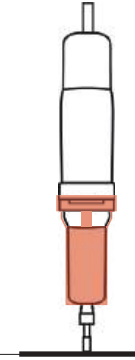


A Project Report On **P2**

Topic: **Die Grinder Attachment for Marble Carvers**



Guide: Prof. Avinash Shende

By: Aamod Narkar | 216130013 | Mdes I.D.

IDC School Of Design
Indian Institute of Technology Bombay



Acknowledgement

I would like to sincerely thank my guide, Prof. Avinash Shende for his invaluable guidance at every stage of the project. Special thanks to my friend Aditya P and Lakshmi C for helping me to make the prototype and documenting my process through photography. I am also grateful to all the faculty, staff and students of Industrial Design Centre (IDC) for their kind help and useful opinions and suggestions. I would like to thank my family for their unconditional support.

Table Of Contents

Approval Form	
Declaration Form	2
Acknowledgement	3
Abstract	4
Design Methodology	11
1. Introduction	12
2. Context Study	13
3. Marble Study	14
4. Team Structure- Task Wise	15
5. Activity Study	16
6. User Persona	17
7. Questionnaire For Users	18
8. Inferences	21
9. Observations	22
9.1. Detailed Observations	23
10. Product Possibilities	24
11. Indian Context	25
11.1 Stone Art Work	27
11.2 Cutting The Stone	27
11.3. India-Rajasthan	28
11.4. Clusters - Kishangarh	29
12. Silicosis	30
13. Understanding Scenario in Tier 1 Cities	32
14. Machine Specifications	33
15. Die Grinder Study	34
15.1. Grip Hand Positioning	35
15.2. Machine Working Angles	36
15.3. Proximity Mapping	37

Table Of Contents

15.4. Time Mapping to Understand Exposure	38
15.5. Dust Emission Study	39
15.6. Right HAnd-Left Hand Co-ordination	40
15.7. Customized Grip Thickness	41
16. Problem Identifications	42
17. Design Brief	43
17.1. Project Scope	43
17.2. Project Aim	43
18. Mood Board	44
19. Ergonomic Considerations	45
20. Ideations	46
20.1. Grip Clamping	47
20.2. Air Flow Channeling	48
20.3. Weight Supporter	49
20.4. Grips	50
20.5. Grip Cross Section	51
20.6. Grip Cross Section	52
20.7. Water Connectivity	53
20.8. Grips	54
20.9. Grips Inspiration- Cycle grip	55
20.10. Grip Structure Detail	56
20.11. Dust Protection	57
20.11.1. Dust Protection Testing	58
20.11.2. Dust Protection and Grip Relation	59
21. Final Concept 01	60
22. Final Concept 02	61
23. User Testing - I	62

Table Of Contents

23.1. Grip Selection	63
23.2 Clamping	64
23.3 Dust Blowing	65
23.4 Weight Supporter	65
23.5 Water Pipe Connectivity	66
24. Revised Ideations	67
25. Revised Concept 01	68
26. Revised Concept 02	69
27. User Testing - II	70
28. Evaluation	71
29. Final Concept	73
30. Dimensional Drawings	74
31. Material And Process	75
32. Rigs For Grip Material	76
33. Final Renders	77
34. Final Prototype	78
35. Conclusions	79
References	80

List Of Images

Fig 1.1: Mumbai Map	12	Fig 10.1: Variety of Marble Products	24
Fig 1.2: Milan Subway, Santacruz W	12	Fig 11.1: India Map Demarcating Stone Art	25
Fig 1.3: Metro Station, Malad W	12	Fig 11.2: Rajasthan	25
Fig 1.4: SV Road, Dahisar E	12	Fig 11.3: Tamil Nadu	25
Fig 2.1: Milan Subway, Santacruz W	13	Fig 11.4: Karnataka	25
Fig 2.2: Footpath Encroachment	13	Fig 11.5: Orissa	25
Fig 2.3: Workshop Exterior	13	Fig 11.1.1: Artisans Creating Intricate Design	27
Fig 3.1: Makrana Marble Mine, Rajasthan	14	Fig 11.2.1: Types of Tools Used For Carving	27
Fig 3.2: Types of Marble	14	Fig 11.3.1: Murti Mohalla Street Views	28
Fig 3.3: Workshop Interior View 01	14	Fig 11.3.2: Different Tools Used For Carving	28
Fig 3.4: Workshop Interior View 02	14	Fig 11.4.1: Cluster View	29
Fig 4.1: Marble Cutting Task	15	Fig 12.1: Dust Emission While Stone Cutting	30
Fig 4.2: Egde Cutting Task	15	Fig 12.2: Protest Regarding Worker Health Issues	30
Fig 4.3: Marble Sticking Task	15	Fig 12.3: Stone Cutting Factory Site	31
Fig 4.4: Marble Polishing Task	15	Fig 12.4: Dust Suction Machine	31
Fig 4.5: Pencil Drawing Task	15	Fig 12.5: Exhaust Fan Installation	31
Fig 4.6: Carving/Engraving Task	15	Fig 13.1: Space Crunch Inside Wokshop	32
Fig 5.1: Activity Study	16	Fig 13.2: Encroachment Outside Workshop	32
Fig 6.1: 9-Users From Mumbai	17	Fig 13.3: Customizable Desk	32
Fig 9.1: Die Grinder Tool Parts	22	Fig 13.4: Low Height Sitting Posture	32
Fig 9.2: Working Posture Preferences	22	Fig 14.1: Die Grinder Machine	33
Fig 9.3: Machine Gripping Ways	22	Fig 14.2: Bits Used For Carving	33
Fig 9.1.1: Grip Customizations	23	Fig 14.3: Die Grinder Specifications	33
Fig 9.1.2: Water Supply Connection	23	Fig 15.1: Fan For Motor Ventilation	34
Fig 9.1.3: Dust Clearing Provision	23	Fig 15.2: Die Grinder Dismantled	34

List Of Images

Fig 15.1.1: Non Detailed Work Grip	35	Fig 20.1.1: Lever To Clamp	47
Fig 15.1.2: Chamfering Work Grip	35	Fig 20.1.2: Two Additional Screws To Clamp	47
Fig 15.1.3: Detailed Work Grip	35	Fig 20.1.3: Existing Screws To Clamp	47
Fig 15.2.1: Machine Tilted 20-60Degrees	36	Fig 20.2.1: Artisan Tilting the Machine to Clear the Working Surface	48
Fig 15.2.2: Machine Held Straight 90 Degrees	36	Fig 20.2.2: Sketch Denoting Control Over Air Vent	48
Fig 15.3.1: User and Machine Proximity Study	37	Fig 20.2.3: Section Indicating Direction Of Flow	48
Fig 15.3.2: Machine-Face Distance Less than 5"	37	Fig 20.2.4: Extrusion to Channel The Air Outwards	48
Fig 15.3.3: Machine-Face Distance Approx 10"	37	Fig 20.2.5: Allowing Sense of Direction While Blowing	48
Fig 15.3.4: Machine-Face Distance Approx 15"	37	Fig 20.3.1: Working Hand Supported on Table/Body	49
Fig 15.4.1: Short Time Range Tasks	38	Fig 20.3.2: Wrist Support Band	49
Fig 15.4.2: Medium Time Range Tasks	38	Fig 20.3.3: Ideations for Wrist Support	49
Fig 15.4.2: Long Time Range Tasks	38	Fig 20.3.4: Wrist Support Strap Testing	49
Fig 15.5.1:Dust Emission When Machine Angled	39	Fig 20.4.1: Ideations for Grips	50
Fig 15.5.2:Dust Emission With No Water Supply	39	Fig 20.5.1: Plans Showing Grip Cross Sections	51
Fig 15.5.3:Dust Emission With Water Supply	39	Fig 20.5.2: Rib Structure Inside Grip	51
Fig 15.6.1: Gripping With Left Hand	40	Fig 20.5.3: Reference Image of Vibration Pads	51
Fig 15.6.2: Gripping With Right Hand	40	Fig 20.5.4: Channels Created by Ribs Allowing Air to Escape	51
Fig 15.7.1: Grip Customization With Tapes	41	Fig 20.6.1: Ideations for Ribbed Cross Section	52
Fig 15.7.2: Grip Customization With Tapes To Fix Pipe	41	Fig 20.7.1: Ideation to Explore Pipe Connectivity	53
Fig 15.7.3: Grip Customization With Cement Bag	41	Fig 20.7.2: Pipe Fixed Internally	53
Fig 16.1: List Of Problems to Address	42	Fig 20.7.3: Issue of Pipe Falling On Hand	53
Fig 18.1: Mood Board Inspiring Design Language	44	Fig 20.7.4: Provision For Clamping Pipe at Top	53
Fig 19.1: Finger Distance Data	45	Fig 20.8.1: Laset Cut Grip Trial Options	54
Fig 19.2: Palm Measurement Data	45	Fig 20.9.1: Mountain Cycle Grip Study	55
Fig 20.1: Initial Ideations	46	Fig 20.9.2: Ergon Mountain Cycle Grips	55

List Of Images

Fig 20.10.1: Grip Pattern Study	56	Fig 24.1: Refined Ideations	67
Fig 20.10.2: Example to Study Grip Pattern	56	Fig 25.1: 3d Visuals For Revised Concept 01	68
Fig 20.11.1: Fan Attacment Over Die Grinder	57	Fig 26.1: 3d Visuals For Revised Concept 02	69
Fig 20.11.2: Diverting Existing Vent Towards One Direction	57	Fig 27.1: User Testing Round II At IDC	70
Fig 20.11.3: Proximity Analysis	57	Fig 28.1: User Testing For Revised Concept 01	71
Fig 20.11.1.1: 3d Printed Prototype 01	58	Fig 28.2: User Testing For Revised Concept 02	71
Fig 20.11.1.2: 3d Printed Prototype 02	58	Fig 29.1: 3d Visual Of Final Selected Concept	73
Fig 20.11.1.3: Testing of Diversion of Vents	58	Fig 30.1: Measurement Drawing For Selected Concept	74
Fig 20.11.2.1: User Gripping Analysis	59	Fig 31.1: TPU Material Applications	75
Fig 20.11.2.2: 3d Model Explorations	59	Fig 32.1: Rigs to Experiment Grips	76
Fig 20.11.2.3: Circular Grip Mockup	59	Fig 33.1: Final Rendered Visualizations	77
Fig 20.11.2.4: Oval Grip Mockup	59		
Fig 21.1: 3d Visual of Concept 01	60		
Fig 22.1: 3d Visual of Concept 02	61		
Fig 23.1: User Testing At Location 01-Santacruz	62		
Fig 23.1.1: User Testing For Grips	63		
Fig 23.2.1: User Test For Clamping By 2 Side Screws	64		
Fig 23.2.2: User Test For Clamping By Quick Release Lever	64		
Fig 23.2.3: User Test For Clamping By Exisiting Screws	64		
Fig 23.3.1: User Testing For Dust Blowing	65		
Fig 23.3.2: User Testing For Vent Diversion	65		
Fig 23.4.1: User Testing For Wrist Support Strap	65		
Fig 23.5.1: Pipe Fixing By User	66		
Fig 23.5.2: User Testing For Water Pipe Connectivity	66		
Fig 23.5.3: Observation For Bit Replacement	66		

Design Methodology



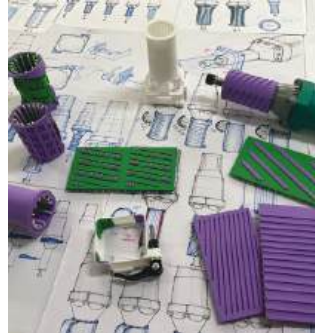
Context Study

During this process different places were explored to document small scale marble workshops. Working spaces and structures were documented, to figure out different types of tools used by the workers. Eventually it was found out that the die grinder machine had the most potential to intervene in terms of design.



Research+ Brief

Many users, using die grinder specifically were observed and documented while performing their task using this tool. This research helped to figure out the requirements and design proposal scope. The brief was formulated on the research collected during this phase and further developed during the process.



Ideations+Prototype-I

Ideations were sketched to satisfy the brief. The ideation was refined further to make them more practical. Rough mockups with paper were laser cut in order to study grips. Different small ideas were 3d printed in order to test them and further take them for user studies.



User Test - I

User tests were conducted to validate each and every design idea with the help of 4 artisans. The prototypes and mockups were taken to the working site and were tested on their own machines. Their insights were documented and were used for further improvisations.



Ideations+Prototype-II

Based on the insights from the user test, further ideations were developed based on them. Two designs were ideated and further 3d printed in order to review them and get them user tested again.



User Test - II

An artisan was called in IDC, IIT Bombay to user test the two designs. His reviews were documented and evaluated while working and eventually one final design was selected. The selected design was further detailed and then the final design was 3d printed.

1. Introduction

Mumbai Map:



Fig 1.1: Mumbai Map

The fascination for stone has transcended all times and ages. Whether it is ornate inlay with onyx black marble, finely latticed soapstone or white marble, the appeal of the stone has been immutable. Both Hindu and Muslim rulers of India patronized this art. The craft in Uttar Pradesh reached artistic heights of excellence during the Mughal period when Taj Mahal was created. Nothing epitomizes best the ethos of Varanasi and Agra than their stone carvings. From intricate architectural masterpieces, perfectly chiseled stoneware to classy tabletops with inlay work, every item is a piece of exclusive artwork.

Mumbai city consist of three major localities which house these small scale marble product workshops. These clusters of workshops, manufacture household products using different varieties of marble. The workers working in these workshops are mainly from Rajasthan and Bihar. These workshops create lot of sound due to constant functioning of various machines, hence they are mainly situated away from the residential areas.

LOCATION 01: Milan Subway, Santacruz West



Fig 1.2: Milan Subway, Santacruz W

LOCATION 02: Metro Station, Malad West



Fig 1.3: Metro Station, Malad W

LOCATION 03: SV Road, Dahisar East



Fig 1.4: SV Road, Dahisar E

2. Context Study

LOCATION 01: Milan Subway, Santacruz West



Fig 2.1: Milan Subway, Santacruz W

The above image shows the plan of location 01. The above locations consists of about 15 workshops



Fig 2.2: Footpath Encroachment

Due to lack of working space and storage, almost all the workshops have extended on the attached footpath.



Fig 2.3: Workshop Exterior

Each workshop is privately owned and measures around 3-5m in width and approx 10m in length. Each workshop consist a team of 3-5 workers, all the workers are male.

3. Marble Study

Marble Source:



Fig 3.1: Makrana Marble Mine, Rajasthan

Makrana marble is a metamorphic rock, found in a single deposit in India, which has a range of about 90–98% Calcium Carbonate. The marble is found only in Makrana, a small town situated 110 km west of Jaipur.

It is a high-quality White marble useful for building construction and decoration. These marbles are highly durable and widely used for flooring and countertops. About 120 thousand tonnes of Marble are produced annually from over 400 mines in this Region, and the state government reserves 55 million tonnes.

Hence, The key points of chemical properties are:-

1. Type of Marble: Calcitic
2. Chemical composition: It consists 98% to 99.9% Calcium Carbonate (CaCO_3) and 2% to 0.1% impurities.
3. Colour shades: Pure white, white with grey shades, and white with pink shades (depends upon the type and level of Impurities)
4. Water Resistance: The presence of 98% calcium carbonate makes it India's highest water-resistant rock
5. Shine: It retains its shine and white color for a very long period
6. Cutting and polishing: It doesn't require chemicals or any other form of treatment but is used in cutting and chiseling.

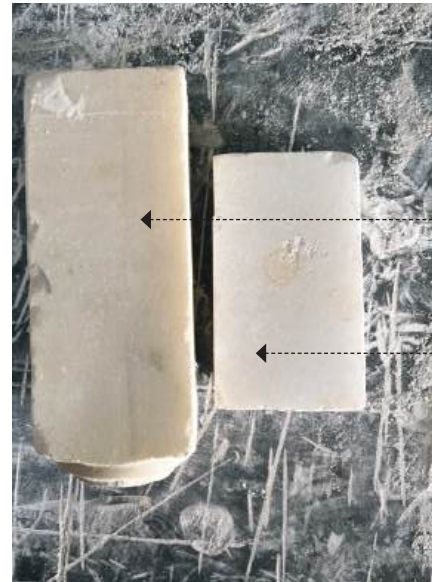


Fig 3.2: Types of Marble

Markrana
White Marble

Australian
White Marble

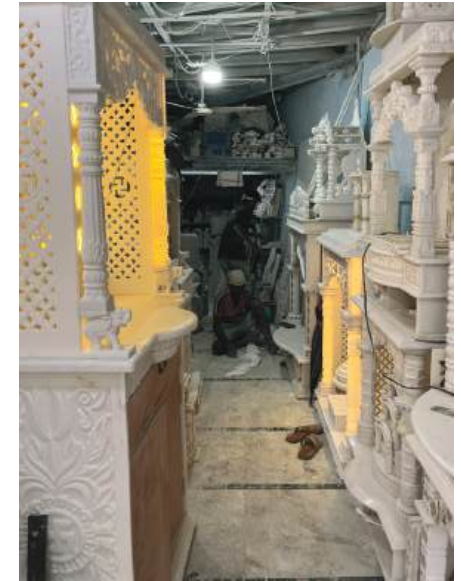


Fig 3.3: Workshop Interior View 01



Fig 3.4: Workshop Interior View 02

Thickness they work with :
15mm to 100mm

Most Common marbles used:

Indian: White Makrana

Non-Indian: Australian White

Other common marble: Green Baroda, Jaisalmer
Yellow, Nizarna, Onyx, Italian Marble

Nature of marble:

All the above mentioned marbles are soft.

Australian marble is softer

Makrana marble is sometimes harder

Cost:

Makrana(2000/sq.ft) is expensive than Australian
white(800/sq.ft)

4. Team Structure- Task Wise

Unskilled tasks

Some workers from the team were given tasks(mentioned below) requiring unskilled labour. The tasks were not dedicated to them, anyone amongst them, could switch between the tasks according to the requirement.

Cutting machine is used to cut the required slab sizes from the big marble size.



Fig 4.1: Marble Cutting Task

Grinder machine is used to cut or chamfer the sharp edges of the marble.



Fig 4.2: Edge Cutting Task

All the cut pieces are fixed together with the help of an adhesive.



Fig 4.3: Marble Sticking Task

Before the pieces are stuck, they are polished with the help of a polishing machine.



Fig 4.4: Marble Polishing Task

Skilled tasks

Some specific workers(also called as karigars) from the team were given tasks(mentioned below) requiring very skilled labour. The tasks are dedicated to them and only they work on these tasks.

Mostly all the drawing is done freehand looking at design. Stencils are used for repetitive designs. Transparent paper is used to copy the same design on another marble piece.



Fig 4.5: Pencil Drawing Task

The grinder (locally called bottle machine) is used to carve or engrave intricate details on the marble. Needs a lot of control and smooth wrist movement for the desired design output.

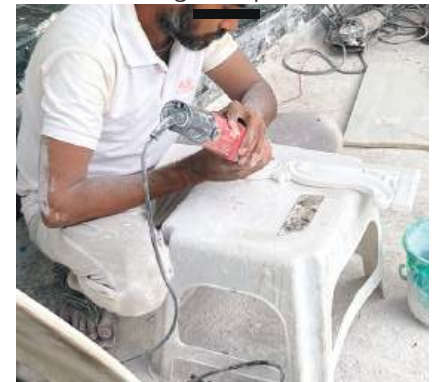


Fig 4.6: Carving/Engraving Task

5. Activity Study

Activity 1: Cutting with Cutter



Skills Required: Low- Majorly cutting is straight
Time required to be in the same position: 2-3mins
Position of work: Preferred to be on ground
Requires Water: Yes
Pain Points: Waist

Activity 2: Edge Treatment



Skills Required: Medium- Rounding of edges
Time required to be in the same position: Avg 2hrs
Position of work: Avg 1 foot above ground
Requires Water: No
Pain Point: Dust Exposure

Activity 3: Drawing



Skills Required: High
Time required to be in the same position: Avg 2-3hrs
Position of work: Avg 1 foot above ground
Requires Water: No

Activity 4: Carving



Skills Required: High
Time required to be in the same position: Avg 1-2 Days
Position of work: Avg 1 foot above ground
Requires Water: yes
Paint Points: Waist, Neck, Dust, Shoulders

Activity 5: Polishing



Skills Required: Low- Relaxed task
Time required to be in the same position: Avg 4-5 hrs
Position of work: Ground
Requires Water: yes

Activity 6: Sticking



Skills Required: Low
Time required to be in the same position: Avg 4-5hrs
Position of work: Depends
Requires Water: No

Activity 7: Final Touch



Skills Required: Low
Time required to be in the same position: Avg 5 hrs
Position of work: Avg 1 foot above ground
Requires Water: yes
Pain Point: Waist, Shoulders

Fig 5.1: Activity Study

6. User Persona

Name: Vidyapati
Origin: Bihar
Years Of Exp.: 6



Name: Fareen Khan
Origin: Rajasthan
Years Of Exp.: 10



Name: Imran Bhati
Origin: Rajasthan
Years Of Exp.: 20



Name: Kalyan
Origin: Rajasthan
Years Of Exp.: 12



Name: M. Wasim
Origin: Rajasthan
Years Of Exp.: 8



Name: Imran Bhati
Origin: Rajasthan
Years Of Exp.: 20



Name: Ram Pawan
Origin: Bihar
Years Of Exp.: 10



Name: Zaheer Ahmed
Origin: Rajasthan
Years Of Exp.: 15



Name: Imran Bhati
Origin: Rajasthan
Years Of Exp.: 20



Fig 6.1: 9-Users From Mumbai

7. Questionnaire For Users

Interview with Imran B.

