Faculty of Engineering Science
Master of Mechanical Engineering
Academic Year 2022-2023

Virtual Product Development (H0A15A)

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Leuven , 27th May 2022

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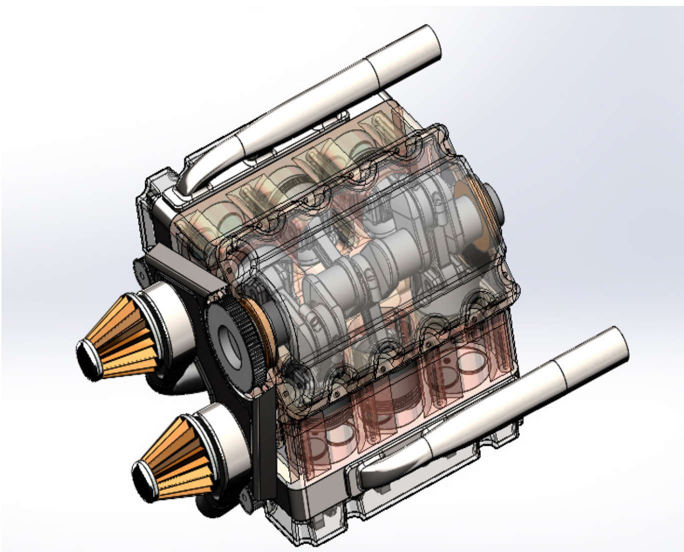
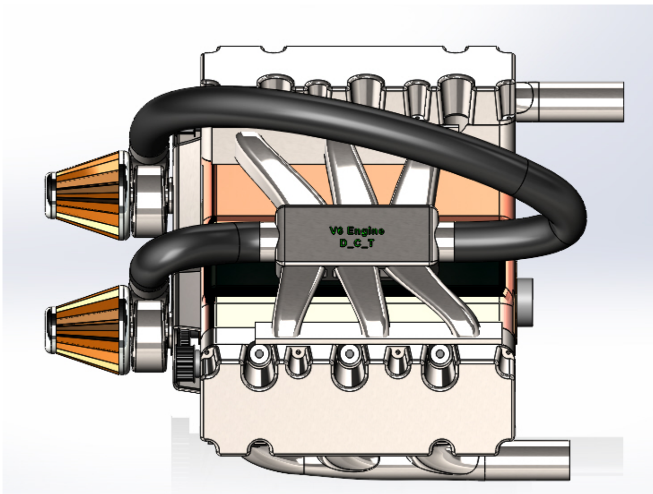
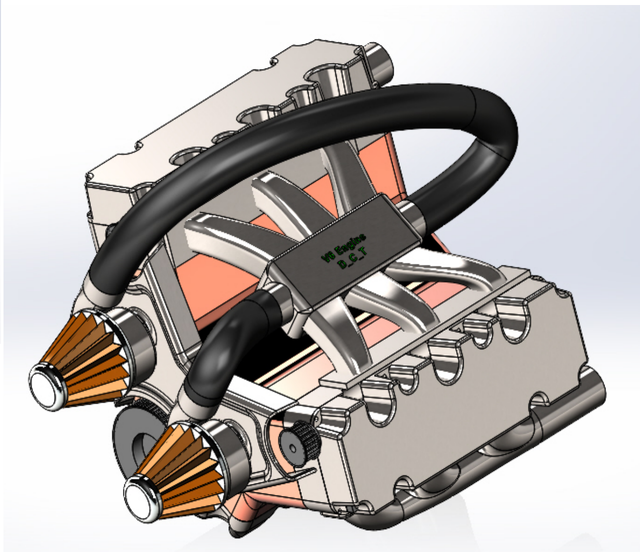
ABSTRACT.

The V6 Engine of Vehicle is the component that I have picked for my project. It was chosen because it had many complex surfaces and parts, giving me a fantastic opportunity to put what I had learned in theory into practice. Over 25 parts were manufactured in total, including more than 5 small and large assemblies. A proper drawing with calculations was used for the CAD. I choose connecting rod as my process of choice. The project is broken down into three sections. Cad modeling is done in the first stage, and process selection is done in the second part based on some well-known manufacturers of that part. In the third section, various file types are analyzed. The activities involved in process planning can be divided as follows:

1. Interpretation of product design data (CAD data, material properties, batch size, tolerances)
2. Selection of machining processes
3. Selection of machining tools
4. Determination of fixtures and datum surfaces
5. Sequencing of operations
6. Selection of inspection devices
7. Determination of production tolerances
8. Determination of proper cutting tools and their parameters
9. Calculation of the overall times (machining, non-machining and set-up times)
10. Generation of process sheets, operation sheets and NC data.



