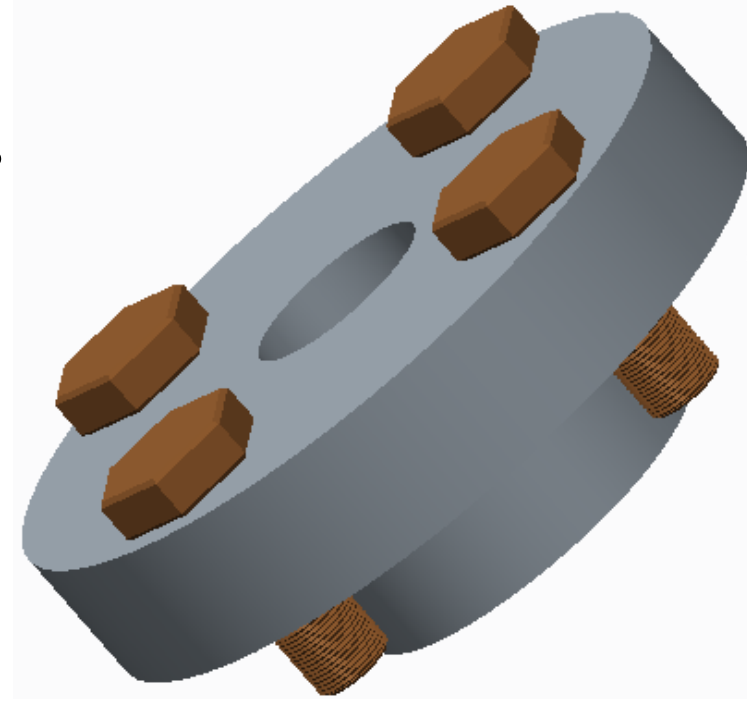
Symmetry and patterns

If the model is symmetrical, benefit from it

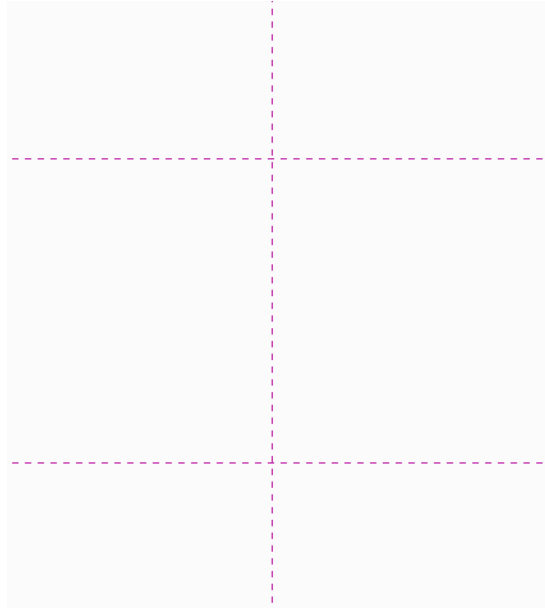
- Don't over-mirror

If you can use patterns, do it

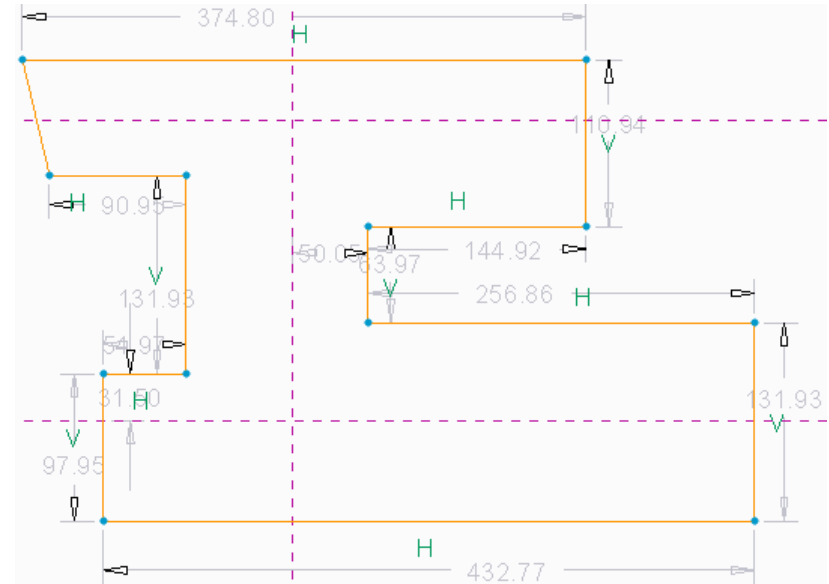
- Can even streamline assembly process



Sketching Order

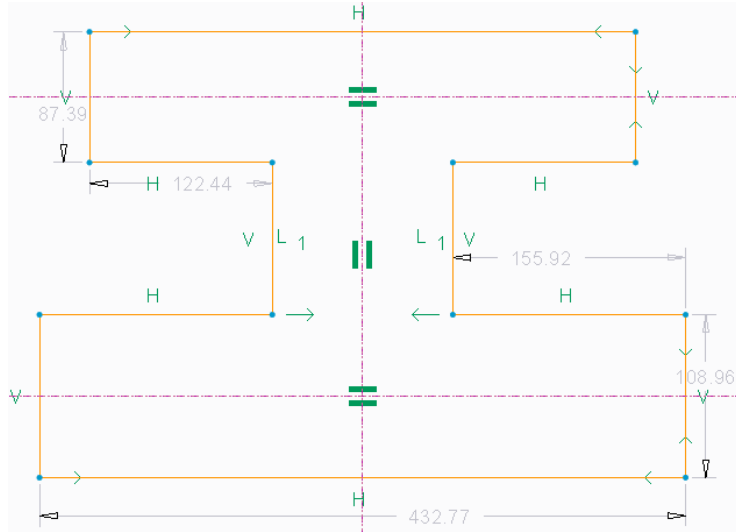


References

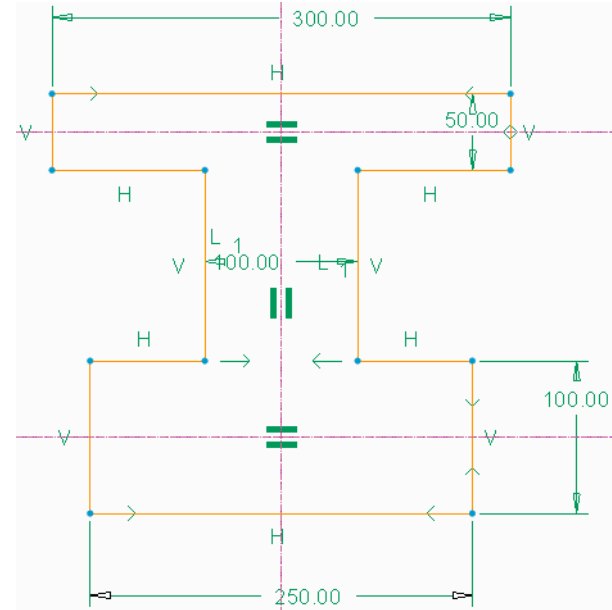


Geometry

Sketching Order



Constrains and dimensions



Values