A) General

1. Where do you belong from? Is this your family occupation?

Ans: I am from Makrana, Rajasthan. Yes, it's a family occupation.

2. How many years are you been into this?

Ans: Approx 20 years

3. Who has taught you to use the tools?

Ans: Since childhood I have seen my father and grandfather doing the marble work. They were very skilled. At my young age I started helping them, that helped me learn and acquire the carving skills.

B) Marbles

1. What are the types/ names of marble used for carving?

Ans: Most common marble used by us is white makrana which in Indian and australian white which is imported from outside India. Other common Indian marbles used are nizarna, pink makrana, green baroda and yellow jaisalmer. And other imported marbles used are onyx and italian marble.

2. What are the variations of the thickness of marbles from minimum to maximum?

Ans: The thickness of the marbles used varies as per client requirements. The minimum thickness I have worked with is 15mm to maximum thickness I have worked with is 125mm.

3. What are the kinds of marbles, like soft to hard and do the tools vary for them?

Ans: All the above mentioned marbles are soft in nature. Makrana which is most commonly used is slightly harder than australian white. Soft marbles are comparatively easier to cut and carve. Yes, tools do vary for harder marble, but we do not work with hard marbles.

4. What are the different stages/processes of making a marble product for example mandir?

Ans: i) First, as per the sizes and the thickness required the desired marble size is cut from the slabs.
ii) Then if the edges of the cut pieces require chamfer or curvature, or any accurate cutting is required, that is done with the help of grinders.
iii) Then artisan draws the design, on the parts that need to be carved.
iv) After the drawing, the artisans with the help of the die grinder, starts carving out the desired design.
v) Pieces are stuck together.
vi) Finally, manual sanding using sand paper is done to give final touches.

5. Any accessories for holding the marble plank? How about the marble plank kept in angle while working?

Ans: Big pieces of marble are heavy so they generally don't move. But in case of small pieces, we use clamps.

7. Questionnaire For Users

6. Cost of the marble?

Ans: Makrana: Avg 2000/sq.ft and Australian: Avg 800/sq.ft

C) Tools

1. How often do they change tools?

Ans: Unskilled labours do regularly as per the task, skilled labours mostly stick to the same tool.

2. Why do they keep adding water at regular intervals during carving/cutting? Why they use sponge for it?

Ans: Water helps in smooth cutting. It helps to achieve sharp edges, restricts marble edge from chipping. And it also allows to settle the marble dust.

3. Does one artisan work on the complete product? Or each task is divided between artisans?

Ans: No, each artisan works on different dedicated tasks. For example if the artisan does carving, he only does carving. So as per the skill levels of the artisans, the overall tasks are divided.

4. Which is their favorite tool?

Ans: All tools are closer to me.

5. Is any tool risky to use?

Ans: Not really, none of the tools are risky if you pay attention while working.

6. What is the reason of covering the top part of the grinder with a cloth/goni?

Ans: As the grinder generally runs for a long time, there are high chances that the top part heats up. Also, some artisans find the cloth useful to create some cushioning as the swivel creates a lot of vibrations.

7. How many times have they got hurt?

Ans: Never with the grinder, but need to be careful using other grinder machines.

8. Specific pain points on their hands/ back? Which tool contributes to that the most?

Ans: Hands and back are generally the ones which get the most strain. But we rest enough after work, and now our body is used to it.

9. What is the life of the tools used? Do you give them for repairing?

Ans: No guarantee, some tools work for 6 months some might face a problem in a month. Yes, if there is any problem, we give it for repairing. As we have extra tools, it does not affect our work.

10. Are current number of tools sufficient for them? Do they require anything more specific?

Ans: Each tool has its own job, and it helps us well. I don't think we require anything more than these tools.

11. Most common used tool?

Ans: For myself, the grinder is the most common tool, as I majorly work on engraving and detailing works.

7. Questionnaire For Users

12. What are the exact number of tools used?

Ans: We use around 5-6 power tools

13. What are the problems in each tool?

Ans: Heating up of few tools and the frequent need of repairing.

14. What is the sticking material used to attach two parts? How do you apply it?

Ans: We use marble glue combining it with an additional agent. Application is done with the help of patra (plate).

D) Postures

1. What is the preferred working position?

Ans: Every artisan has its own preferred working position. It mostly depends on the task they perform.

2. What is that exact ideal height?

Ans: There is no specific height, we generally prefer to sit at low heights because marble slabs are sometimes heavy so its easy to lift them on lower heights.

3. Is it ideal to hold the marble in one hand whole working?

Ans: If it's a small piece its possible, but not in case of a heavy piece.

E) Wages and Health

1. Health problem they face? (Noise/dust)

Ans: Makrana stone is rich in calcium, hence I don't think it affects our health. Noise is something which we can't help, but now we are used to it.

2. Wages vs time taken for the art work (average sized mandir for example)?

Ans: Monthly salary of an artisan is around 25k. Time taken for small mandir is around 3-4 days, medium sized mandir around 7 days and big sized mandir around 15 days.

3. What are their working hours?

Ans: 10-12 hours

4. What all other products they have made?

Ans: Dishes, fountains, soap trays, pen holders, show pieces, etc.

8. Inferences

UNSKILLED TASK

Unskilled tasks majorly consists of cutting, grinding, polishing.

Tools used for these tasks are Cutter, Grinder, Polish Machine.

Unskilled works requires comparatively lesser hours of continuous work on single design.

Unskilled task can be done by any other artisan. It can be adjusted as per the work requirements.

Unskilled tasks does not require very continuous attention of the artisan working on it.

These task do not require continuous change of angles of holding machine.

These are not very wristy jobs.

As it does not require continuous attention, it does allow the artisan to change his body posture.

It in some cases exposes the artisans with marble dust and continuous noise.

Only polish machine is required to be held in both the hands.

SKILLED TASK

Skilled tasks majorly consists of drawing and carving.

Tool used for the carving is Swivel/ Die grinder.

Skilled work like carving requires longer hours of continuous work on single design.

Carving can be only done by the skilled labour(Karigar), any other unskilled labour won't be able to do it.

Carving requires very continuous attention of the artisan working on it.

Carving requires continuous change of angles of holding machine.

Carving is a very wristy job.

As carving requires continuous attention, it does not allow the artisan to change his body posture for long stretches of time.

Carving with swivel exposes the artisans with lot of marble dust and continuous noise.

Swivel machine while carving requires to be held by both the hands.

9. Observations

Tool



Fig 9.1: Die Grinder Tool Parts

Important part of the tools were observed:

- Machine is gripped in various manner as per the task.
- Various bits for different carvings.
- Machine is provided with a rubber grip.

Posture



Fig 9.2: Working Posture Preferences

Various postures while working were observed:

- Generally low height was preferred.
- Temporary table height varied from 6 inches too 1.5 feet.

Gripping Angle



Fig 9.3: Machine Gripping Ways

Various postures while working were observed:

- Machine is needed to be gripped at various angles to achieve different levels of chamfers and smooth surfaces.

9.1 Detailed Observations

Grip



Fig 9.1.1: Grip Customizations

Grip Modifications:

- Original grip was replaced after it wearing out.
- Original grip not helpful in providing damping and heat protection
- Cement bag, tape used as grips

Watering



Fig 9.1.2: Water Supply Connection

Water Supply Provisions:

- Water supply is preferred while cutting a hard stone.
- Continuous water flow over the cutting die helps reduce dust emission.

Blowing



Fig 9.1.3: Dust Clearing Provision

Blowing Of Dust:

- The vents on the center part of the machine is used to blow away the marble dust collected over the carving area.

10. Product Possibilities

Statues

Dishes

Utensils

Fountains

Animal Momentos

Diyas

Penstands

Flower Pots

Candle Holders

Ash Trays



Fig 10.1: Variety of Marble Products

11. Indian Context

Stone was amongst the first material used by prehistoric man to create tools. Though items made from stone gave way to, items made from metal, stone continued to be one of the preferred material for making sculptures.

The stone-carving tradition in India is one of the richest in the world. Guilds of masons and stone carvers have existed here since the 7th century B.C. The skills were handed down as family lore from father to son, a practice prevalent in some parts of the country even today.

India has a rich tradition of stonework, as is evident from temples in Khajuraho, Konark, Martand in Kashmir and Ellora etc, which have richly carved sculptures and relief work on them. Large temple complexes of Ramashwaram, Dilwara and Tirupati not only are marvels in stone, but they reflect a high degree of sophistication reached by craftsmen engaged in stone craft.



Fig 11.1: India Map Demarcating Stone Art

Other States where Die Grinder is used for stone carving:



Fig 11.2: Rajasthan



Fig 11.3: Tamil Nadu



Fig 11.4: Karnataka



Fig 11.5: Orissa

11. Indian Context

Stone craft in India is not only restricted to ornate carvings on temples or sculptures of deities, but it is also used in making items like carved panels, tiles, paper weights, pen stands, models of historical buildings, sculptures of animals and humans etc.

Different and varied stone crafts exist in different parts of India:

Different types of stones like, marble, soapstone, sand stone etc are used by craftsmen in India. Large blocks of stone are quarried and then taken to various craft centers. The basic design is traced on the stone and it is given a crude shape. The final carving is then carried out and the items are polished.

Madhya Pradesh has a rich tradition of stone craft. Gwalior is known for jali (lattice) work. Animal and human figures are created in Jabalpur and Tikamgarh. The tribal region of Bastar is well known for sculptures of tribal gods and memorial pillars.

In Andhra Pradesh the main centers of stone craft are Durgi, Allagadda and Tirupati. These centers excel in making of intricately carved figures of gods and goddesses. The craftsmen here strictly follow ancient rules pertaining to carving and making sculptures.

Gujarat is known for marble sculptures from Ambaji. Rural areas of Bihar are known for utensils made from black stone.

Rajasthan has the best marble and sandstone quarries in India. The craftsmen here have an age-old tradition of carving and making sculptures. The marble quarry of Makrana has contributed to making of Taj Mahal at Agra and marble from here is also used in the making of exquisite Dilwara Jain temples at Mt Abu. The craftsmen here follow the rules laid down in Shilpa-shastra, while creating images of gods and deities.

Jaipur is the center of marble carving in Rajasthan. Craftsmen, not only create figures of deities, but also make household items like bowls, trays, items for kneading dough etc. Ajmer, Udaipur, Jodhpur, Bikaner and Jaipur are main centers of jali making.

Tamilnadu, Karnataka and Orissa are also famous for figurines and items made from stone. The craftsmen from Orissa use soft soapstone to make finely carved sculptures of gods and goddesses.

Uttar Pradesh has many craft centers engaged in making different items from stone. Hamirpur district is known for statues made from locally available red soft stone. The raida community of Banaras, is responsible for making a range of marble items include tableware, plates, glasses bowls, food containers, candle stands, etc. Agra is famous for its intricate marble inlay work, drawing inspiration from the Taj Mahal. Floral and geometric patterns dominate designs created here. Popular items include models of Taj, bowls, boxes, lamps, vases and pitchers. Intricately carved friezes, panels and trellis or jali work done in exquisite designs is a specialty of this place. Vrindavan and Mathura are popular for alabaster work. At times alabaster items are studded with precious stones.

Jhansi region known for a dark brown stone, spotted with yellow. Lamp stands, pastel, incense stick holders are made out of this stone.

11.1 Stone Art Work

The artwork on stone is a combination of carving, inlaying engraving, sculpture and undercut (art of making multi layered decorative items out of one single piece of stone, hollowed from inside). Designs are made by cutting the stone and varying fine patterns on it. In fact, stonecutters and sculptors work hand in hand. The base material of work is marble or soapstone.

Marble is brought from the quarries of Makarana, Rajasthan. The choicest work from Agra can be seen in black and white marble from Rajasthan, or Alabaster of Italy, with semi precious materials such as Cornelian, Malachite, Lapis Lazuli, Mother of Pearl, Onyx Agate and Shazar laid into it. Use of inexpensive shells instead of semi precious stone make for reasonably priced gift items. The famous inlay work of Agra reflects the mosaic work used in Taj Mahal and Fatehpur Sikri. At present, this work is limited and enjoys an exclusive foreign demand



Fig 11.1.1: Artisans Creating Intricate Design

11.2 Cutting The Stone

Before machines were introduced, stonecutters and carvers had only the hammer and chisel at their disposal. The artisans of yesteryears also had to hunt for the right type of stone, and learn the art of quarrying. The markets are well developed now and traders sell cut size sand stone and soapstone, as well as expensive stones like granite and marble. While practices in most part of Varanasi are still old fashioned, artisans in Agra use mechanized tools.

In the alleys and by-lanes of Agra, artisans can be seen operating country made machines for cutting, grinding, buffing and polishing of stone. In spite of the use of these simple machines, it requires a very skillful manipulation of chisel and hammer to bring out curvilinear patterns and designs. Grinding and polishing is a multi stage process, using graded grit of hard stone, followed by continuous rubbing with pigments and wax.

There are two categories of artisans- Sadakars and Pachikars. While basic cutting and carving aided by machines is done by skilled Sadakars, exclusive inlay work, requiring the expertise similar to cutting and polishing of jewelry stones using chisels and grinding stones is done by experienced Pachikars.



Fig 11.2.1: Types of Tools Used For Carving
Aamod S. Narkar |216130013

11.3 India-Rajasthan

Marble carving in India wouldn't be anywhere without Rajasthan. Rajasthan's marble carving capital is Jaipur. Craftsmen construct a variety of domestic objects, including bowls, trays, and devices for kneading dough, among other things. Murtikars, or Jaipuri marble carvers, created magnificent statues of Gods and Goddesses, temples, and inlays out of the purest marble.

Makrana, in Rajasthan, is one of India's oldest and most prestigious marble quarries. Marble is a metamorphic rock. The quantity of calcium carbonate in the limestone, as well as the presence of mineral impurities, determine the quality and whiteness of marble. When limestone undergoes the conditions of high temperature and great pressure, marble is formed. The purest marble, such as that mined at Makrana, is made up of almost 99 per cent calcite crystals. As a result, gives it its amazing pristine white colour.

Murti Mohalla situated between Kishanpole and Chandpole in the walled city of Jaipur, is the biggest manufacturing center for marble statues of Hindu and Jain deities. Jaipur also produces Human figurines, animals, and exquisite-bowls, carved marble vases, carvings and portraits. The entire world has great admiration for marble works of Jaipur.

Craftsmen in India use different kind of stones like marble, soapstone, sand stone etc. Large blocks of stone are quarried and then taken to various craft centers. The basic design is traced on the stone and it is given a crude shape. The final carving is then carried out and the items are polished.

Apart from carving beautiful idols of gods and goddesses such as that of Shiva, Radha-Krishna, Hanuman, Ganesh, Ram-Sita etc., artisans make products to be used in office, home and kitchen. They make simple and elegant forms like pen holders, paper weights, bookracks, card holders, ash trays, napkin holder, spoon holders, toothpick holders, storage jars, coaters, dinner sets, chaklas and belans, cups, saucers, serving-trays, candle-stands, photo frames, mirror frames, usher bowls, soap dish, soap dispenser, incense stick holders, flower pots, jewellery boxes etc.

Even as the bazaar continues to dwell in the narrow lanes of the heart of the city, a considerable number of workshops have been moved to the outer parts. This is a result of a government initiative to check on the noise pollution (caused by the hammering, machinery used to drill and chisel the boulders) and dust levels that harm human health. Marble otherwise is quite an eco friendly material. With the transportation becoming an easier facility, the demand for these marble splendours has only increased.



Fig 11.3.1: Murti Mohalla Street Views



Fig 11.3.2: Different Tools Used For Carving

11.4 Clusters- Kishangarh

A cluster is defined as a geographic concentration (a city/town/few adjacent village and their adjoining areas) of units producing near similar products and facing common opportunities and threats. An artisan cluster is defined as geographically concentrated (mostly in villages/townships) household units producing handicraft/handloom products. In a typical cluster, such producers often belong to a traditional community, producing the long-established products for generations. Indeed, many artisan clusters are centuries old Artisan.

Stone Carving:

The fine stone-carving or fragile jali work in stone is very typical of this area. Jaipur, Thanagazi, Kishori Makrana, Jodhpur, Jaisalmer, and Dungarpur are the main centres. Well Ornamented domestic wares in stone is beautifully designed with lot of attention to the art and its elegancy. A special feature is the carving of the Sun God, not found in other parts of Rajasthan.

Special stones found here are sand stone, yellow lime stone, colored and white marble. One can enjoy screens with tracteries, and luxuriously carved doors ornamented with brass motifs. The green-spotted copper coloured tamra stone found in is used in making images. Dungarpur has a soft shaded stone which turns black when oiled and is used for icon-making.

The stone craft of Rajasthan include marble boxes, wall plates, table tops, coasters, and ashtrays inlaid with semi-precious stones and mother of pearl in pleasing pietra dura designs that is derived from the Mughal monuments and paintings. Even the Gurara stone carvings, paperweights, and Rubic cube like candleholders, which take four different sizes, are considered as the intricate craftsmanship of the artisans of Rajasthan.

Apart from creating different articles that catch the fancy of the local people and the tourists as well, the artisans create exclusive items that are placed in the trendy house to suit the decorative purpose.

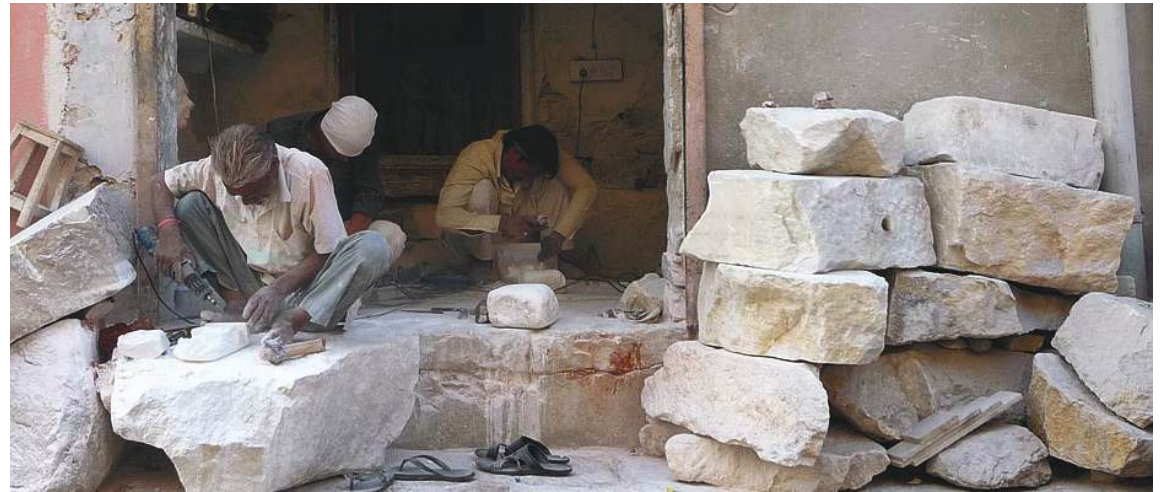


Fig 11.4.1: Cluster View

Process:

The crafts person while working on the sajar pathar first studies the natural design contains in the stone selected to work upon. The shaping is done thereafter very carefully with chisel and hammers. Water is sprinkled repeatedly to avoid heat generation. The stone is smoothened by rubbing with sand papers or file.

Dimensions of the figure to be manufactured are marked on a stone slab. Extra edges are removed from the slab by beating with a hammer. Big pieces of stone are cut vertically into smaller slabs, and rough sketches are made on it. The article is taken out from the slab with the aid of a saw. This slab is now converted in the form of the desired figure with a hammer and a chisel. Minor carvings are done by pointed chisel. A hammer and chisel do further smoothening. Before carving the stone is kept in boiling water overnight and treated chemically. This smoothenes and whitens the surface of the stone. Polishing is done for the final finishing with sand or carborundum pieces. Several of the carved artifacts are painted. Others are fitted with the looking glasses, brass fittings etc.

In carving an image, the stone carver sketches a rough outline of the sculpture on the stone - block. The craftsmen, sprinkle water on the stone during the course of their work because of the friction generated due to the constant chiseling away of the unwanted material results in the tools heating up. Finishing is accomplished in a variety of ways from sand-papery, polishing with multani-mitti or clay, oil and cloth.

An outline is drawn on hard or soft stone which is already cut to the appropriate size. Once the outline is incised indicating the shape, the final figure is brought out by removing the unwanted portions. While for the harder stones this is done by chiseling out the extra material, with softer stones. This is done by scraping out the same with a sharp flat-edged iron tool.