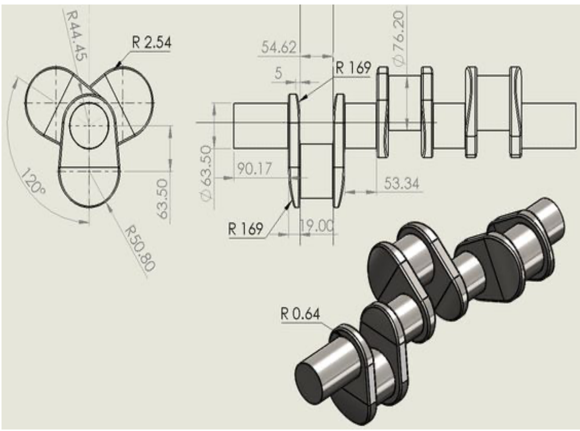


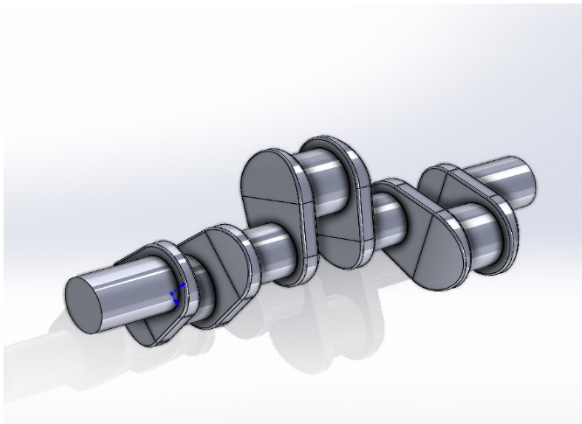


CHAPTER 1.
CAD Modelling

1.1. Engine Crankshaft:

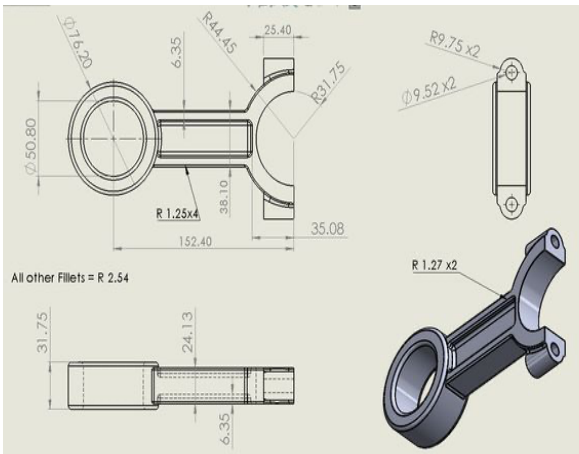
Features Used: One of the main feature used was **MOVE / COPY.** When a pair of camshafts was made then we needed to move the camshaft relative to axis so we used the command to move the second pair at 120 degrees and for the third pair -120 degrees was set. Other mostly used features included Chamfer and Fillet.

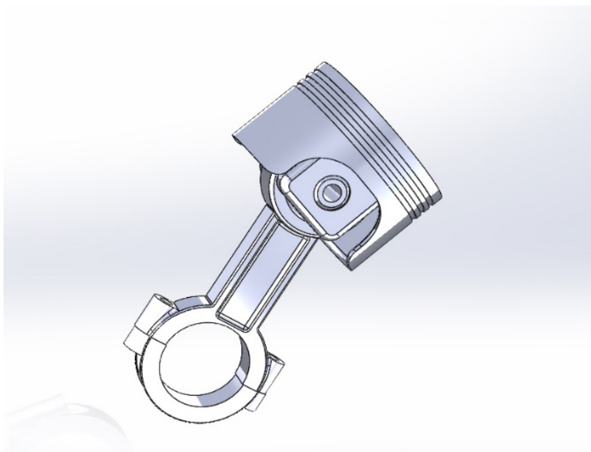




1.2. Piston V6:

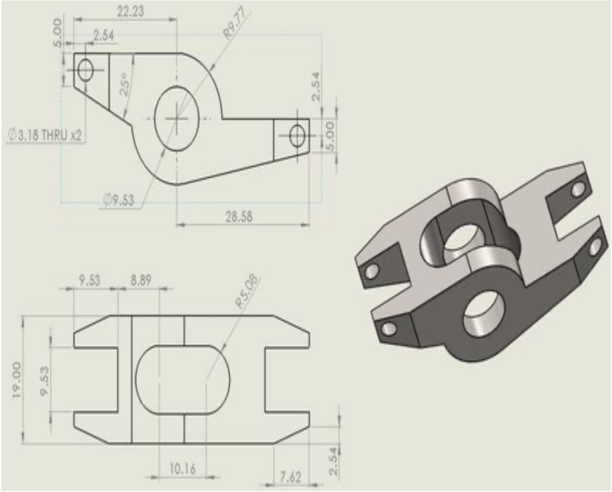
Features: It was a mini-assembly in which we made all the parts (cylinder head, nuts) and then assembled them together. Some commonly used features included Extrude, Hole Wizard, Chamfer and Fillet.