The goal of parametric design

Reduce the configure-to-order times

Reducing costs

Improving your value

Speed up iteration cycles

Better communication

Making life easier

The hard part

There are no one correct way

Your skills will improve when practicing

Use your time to fix mistakes

- You learn most while fixing it

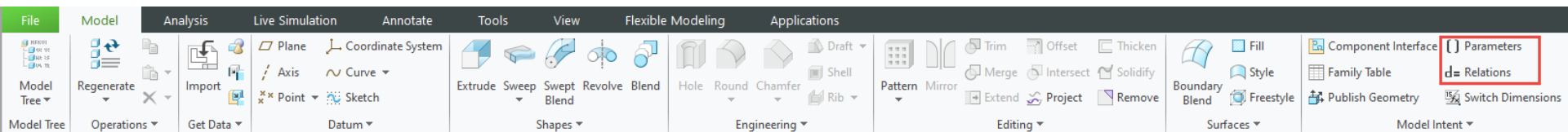
Do not hesitate to change bad plan

- Do not try to save it

Parameters & relations

Tools in Creo

Can be found in *Model Intent* group



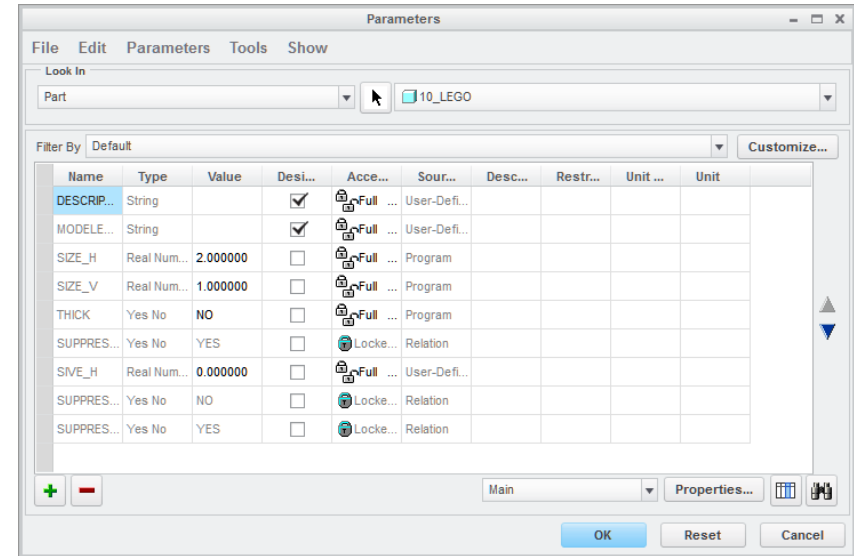
Parameters

Lists all parameters in the model

- Can add/remove those

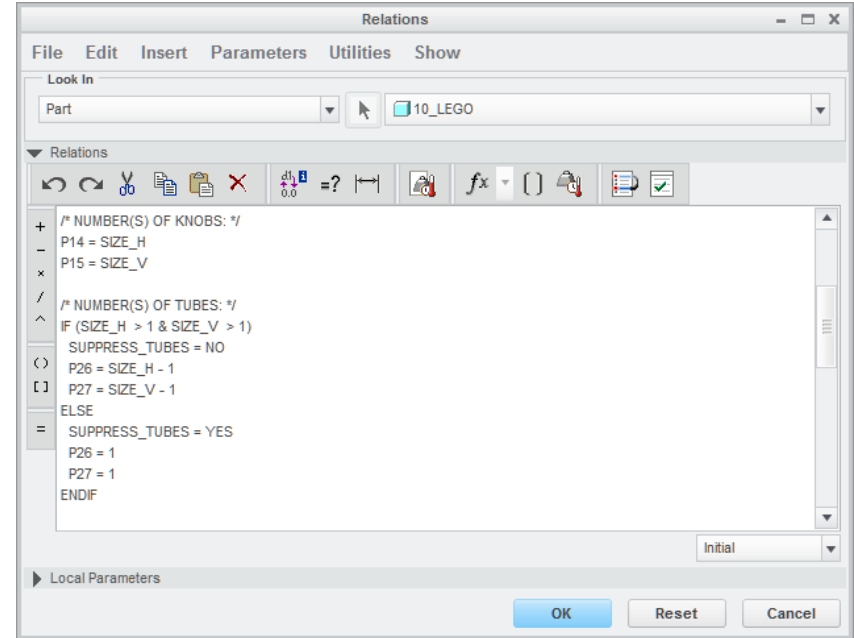
Four types

- Integer (for ex. 3)
- Real Number (for ex. 3.14)
- String (for ex. "Steel")
- Yes No i.e. Boolean



Relations

Lists relations (i.e. model code) in the model. Relations between dimensions and parameters.



If Else

IF (condition)

...

ELSE

...

...

ENDIF

IF to state condition

- For ex. IF (d7>4)

