

# DESIGN OF A TEA-LEAF PLUCKING AID

PRODUCT DESIGN PROJECT II

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2015



DEGREE PROJECT 2 REPORT

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Fig 1.1 - A tropical tea-tasting set  
[www.uscomex.com/assets/images/Tea.jpg](http://www.uscomex.com/assets/images/Tea.jpg)

## DECLARATION

I declare that this written submission represents my own ideas in my own words and where others ideas and words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all the principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission.

Student Signature:

Student Name : Gourab Saha

Roll No : 136130006

Date:

## APPROVAL SHEET

The project titled "Design of a Manual Tea-leaf plucking Aid" by Gourab Saha is approved for the partial fulfillment of the requirement for the degree of Master of Design in Product Design.

Guide:



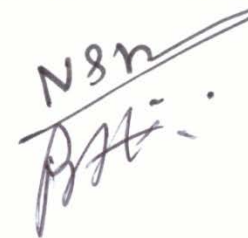
Co-Guide:



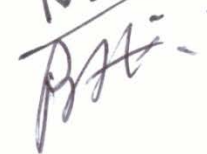
Chairman:



External Examiner:



Internal Examiner:



Date:

25/11/2014.

## ACKNOWLEDGEMENTS

The manual-tea plucking aid project materialised to this extent as a cumulative effort and guidance of Prof Purba Joshi & Prof. GG Ray.

I also take this opportunity to thank Mr. Gautam Saha & team for facilitating visits to tea-gardens in Darjeeling, Ms. Souravie Ghimiray for translation and interview assistance,

I am grateful to the entire Product Design faculty at IDC for their invaluable feedback, to my classmates for their support & to the Industrial Design Centre for giving me this opportunity.

1. INTRODUCTION
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3. SECONDARY RESEARCH
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11. FINAL DESIGN PROPOSAL
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## 1.0 PROJECT OVERVIEW

At present, India is the second largest producer of tea in the world & accounts for the employment of more than 2 million people \*. It occupies an important role in the Indian economy not only due to its capacity to earn foreign exchange, but also because it impacts the livelihoods of scores of people employed directly and indirectly by the industry.

At the bottom of the tea industry pyramid are the tea plantation workers, who are prone to various occupational hazards such as musculo-skeletal disorders or absorption of harmful alkaloids (sap-like chemical) into their skin. This project attempts to understand and address some of the core issues associated with hand-plucking of tea leaves.

The iterative industrial design process has been utilised in an effort to bring about a meaningful design intervention into the lives of tea-leaf pluckers.

### TEA ESTATE OVERVIEW

- Started close to 150 years ago ,spans an a total area of about 320 hectares, includes the plantations, factory , labour housing quarters (labour line) ,managers' bungalows, hospital ,primary school etc.
- Harvests 3 main categories of tea leaves, some planted up to 150 years ago:
  - 1.China Hybrid - Exclusive Darjeeling Tea , Export Quality
  - 2.Assam Hybrid - Tea for the masses
  - 3.Clones – various types
- Each specific type has different process parameters for manufacture.
- Plants approximately 2-3 hectares of new tea plants every year.
- The plantation is divided into various sections, each section spanning areas between 1-20 hectares. Each section has dedicated workers and their respective labour lines.
- Working shift commences at 7:30 am & ends at 4pm, with 2 breaks in between for rest ,lunch & weigh-ins.
- Each tea-plantation worker plucks an average of about 10 kgs of tea leaves per day. (This may be up to 30 kgs in plains).
- For every 10 kg of tea leaves plucked, only about 2.5 kg of useful product may be derived from it.
- Only the tender buds (2½ leaf rule) of the plants may be utilised for production.The peak production season is between May & September.
- Leaves are processed within 24 hours of plucking them ,to retain freshness

## 2.1 ORTHODOX TEA PROCESSING



Fig 1.5-A Typical Darjeeling Tea Estate



## 2.2 INTERVIEWS : TEA-LEAF PLUCKERS

### 1. Permanent Workers ( Approx 700 ) :

Along with wages receive the following benefits: Labourer housing ,primary schooling for children , estate hospital access,etc.

### 2. Temporary Workers ( Approx 300 ) :

Receives wages , upon recommendation may become permanent

### 3. Casual Workers ( Number Varies ) :

Are hired from the village-basti on an as required basis in peak seasons

\*Average daily wage per worker ( excluding benefits ) : Rs 95 approx.

