Manufacturing Process Capability

Reverse Engineering Coursework

This is the report about a part of the vacuum

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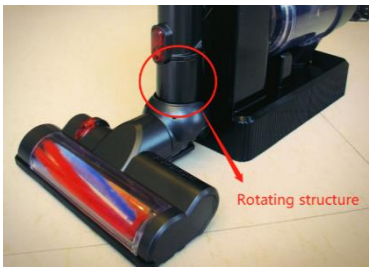
1. Introduction

The product is a handheld wireless vacuum cleaner. To achieve this function, it mainly contains five parts which are vacuum head, vacuum tube, dust collection box, handle, and charging box. (Figure1). When users use the vacuum, under the force of the vacuum, the dust passes through the electric brush installed at the vacuum head and enters the vacuum tube. Then they are collected in the dust collection box. The integrated design, combining the handle and the dust collection together, limits the size of the box but also greatly saves space. In order to suit different environment and clean corners of rooms, the design of rotating structure (Figure2,3) which provides 180° rotation for the head is important. The following report will discuss on aspects related with materials, manufacturing route, critical features and quality control of the wireless vacuum cleaner.



2. Material and properties

It is important to choose the proper material to meet the design requirements. The material of the rotation part is ABS. ABS is a normal industrial plastic which is widely used in electrical instruments, textile and construction industries. Its good impact and wear resistance and relatively strong strength enable the vacuum to rotate frequently. In addition, as its good properties, easy processing, product size stability and good surface quality, this part can be mass produced and connect the vacuum head and tube smoothly.

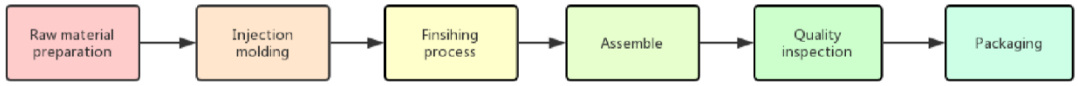
Properties	Details
Impact resistance / Toughness	For ABS, the most outstanding mechanical properties are impact resistance and toughness. Two major categories could be ABS for extrusion and ABS for injection molding, then high and medium impact resistance. The characters of ABS can be adjusted through increasing the proportions of polybutadiene in relation to styrene and acrylonitrile. High impact resistance and toughness provide stable structures and functions for the machine.
Density & Price	The average density of ABS is 1.060 to 1.080 g.cm-3. Compared to the other industrial plastics, such as POM with the density of 1.42 g.cm-3,

	ABS seems more economic in production and transportation. Moreover, considering ergonomics, relatively light weight makes people more comfortable. The price of ABS is 13,000 per ton, which is lower than other plastics with same properties.
Manufacturing	ABS is easily machined. Common machining techniques include turning, drilling, milling, sawing, die-cutting and shearing which lets various shapes can be achieved. For the rotating parts, the complex shape is made by injection molding.
Electrical insulation	ABS shows outstanding electrical insulation. As a handheld appliance, the good electric insulation of the material can prevent the user from electric shock and improve the safety.

Although POM and ABS both provide high strength of the product. Compared with POM, ABS is more cheap and its lower viscosity is more suitable for injection modeling.

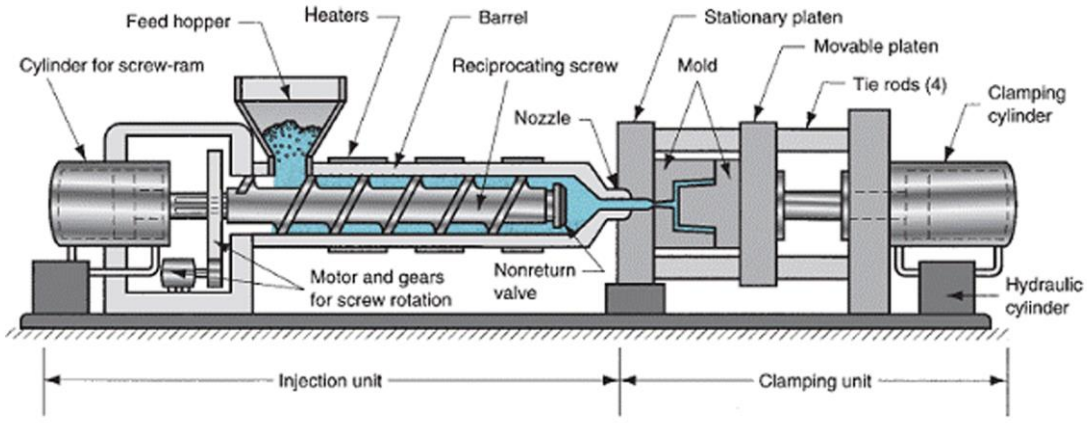
3. Manufacturing process and critical features

Based on theory of manufacturing capability, the most suitable manufacturing route will be injection molding for this part with complex structures and high accuracy requirement for some areas. The main process of injection molding shows below.