12. Silicosis

Silicosis is an incurable, debilitating occupational disease caused by the inhalation of silica dust. More than 22,000 cases of silicosis have been detected and certified in the state of Rajasthan in India and more than INR 2,500 Million has been disbursed as monetary relief to silicosis victims. The state has formulated a comprehensive policy on detection, prevention, control and rehabilitation of pneumoconiosis with special emphasis on silicosis. It has also started an online portal for the disbursement of relief. Analysis of data of 4977 cases of silicosis including 741 cases of death due to silicosis shows that the stone carving industry is the most affected, contributing to 38.3% of silicosis cases and 40.5% of deaths due to silicosis, occurred in the age group of 31 to 40 with a peak in 31 to 35 and 36 to 40 age groups respectively. Further, there is a significant difference of age group trends in occurrence and death due to silicosis between mining and stone carving districts.



Fig 12.1: Dust Emission While Stone Cutting

Union leader Ganesh, 31, was diagnosed with the frequently fatal lung scarring disease silicosis at the age of 29. He is unable to walk more than a hundred metres and struggles for breath while talking. Despite his failing health, Ganesh (right) came out to lead the rally because he said he wants to ensure that other workers do not suffer like him.

Pindwara is home to about 230 factories that have built some of India's most famous temples. On May Day, 400 workers occupied the streets of Pindwara's RIICO – the industrial area where the biggest of these factories are located. The workers had one rallying cry – freedom from the occupational disease of silicosis.

According to the Sirohi district's health department, over 1,650 of these temple-building workers are dying after contracting the untreatable lung disease. Workers' advocates say this is an under-estimate, as screening for the disease only started in the area three years ago. Union leader Ganesh, 31, was diagnosed with the frequently fatal lung scarring disease silicosis at the age of 29. He is unable to walk more than a hundred metres and struggles for breath while talking. Despite his failing health, Ganesh (right) came out to lead the rally because he said he wants to ensure that other workers do not suffer like him.

Pindwara is home to about 230 factories that have built some of India's most famous temples. On May Day, 400 workers occupied the streets of Pindwara's RIICO – the industrial area where the biggest of these factories are located. The workers had one rallying cry – freedom from the occupational disease of silicosis.

According to the Sirohi district's health department, over 1,650 of these temple-building workers are dying after contracting the untreatable lung disease. Workers' advocates say this is an under-estimate, as screening for the disease only started in the area three years ago.

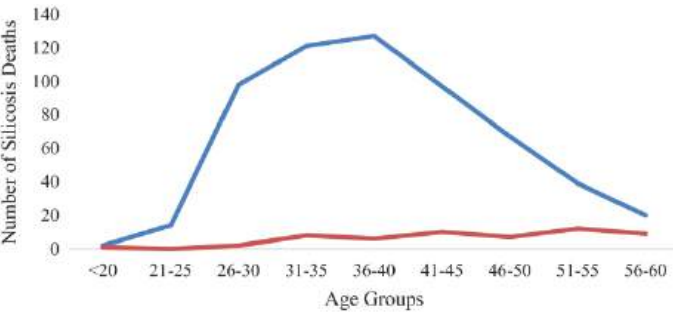


Fig 12.2: Protest Regarding Worker Health Issues

12. Silicosis

Table Showing Approximate Crystalline Silica Content Of Different Materials

Sandstone	70–90%
Concrete, mortar	25–70%
Tile	30–45%
Granite	20–45%, typically 30%
Slate	20–40%
Brick	Up to 30%
Limestone	2%
Marble	2%



The study has revealed that Pindwara's stone carving factories are death zones with life-threatening levels of silica-rich dust, with PM 2.5 dust crossing unsafe levels over 3 times! In many factories, the PM 10 dust was higher than the maximum reading limit of our air quality monitoring machines. Moreover, lung function tests reveal that 70% of the workers in these factories have highly comprised lung capacities.



Fig 12.3: Stone Cutting Factory Site

Though prevention is becoming a priority, there is a lack of understanding in Jaipur about how to take this agenda forward. Ensuring safety will need strong policy decisions on industry regulation, in addition to introducing effective dust-control technology, which is both worker-friendly and suited for the informal work conditions found across Rajasthan's stone economy.

So Called Solutions



Fig 12.4: Dust Suction Machine



Fig 12.5: Exhaust Fan Installation

13. Understanding Scenario in Tier 1 Cities



Fig 13.1: Space Crunch Inside Workshop

Each workshop has a team of approx four workers. On an average each workshop measures 3/5m in width and 8/10m in length. Each workshop has a display area in the front where the ready product are displayed. Back side of the space is mostly used for storage of marble slabs. The space in between is used to make the marble products.



Fig 13.2: Encroachment Outside Workshop

Due to lack of space and difficulty in the internal circulation, almost each workshop has extended its working space over the adjoining footpath. It being open air, workers prefer to sit outside and work as it provides better ventilation.



Fig 13.3: Customizable Desk

Because of the space constraints inside the workshop, the artisan do not prefer to have a fixed working station. They prefer to create their own platforms as per the requirements and preferred heights.



Fig 13.4: Low Height Sitting Posture

As water is required while carving harder stones like makrana marble, they have a pipe connection which provides water from a can. The water from the pipe keeps dripping on to the rotating bit, due to gravity as its kept above their height of their preferred working posture.

14. Machine Specifications

Mainly die grinders of two company makes were observed in Mumbai:

- > DCA
- > Dongcheng



Fig 14.1: Die Grinder Machine

Diffrent bits are used as per the required tasks.
Bits of varying diameters, ranging from 2mm to 20mm.



Fig 14.2: Bits Used For Carving



Fig 14.3: Die Grinder Specifications

Brand	DCA
Item Dimension- LxWxH	45.7 x 11.4 x 11.7 cm
Power Source	Corder Electric
Voltage	220 V
Wattage	400 W
Speed	27000 r/min
Net Weight	1.8 Kg

15. Die Grinder Study

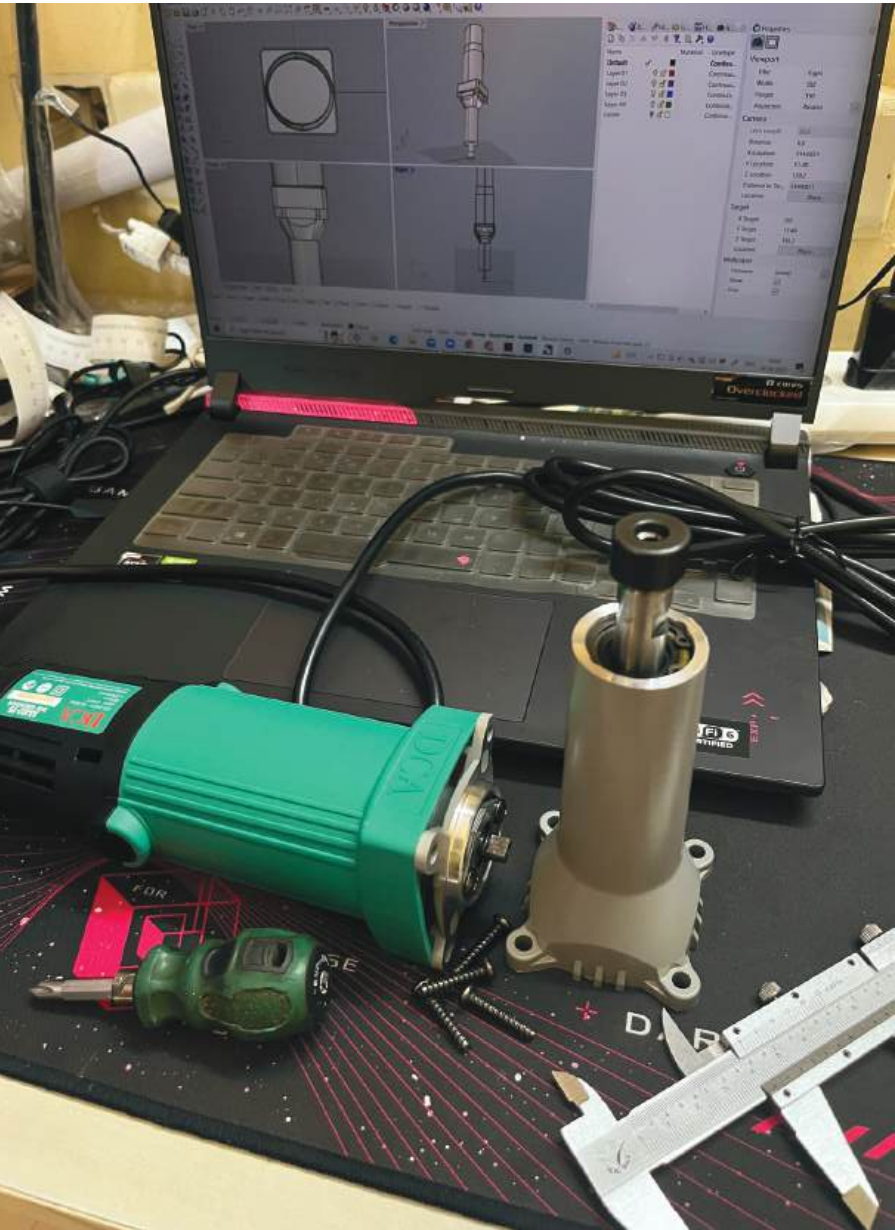
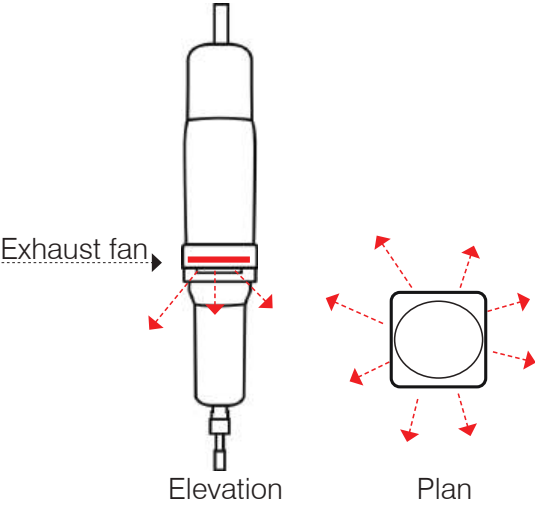


Fig 15.2: Die Grinder Dismantled

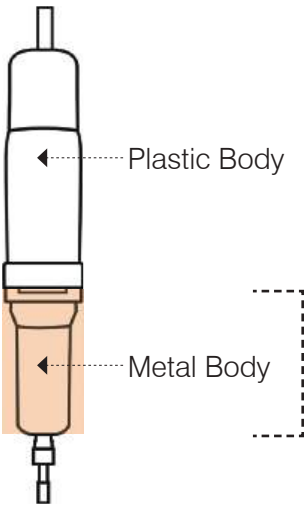


Fig 15.1: Fan For Motor Ventilation



When the die grinder machine was opened, it was observed that:

- > They is a rubber fan inside, which rotates when the machine is on, and helps cool the motor inside.
- > The throw of the air is from all sides of the machine.
- > The throw of the air is not equal on each side.
- > Due to the screws in each corner, it creates vent slots on each side of the machine.



This indicated surface area starts heating up while usage of the machine over a period of time on continuous working. Hence it is observed that this part is covered with some external material, to prevent heat and vibrations.

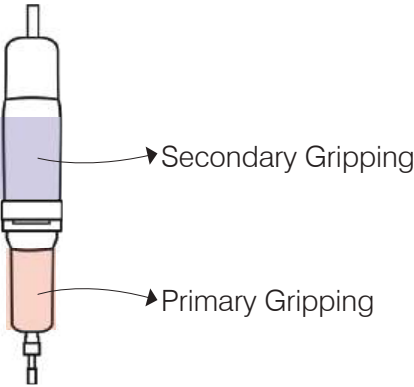
15.1 Grip Hand Postioning

Case 01



Fig 15.1.1: Non Detailed Work Grip

This grip is preferred when the carving work is not detailed or the work is repetative where much skills are not needed.

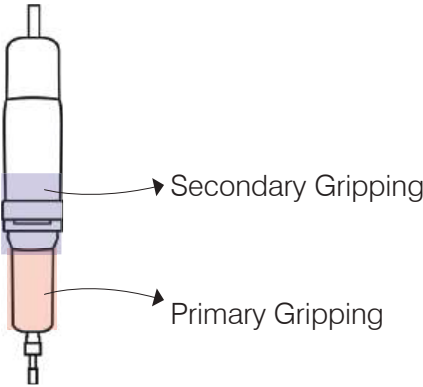


Case 02



Fig 15.1.2: Chamfering Work Grip

This grip helps to support the machine when it is tilted in order to achieve chamfers on marble edges.

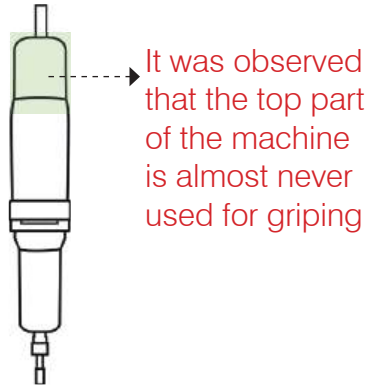
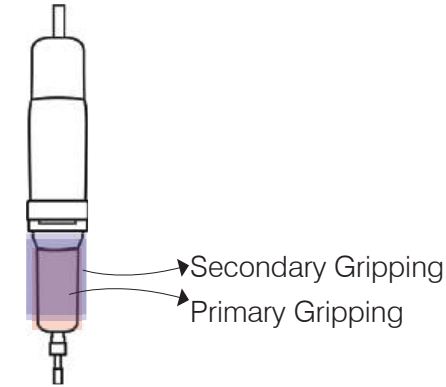


Case 03



Fig 15.1.3: Detailed Work Grip

This grip is allows the artisan to get a better hold of the machine so that he can carve out detailed design and able to achieve most control over the machine to move it as per the design.



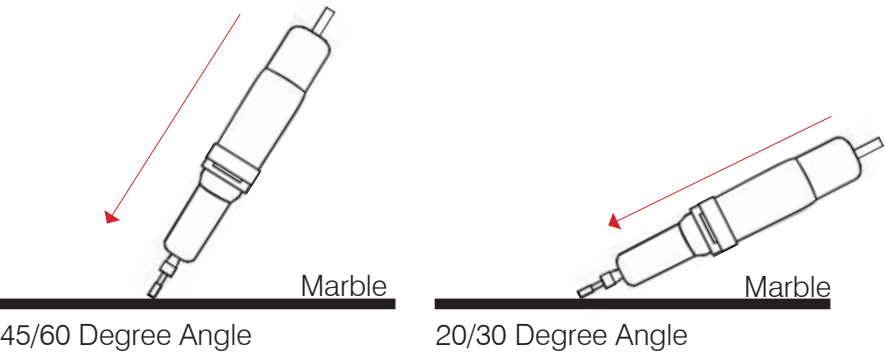
15.2 Machine Working Angles

For Chamfering



Fig 15.2.1: Machine Tilted 20-60Degrees

It is observed that the machine is required to be tilted at various angles to achieve the desired finish. These angles requires free and swift motion of the wrists allowing the karigar to move machine in any angle to create chamfers and smooth surfaces.

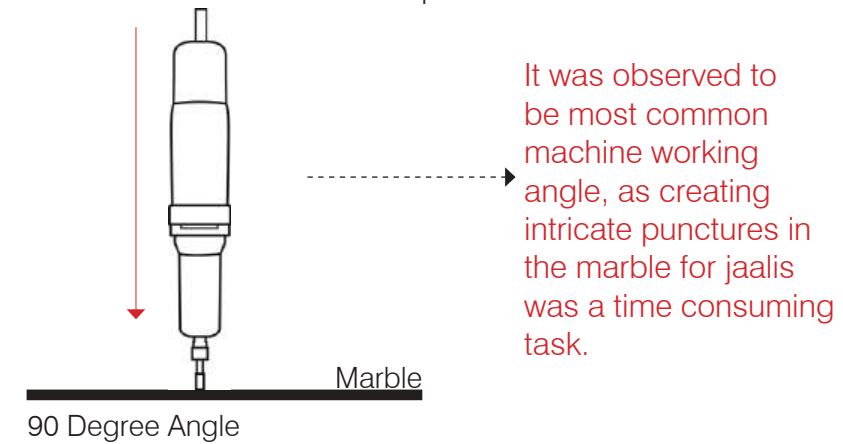


For Drilling



Fig 15.2.2: Machine Held Straight 90 Degrees

To create depression while carving out marble or to create intricate jaalis, the machine is needed to be held vertically for longer period of time to achieve the desired output.



It was observed to be most common machine working angle, as creating intricate punctures in the marble for jaalis was a time consuming task.

15.3 Proximity Mapping



Fig 15.3.1: User and Machine Proximity Study

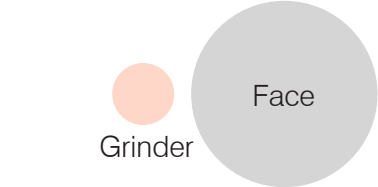


Fig 15.3.2: Machine-Face Distance Less than 5"

Observed to be most regular head and grinder distance, as the user needs to observe closely while working.

In this condition the face is closest to the die grinder as the artisan need to see the details while carving.

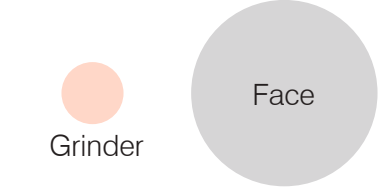


Fig 15.3.3: Machine-Face Distance Approx 10"

In this condition the face is little far away as the machine is tilted in order to create .



Fig 15.3.4: Machine-Face Distance Approx 15"

This condition allows the face to be away as the carving does not need much detailing.

15.4 Time Mapping To Understand Exposure

Day Starts: 9am | Lunch Break: 1:30-3pm | Day Ends: 7pm

Time taken: 2-3 Hours



Fig 15.4.1: Short Time Range Tasks

Time taken: 8-10 Hours



Fig 15.4.2: Medium Time Range Tasks

Time taken: 15-18 Hours



Fig 15.4.2: Long Time Range Tasks

15.5 Dust Emmission Study



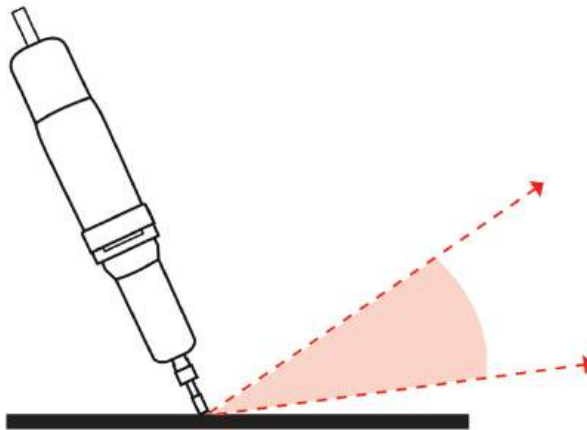
Fig 15.5.1:Dust Emmission When Machine Angled



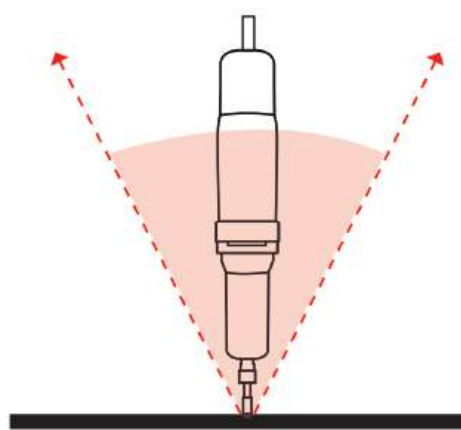
Fig 15.5.2:Dust Emmission With No Water Supply



Fig 15.5.3:Dust Emmission With Water Supply

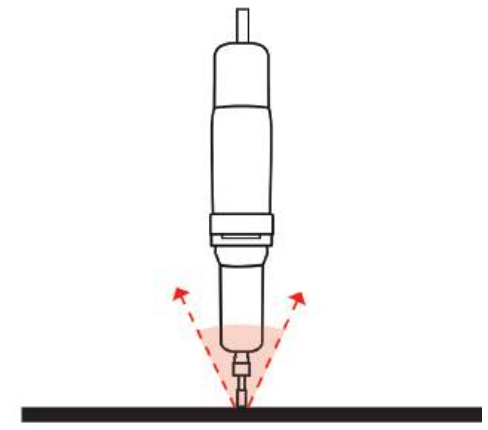


While chamfering at an agle, the dust is emitted side ways and not straight up towards the artisan's face.



If the machine is almost straight while carving then that ends up emitting the marble dust upwards in all directions, increasing the chances of the dust hitting the artisan's face.

40



If the water supply is used while carving, it definitely helps in reducing the dust emission by settling the marble particles in the flowing water.