## TYPICAL EQUIPMENT USED

1. Woven bamboo basket (Doko) : Rs 70 – 80 easily available in village

2. Fibre Rope (Nunglo): Rs 10 -20 , for propping up Doko

3. 1 pair gum-boots : Rs. 120 (Company Allowance)

4. Tarpaulin Cover : To wrap around waist (monsoons)

5. Umbrella: During monsoons

6. Thick fabric on scalp : To prevent abrasion on head

7. Cotton Gloves : Worn by a few pluckers

## A DAY IN THE LIFE OF A TEA PLANTATION WORKER

05:00 am Wake up , cook breakfast & lunch , Feed children

07:00 am Leave home, walk to assigned section

07:30 am Report to plantation section , shift starts

11:15 am 1st weigh-in , 20 minute rest period

12:00 pm Lunch break starts

12:30 pm Lunch break ends

02:00 pm 2nd weigh-in, Rest Period

04:00 pm 3rd weigh-in, Shift Ends

04:15 pm Arrive at home , Rest

05:00 pm Household chores : cleaning, washing ,cooking dinner

08:00 pm Dinner , Prepare for following day

09:00 pm Sleep

\*As narrated by Mrs. Indu Rai , June 2014



Fig 1.6-Mrs. Nikita Tamang

### WORKER PROFILE:

Name : Mrs. Nikita Tamang (Temporary)  
Age : 28 yrs Experience : 1 month

### DIFFICULTIES FACED:

- Pain in hands
- Joint pain in the knee
- Abrasion of fingers
- Discomfort in scalp
- Lower back pain

### ADDITIONAL INSIGHTS:

Chose this job because :

- Proximity from home
- Allows her to watch her kids
- Company benefits when permanent



Fig 1.7-Mrs. Indu Rai

### WORKER PROFILE:

Name : Indu Rai (Permanent worker)  
Age : 33yrs Experience : 4 yrs

### DIFFICULTIES FACED:

- Pain on hands
- Pain in the knees, thighs
- Abrasion of fingers
- Burning of Scalp
- Lower & upper back pain

### ADDITIONAL INSIGHTS:

- Black deposition on fingers that cannot be washed off.
- Alternate uses of doko include : collecting fire-wood for cooking, grass for goats etc, enclosure for chickens



Fig 1.8-Mrs. Shashikali Rai

### WORKER PROFILE:

Name : Shashikali Rai (Permanent worker)  
Age : 45yrs Experience : 13 yrs

### DIFFICULTIES FACED:

- Pain & stiffness on hands
- Pain & stiffness in the knees, thighs
- Abrasion of fingers
- Burning of Scalp
- Lower & upper back pain
- Regular Headaches & burning of eyes

### ADDITIONAL INSIGHTS:

- difficulties multiplied after the age of 40
- limited load-bearing capacity & mobility
- Stiffness in joints of the limb

## 2.2 INTERVIEWS : TEA-LEAF PLUCKERS



## 2.3 INTERVIEWS : MANAGEMENT

### ESTATE MEDICAL OFFICER : INTERVIEW

Common ailments that workers come to the estate hospital include :

#### 1. Musculo Skeletal Issues :

Joint and muscle pain usually on their back, hands and legs. This is due to the difficult terrain in hilly regions, poor posture and lack of exercise. Medication is prescribed for relief, however, this is a short term solution.

#### 2. Injuries:

Quite a few of these are from slipping and falling, whilst trying to manoeuvre through difficult hilly terrain. Most of these wounds are inflicted on their hands and legs.

#### 3. Costochondritis:

Upto 60% of the patients suffer from Costochondritis at some point-it is an acute and often temporary inflammation of the structure which connects each rib to the sternum. Costochondritis may be the result of physical trauma (due to direct injury, strenuous lifting, or severe bouts of coughing). Treatments include – rest and compression strapping.

### TOP MANAGEMENT : INTERVIEW

There has been a steady decline (close to 50%) in both the number of teaplantation workers & load bearing capacity over the last 10 years. This decline is due to various reasons , many prefer to work in different areas offering better wages. Many of the primary educated workers choose to migrate to cities to take up sales- rep jobs in malls etc. The wages have to be controlled in order to prevent tea prices in the market from escalating.

Tea plucking machines have been tested and successfully implemented in the plains , however , the difficult hilly terrain in Darjeeling has held up efficient full scale implementation. The machines have been brought in to cope with the steady decline in the number of workers. Although the tea harvesting machines increase the production rate ,there is a deterioration in quality. Labour unions have shown strong opposition to this mechanisation of tea harvesting.