ELSE if statement not right

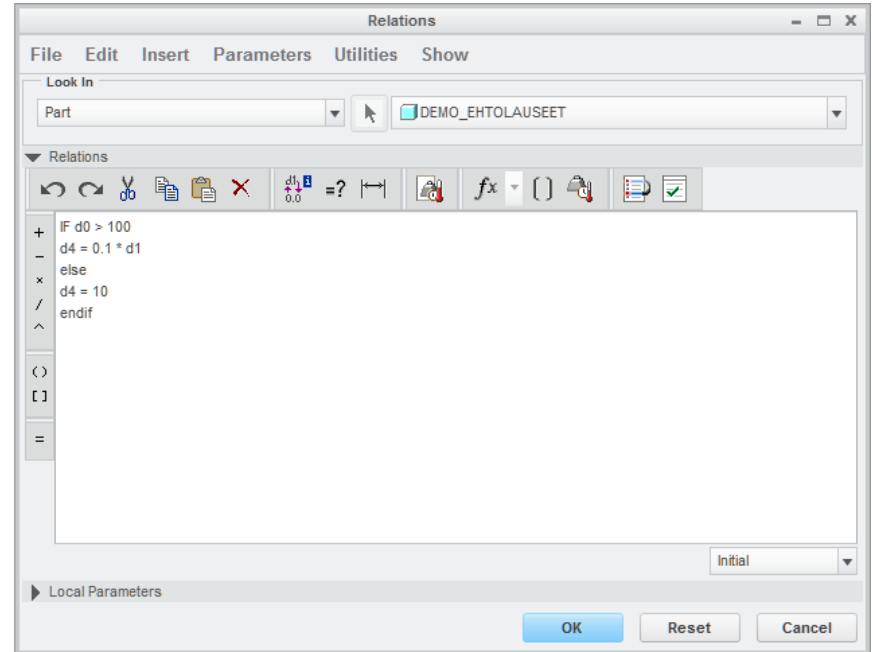
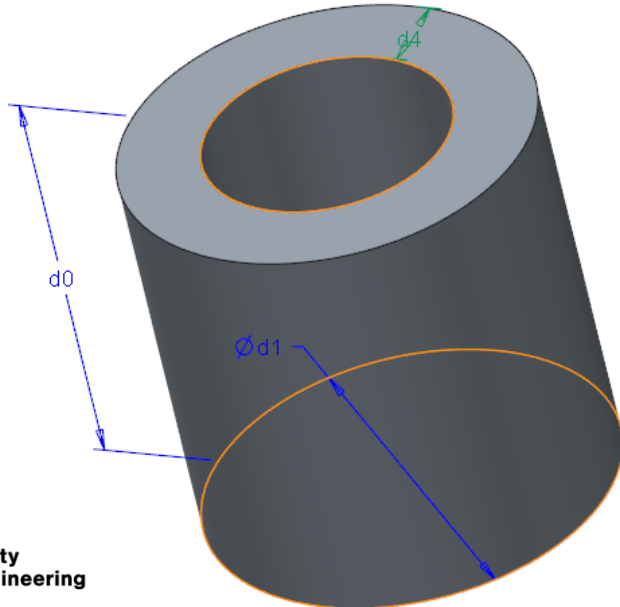
- Optional

ENDIF closes the IF loop

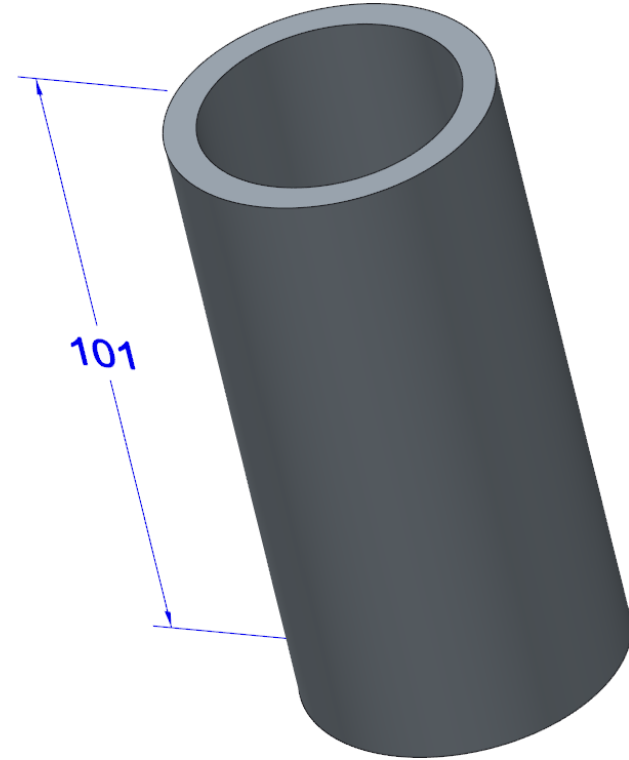
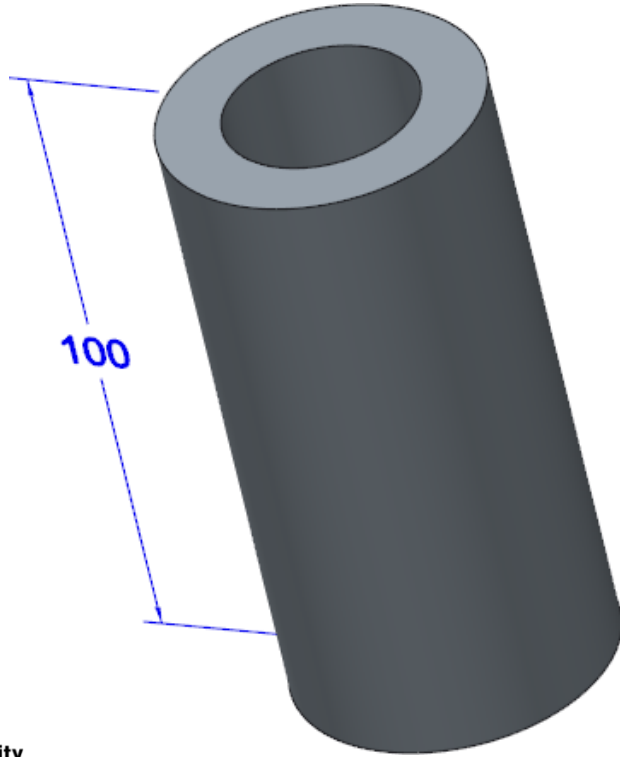
- No bracets