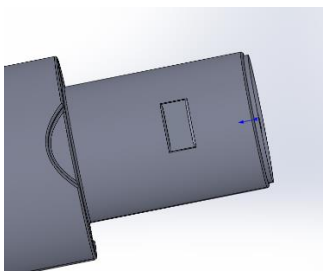
(The process of injection molding)

Injection molding is a manufacturing process for producing parts by injecting molten material into a mold. (WIKIPEDIA, 2019) ABS, a kind of thermoplastic materials, is fed into a heated barrel, mixed (Using a helical shaped screw), and injected (Forced) into a mold cavity. Then it cools and hardens to fit the constructions of the mold. The machine show in the figure below.



Critical surface is defined as the features play important roles to ensure the function of the part. For the rotation part, it mainly contains three critical features, the columnar structure connected with the vacuum tube, the protruding shaft structure ensuring two parts can rotate in various angles and structures which protect the internal wires.

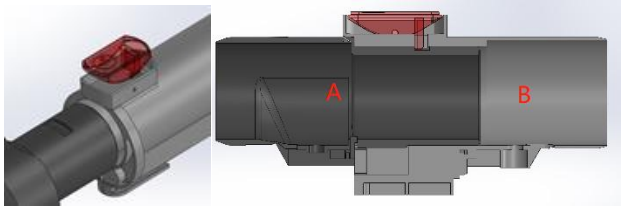
- **The columnar structure**



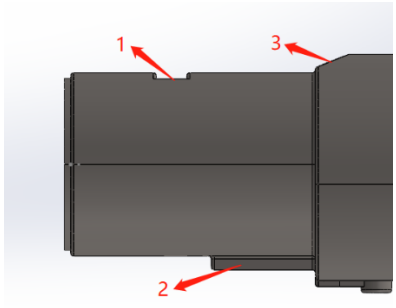
Features explanation

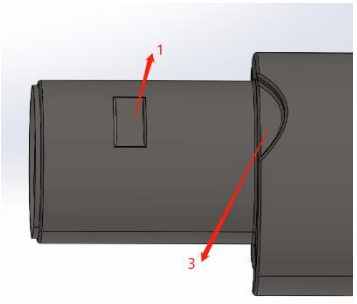
Function: This part enables the rotating structure and the vacuum head can connect with each other.

Connect method: The method that two parts connect with each other shows below.



Detail explanations:





1) Groove

The movement of two parts is controlled by the switch. When two parts fit with each other, the switch will lock the groove (in the diagram) to ensure a stable structure and a expedite tube for transporting the dust.

2) Slide

The slide will fit with the slideway which is designed on the part B, which can prevent dislocation.

3) The edge fitted with the switch

The design can help the user distinguish the two parts and install them easier.

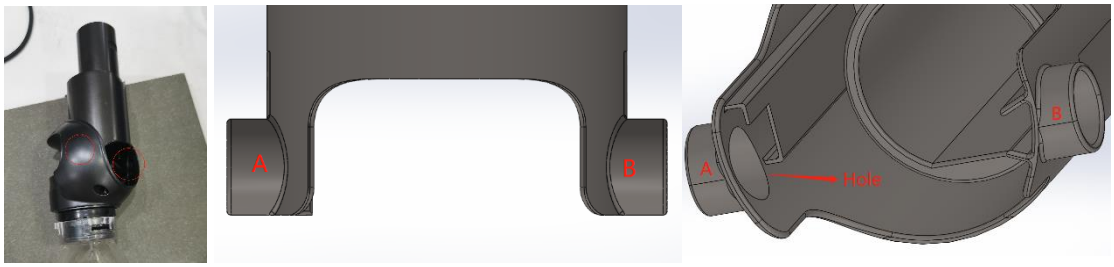
Surface quality:

In order to ensure the high work efficiency of the vacuum, it should have high air-tightness and should not leak the gas and the dust. So, it is necessary for contact areas have high accuracies and nice surface finish. Based on the chart (GB/T 14234-93), the toughness of the surface is around 0.025-0.16 μm.

Geometrical accuracy

According to the standard GB/T 14486-2008, ABS with shrinkage from 0% to 1% is high to the accuracy level MT2. Based on the chart (in the appendix), the tolerance of this part is 0.22mm. As it is based on the diameter of the tube, therefore, it follows H8f7 shaft basis tolerance, maximum is -0.013mm, minimum is-0.028mm.