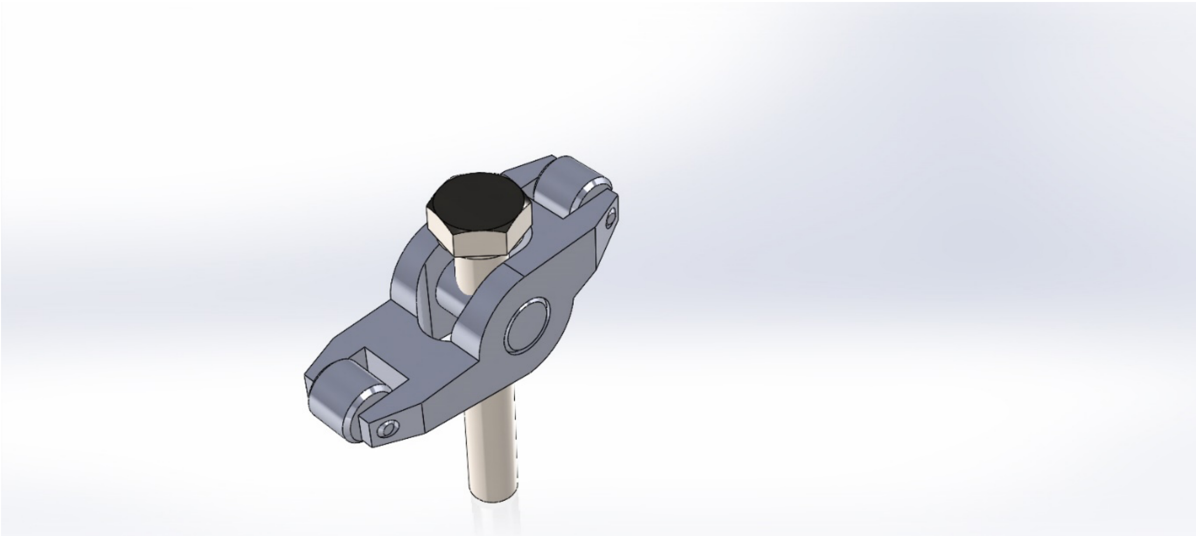




1.3. Rocker Arm:

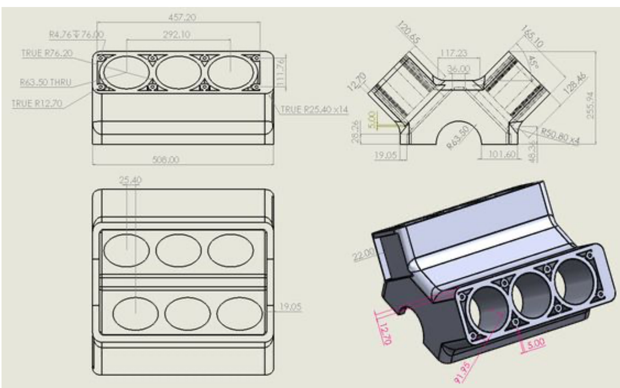
Features Used: It was again a simple assembly made through use of simple and advanced features (extrude, chamfer, fillet, hole wizard, slot). In this we also exported the Hexagonal Screw from Solidworks Library. In the assembly, common assembly features such as collinear and concentric options were used to combine the assembly. Both exploded and combine view are displayed.

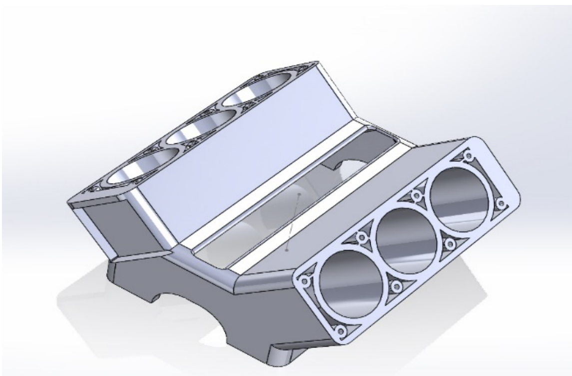


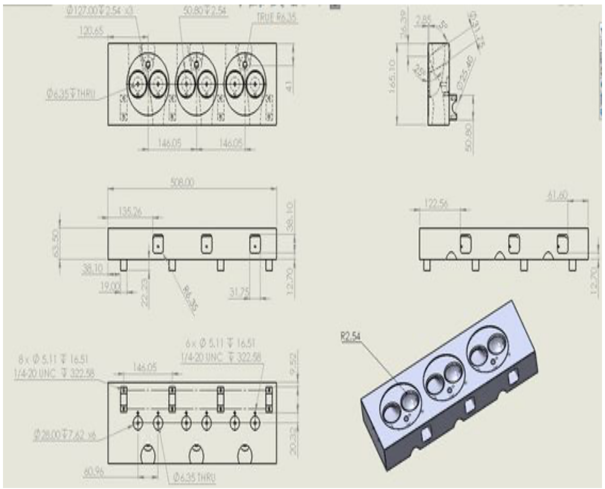


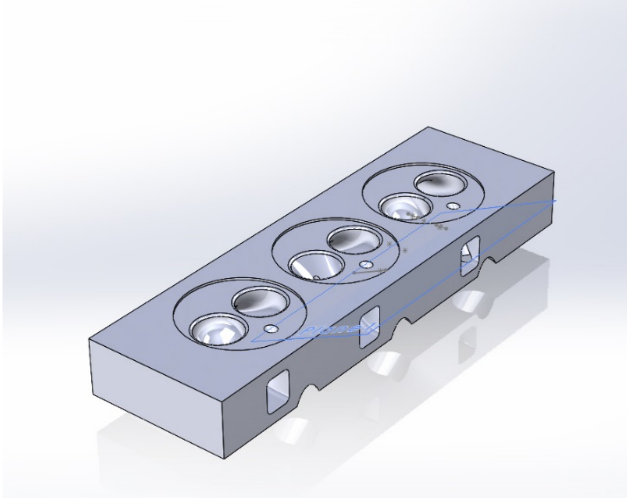
1.4. Engine Block and Cylinder Head:

Features Used: Although both these part look very simple but here a lot of new features such as Convert entities, Draft, Shell, Mirror, Loft, Hole wizard, Reference geometry and Planes creation was used.