Fig1.16- Interviewing

### MUSCULOSKELETAL ISSUES

- Hand fatigue , inflammation and stiffness – due to sustained contraction of muscles.
- Abrasion of fingers due to repetitive plucking motion.
- Upper and lower back pain due to poor working posture.
- Joint pain and stiffness in their legs due to long hours of standing & difficult terrain.

### INJURIES & AILMENTS

- Injuries from falling.
- Sickle injuries during pruning of tea bushes.
- Costochondritis
- Leeches, insect & snake bites.

### MECHANISED HARVESTING

- Existing machines are not manoeuvrable in hilly terrain.
- Existing machines come with their own set of issues-leaf quality etc.
- Strong opposition by labour union to replacement of workers by machines.

### LABOURER HOUSING

- Discomfort due to cramped spaces.
- Poor utilisation & planning of living spaces.

Fig1.17-Traumatised Fingers



## 2.5 DESIGN DIRECTION

After analysing the inferences from the initial field study , I decided to focus on issues related with manual tea-plucking.

Most of the tea-workers interviewed had reported musculoskeletal issues in their hands such as inflammation ,muscle pain, stiffness & injury to fingers – all associated directly to the activity of plucking.

Additionally , there seemed to be an underlying social issue associated with manual tea pluckers – their injured hands made them easily recognisable even when they weren't picking in the fields.

A design intervention to aid manual tea-plucking would tremendously affect their lives.

A) Manual Tea Plucking : Darjeeling  
Fig2.1-thumb101.shutterstock.com/



B) Razor Strapped Finger  
Fig2.2-www.hojotea.com



## 3.1 PARALLEL PRODUCTS – HAND PLUCKING

### HAND-PLUCKING OF LEAVES

#### TEA PLUCKING METHOD :

Hand plucking of tea , usually a 2 and a half leaf rule is observed .

#### EFFECT ON PRODUCTION RATE:

Full basket weighs 10 kgs , depending on the season a single worker may average upto 30 kgs per day.

#### QUALITY OF PLUCKED LEAVES:

With strict discipline and set standards, produces the best quality tea.

#### APPROXIMATE COST:

close to Rs 95 per day.

#### ADVANTAGES/DISADVANTAGES:

- Results in musculoskeletal issues in the hands, includes inflammation ,stiffness & fatigue due to repetitive actions performed and the sustained contraction of hand muscles.
- Causes injuries to palm and fingers – cuts ,abrasions ,leech bites.
- Results in black deposition on fingers
- Dynamic two-handed motion is recommended by ergonomists.