- **protruding shaft structure**



Function: This part enables the head of the vacuum isn't limited by the tube and can rotate in various angles.

Connect method: The protruding part, A and B, inserts in the hole of part C.

Detail explanations:

Part A and Part B are symmetry along the center line of the whole part. However, only the part A has the hole, as wires need to pass through.

Surface quality:

In order to ensure the movement of two parts, it should have the smooth surface. So, it is necessary for contact areas have high accuracies and nice surface finish. Based on the chart (GB/T 14234-93), the toughness of the surface is around 0.025-0.16 μm.

Geometrical accuracy:

There are three main kinds of fit ways, clearance fit, interference fit and transition fit. For this part, clearance fit is suitable.

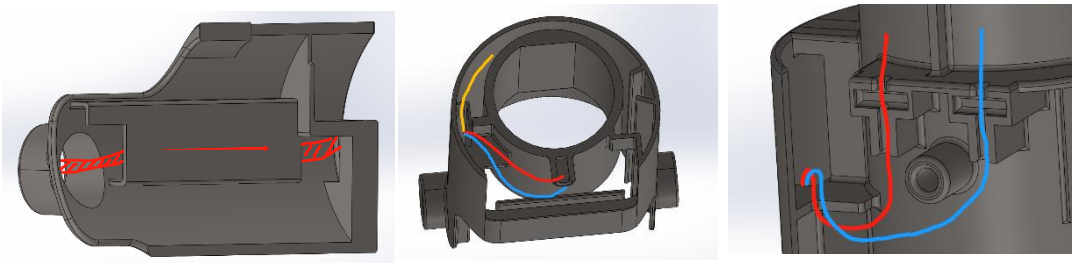
According to the standard GB/T 14486-2008, ABS with shrinkage from 0% to 1% is high to the accuracy level MT2. Based on the chart (in the appendix), the tolerance of this part is 0.22mm. As it is based on the diameter of the tube, therefore, it follows H8f7 shaft basis tolerance, maximum is -0.013mm, minimum is-0.028mm.

Other properties:

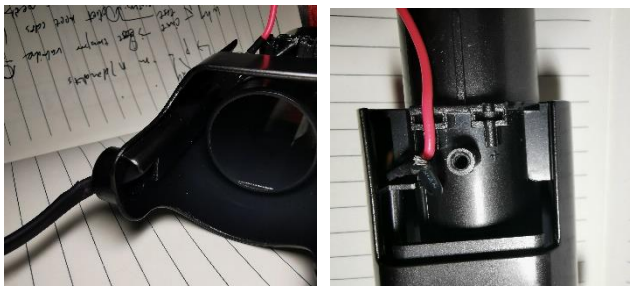
As part A and B always rub with C, enough fatigue resistance and hardness are considered.

- **Wire protection**

Wires will pass through this part, so their positions need to be limited. Three structures are designed for this function.



Function: Three wires pass through the hole and separate with each other. The yellow wire connected with the motor goes to the back of the part. The red(positive pole) and blue(negative pole) wires go to the front of the part and pass through the grooves shown in the diagram 3.



Surface quality:

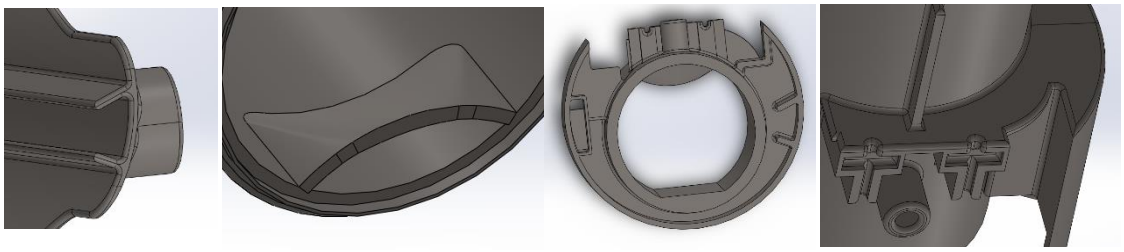
There is no special requirement for surface finishing.

Geometrical accuracy:

As the rubber is relatively soft material, grooves do not need to be high accuracy.