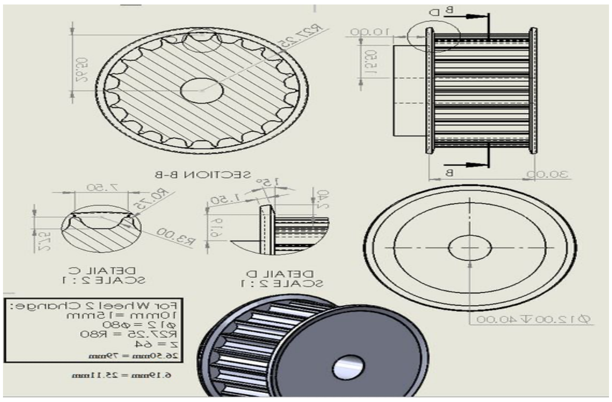


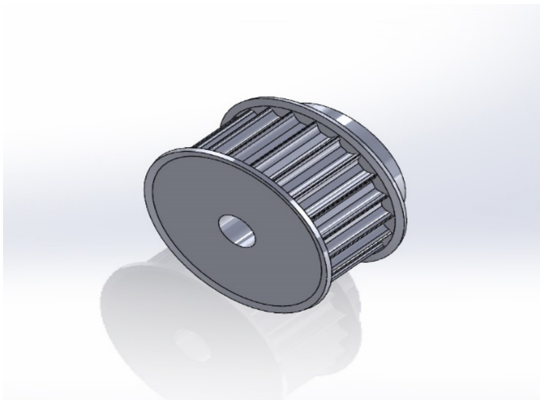


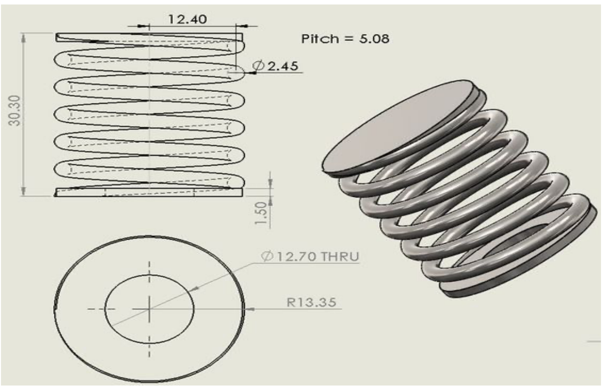


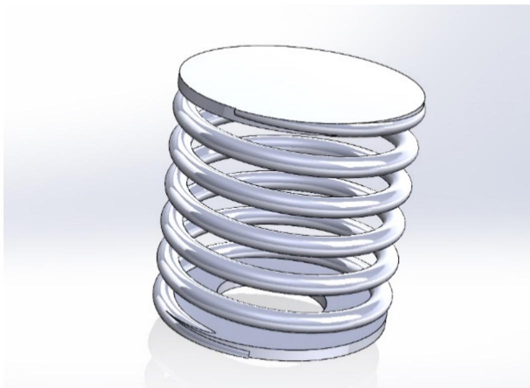
1.5. Belt Wheel, Exhaust Manifold, Rocker Spring and Valve:

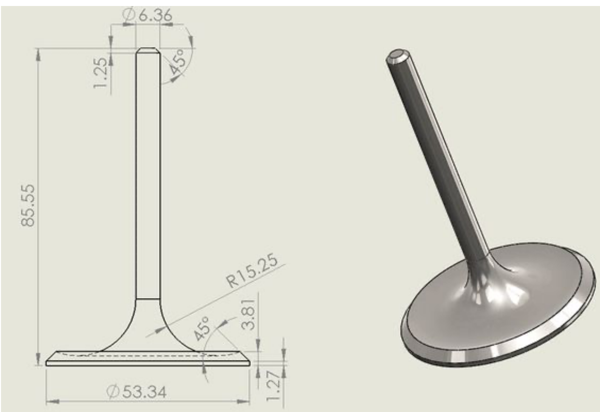
Features Used: Revolve, Shell, Draft, Boundary Boss/Base, Helix and Spiral Curves are some of the new features we used with all the old features.