15.6 Right Hand - Left Hand Co-ordination

Left Handed Karigar



Fig 15.6.1: Gripping With Left Hand

If the artisan is left handed then the left hand grips the bottom part of the machine and the right hand grips the upper part.

Right Handed Karigar



Fig 15.6.2: Gripping With Right Hand

If the artisan is right handed then the right hand grips the bottom part of the machine and the left hand grips the upper part.

15.7 Customized Grip Thickness

Thickness: Two tapes-2/3 mm



Fig 15.7.1: Grip Customization With Tapes

It was observed that the artisan had customized his grip by applying multiple tapes and paper in order to provide better grips and protection from heating of machine.

Thickness: Cloth+Tape(to fix pipe)-5/6 mm



Fig 15.7.2: Grip Customization With Tapes To Fix Pipe

It was observed that the artisan had used some cloth and fixed it by wrapping brown tape over it. The brown tape was also used to attach the pipe over the grip making it easy for water supply.

Thickness: Cement Bag -10 mm



Fig 15.7.3: Grip Customization With Cement Bag

It was observed that the artisan had used cement bags to cover the grip area of the machine. The cement bag helped in providing good damping and protection from heat.

16. Problem Identification

PRIMARY

SECONDARY

Grips	Water Supply	Dust Blowing	Dust Protection	Weight
Different materials were wrapped around the machine bottom part for cushioning and protection from heat.	4mm dia water pipe fixed on the outer side by tape creating irregular grip.	As the venting(on 4 sides) of the machine is irregular, carvers dont find a point of direction.	No protections adapted by the user to prevent himself from marble dust.	Elbow rested on marble or legs to support the weight of the machine on hand.
				

Fig 16.1: List Of Problems to Address

17. Design Brief

To design a low cost attachment for the die grinder for small scale industrial marble carvers, which primarily addresses issues related to:

- > Grip Ergonomics
- > Water Connectivity
- > Air Channeling

17.1 Project Scope

To intervene with the help of a design solution on to the existing machine(die grinder) without changing any part of the machine.

17.2 Project Aim

Aim is to provide a simple solution by creating a subtle design change in order to maintain the relation between the tool and the carver.



18. Mood Board



Fig 18.1: Mood Board
Inspiring Design Language

19. Ergonomic Considerations

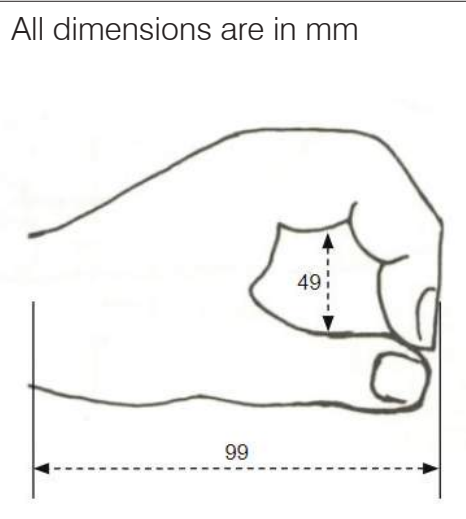


Fig 19.1: Finger Distance Data

Grip Inside Diameter, Maximum

Maximum inside grip diameter, measured by sliding the hand down a graduated cone until the tips of the thumb and the middle finger remain touched to each other.

		Percentile				
		5th	25th	50th	75th	95th
Grip Inside Diameter, Maximum	Male	42	46	49	51	56

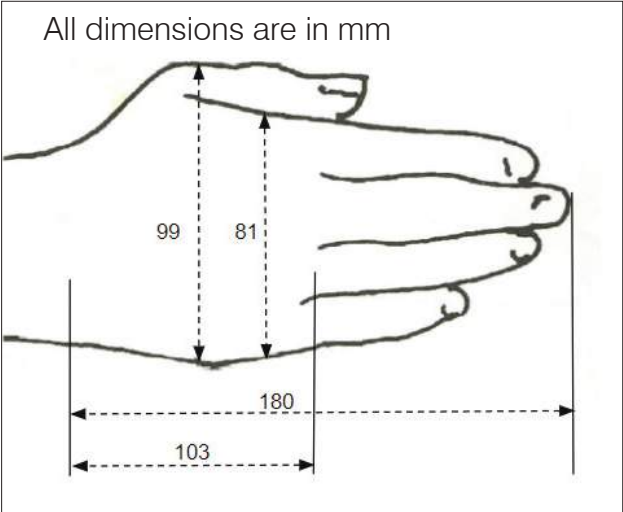


Fig 19.2: Palm Measurement Data

Hand breadth, with thumb

Maximum breadth across the palm with the thumb at right angle to the long axis of the hand.

Hand breadth, without thumb, at metacarpal

Maximum breadth across the palm at the distal ends of the metacrapal bones(where the fingers join the palm) of the index and the little finger.

		Percentile				
		5th	25th	50th	75th	95th
Hand breadth with thumb	Male	86	93	99	104	111
Hand breadth w/o thumb at metacarpal	Male	72	77	81	85	90

20. Ideations

Explorations in different directions were sketched in order to try and test every possibility. It started with sketches of each and every element of the attachment, in order to detail every aspect. Later all the sketches were combined and looked at in totality.

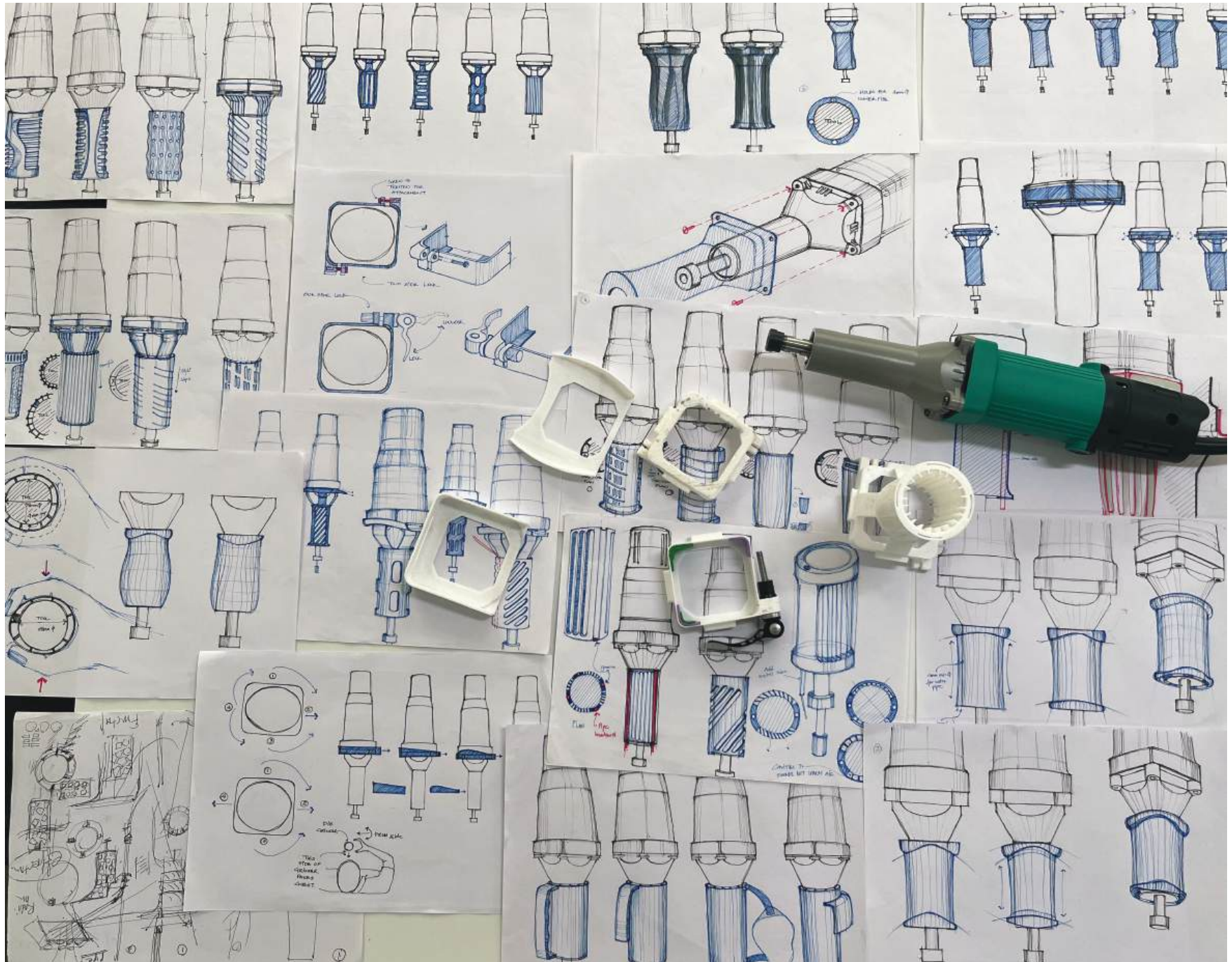


Fig 20.1: Initial Ideations

20.1 Grip Clamping

This idea was inspired from the lever clamp which is used in cycles majorly. It is very easy to lock and unlock but adds on to the weight of the attachment.

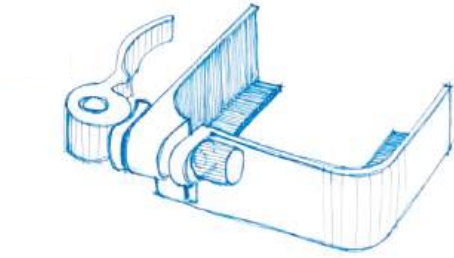


Fig 20.1.1: Lever To Clamp

This idea is similar to the fixing method of grips on to cycles. It has two screws at diagonally opposite ends to endure better clamp, but needs a separate allen key to fix it.

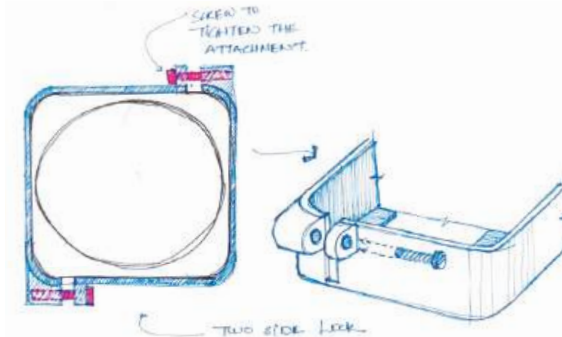


Fig 20.1.2: Two Additional Screws To Clamp

The idea was to make use of the existing screws of the machine itself to attach this attachment on to it but if ever it has to be removed it is tedious task.

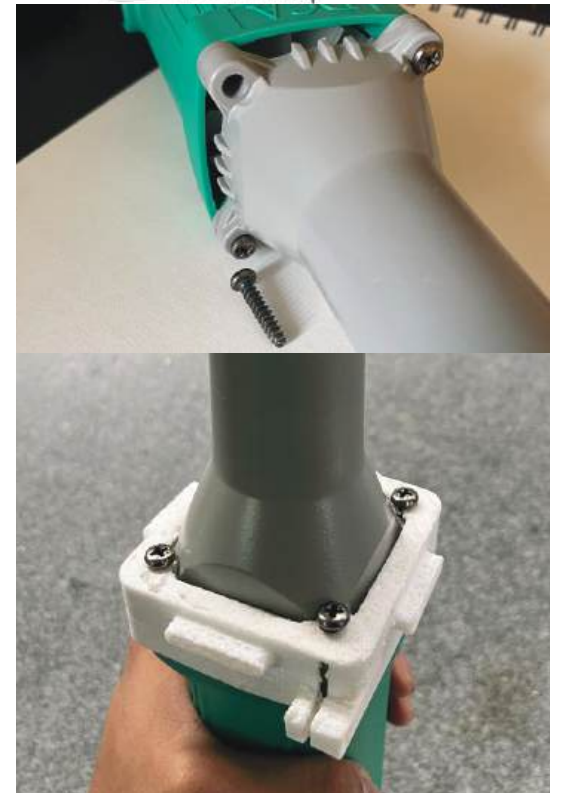
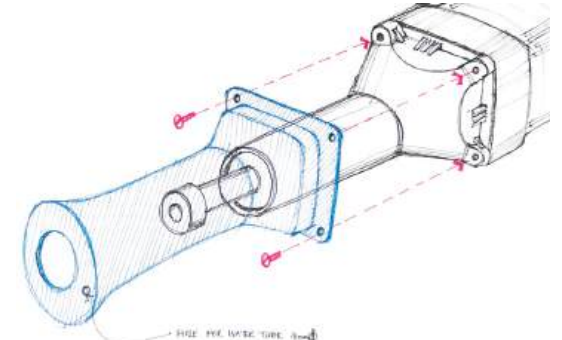


Fig 20.1.3: Existing Screws To Clamp

20.2 Air Flow Channeling

Machine vent used to blow the marble dust



Fig 20.2.1: Artisan Tilting the Machine to Clear the Working Surface

The air from the vent coming out from all the four slots, is observed to be irregular in direction.

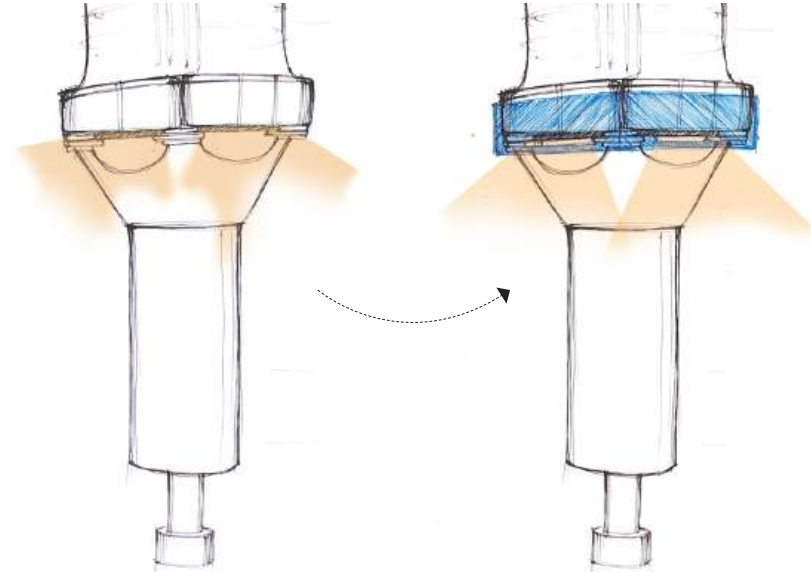


Fig 20.2.2: Sketch Denoting Control Over Air Vent

Addition of a cap with provisions of cutouts that helps to channelize the air flow, and directs it out in one direction on each side.

The sectional diagram indicates the channelizing of the vent helping the carver to direct it on to the required area.

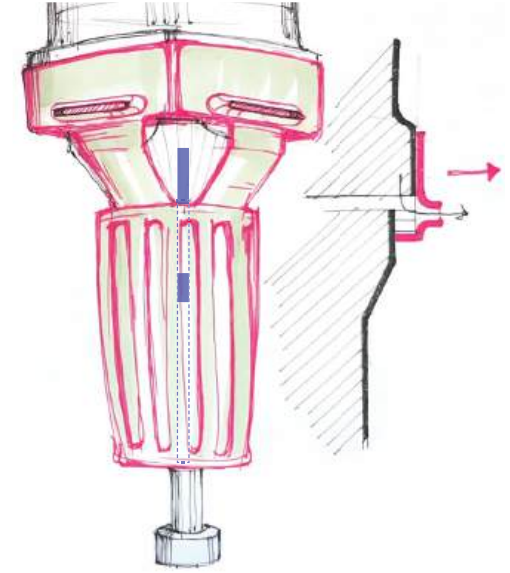


Fig 20.2.3: Section Indicating Direction Of Flow



Fig 20.2.4: Extrusion to Channel The Air Outwards

A mockup was 3d printed in order to test the blowing accuracy.

The images on the right show that it allowed the user to know the direction of the air flow for him to point it at a certain area.



Fig 20.2.5: Allowing Sense of Direction While Blowing
Aamod S. Narkar | 216130013

20.3 Weight Supporter

The weight of the machine being almost 2 kgs. The user is observed to rest the elbow over his body or table during the long working hours.



Fig 20.3.1: Working Hand Supported on Table/Body

Some ideation indicating additional handle for better support but increases the attachment weight

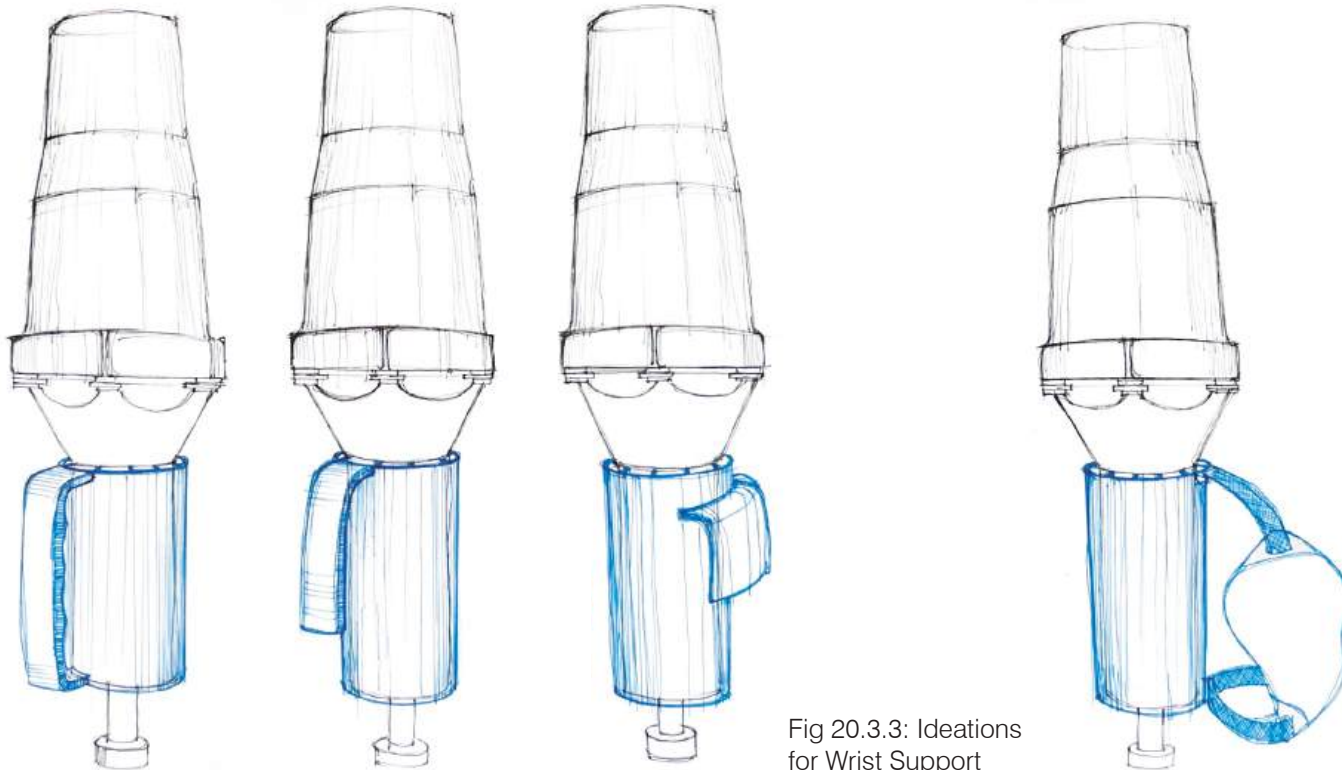


Fig 20.3.3: Ideations for Wrist Support

DSLR wrist support bands were used as reference, as they help distribute the load over the palm.



Fig 20.3.2: Wrist Support Band

DSLR band could be fixed on this attachment to help reduce load on the wrist.

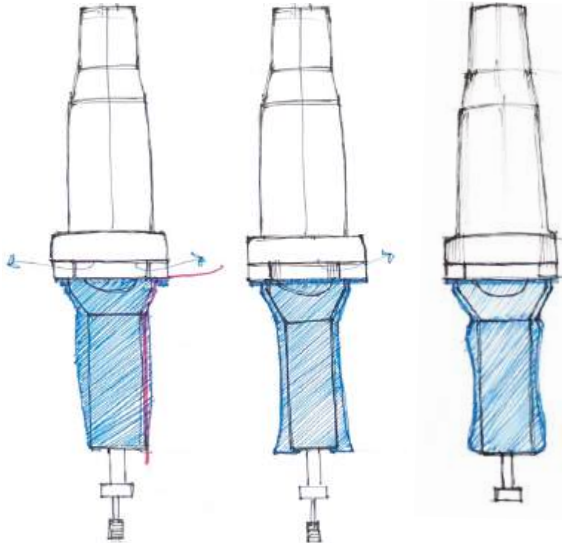
Mockups with the wrist supporting band to test the idea.