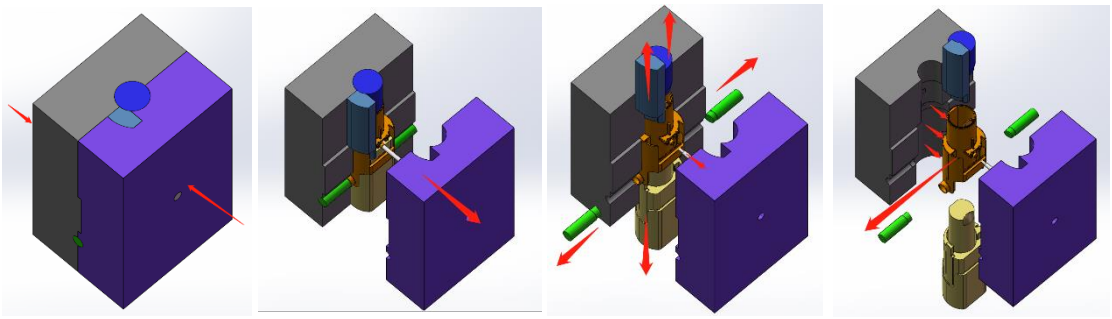
- **Other structures**

error proofing structures & strength structures



4. Production

4.1 Injection molding



Step1: Close the diet and inject the melt

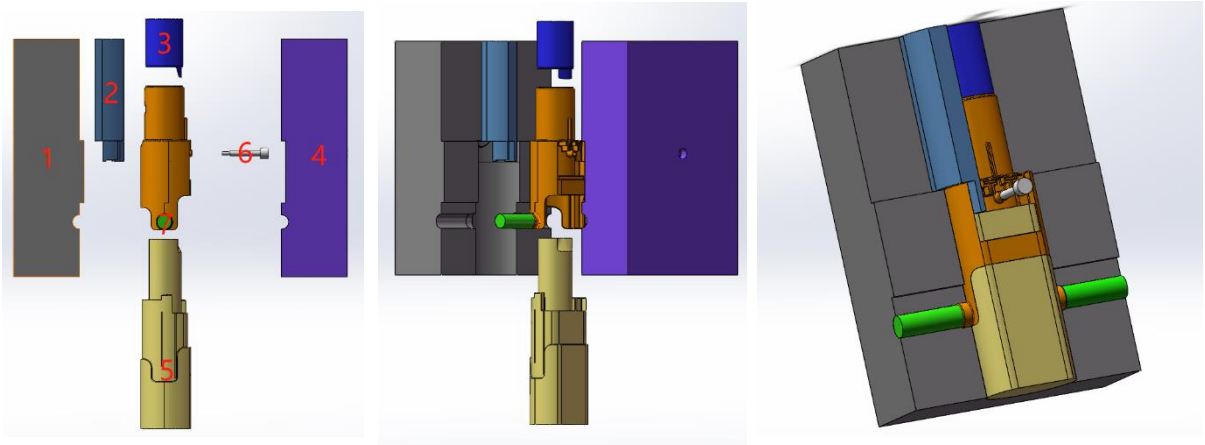
Step2: Open the moveable model

Step3: Move models which are perpendicular to the edge of two main molds

Step4: Ejector pins push part out

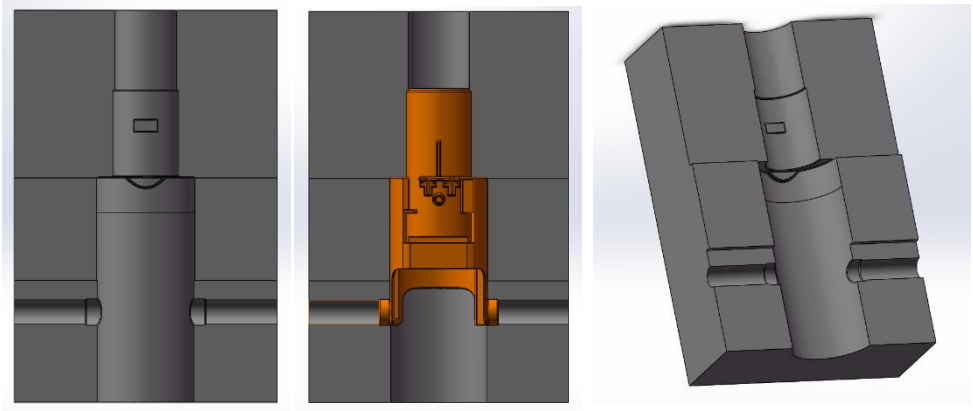
After the part has been finished in injection modeling, it still needs post treatment such as polish. Then it will be assembled with the head of vacuum in the factory and tested for thousands of times to ensure it can be used for long time. After all the steps, it will be produced in mass and sold to the market.