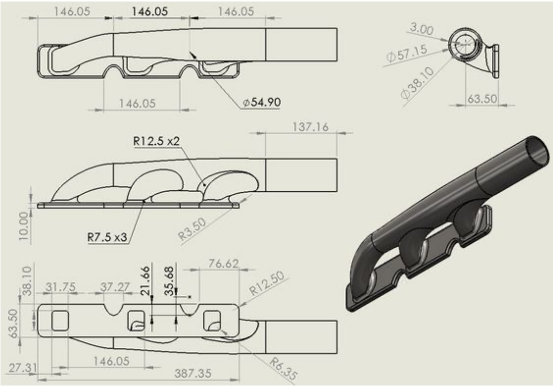


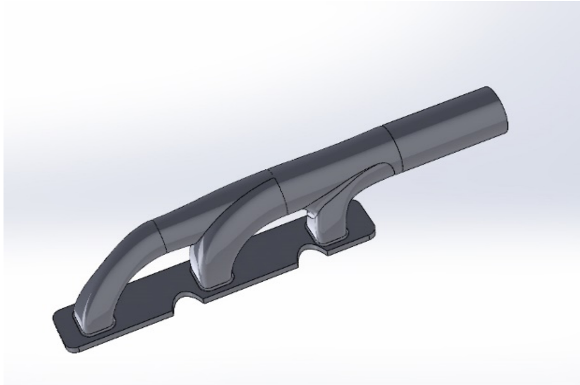






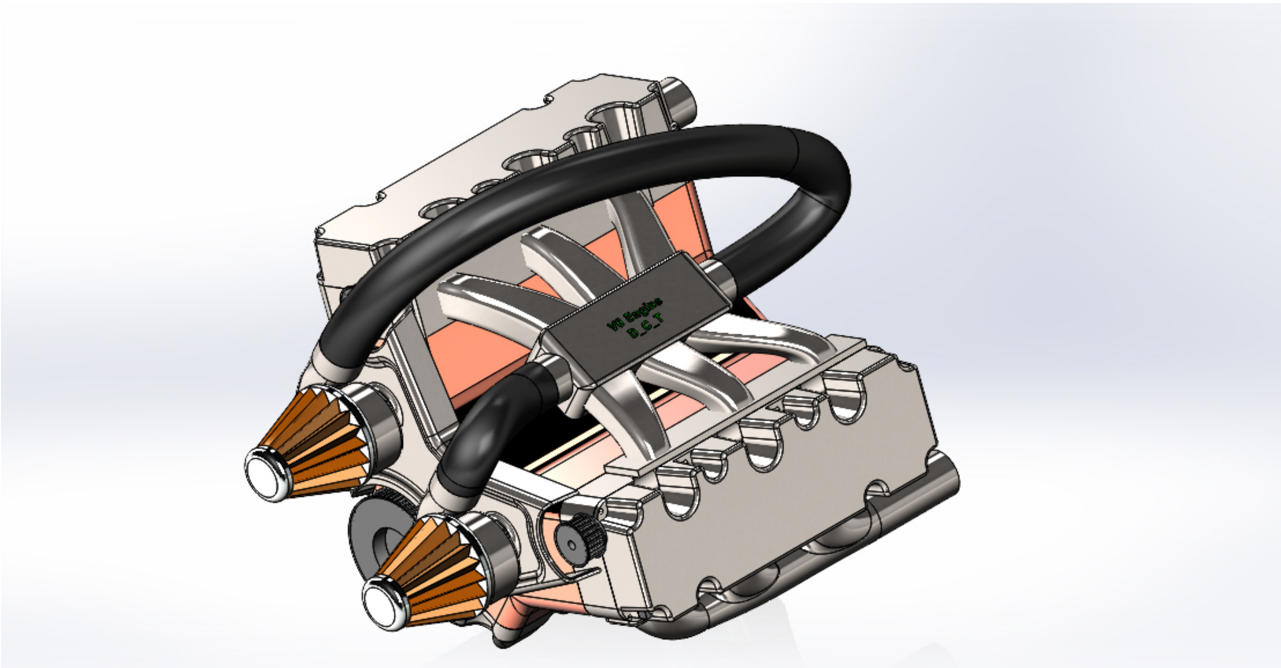






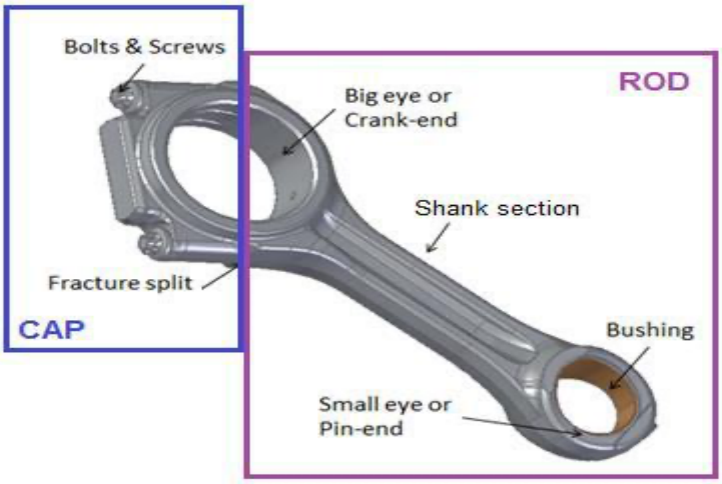
1.6. Full Housing Assembly:

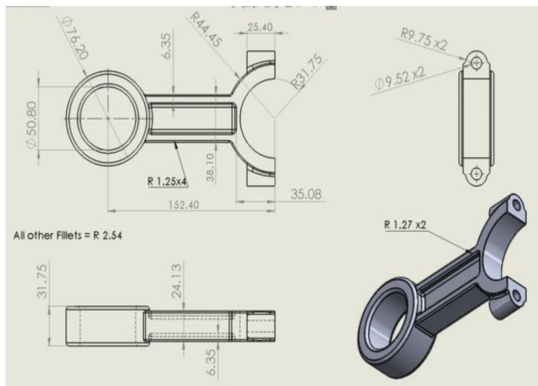
Features Used: Concentric, Coincident, Width selection, Copy with mates,



CHAPTER 2.
PROCESS SELECTION

2.1. Selection of Connecting Rod

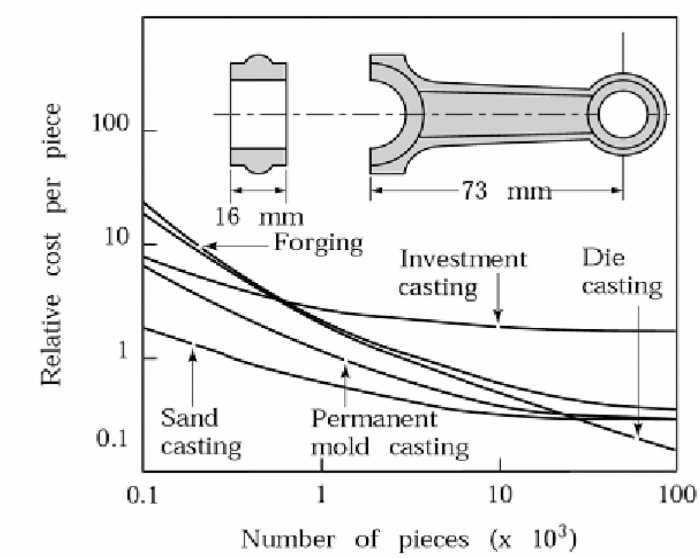




The connecting rod can be divided in two main parts: the cap and the rod, which allow its assembly with the crankshaft. These two parts contain the following characteristic elements:

- Pin-end or “small eye” – small bore to connect the connecting rod to the piston by the piston pin.
- Bushing –piece inserted in the pin-end to accommodate the piston pin.
- Shank section – link between pin- and crank- ends.
- Crank-end or “big eye”– big bore to connect the connecting rod to the crankshaft

2.2. Selection of Forging as Primary Manufacturing Process:



Production No: 10000

Step 1: Since we want to produce 10000 parts and our primary manufacturing process is Solid Forming thus by looking at the Table 5.4 we get that our relative quantity is 10000/2000 =5, thus it is a relative high quantity and we go to Table 5.4.