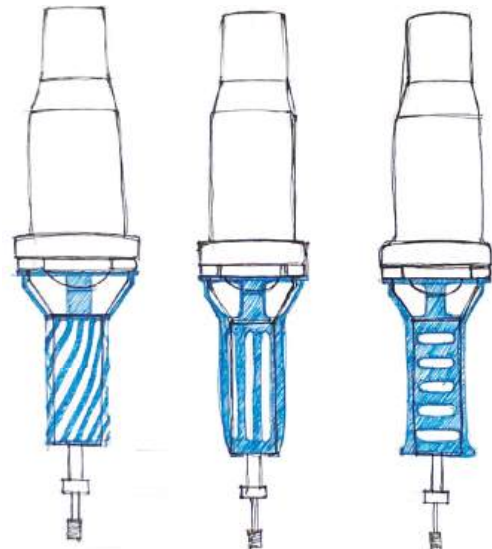
Fig 20.3.4: Wrist Support Strap Testing
Aamod S. Narkar | 216130013

20.4 Grips

Grip Ideations



The initial ideations started with grips being completely solid.



Later slits and cutouts were added in the grip in order to make it light weight.

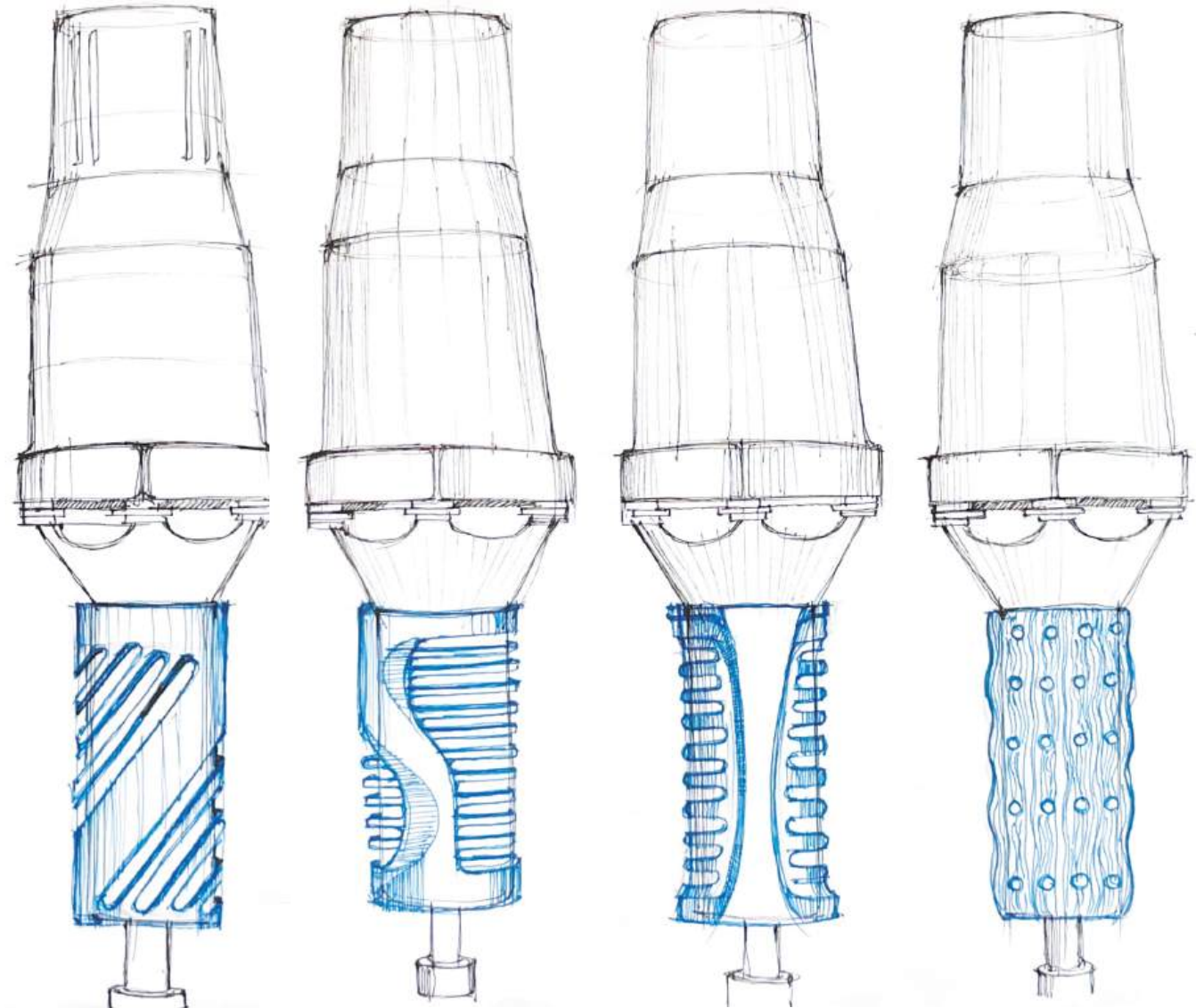
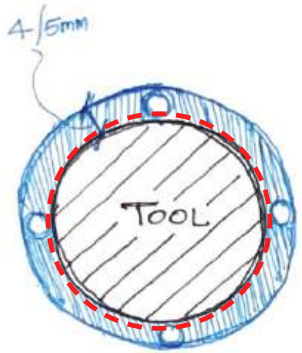


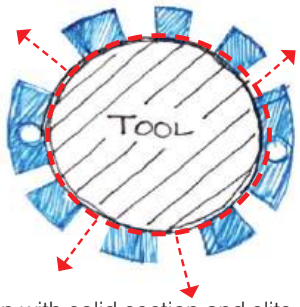
Fig 20.4.1: Ideations for Grips

Explorations in the grip started in many directions. Three main criterias behind grip design were incorporation of water pipe in it, making grip more ergonomic and to design it in a way that it helps keep hand away from machine heat. Initially the grip was completey solid but that would make the attachment quite heavy, hence slits were encorporated to reduce its weight and also make it economic. The slits patterns were explored in many ways for better control and allow the heat to pass.

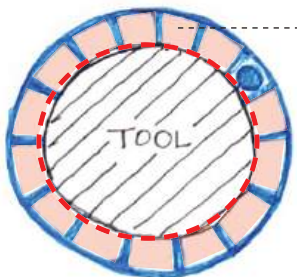
20.5 Grips Cross Section



Plan with solid section, heat dose not find way to escape



Plan with solid section and slits, but allows heat to escape directly on the holding palm



Plan with cavities, which allows heat to escape from the top
Fig 20.5.1: Plans Showing Grip Cross Sections

The ribs along the inner diameter of the grip creates channels which are open at both ends and hence create a space for the hot air to escape out from the top (as warm air rises up) and not come in the way of the palm holding the machine.

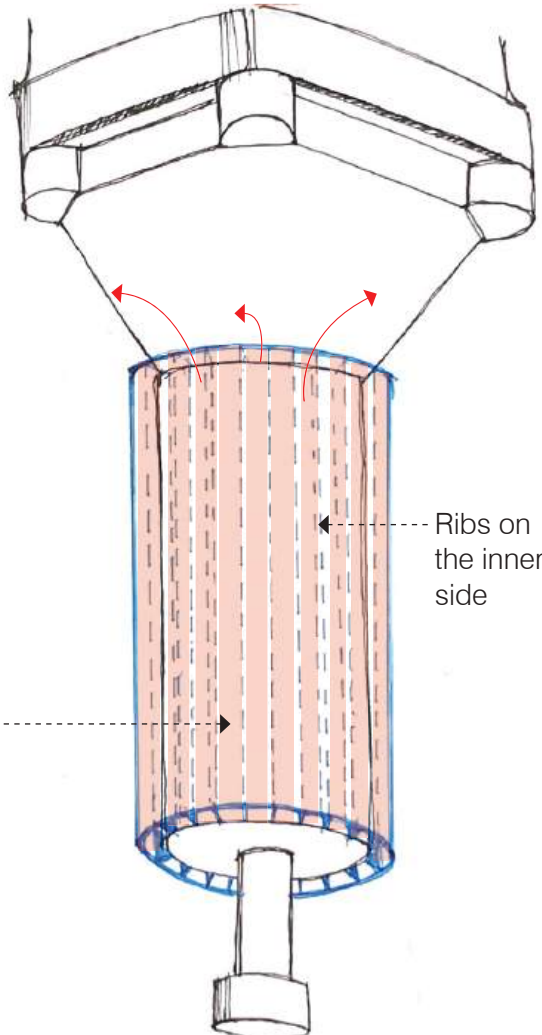


Fig 20.5.2: Rib Structure Inside Grip

Vibration pads have also similar cross-section. The ribs help to provide better absorption and grip on the surface.



Ribbed Rubber Pads

Fig 20.5.3: Reference Image of Vibration Pads

Ribs creating channels

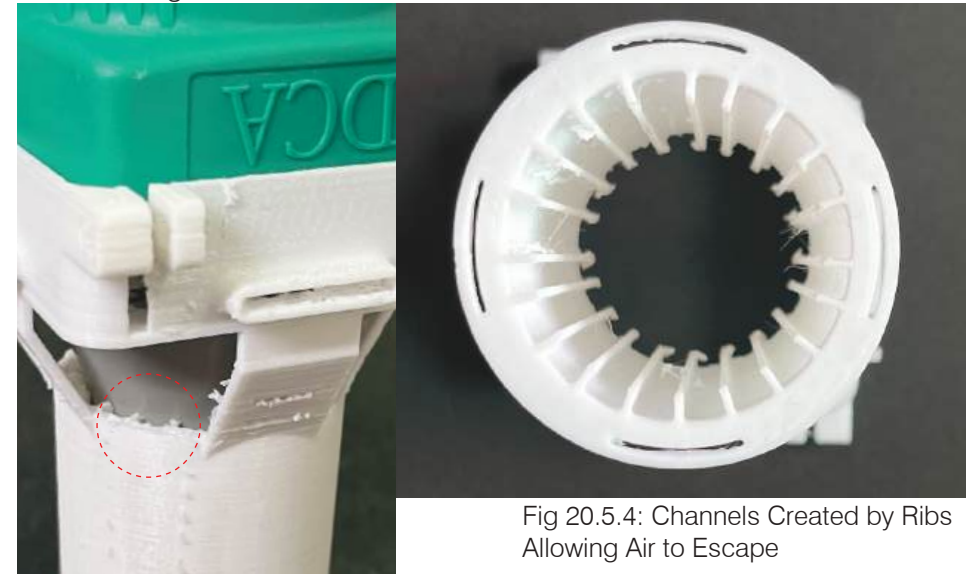


Fig 20.5.4: Channels Created by Ribs Allowing Air to Escape

These explorations try to eliminate the slits and cutouts on the grip curvature, rather creating a space between the grip surface and the machine surface with the help of the ribs (along the circumference). The ribs on the inner side of the grip also make the surface stronger and contribute in better absorption of the vibrations.

20.6 Grips Cross Section

Further the explorations were started, to design various cross sections of the grip by changing the patterns of the ribs in order to make it look visually appealing and add to the look of the attachment. The space between the ribs were made broader with varying thicknesses, keeping in mind the encorporation of the 4mm dia water pipe. Prototypes were 3d printed and fixed on the machine for trials.

Compared to the existing rubber grip that was provided by the manufacturer, having a closed grips with vent openings at the top was personally felt better. Low quality rubber, with less thickness and slits on the surface did not provide a better experience.

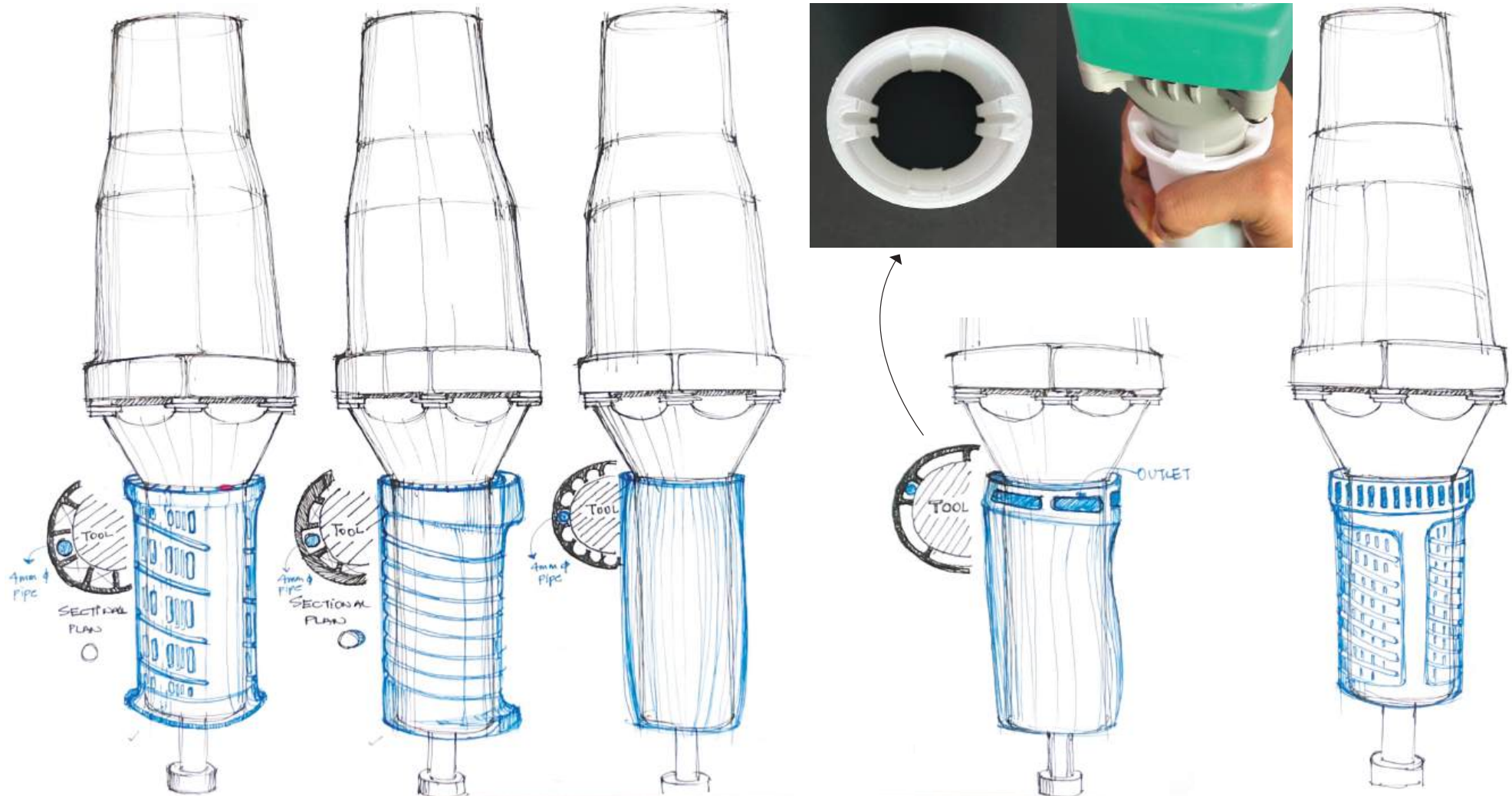
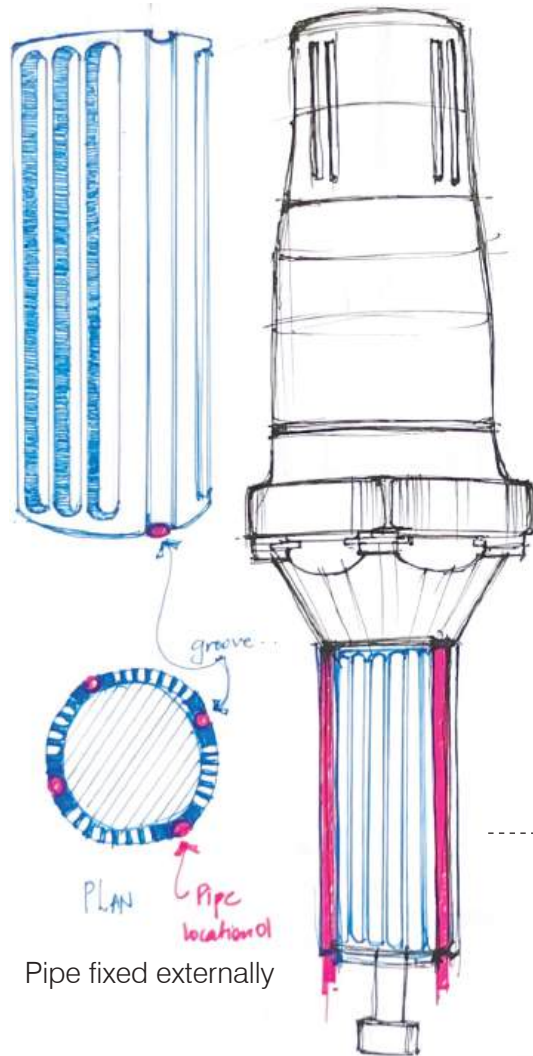


Fig 20.6.1: Ideations for Ribbed Cross Section

20.7 Water Connectivity

Two category of ideations were sketched in order to incorporate water pipe within the grip thickness:

- To fix it externally over the grip by providing a slot. May be more than one slot. But was predicted that the pipe would fall off the slot(if not inserted properly) while working.
- By inserting it, in the inner side of the grip, in the available ribs. The space between the ribs could be less than 4mm. This helped in the way to make sure pipe is intact and safe. One problem was predicted that if the pipe needs to be removed, the entire attachments needs to be removed.



Pipe fixed externally

Fig 20.7.1: Ideation to Explore Pipe Connectivity

Pipe needs to be fixed inside the attachment before clamping the attachment to the device.

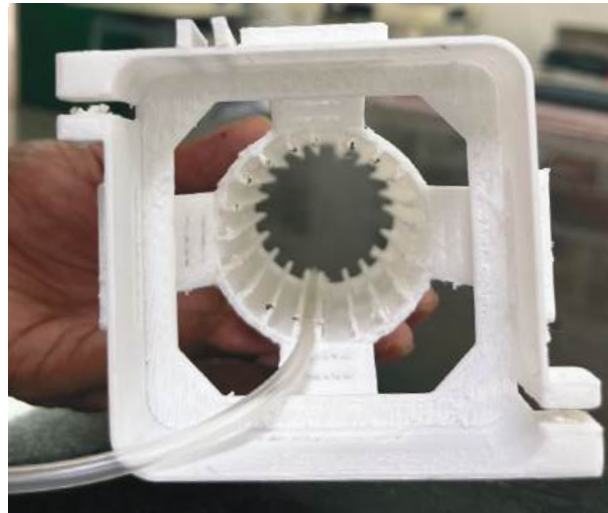


Fig 20.7.2: Pipe Fixed Internally

Pipe fixed internally

Problem was observed that the water pipe taped on the grip was falling over his hand causing inconvenience and irritation while working.



Fig 20.7.3: Issue of Pipe Falling On Hand

A groove provided on the top part of the grip, which enables to fix the pipe into it, in order to avoid it falling on the hands while holding the machine.

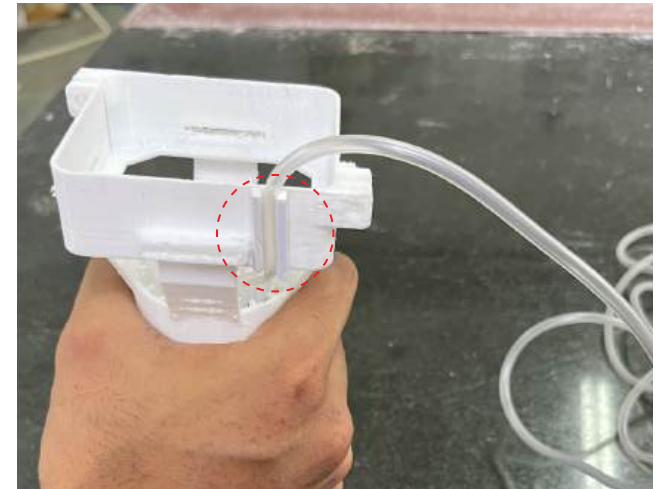
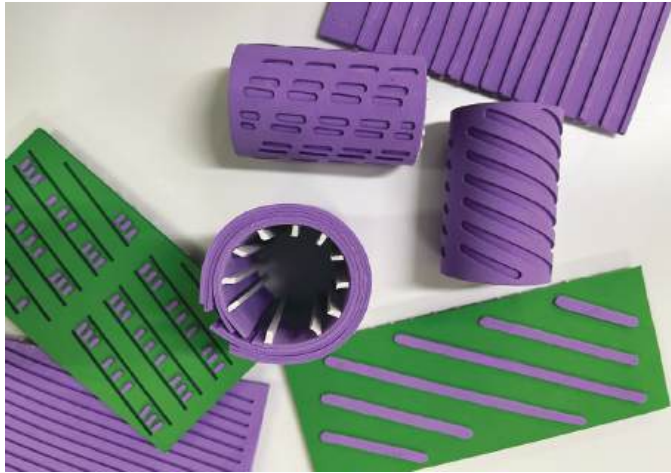


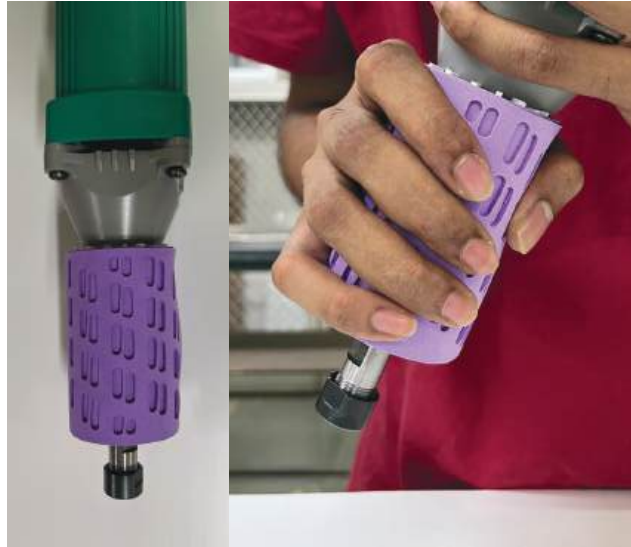
Fig 20.7.4: Provision For Clamping Pipe at Top

20.8 Grips

Grips with different patterns were laser cutted and fixed over the machine to check gripping comfort.