## 3.2 PARALLEL PRODUCTS – SHEAR PLUCKING

A) Tea Sparaes Enterprises : India  
Sinhals Tea Harvesting Shears

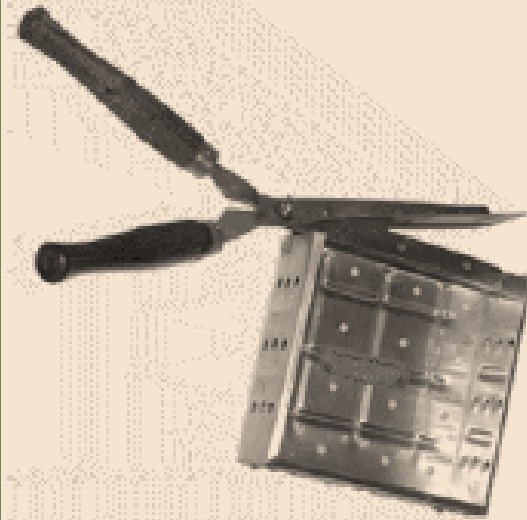


Fig2.3-www.teaspares.com

B) Taiwanese Tea Leaf Scissors



Fig2.4-culture.teldap.tw/culture

C) Falcon Garden Tools, Punjab , India:  
Tea Leaf Plucking Shears



Fig2.6-www.greenmylife.in

D) P.P.P. Jinadasa (Pvt) Ltd. ,Sri Lanka  
Selective Tea Harvester

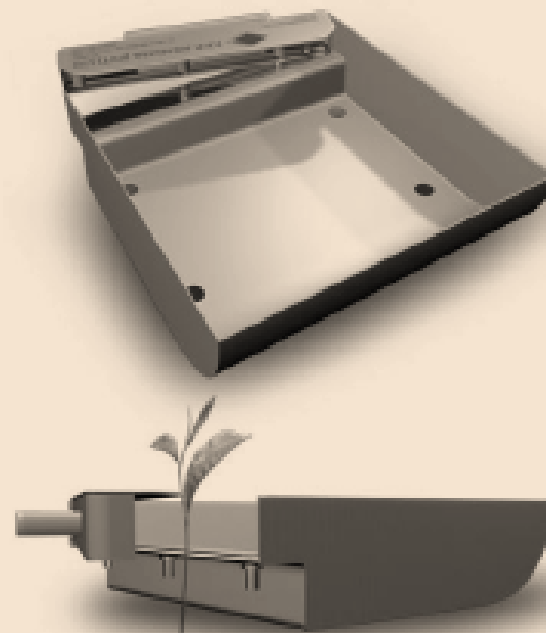


Fig2.5-www.tnmachinery.com

### SHEAR-TYPE PLUCKING

#### TEA PLUCKING METHOD :

These are hedge type clippers with a catcher-tray attached, where pluckers throw the contents of the tray over the shoulder into their back strap basket.

#### EFFECT ON PRODUCTION RATE:

Production rate is about 2-3 folds of hand picking.

#### QUALITY OF PLUCKED LEAVES:

It is difficult to control the standard of leaf, as the plucker is inclined to dip into the bush and remove immature shoots and maintenance leaf.

#### APPROXIMATE COST:

Is the daily wage of the manual plucker : May be close to Rs 100 per day + The cost of the shears.

#### ADVANTAGES/DISADVANTAGES:

- Easier than manual plucking , but continues to utilise a variety of motions from the shoulder to the fingers.
- Poor leaf quality.
- Relatively low initial and maintenance cost.
- Avoids injuries to palm and fingers – cuts ,abrasions ,leech bites etc.
- Catcher bags/trays get stuck onto the tea bushes.
- May cause shoulder & upper arm discomfort – due to weight bearing technique.
- Static loading on one hand causes fatigue on that hand.

### 3.3 PARALLEL PRODUCTS – HAND PLUCKING

A) Kawasaki (gasoline operated): One man plucking machines

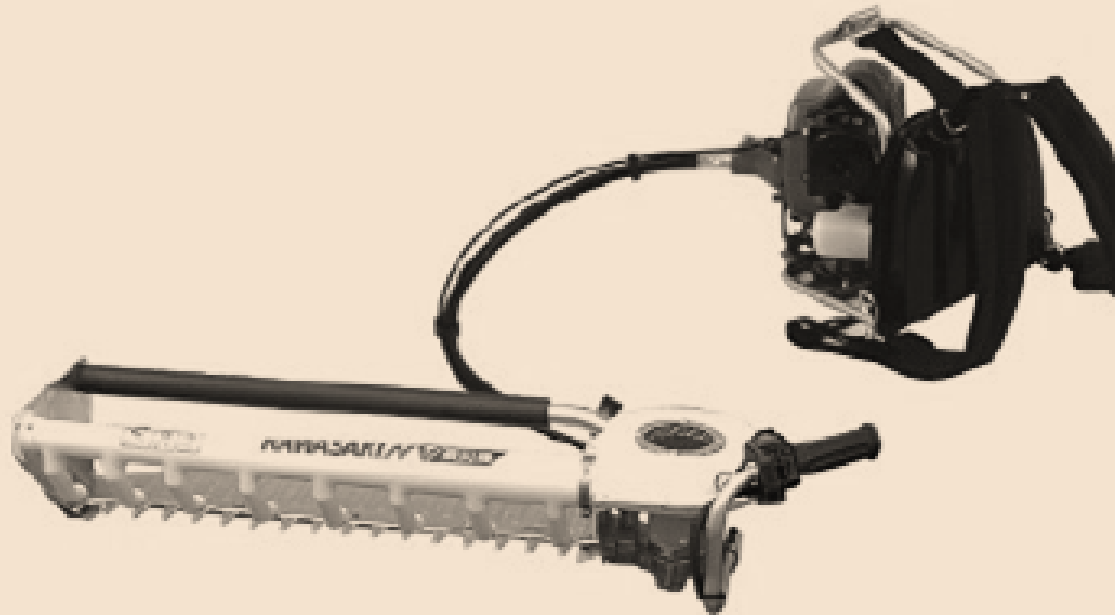


Fig2.7-[imgusr.tradekey.com](http://imgusr.tradekey.com)

B) Forbes & Walkers (battery operated) Tea Harvesting machine



Fig2.8-[www.chinathme.com](http://www.chinathme.com)

#### SINGLE PERSON MECHANISED TYPE

##### TEA PLUCKING METHOD :

These machines are either battery or petrol operated and feature a rotary or reciprocating blade arrangement with an attached collection bag.