An Example

If the height of the part (d0) is over 100, then thickness (d4) is 10%



An Example



Logical Operators

> greater than, => equal or greater than

< smaller than, =< equal or smaller than

== equal

& and

| or



Dimensions' Symbols

d# feature dimension

- Real number

p# amount of patterned features

- Integer (for ex. 3.6 \rightarrow 3), can't be zero

sd# sketch's dimension

Program creates numbers (#) automatically



Suppressing Features

Features can be scribed to be suppressed

- Thru Program tool in Model Intent

You suppress feature, not to remove it

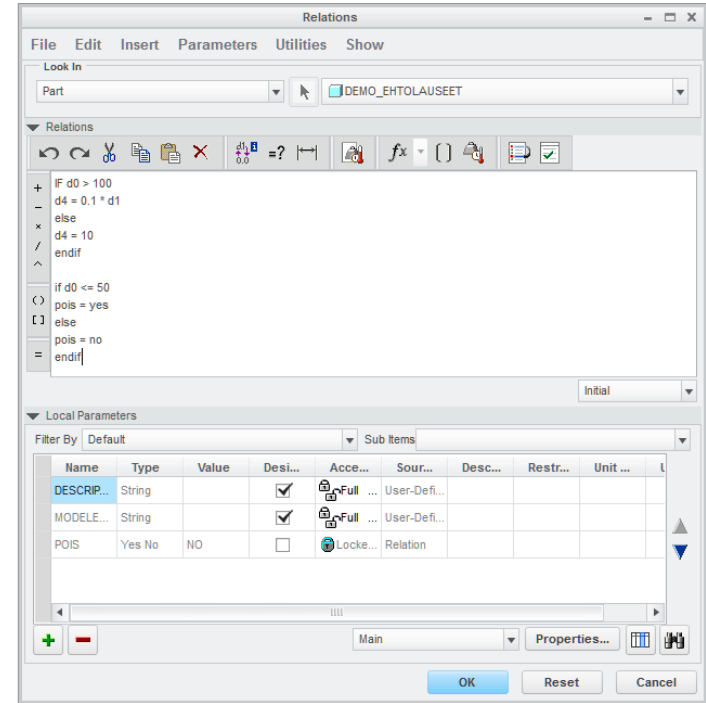
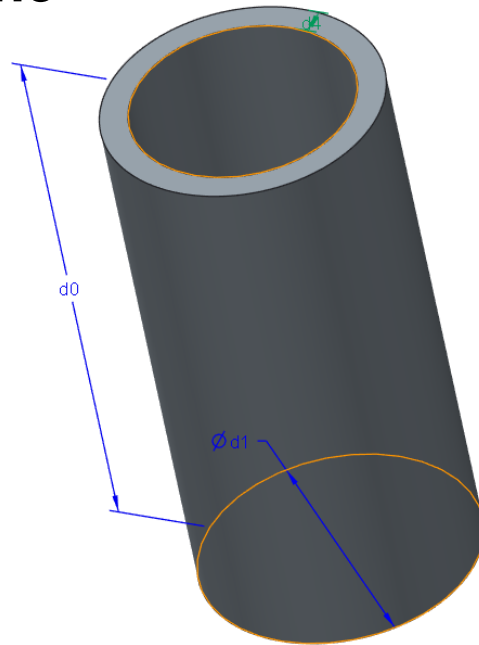
- Symbol black box before feature's name