Option 01



Option 02



Option 03



Option 04



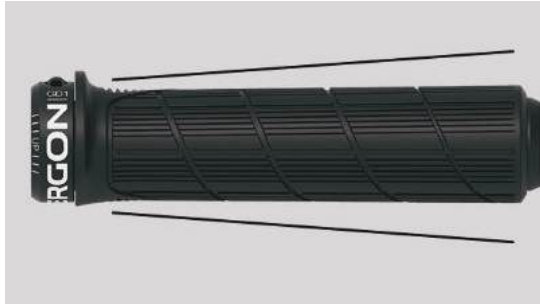
Option 05



Fig 20.8.1: Laset Cut Grip Trial Options

20.9 Grips Inspirations- Cycle Grips

Grips designed for mountain cycling for better gripping and damping against the rocky terrain, hence used as reference.



The GD1 has a conical, tapered shape. The grip diameter gradually increases towards the end of the grip. This increases the damping properties towards the end of the grip while the inboard diameter stays slim and responsive.



The anti-slip tread pattern along with the new super soft thumb zone provides maximum grip. The overall design requires maximum control with less gripping force.



Curvature at the ends for better gripping and control.

Fig 20.9.1: Mountain Cycle Grip Study



Fig 20.9.2: Ergon Mountain Cycle Grips
Aamod S. Narkar | 216130013

20.10 Grip Structure Details

The directions of the ridges in the grip against the direction of the fingers holding it, helps to increase its friction coefficient.



Fig 20.10.1: Grip Pattern Study

For Example:

The side of any cold drink bottle cap has verticle grooves on its surface, which are against the direction of the fingers while turning it.



Fig 20.10.2: Example to Study Grip Pattern

20.11 Dust Protection

Ideation 01: To add a additional attachment of a fan at the top part of the machine directing it down on the chest to block the dust particles reaching face

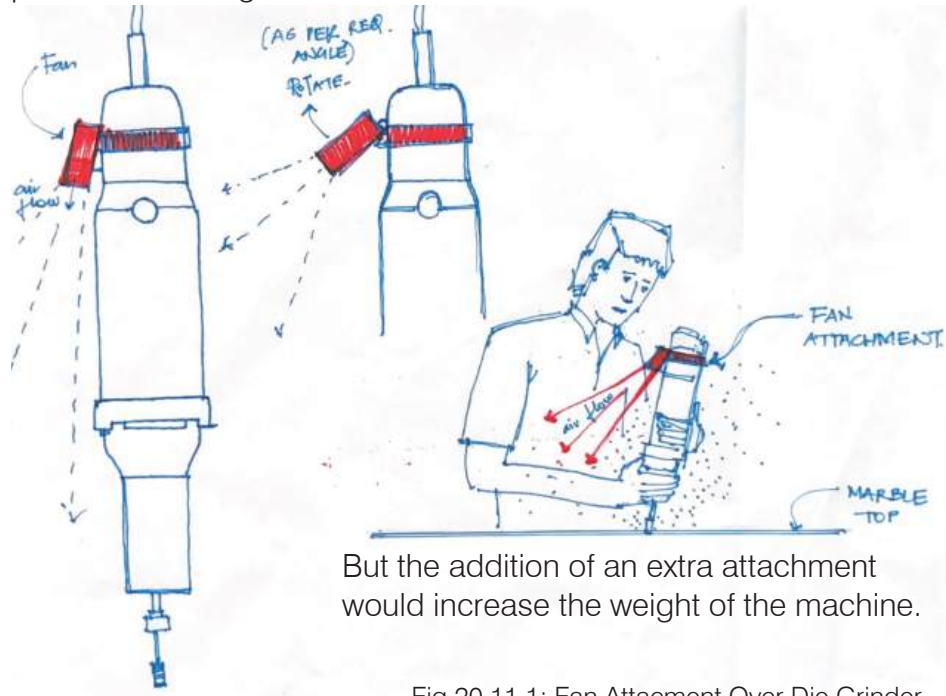


Fig 20.11.1: Fan Attachment Over Die Grinder

Ideation 02: The plan was to use the air blow from the machine vent itself to block the dust particles reaching face

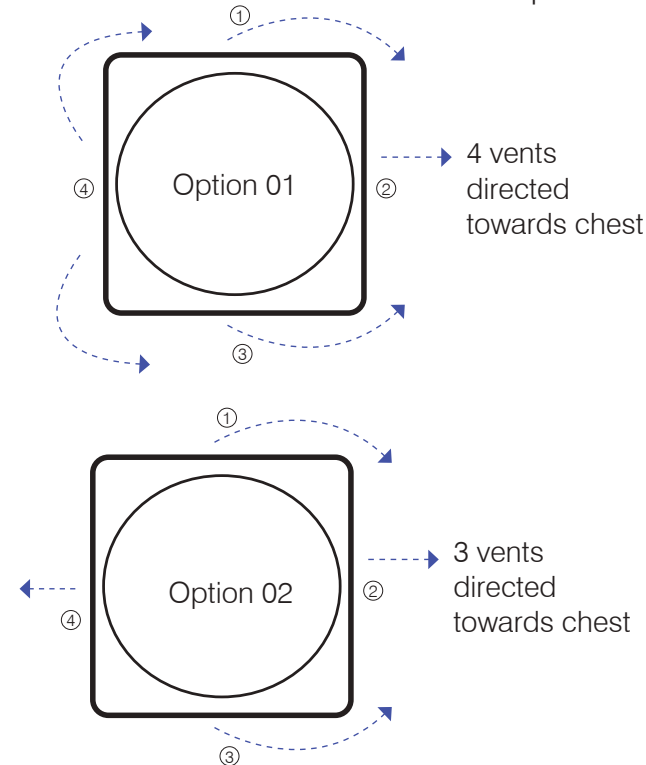
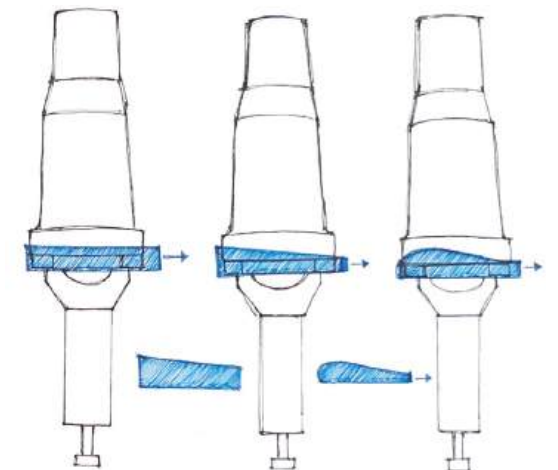


Fig 20.11.2: Diverting Existing Vent Towards One Direction

Images showing close proximity of the carver and the point of dust emission:



Fig 20.11.3: Proximity Analysis



20.11.1 Dust Protection Testing

Attachment option 01:

Curved in order to direct the air flow, but that led the walls of the attachment to be far from the air source and hence did not prove to be effective in directing the air vent.



Fig 20.11.1.1: 3d Printed Prototype 01

Attachment option 02:

The design was revised and made more compact and closer to the source of air flow, so that the air coming out hits the walls of the attachment and gets diverted towards one direction.



Fig 20.11.1.2: 3d Printed Prototype 02

Paper deflection without attachment:

Hardly any deflection in the paper was observed as air from only one slot was directed on the paper, which was not powerful enough at this distance.



Paper deflection with attachment:

Comparatively a lot deflection in the paper was observed as air from three slots was directed on the paper, which was powerful enough at the same distance.

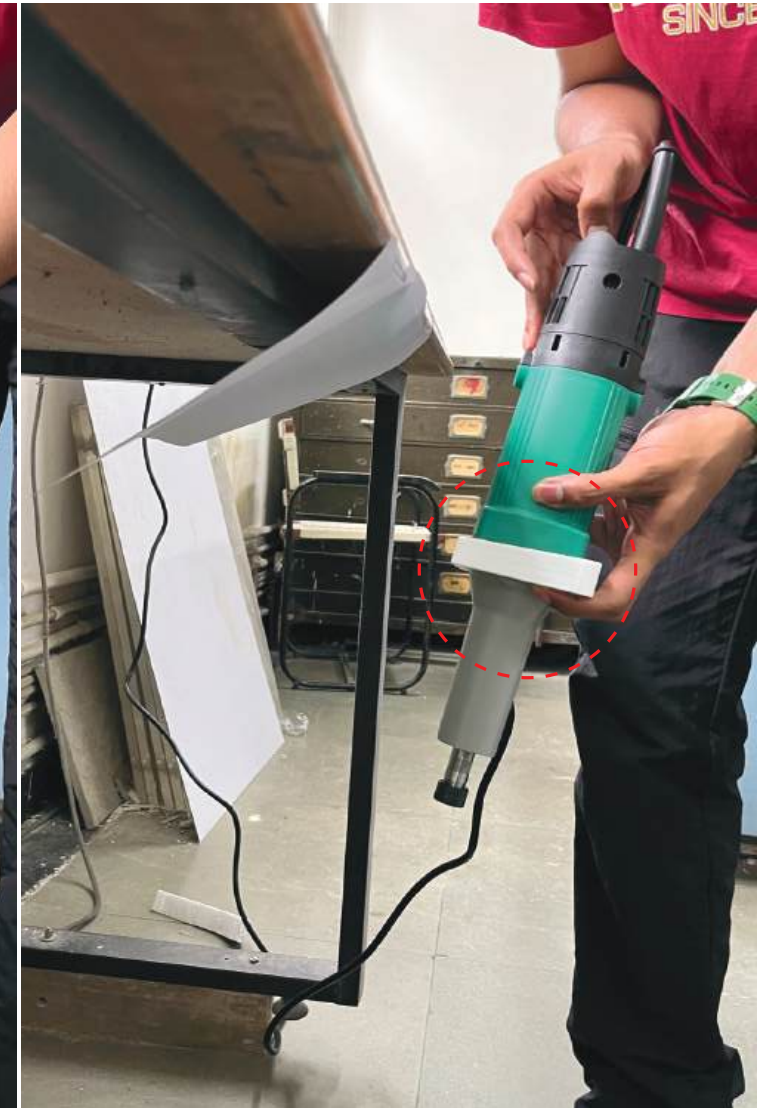
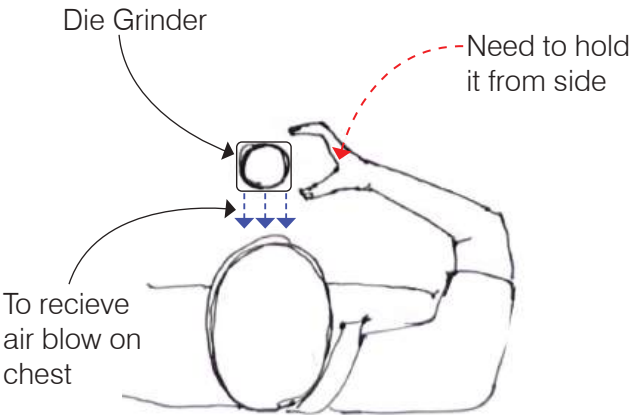


Fig 20.11.1.3: Testing of Diversion of Vents
Aamod S. Narkar | 216130013

20.11.2 Dust Protection And Grip Relation



Fig 20.11.2.1: User Gripping Analysis



From the user study(refer 2 images) it was observed that if the user holds the machine from right, he would face one side of the machine to recieve the air blow on the chest.

Round shaped grip with bulge at the top and bottom to indicate the user its holding direction.



Fig 20.11.2.3: Circular Grip Mockup

3d modelling of various grip possibilities

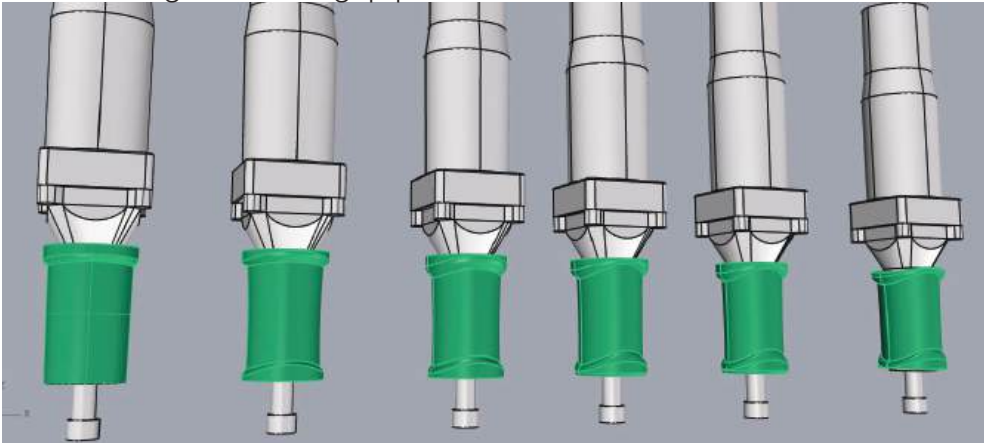
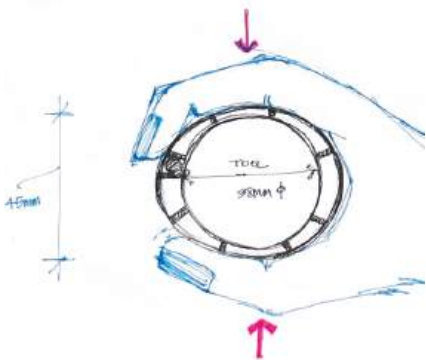


Fig 20.11.2.2: 3d Model Explorations



Oval shaped grip in order to make the user hold it in the desired direction



Fig 20.11.2.4: Oval Grip Mockup

21. Final Concept 01

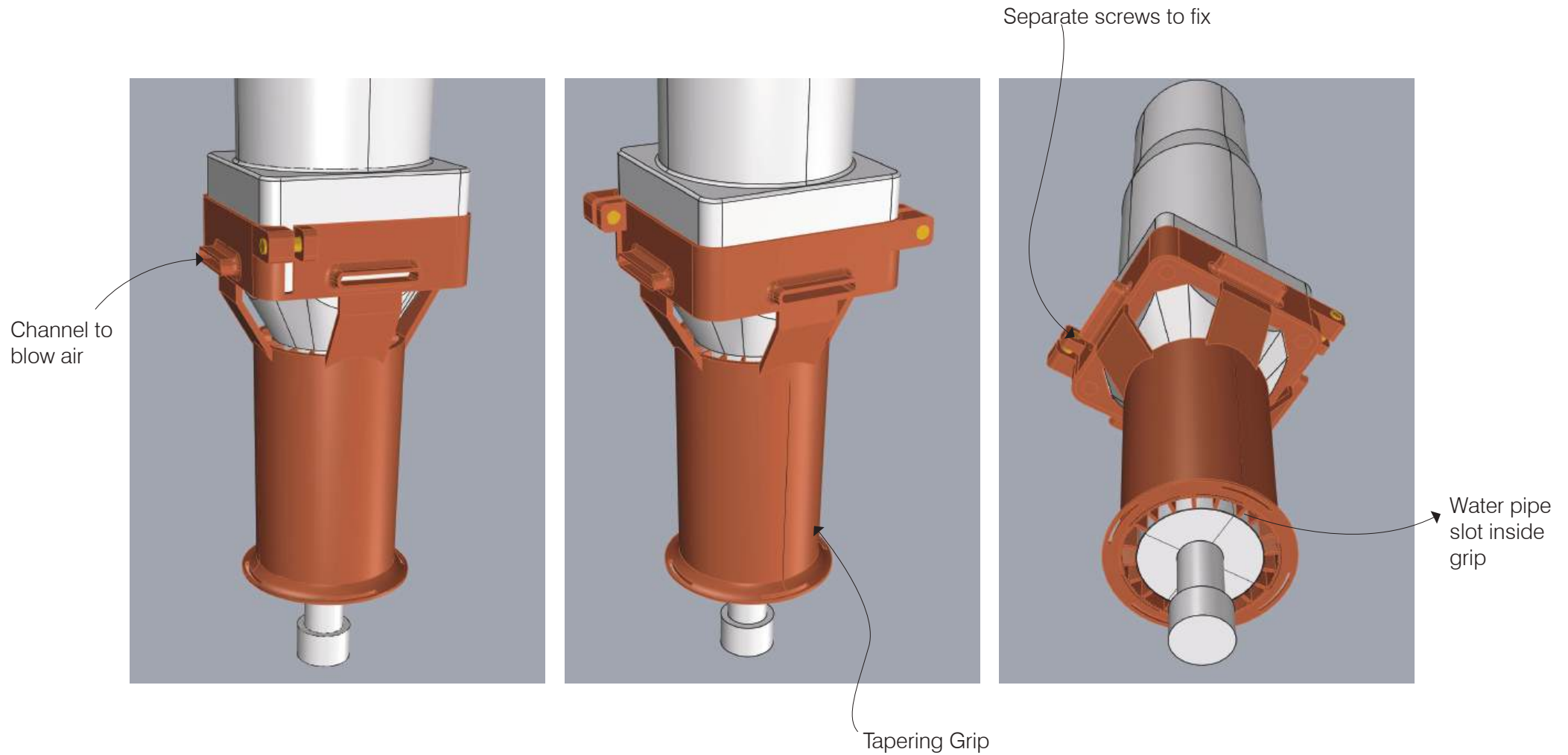


Fig 21.1: 3d Visual of Concept 01

22. Final Concept 02

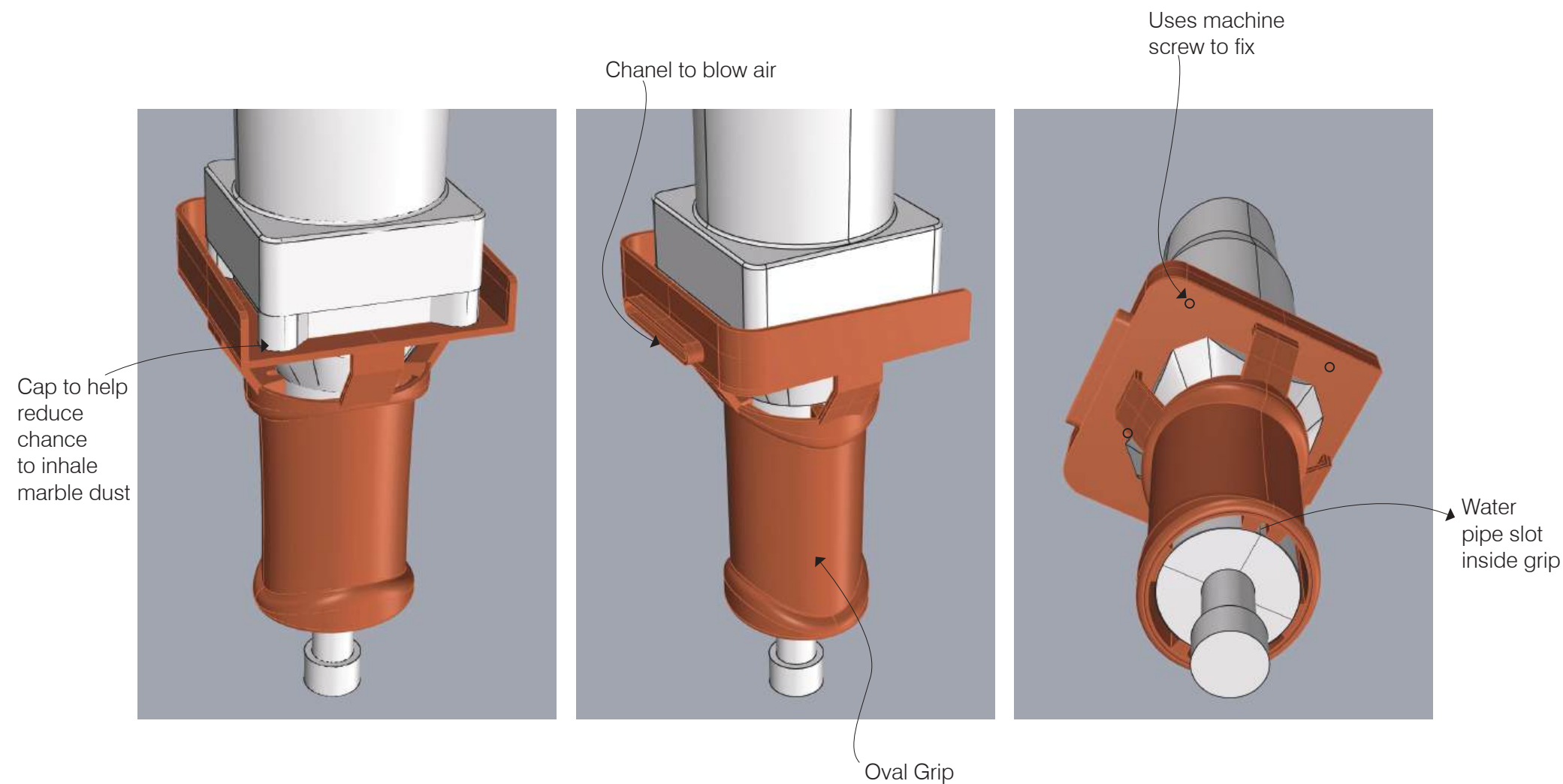


Fig 22.1: 3d Visual of Concept 02

23. User Testing - I

The mockups were user tested with 4 carvers at the Location 01(Santacruz west). Their inputs were recorded in order to update the design further.