4.2 Mold Design

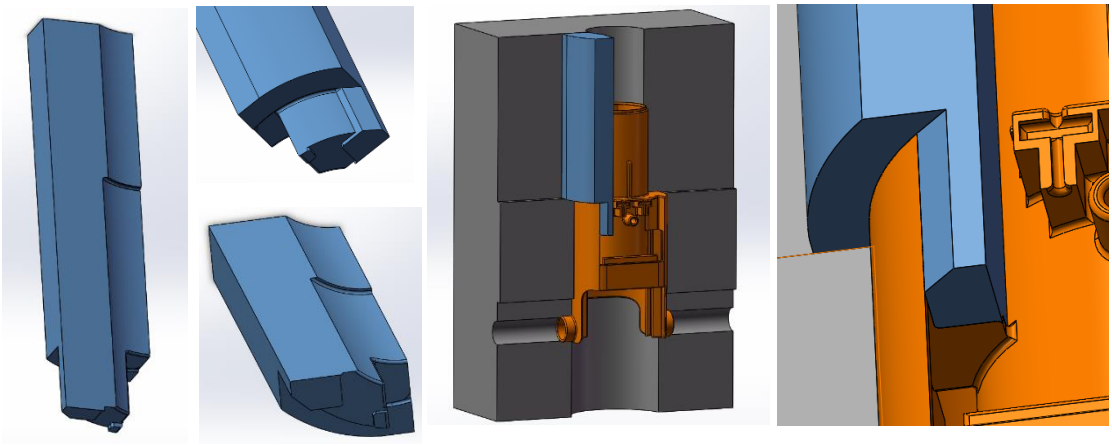


There are 7 main parts of the model.