Step 2: Shape complexity is open type and is long and have thick and thin section

Step 3: Priority 1 is column G14 – Forging

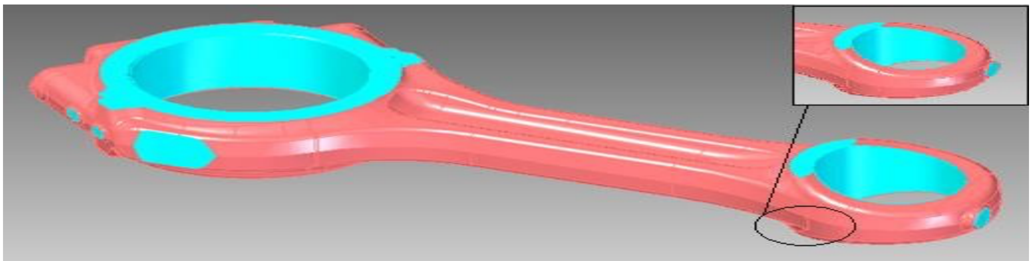
Reason 1:
I have taken this image from one of the research paper which shows that which process should be used for production of connecting rod. An important thing to note in the above figure is that when no of parts are increased, we see that Sand casting, Permanent mold casting, Die casting and Forging converge and at around 50,000 parts, all of them intersect which means that if we select a batch of 50,000 so we can go with any of the four processes. But following what we learned in the class, since Connecting Rod is a **OPEN shape part** (can be divided into two parts by a plane) and because we want to produce more than 2000 parts which means that the best process based on the **Shape complexity is B** (forming from solid by deformation). Thus, forging is the best way to produce it.

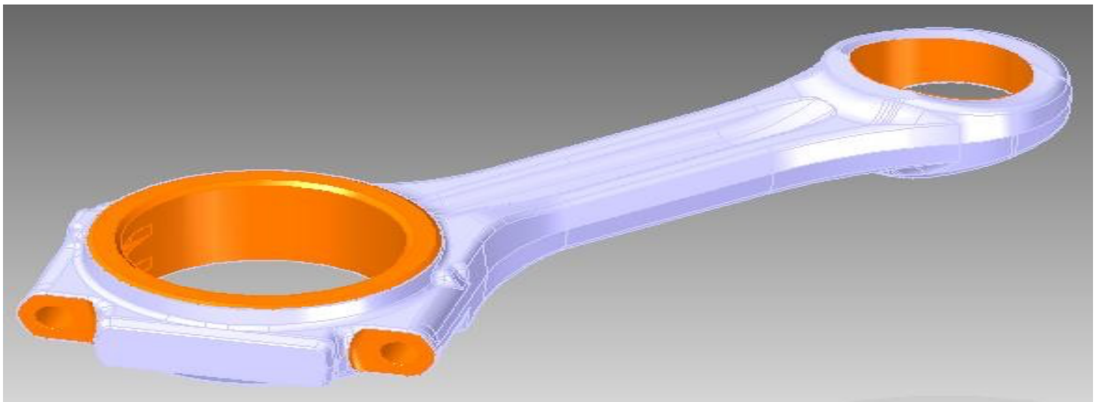
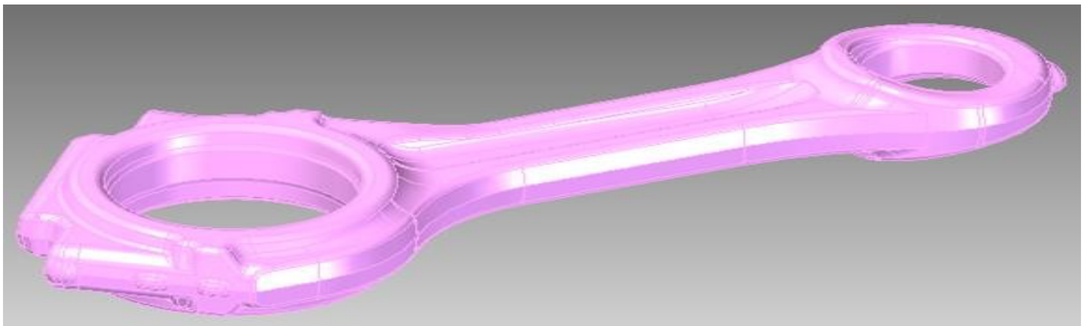
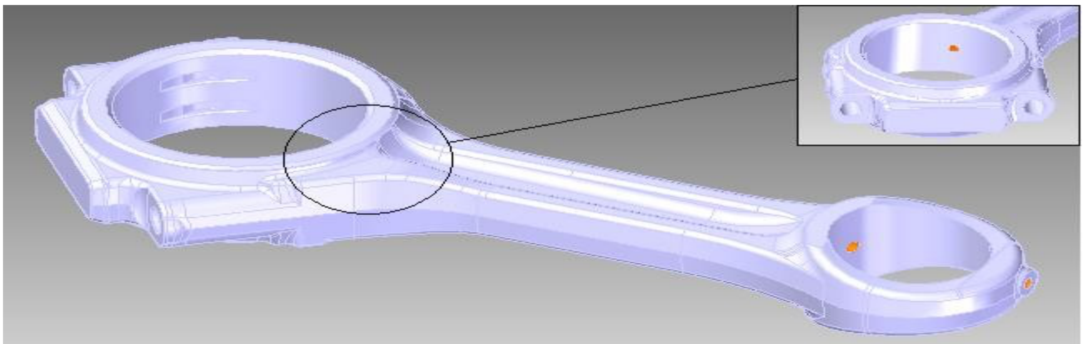
Reason 2:
Another important reason is that connecting rod is subjected to very high inertial forces and bearing loads, it should be able to withstand those forces for high number of cycles. To reduce the forces exerted during operation, the connecting rod should weigh as little as possible and should have very high fatigue strength. While reading several research papers, I came to the decision that since, in Europe and Asia, forged connecting rods seemed to be the preferred method of manufacturing because they require less machining, and has a much higher material utilization efficiency, leading to lower final cost of the finished product.. That's why we will choose forging (G14) as our primary manufacturing process and our batch size will be around 10000.