Fig 23.1: User Testing At Location 01-Santacruz

23.1 Grip Selection



Fig 23.1.1: User Testing For Grips

	01	02	03	04	05	06
Grip Thickness	4	4	3	3	3	4
Grip Form	4	4	4	1	1	2
Touch Experience	3	3	3	2	1	3

23.2 Clamping

The extrusions on the attachment to fix side screws in order to clamp it to the machine, were coming in the way of the artisan while performing his tasks. He preferred more cleaner surface for better grip. Hence this detail was rejected.



Fig 23.2.1: User Test For Clamping By 2 Side Screws

The quick release lever on the attachment to clamp it to the machine, was coming in the way of the artisan while performing his tasks. Also the self weight of the lever was adding on to the weight of the machine. Hence this detail was rejected.



Fig 23.2.2: User Test For Clamping By Quick Release Lever

Using of the existing four screws to fix the attachment on the machine did not create any obstruction while holding the machine hence was approved. Also the attachment could be once fixed at the start and never removed later.

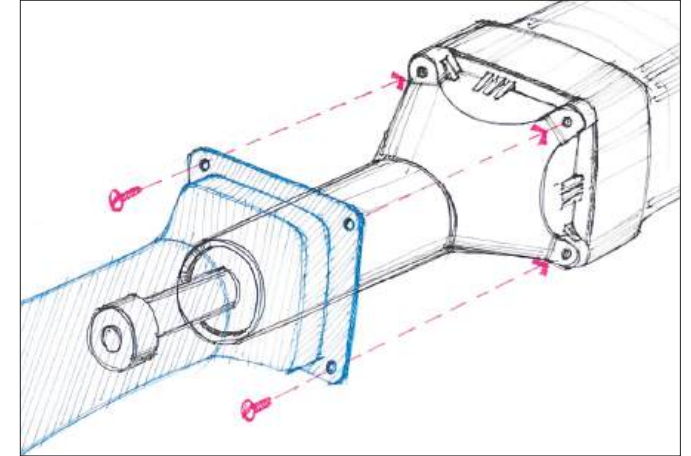


Fig 23.2.3: User Test For Clamping By Existing Screws

23.3 Dust Blowing



Fig 23.3.1: User Testing For Dust Blowing

It was observed that the idea to channelize the vent was successful. The cutout in the attachment at the top helped the user to get a sense of the location from where exactly the air is coming so he could clear dust effectively. It helped the user to aim at a desired location. Also a positive observation was that, as the cutout was on all 4 sides, the user never had to look for the opening. As the top was tightly fixed to the machine, it did not hamper the grip. The user found the openings to be smaller which could be made bigger.

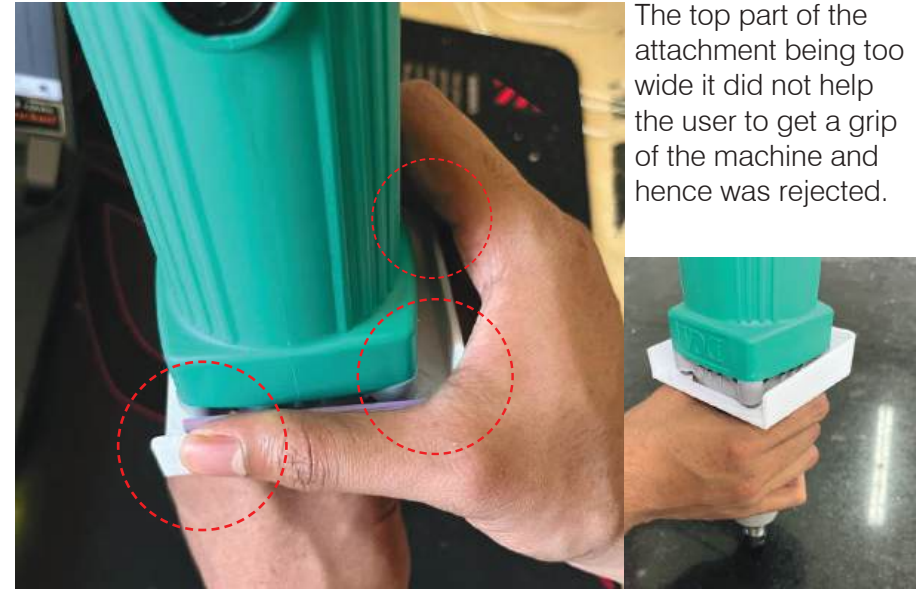


Fig 23.3.2: User Testing For Vent Diversion

The top part of the attachment being too wide it did not help the user to get a grip of the machine and hence was rejected.

23.4 Weight Supporter



Fig 23.4.1: User Testing For Wrist Support Strap

The first observation made was that the user was very much unknown to this strap concept, also he was not able to figure out how to wear it by himself. After explaining him how to fix it, he still was confused. After helping him to fix the strap on his right hand, the user experienced that the wrist support band was restricting his wrist movement and was very much uncomfortable while performing his task. Due to the constant change in the wrist movement, the support strap was loosening and not staying intact, which was killing the purpose of the strap. Hence this concept was rejected.

23.5 Water Pipe Connectivity



Fig 23.5.1: Pipe Fixing By User

It was observed that the user liked the idea of the water pipe being incorporated in the grip itself. He was unsure of how to fix the pipe at first, as the pipe goes inside in the grip area and gets fixed on the outer side at the top area. This led to some confusion, he preferred if the pipe fixing would be very straight forward. But after explaining the method he understood it.



Fig 23.5.2: User Testing For Water Pipe Connectivity

Observations were made that the clipping of the pipe at the top part of the grip helped the pipe to stay away from the hands of the user while working. As the exact location to fix the pipe in the inner of the grip was not made obvious, it created some confusion while fixing. Since the pipe was incorporated inside the grip, whenever the pipe had to be removed the entire attachment had to be unscrewed.



Fig 23.5.3: Observation For Bit Replacement

A problem related to fixing the pipe inside the attachment was observed. As in this case (above image) the user had to replace the bit as per the change in his task. In order to do that he had to detach the pipe that he had fixed via tape and once the bit was changed and fixed, he attached the pipe with a new tape. So it was understood that fixing the pipe inside the attachment was not an ideal way to clamp it, rather could be clamped externally so that it can be easily removed whenever required, keeping the attachment intact.

24. Revised Ideations

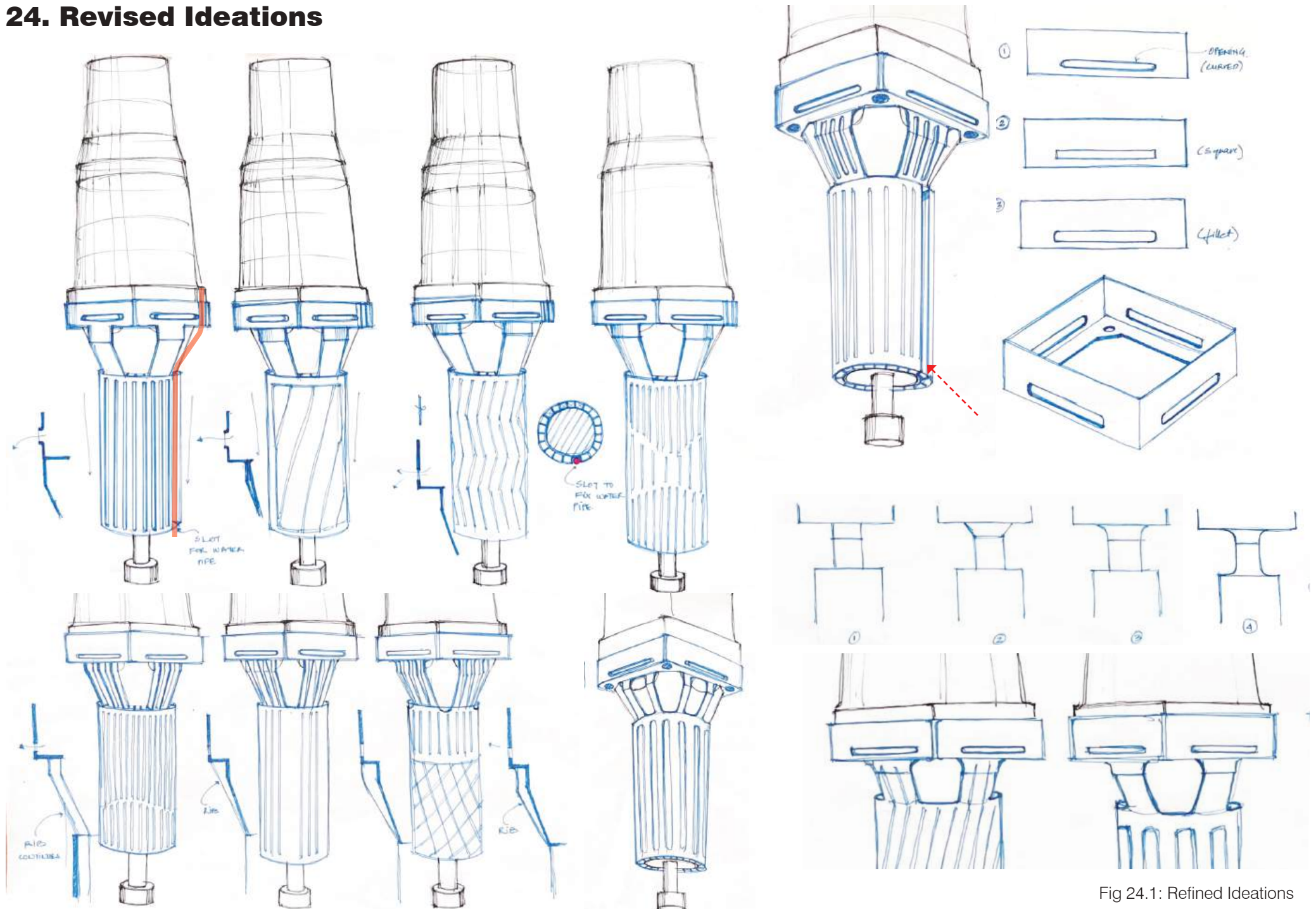


Fig 24.1: Refined Ideations

25. Revised Concept 01

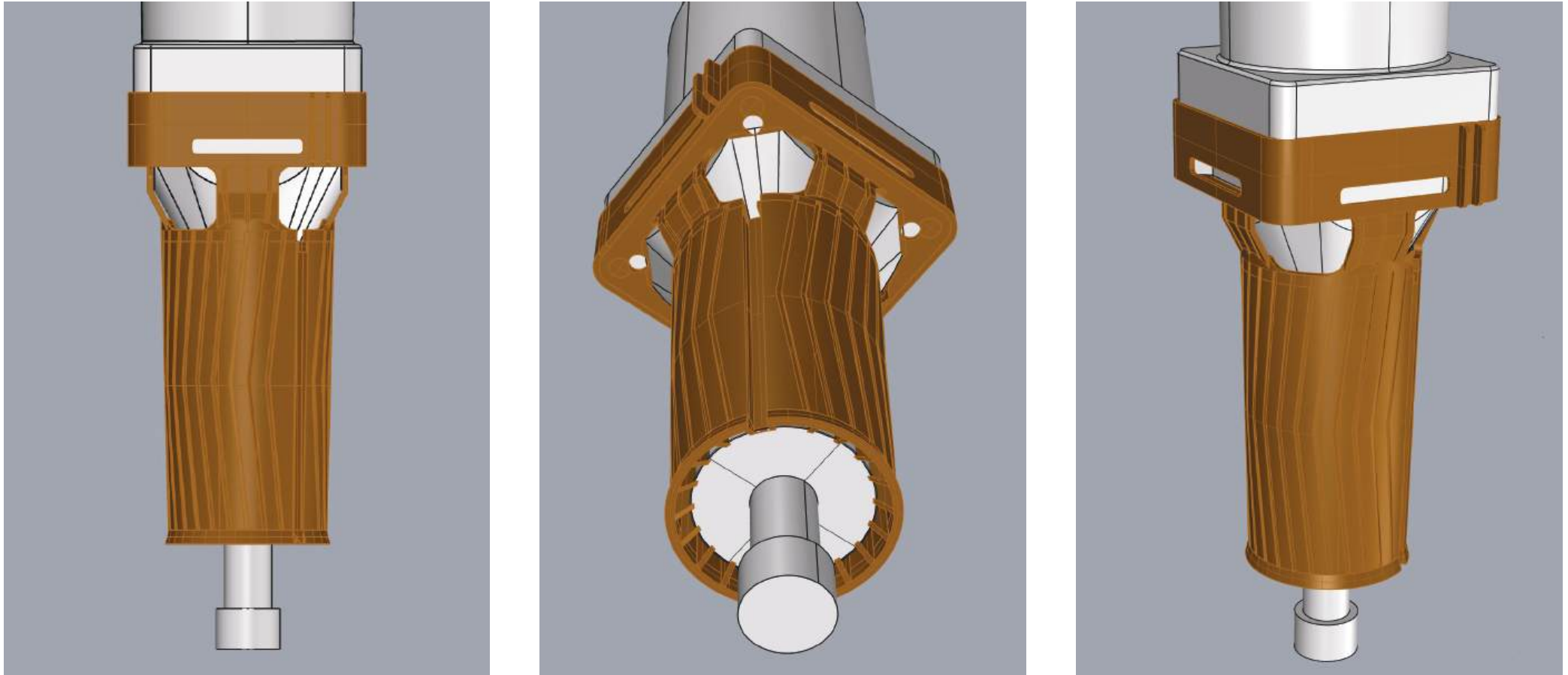


Fig 25.1: 3d Visuals For Revised Concept 01

Advantages:

- > More gripping area compared to concept 02
- > Fillet at the ends of four strips makes attachment more stronger
- > Does not hamper gripping

26. Revised Concept 02

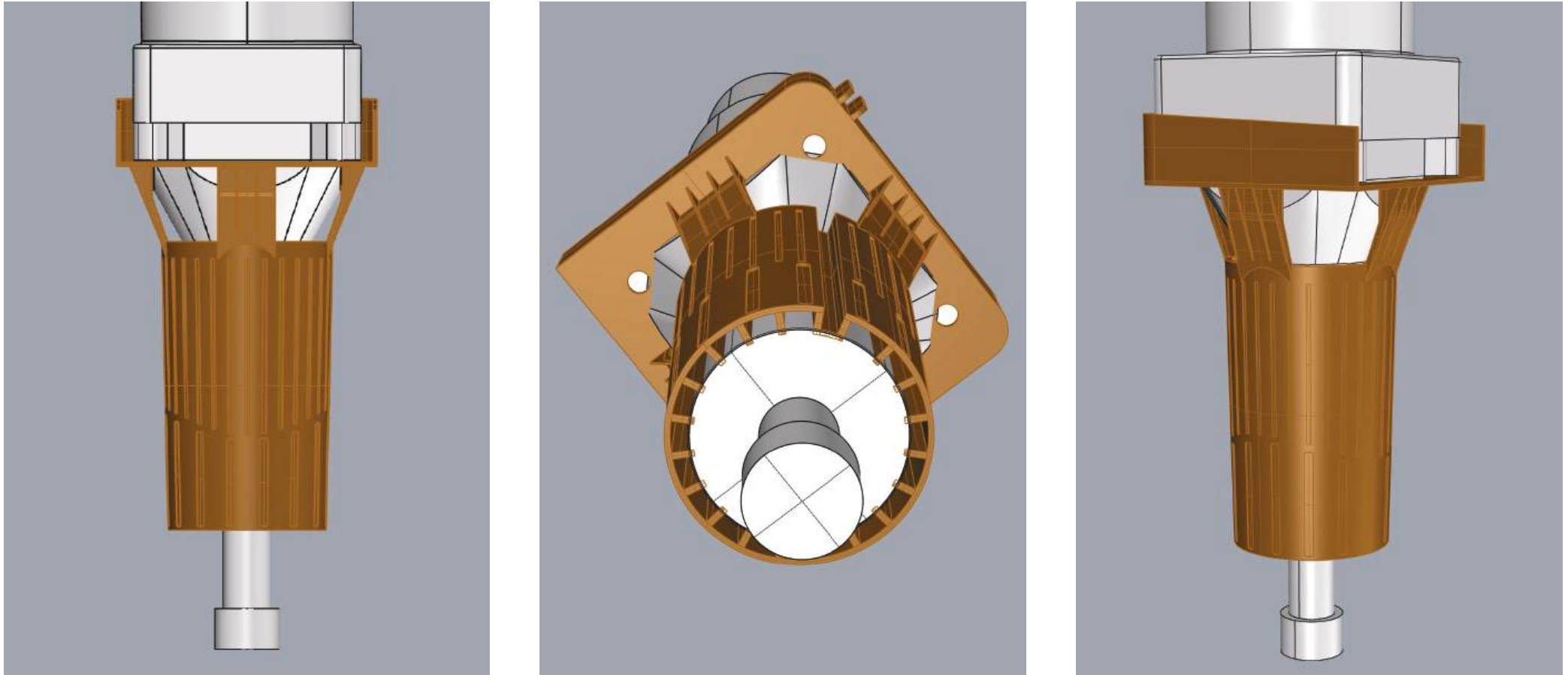


Fig 26.1: 3d Visuals For Revised Concept 02

Advantages:

- > Blow of dust more strong than concept 01
- > Light weight compared to concept 01
- > Ribs on four strips increasing its strength

27. User Testing - II

The mockups were user tested with carver at IDC, School Of Design. Their inputs were recorded in order to update the design further.



Fig 27.1: User Testing Round II At IDC

28. Evaluation

Concept 01

Water Connectivity:



Easy external fixing of water pipe

Air Flow Channeling:



Assisting dust blow effectively

Better Grip:



Attachment not hampering grip

Other Gripping Positions:



Fig 28.1: User Testing For Revised Concept 01

Observations:

- User preferred external fixing of water pipe over internal fixing.
- Anti-slipping pattern(verticle) and longer length helped user for better griping at various working angles.
- Verticle pattern also dose not allow dust to accumulate in the gaps.
- All 4-sides closed with vents slots preffered over one side open.
- Fillets in opt1 preferred as they did not hurt fingers.
- Connector between bottom part and the top part seemed week(in opt01)

Concept 02

Water Connectivity:



Easy external fixing of water pipe

Air Flow Channeling:



Assisting dust blow but not in some case allowing dust to hit face

Better Grip:



Attachment hampering grip to some extent

Other Gripping Positions:



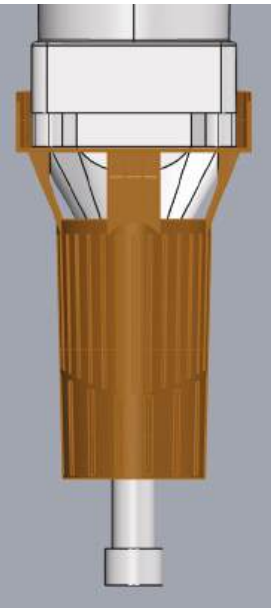
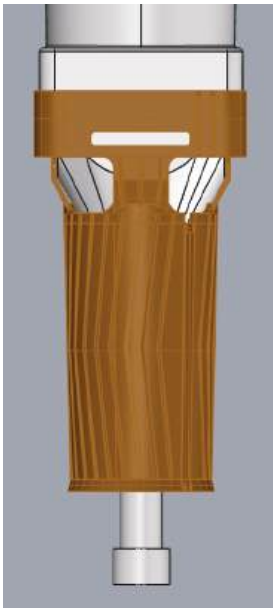
Fig 28.2: User Testing For Revised Concept 02

Observations:

- User preferred external fixing of water pipe over internal fixing.
- Pipe got dislocated by his own hands while changing the grip positions.
- Diverting vents towards one side did not help as it led dust to enter user's eyes (when faced towards him) while performing task.
- Every time the user had to search for the open side to blow away the dust.
- Ribs being straight it hurt the fingers.
- Slight awkward gripping on the top part.