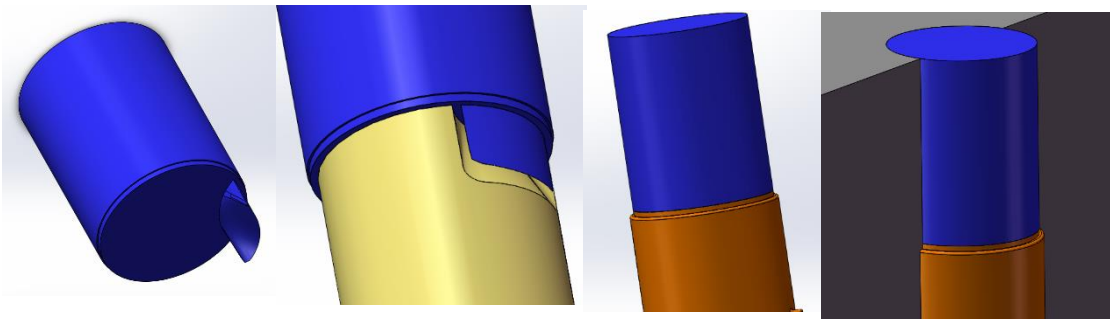
Part1



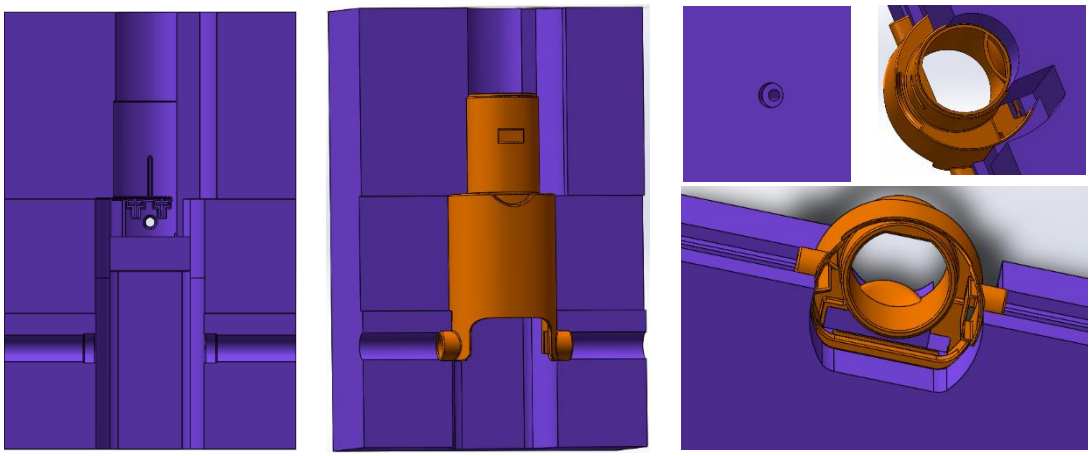
Part2



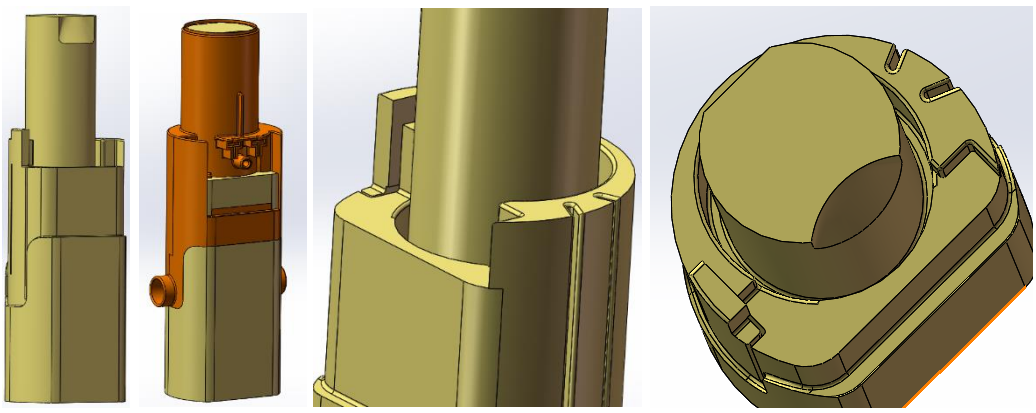
Part3



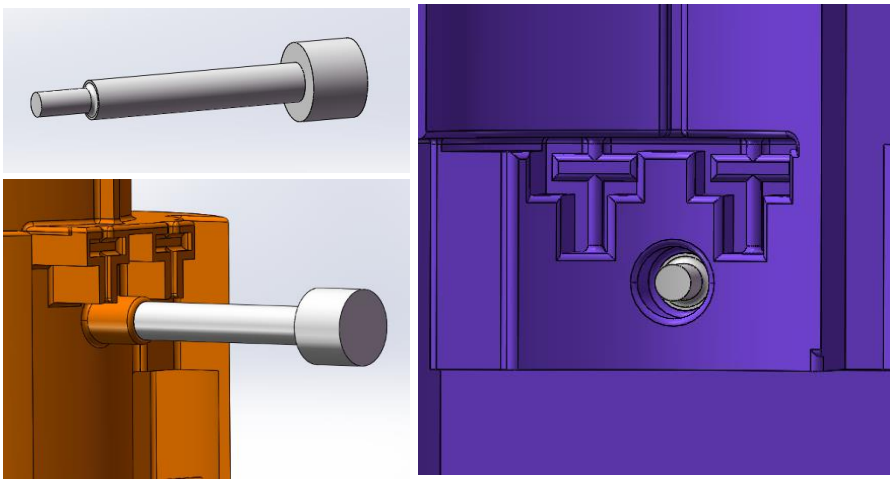
Part4



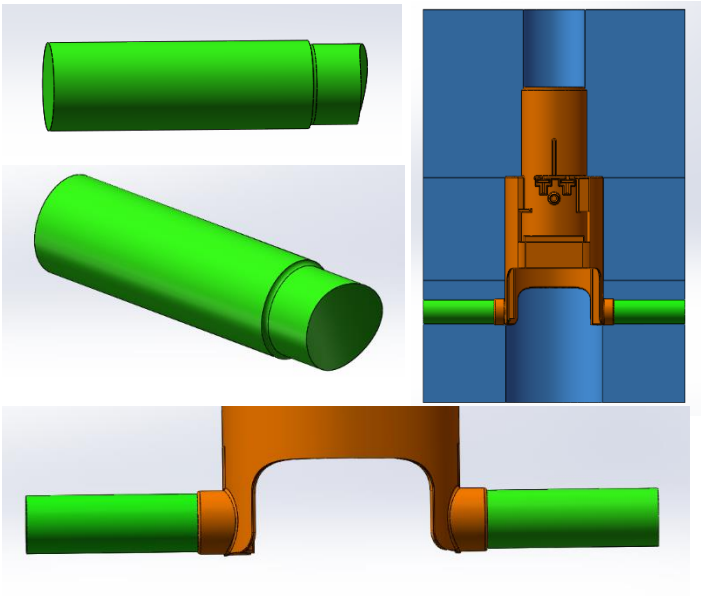
Part5



Part6



Part7



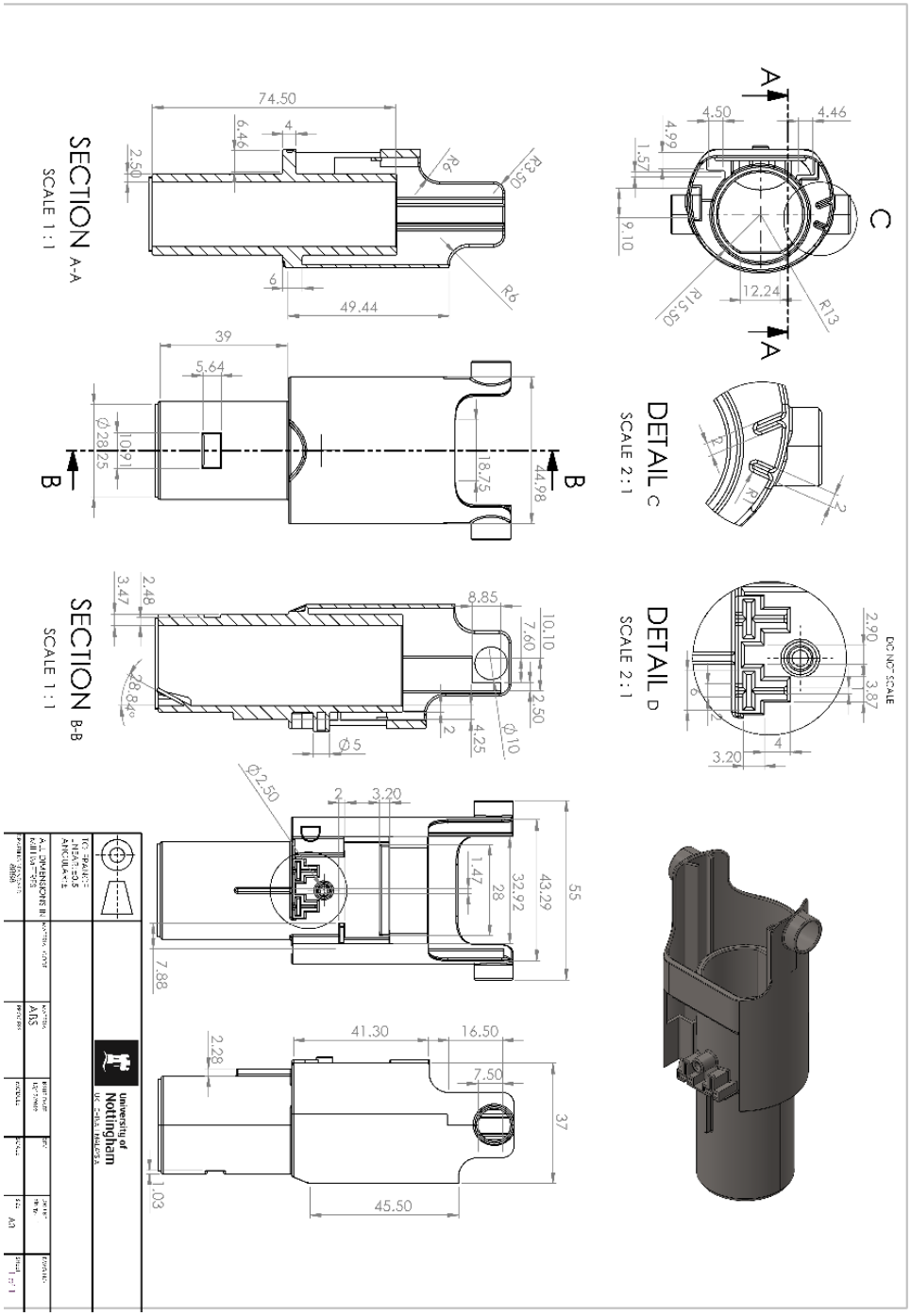
4.3 Model Manufacture

D531 is one of the most popular handle wireless vacuum, so the estimation of the production volume is over 100000 pieces annually, the material for the mold is supposed to be hardened steels with hardness from 48-65 HRC. Firstly, classic machining, milling or drilling, is utilized to process bulk materials to primary shapes. Then, the EDM, electro discharge machining, is added to produce details of the shape, however, this technique will cause a white layer which influences the strength of the surface of the cavity. So, grinding /polishing operations are needed to removed this layer. Finally, in order to ensure the surface quality of the part, human labors are required to polish molds, which makes the surface reaches to the high level of accuracy. In addition, the surface roughness height of injection mold should be smaller than 0.1 μm after polishing.

4.4 Post treatment

As the picture 1 shows, after injection modeling, labors need to cut the gate manually, which may leave a mark on the surface of the part. The protrusions of words which distinguish the positive and negative of wires are made by laser cutting.