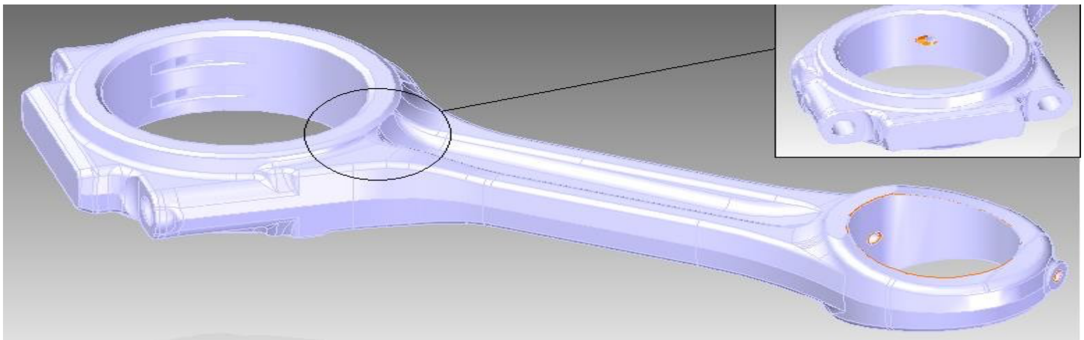
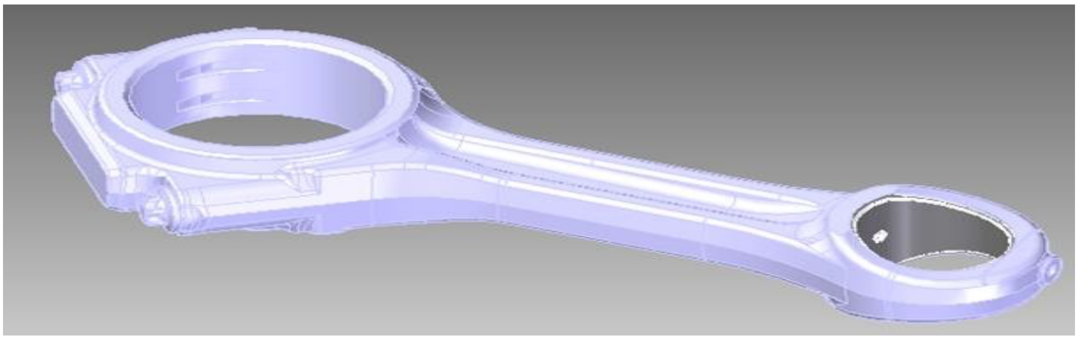
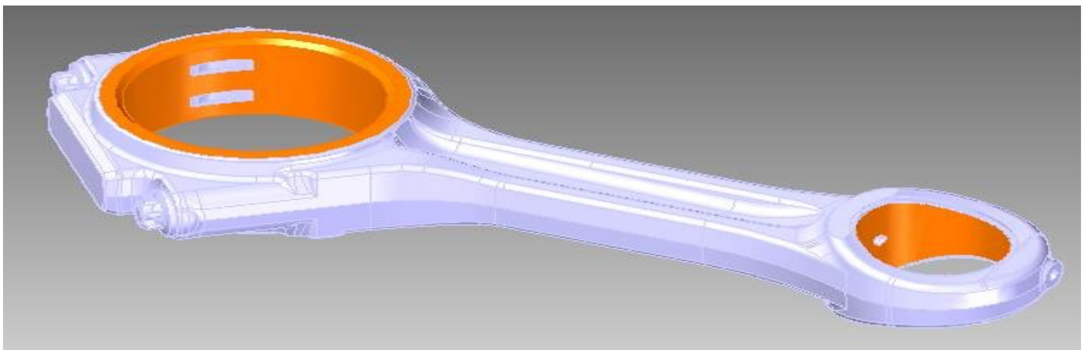
Sand casting:
If we want to create our part using a liquid process, Sand casting is the greatest option, according to what we've learned, because the thickness of our part is in the 3-5mm region, so we can utilize it. Similarly, there are no weight or material constraints, therefore sand casting will be the second alternative.

2.2. SELECTION OF MACHINING PROCESSES, TOOLS FOR WHOLE PROCESS:

2.2.1. Operation sequence Connecting Rod

	
Op. 20	1. Milling upper flat surface, outer chamfer, small flat surfaces in crank end and upper flat surface pin end 2. Milling code and two small lateral surfaces 3. Milling surface for oil entry 4. Drilling crank end + inner chamfer 5. Drilling pin end 6. Milling upper surface pin end i n the other side

Op. 30	
	1. Milling upper surface crank end 2. Drill crank end and chamfer Table rotation 3. Milling flat surface for screws 4. Drill screws 5. Drill screws and chamfer 6. Thread Table rotation 7. Rough pin end drilling 8. Finishing pin end drilling
Op. 10	
	1. Engraving (code)
Op. 40	
	1. Oil hole drilling

Op. 50	 1. Chamfer pin end both sides 2. Chamfer oil holes in pin end 3. Chamfer oil hole in crank end
Op. 60	 1. Laser: makes a notch in inner surface of crank end 2. Split fracture: separate cap and rod 3. Screws: apply a small torque, loose them, final torque 4. Press bushing in pin end
Op. 65	1. Weight connecting rod 2. Cut accordingly to weight to balance connecting rod’s weight
Op. 70	 1. Fixture 1: Load/unload parts 2. Fixture 2: Rough machining crank end and lock slots 3. Fixture 3: Tolerances in crank end and in width 4. Fixture 4: Pin end (rough machining and finishing)