Suppressing Features

Parameter POIS for stating the status of the feature

- Does not yet suppress it!



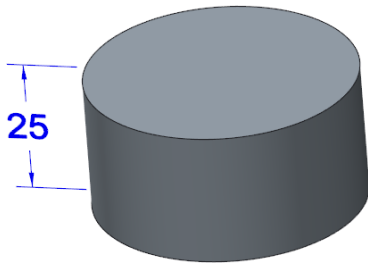
Suppressing Features

Program list is a guide how to build model

- A text file

You can create own conditions to the list

- IF – END IF structure



```
demo_ehtolauseet.pls - Notepad
File Edit Format View Help

if pois == no
ADD-FEATURE (initial number 6)
INTERNAL FEATURE ID 60
PARENTS = 40(#5) 1(#1)

CUT: Extrude

NO.    ELEMENT NAME    INFO
---
1      Feature Name    Defined
2      Extrude Feat type Solid
3      Material        Remove
4      Section         Defined
4.1    Setup Plane     Defined
4.1.1  Sketching Plane Surf:F5(EXTRUDE_1)
4.1.2  View Direction  Side 1
4.1.3  Orientation     Right
4.1.4  Reference       RIGHT:F1(DATUM PLANE)
4.2    Sketch          Defined
5      Feature Form     Solid
6      Material Side    Side Two
7      Direction        Side 1
8      Depth            Defined
8.1    Side one         Defined
8.1.1  Side one Depth  None
8.2    Side Two         Defined
8.2.1  Side Two Depth  Thru All

SECTION NAME = Section 1

FEATURE'S DIMENSIONS:
d4 = (Displayed:) 5 General_Dims
    ( Stored:) 5.0 ( 0.1, -0.1 )

END ADD
end if

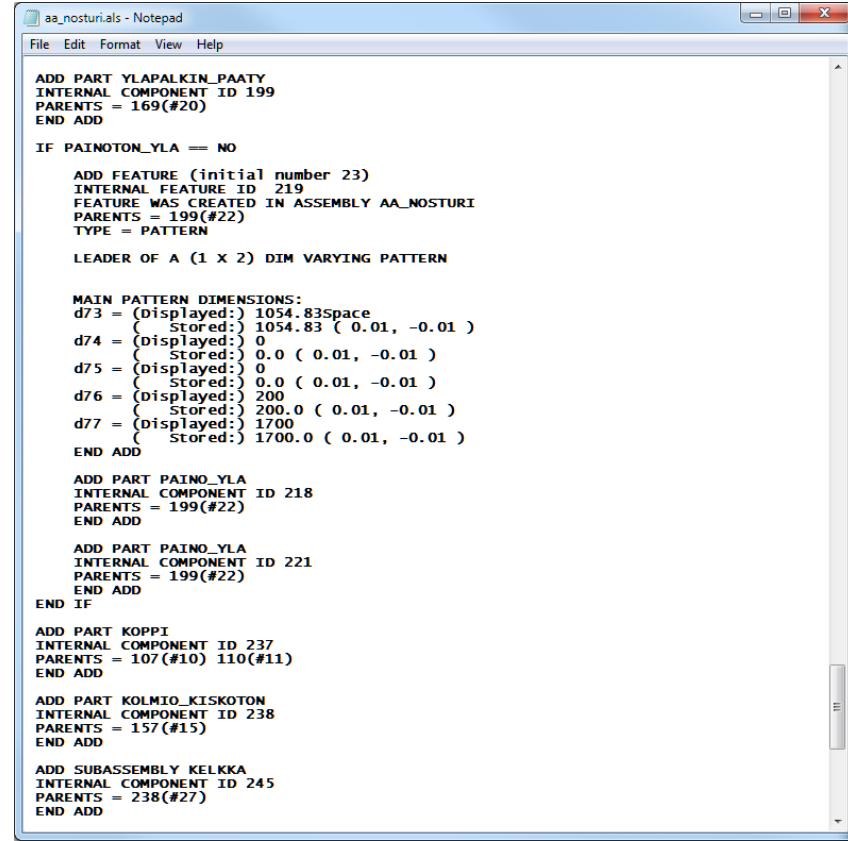
MASSPROP
END MASSPROP
```