5. CAD drawing

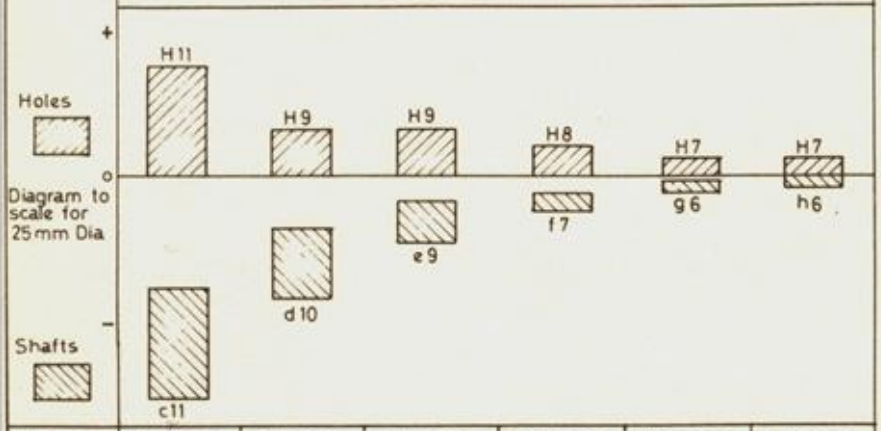


The appendix

Extracted from BS 4500:1969

BRITISH STANDARD DATA SHEET No. 4500 A.

SELECTED ISO FIT — HOLE BASIS (SHEET No.1.)



Nom sizes		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance	
Over	To	H11	c11	H9	d10	H9	e9	H8	f7	H7	g6	H7	h6
mm	mm	0·001	0·001	0·001	0·001	0·001	0·001	0·001	0·001	0·001	0·001	0·001	0·001
–	3	+ 60 0	− 60 −120	+ 25 0	− 20 − 60	+ 25 0	− 14 − 39	+ 14 0	− 6 − 16	+ 10 0	− 2 − 8	+ 10 0	− 6 0
3	6	+ 75 0	− 70 −145	+ 30 0	− 30 − 78	+ 30 0	− 20 − 50	+ 18 0	− 10 − 22	+ 12 0	− 4 − 12	+ 12 0	− 8 0
6	10	+ 90 0	− 80 −170	+ 36 0	− 40 − 98	+ 36 0	− 25 − 61	+ 22 0	− 13 − 28	+ 15 0	− 5 − 14	+ 15 0	− 9 0
10	18	+ 110 0	− 95 −205	+ 43 0	− 50 −120	+ 43 0	− 32 − 75	+ 27 0	− 16 − 34	+ 18 0	− 6 − 17	+ 18 0	− 11 0
18	30	+ 130 0	− 110 −240	+ 52 0	− 65 −149	+ 52 0	− 40 − 92	+ 33 0	− 20 − 41	+ 21 0	− 7 − 20	+ 21 0	− 13 0
30	40	+ 160 0	− 120 −280	+ 62 0	− 80 − 180	+ 62 0	− 50 − 112	+ 39 0	− 25 − 50	+ 25 0	− 9 − 25	+ 25 0	− 16 0
40	50	+ 160 0	− 130 −290										
50	65	+ 190 0	− 140 −330	+ 74 0	− 100 − 220	+ 74 0	− 60 − 134	+ 46 0	− 30 − 60	+ 30 0	− 10 − 29	+ 30 0	− 19 0
65	80	+ 190 0	− 150 −340										
80	100	+ 220 0	− 170 −390	+ 87 0	− 120 − 260	+ 87 0	− 72 − 159	+ 54 0	− 36 − 71	+ 35 0	− 12 − 34	+ 35 0	− 22 0
100	120	+ 220 0	− 180 −400										
120	140	+ 250 0	− 200 − 450	+ 100 0	− 145 − 305	+ 100 0	− 84 − 185	+ 63 0	− 43 − 83	+ 40 0	− 14 − 39	+ 40 0	− 25 0
140	160	+ 250 0	− 210 − 460										
160	180	+ 250 0	− 230 − 480										
180	200	+ 290 0	− 240 − 530	+ 115 0	− 170 − 355	+ 115 0	− 100 − 215	+ 72 0	− 50 − 96	+ 46 0	− 15 − 44	+ 46 0	− 29 0
200	225	+ 290 0	− 260 − 550										
225	250	+ 290 0	− 280 − 570										
250	280	+ 320 0	− 300 − 620	+ 130 0	− 190 − 400	+ 130 0	− 110 − 240	+ 81 0	− 56 − 108	+ 52 0	− 17 − 49	+ 52 0	− 32 0
280	315	+ 320 0	− 330 − 650										
315	355	+ 360 0	− 360 − 720	+ 140 0	− 210 − 440	+ 140 0	− 125 − 265	+ 89 0	− 62 − 119	+ 57 0	− 18 − 54	+ 57 0	− 36 0
355	400	+ 360 0	− 400 − 760										
400	450	+ 400 0	− 440 − 840	+ 155 0	− 230 − 480	+ 155 0	− 135 − 290	+ 97 0	− 68 − 131	+ 63 0	− 20 − 60	+ 63 0	− 40 0
450	500	+ 400 0	− 480 − 880										

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