28. Evaluation

Scoring on 5



Attachment’s Design Considerations

Water Pipe Connectivity	4	3
Dust Blow Efficiency	4	3
Grip Pattern	3	2
Grip Length	4	3
4 Connectors	3	3
Ligth Weight	3	4
Fillets/Curvatures	4	2
Robust Design	3	4

29. Final Concept

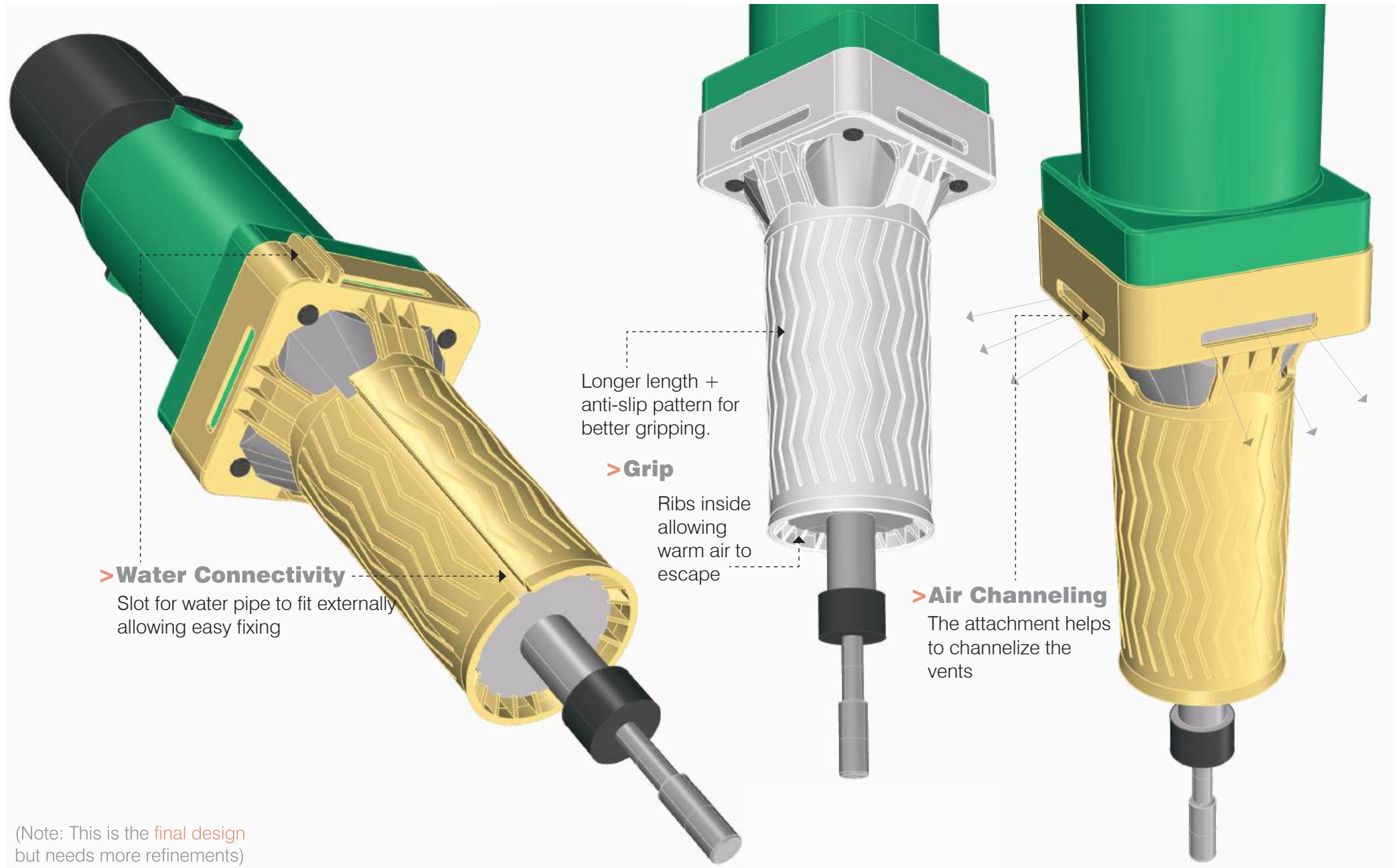


Fig 29.1: 3d Visual Of Final Selected Concept

30. Dimensional Drawing

Note: All the measurements are in mm.

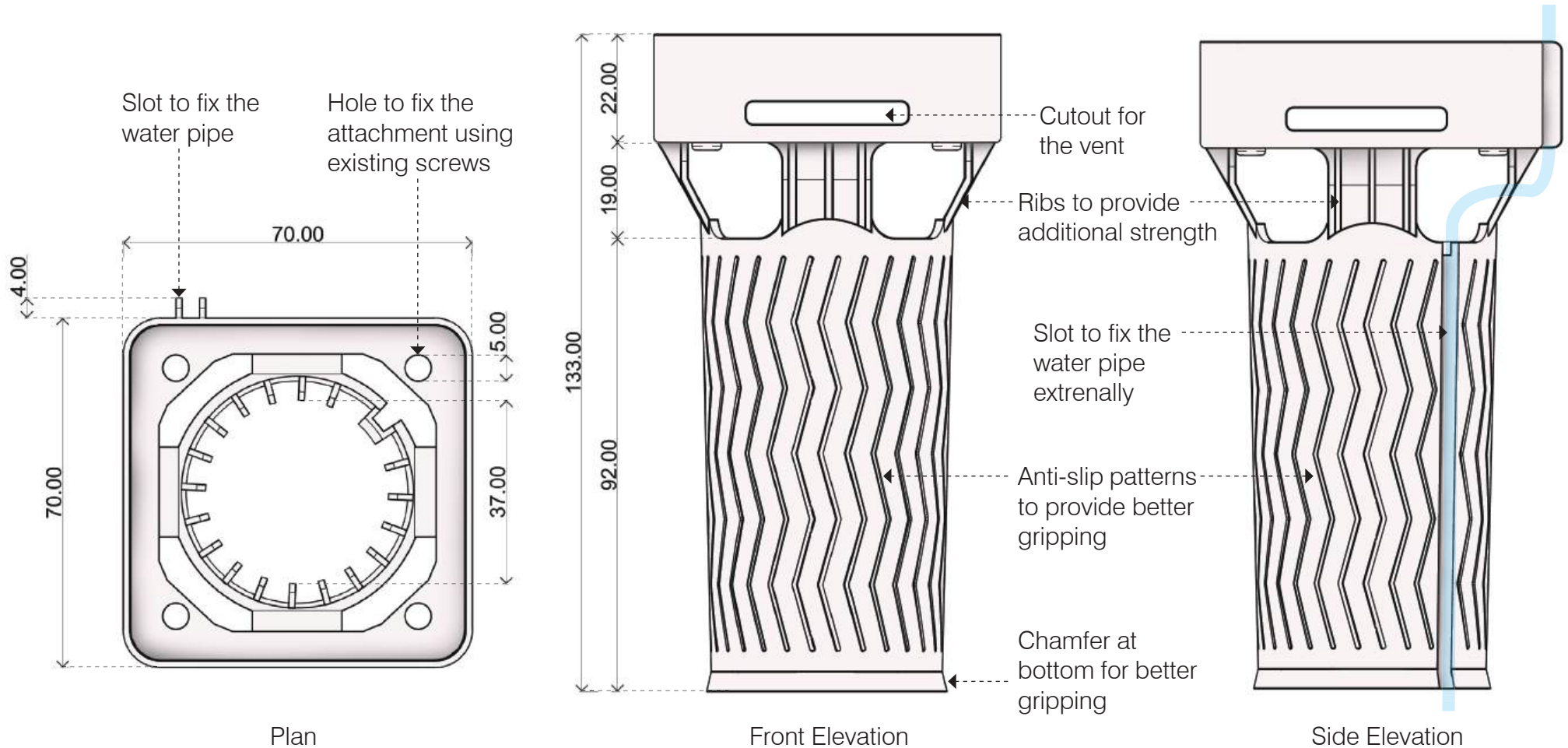


Fig 30.1: Measurement Drawing For Selected Concept

31. Material And Process

TPE:

Types:

TPV: Thermoplastic vulcanizates

TPU: Thermoplastic urethanes

TPO: Thermoplastic olefins

SBC: Styrenic block copolymers

COPE: Copolyester elastomer

PEBA: Polyether block amide

Eco friendly:

There are several reasons TPEs are a more eco-conscious option than thermoset materials like rubber or silicone. Thermoplastic itself means “the ability to be reprocessed by heat.” Because of this, scrap materials during the manufacturing process can be reused. Or, if a product is made incorrectly or needs to be adjusted during the prototyping phase, it can simply be heated again and reshaped, creating no waste. With thermoset materials like a rubber tire, the options are much more limited.

Light Weight:

Thermoplastic elastomers are also used to make products more lightweight. Because silicone will sink, TPEs are a better option if your application requires the material to float. Additionally, automotive parts and devices made from TPE make vehicles lighter and more fuel efficient. Glass or other heavier materials can be replaced with a lighter, TPE-made product so you can fit more inventory on delivery trucks. This reduction in weight allows trucks to move with greater fuel efficiency, and fewer trucks are needed on the road in general.

Properties:

- easily manufactured
- bonded to rigid polymers
- thermal resistance
- colored
- produced to a specific hardness, toughness or surface feel requirement
- recyclable
- chemical resistant or fire retardant
- noise and vibration dampening

Hardness:

One of the first things to consider is the necessary hardness for your application. The versatility of TPEs enables production along a full spectrum of hardness levels, from the consistency of a gummy bear to that of a bowling ball. Another important consideration is the surface feel and amount of friction. Some products call for a grippy surface, like the handle of a fishing pole. Others require a smooth, nearly frictionless feel, like a phone case that you want to easily slip in and out of your pocket.

Main Advantage:

TPEs are often chosen over similar materials like rubber or silicone for several reasons. One of the most commonly cited advantages of TPEs is the ability to produce products via high-volume injection molding, which is an extremely cost-effective process. This means a large volume of product (anywhere from tens of thousands to over a million units) can be created by heating the TPE blend and injecting it into a mold, where the TPEs cool and form the desired shape. Working with TPEs also gives you extensive design freedom, customization and color options.

TPU:

Thermoplastic polyurethane (TPU) is a melt-processable thermoplastic elastomer with high durability and flexibility.

TPU provides a large number of physical and chemical property combinations for the most demanding applications such as automotive, wires and cables, breathable films for leisure, sports and textile coatings, weatherable, non-yellowing films etc.

It has properties between the characteristics of plastic and rubber. Thanks to its thermoplastic nature, it has several benefits over other elastomers are unable to match, such as:

Excellent tensile strength, high elongation at break, and good load bearing capacity

This is a block copolymer with alternating hard and soft regions on its molecular backbone, containing urethane linkages. TPU is noted for its mid-to-high hardness, good clarity, moderate compression set, and good wear, abrasion, and tear resistance. It's suitable for outdoor applications and must be dried prior to molding.

Application:



Fig 31.1: TPU Material Applications

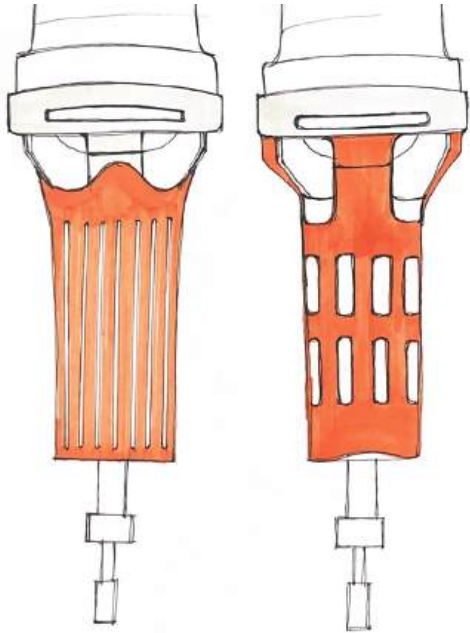
32. Rigs For Grip Material

Initial Trial 01:

Substrate-ABS, Overmolding Of TPU

Prob 01: Diameter gets thicker

Prob 02: Production gets expensive

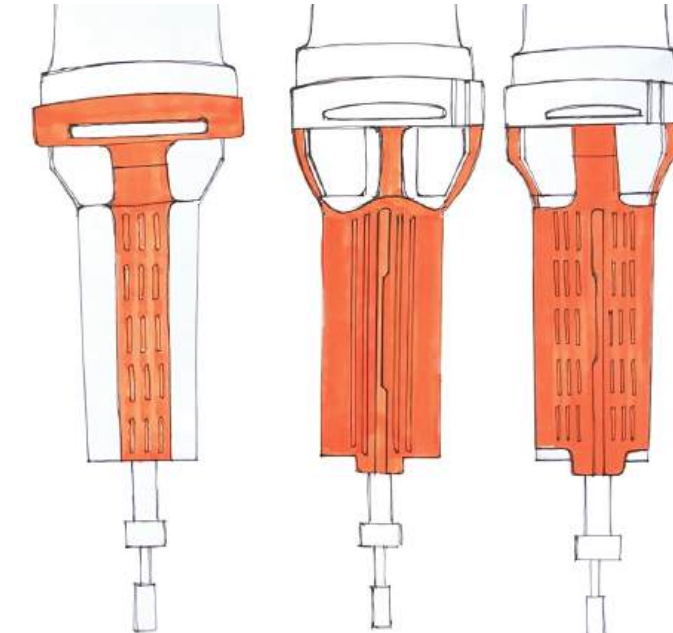


Later Trial 02:

2 parts- ABS and TPU fused with overlapping.

Prob 01: Can get weak at the connection point

Prob 02: Production gets expensive



Final Trial 03: SELECTED

Completely made of TPU

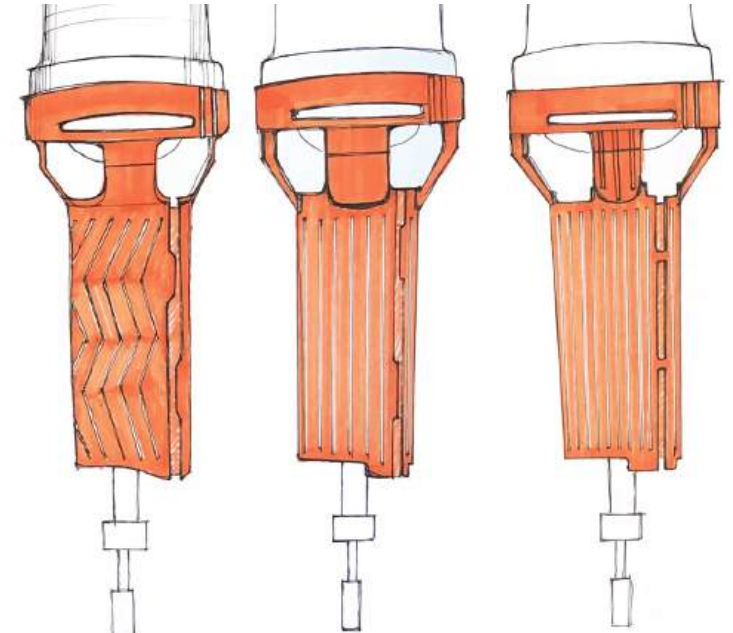


Fig 32.1: Rigs to Experiment Grips

33. Final Render

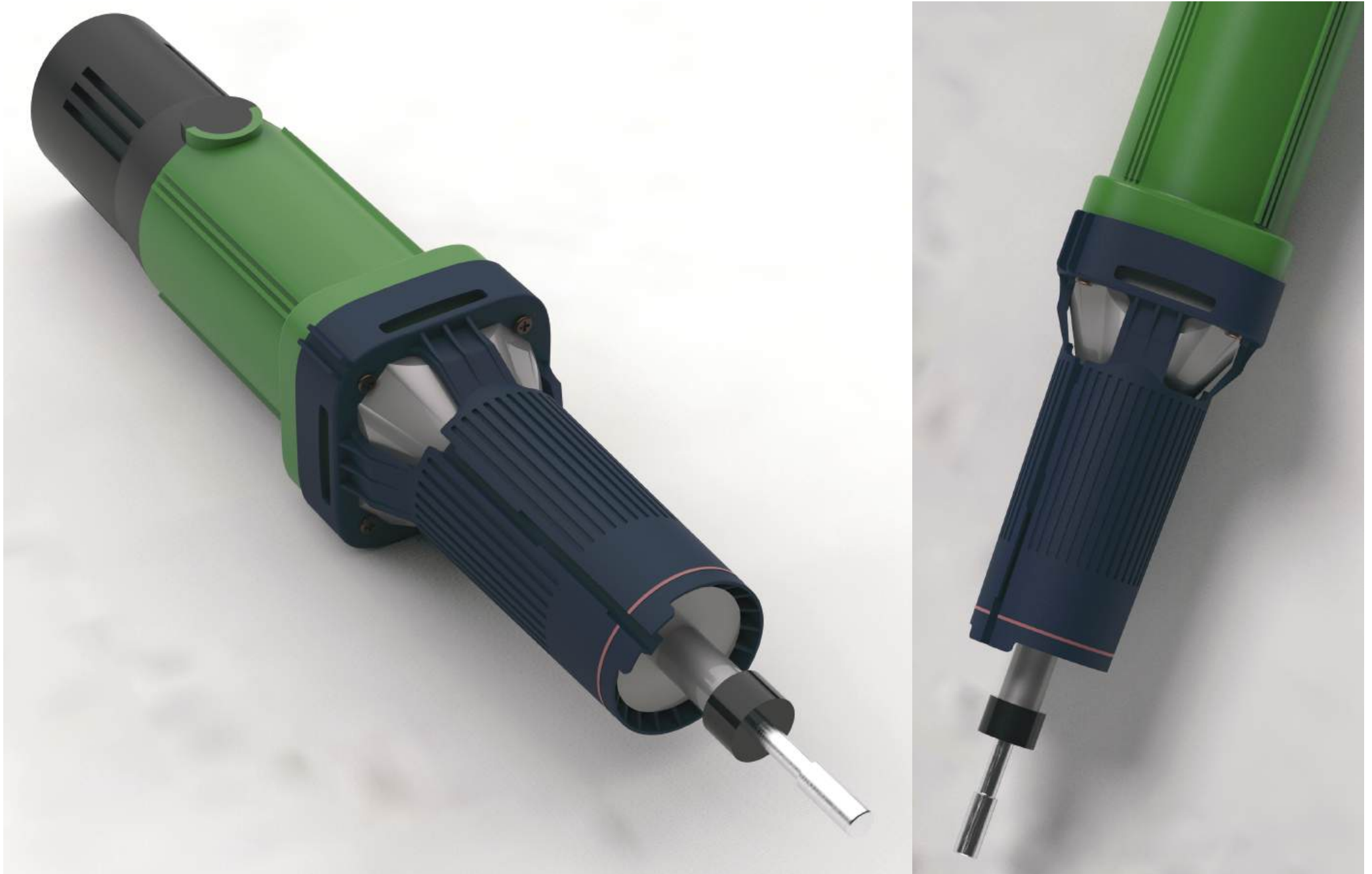


Fig 33.1: Final Rendered Visualizations
78

34. Final Prototype



35. Conclusions

Main object of the project was to redesign an attachment which deals with the the three major requirements of water connectivity to help cut hard stone as well as settle the marble dust at the source, efficiency in blowing of the dust away and lastly better gripping helping prolonged working ours with damping solution.\

It was challending to make sure the user accepts the attachment easily, and accepts it as a part of the machine. By user testing I did found out, this attachment was better than what customizations users had adopted.

This attachment could be further user tested across states in India for its functionality.

References

<https://www.ergonbike.com/en/product-details.html?a=griffe&anr=42440016&s=gd1>

<https://www.inclusivedesign toolkit.com/UCdex/dex.html>

<https://www.cleanskinmtb.com/ridgeline-lock-on-grips>

<https://www.hazards.org/workingworld/stonedead.htm>

<https://science.thewire.in/health/india-temple-builders-workers-silicosis-disease/>

<https://gaatha.org/Craft-of-India/research-marble-sculptures-making-craft-jaipur/>

<https://artsandculture.google.com/story/cAUhrXva9A6Jw>

<https://www.thestonestudio.in/stone-carving-in-odisha/>

<https://rajasthanstudio.com/>

<http://www.craftclustersofindia.in/>

<http://www.craftclustersofindia.in/site/index.aspx?Clid=280> http://www.india-crafts.com/stone_heritage_utar_pradesh/index.html

<https://omnexus.specialchem.com/selection-guide/thermoplastic-polyurethanes-tpu>

<https://www.avient.com/products/thermoplastic-elastomers>