Suppressing Parts

Same tool, but in assembly level

- ADD PART – END ADD

Good tool for creating a configurable models

A screenshot of a Notepad window titled 'aa_nosturi.als - Notepad'. The window contains a series of commands for creating and configuring parts in a CAD assembly. The code includes commands for adding parts (YLA_PALKIN_PAATY, PAINO_YLA, KOPPI, KOLMIO_KISKOTON), defining internal components, setting parent relationships, and defining a pattern with dimensions. The code is as follows:

```
File Edit Format View Help

ADD PART YLA_PALKIN_PAATY
INTERNAL COMPONENT ID 199
PARENTS = 169(#20)
END ADD

IF PAINOTON_YLA == NO

  ADD FEATURE (initial number 23)
  INTERNAL FEATURE ID 219
  FEATURE WAS CREATED IN ASSEMBLY AA_NOSTURI
  PARENTS = 199(#22)
  TYPE = PATTERN

  LEADER OF A (1 X 2) DIM VARYING PATTERN

  MAIN PATTERN DIMENSIONS:
  d73 = (Displayed:) 1054.83Space
  (Stored:) 1054.83 ( 0.01, -0.01 )
  d74 = (Displayed:) 0
  (Stored:) 0.0 ( 0.01, -0.01 )
  d75 = (Displayed:) 0
  (Stored:) 0.0 ( 0.01, -0.01 )
  d76 = (Displayed:) 200
  (Stored:) 200.0 ( 0.01, -0.01 )
  d77 = (Displayed:) 1700
  (Stored:) 1700.0 ( 0.01, -0.01 )
END ADD

ADD PART PAINO_YLA
INTERNAL COMPONENT ID 218
PARENTS = 199(#22)
END ADD

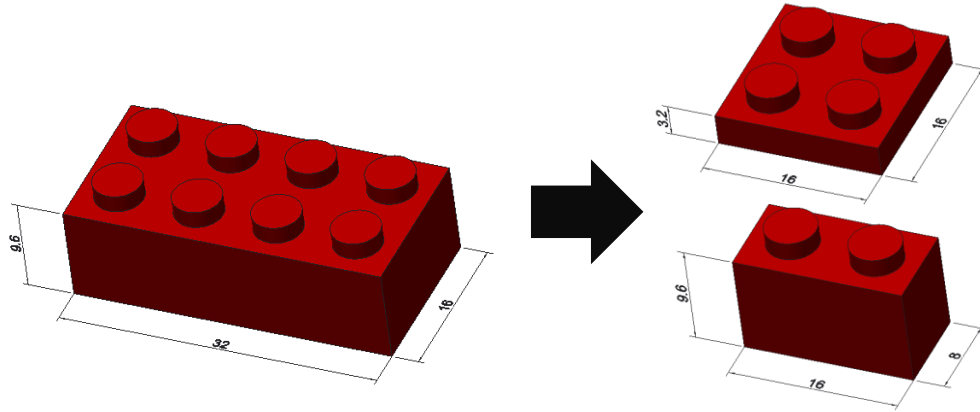
ADD PART PAINO_YLA
INTERNAL COMPONENT ID 221
PARENTS = 199(#22)
END ADD
END IF

ADD PART KOPPI
INTERNAL COMPONENT ID 237
PARENTS = 107(#10) 110(#11)
END ADD

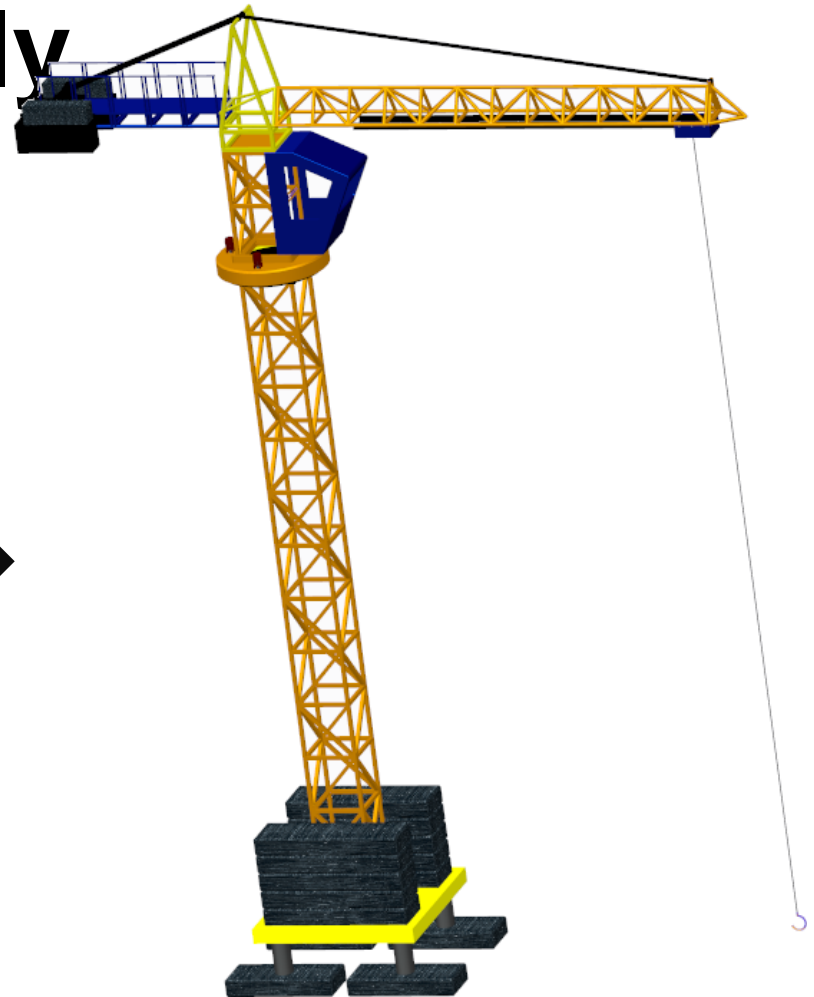
ADD PART KOLMIO_KISKOTON
INTERNAL COMPONENT ID 238
PARENTS = 157(#15)
END ADD

ADD SUBASSEMBLY KELKKA
INTERNAL COMPONENT ID 245
PARENTS = 238(#27)
END ADD
```