##### EFFECT ON PRODUCTION RATE:

5-10 fold increase in production rate in comparison to manual hand plucking.

##### QUALITY OF PLUCKED LEAVES:

Poorer leaf standard is comparison to manual and shear plucking.

##### APPROXIMATE COST:

INR 1 lakh per piece

##### ADVANTAGES/DISADVANTAGES:

- Results in static loading on 1 leading hand .And consequently fatigue.
- Added weight of motor /engine in device.
- Can attribute to loss of 10 workers jobs.
- Poor leaf quality and high initial investments
- Maintenance cost is incurred
- Noise of running the machine.

### 3.3 PARALLEL PRODUCTS – MECHANISED TYPE

A) Kawasaki HI 40-DN (Straight Handle) 2 Men Plucking Machine  
Fig2.9-newcentury-japan.com



B) Willames Tea UL750 Selective Tea Harvester  
Fig2.10-www.cmeri.res.in



#### TWO PERSON MECHANISED TYPE

##### TEA PLUCKING METHOD :

These tea plucking machines are held by two people and harvest tea leaves while walking along side the tea bushes rows.

The tea leaves are harvested by hedge trimmer type reciprocating blades and are blown into the attached tea collecting container automatically

##### EFFECT ON PRODUCTION RATE:

15-20 fold increase in production rate in comparison to manual hand plucking.

##### QUALITY OF PLUCKED LEAVES:

Poorer leaf standard is comparison to manual and shear plucking.

##### APPROXIMATE COST:

INR 1.6 lakh per piece

##### ADVANTAGES/DISADVANTAGES:

- Load bearing method causes bending towards one side while using the product- this would result in fatigue and back issues due to unbalanced loading.
- Can attribute to loss of 15-20 workers jobs.
- Poor leaf quality and high initial investments.
- Maintenance cost is incurred.
- Heavy & difficult to manoeuvre.



### 3.3 PARALLEL PRODUCTS – MECHANISED TYPE

#### SELF-PROPELLED HARVESTORS

##### TEA PLUCKING METHOD :

These are generally diesel or gasoline powered machines that harvests tea by reciprocating or rotary blades over the tea bushes.

##### EFFECT ON PRODUCTION RATE:

40 fold increase in production rate in comparison to manual hand plucking.

##### QUALITY OF PLUCKED LEAVES:

Poorer leaf standard is comparison to manual and shear plucking.

##### APPROXIMATE COST:

Very High

##### ADVANTAGES/DISADVANTAGES:

- Can attribute to loss of 40 workers jobs.
- Poor leaf quality and high initial investments
- Maintenance cost is incurred.
- Requires plane land for use.
- Requires careful planning of gaps in field

#### MUSCULOSKELETAL ISSUES:

- Static Loading on hands results in fatigue.
- Incorrect load bearing posture such as side bending is not recommended.
- Unbalanced distribution of load on hands and body.

#### QUALITY OF PLUCKED LEAVES

There is substantial degradation in the standard of leaves harvested (in comparison to hand-plucking) using the machines to accommodate higher production rates.

#### PROBLEMS WITH USAGE:

- Catcher tray/bag gets stuck in the tree bushes.
- Machines & their accessories are heavy, bulky and difficult to carry.
- Machines are difficult manoeuvre in hilly terrain.
- Some machines require carefully planned paths.

#### HIGH INITIAL INVESTMENTS

- Apart from the shear-type harvesters, all other types cost upwards of Rs. 1 lakh.
- Large retail gap between categories.
- Regular maintenance of machines have an incurred cost.

#### LOSS OF JOBS

- Hundreds and thousands of house holds are dependant on manual tea plucking for their livelihoods.
- The increased use of tea-harvesting machines are replacing the jobs of upto 20 workers at a time.

### DESIGN OBJECTIVE

To design a device that is supportive to manual tea plucking. The device must minimise human injury and maintain high leaf standard.