2.2.2. Standard Manufacturing Process Plan of Connecting Rod in the World:

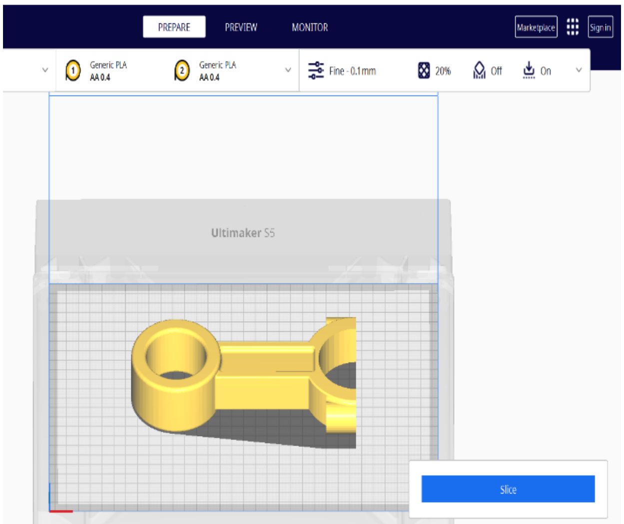
OP	Volvo Car Engine (Floby, Sweden)	Scania (Sweden, Södertälje)	OP
10	Milling flat bolt surfaces Milling of engraving surface Rough boring pin & crank end with chamfers Finishing pin end	Rough mill faces Rough mill lateral faces Rough boring crank end Rough boring pin end	20
20	Drill short hole Drill long hole with smaller diameter Thread Broaching	Rough mill face Fine boring crank end Fine boring pin end Mill bolts seat faces Drill holes Thread holes	30
30	Fracture splitting Assemble bolts & torque Loose screws, blow and retighten	Engraving	10
40	Press bushing Drill oil hole	Drill oil hole	40
50	Grinding crank & pin end	Wash	45
60	Trapezoid shape milling	Chamfer pin end Chamfer oil holes	50
70	Weight connecting rod and cut accordingly	Wash Dry Cool down	55
80	Pre-finishing crank end Pre-finishing pin end	Laser notch Fracture splitting Assemble bolts & torque Press bushing	60
90	Honing crank end Honing pin end	Weight connecting rod and cut accordingly	65
100	Washing Drying	Rough/fine mill crank end Rough/fine mill pin end Mill lock slots Engraving	70
110	Quality control Engraving Packaging	Washing Drying Cooling down	80
		Quality control & packaging	90

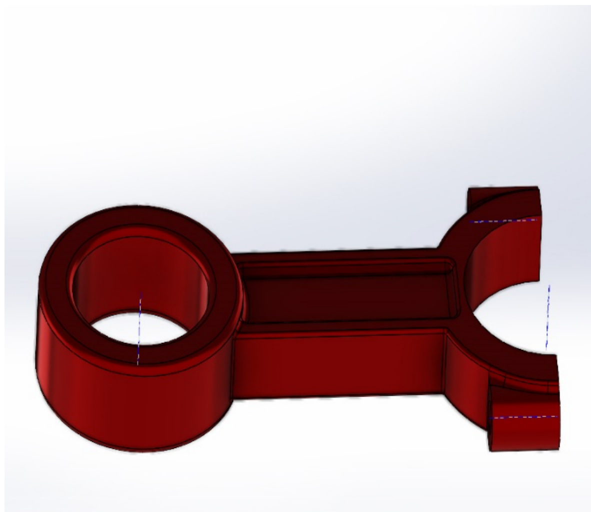
CHAPTER 3.
DIFFERENT FORMATS ANALYSIS

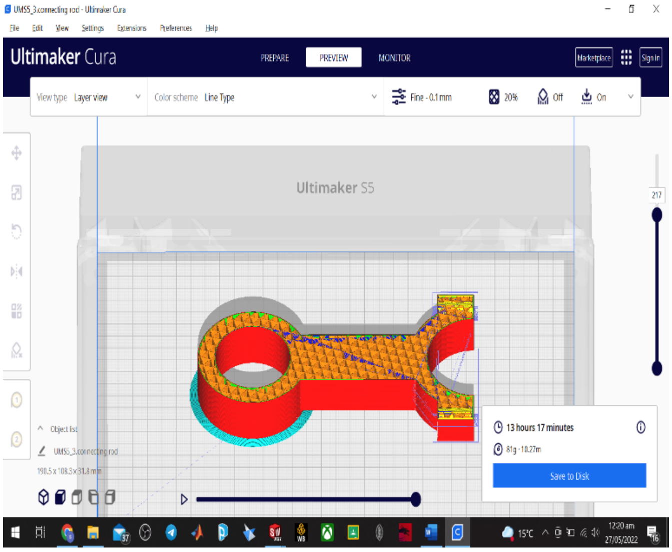
For analysis of different file formats, I used **ULTIMAKER CURA** software where we added our STL format connecting rod. The rod was painted red to check whether it retains the color information or not but in the 3d printer software, we witness that there was no information regarding the color which is one of the main drawback of using STL formats. A good substitute would be STEP format that retain greater details as compared to all but it cannot be used for 3d printing.

3.1. STL FILE:

- Transfer no data regarding color.
- Its useful for 3D printing but not so much useful
- After opening it in Ultimaker Cura, we get a printing time of 13hr and 17 minutes.
- It does not record any data regarding textures or appearance that why color is not read in Cura.
- Although it has been used widely as a standard format for 3d printing but because it miss some of the key details, that’s why it can be hard for such type of formats to survive in future.







3.2. IGES FORMAT:

- It's great for solid surfaces.
- In other formats around curvatures, details are lost but IGES files maintain details especially in curvatures.
- But because it's a very old format that's why there might be some errors or lost of data.

3.3. STEP FORMAT:

- Biggest advantage is that it remembers multiple colors, but it cannot be 3D printed because of which I did not tested it in Ultimaker CURA.
- In addition to color, it also remembers complex product-based data such as tolerance, material properties etc.