Parametric Parts



Parametric Assembly



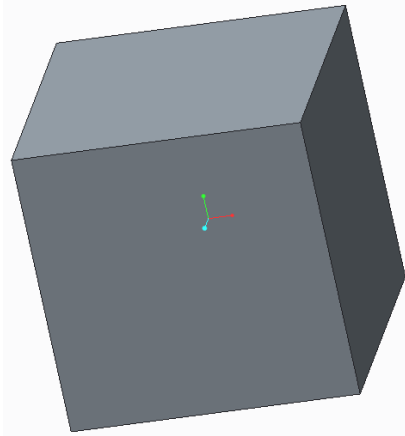
How NOT to create a ball



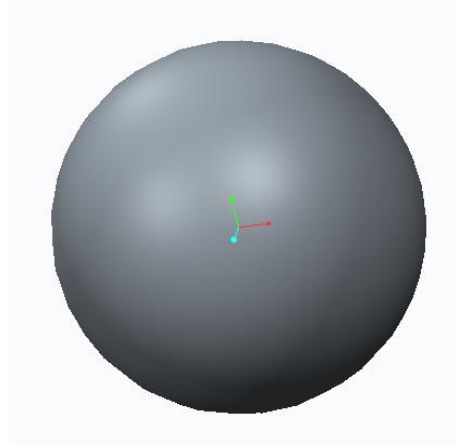
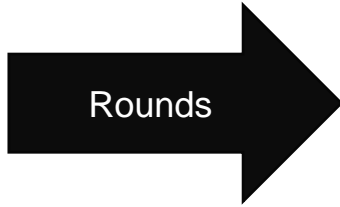
How NOT to create a ball

Round and Chamfer are tools for fine-tune models, not to create primary shapes!

Extrude 1



Rounds





aalto.fi



Aalto University
School of Engineering