### DESIGN BRIEF

The device shall adhere to the following check-points :

1. The device should alleviate musculoskeletal issues associated with manual tea plucking such as muscle & joint pain , inflammation & stiffness.
2. The aid must protect the tea-pluckers hands & fingers from injuries, abrasion , insect bites & deposition of harmful chemicals.
3. Use of the device to pluck tea should not diminish the quality of leaves plucked.
4. The device must be easy to manoeuvre & carry in difficult hilly terrain.
5. The device must be economical to produce.

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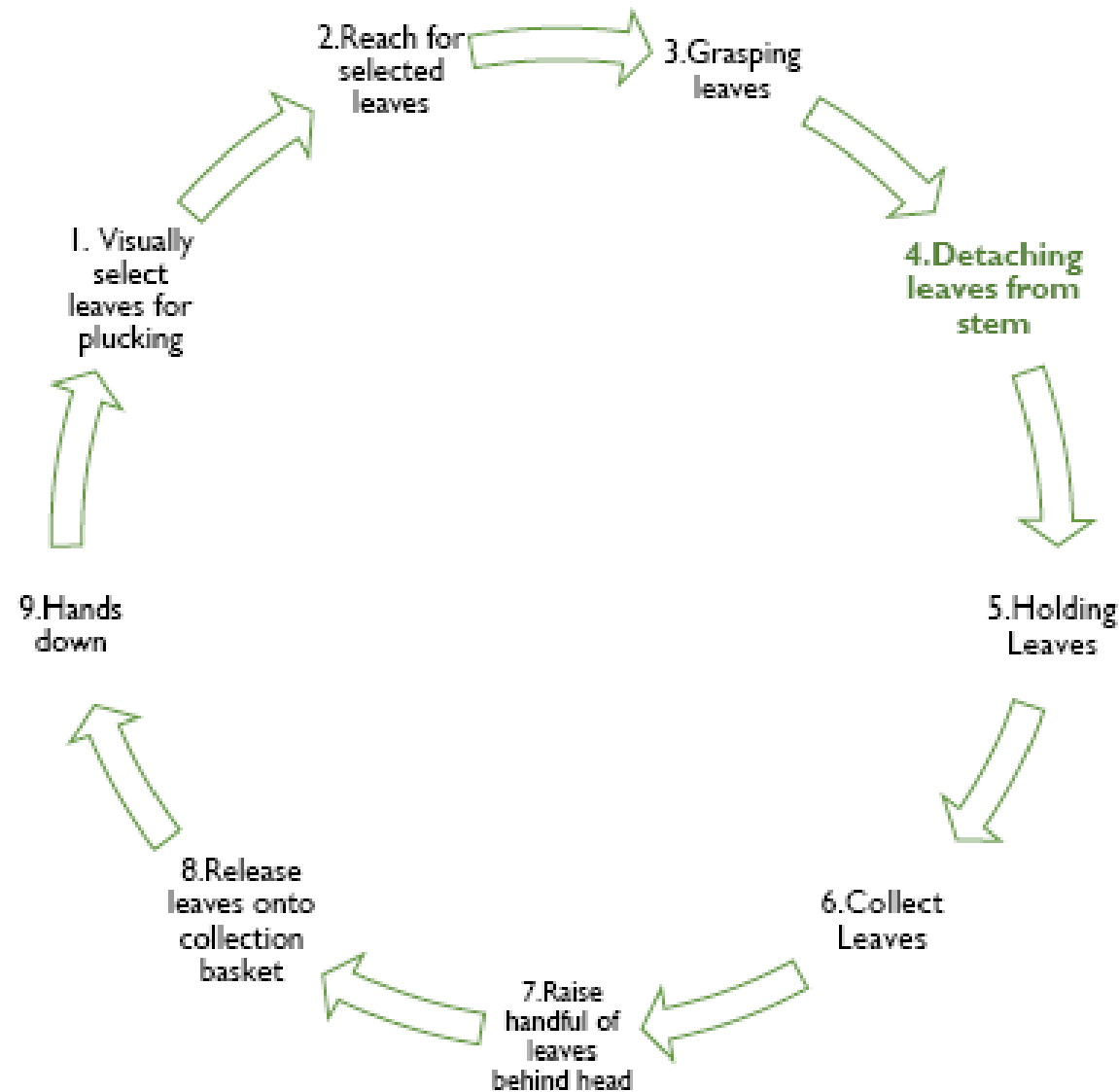
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## 5.0 ERGONOMIC CONSIDERATIONS



### ERGONOMICS APPROACH:

The activity of plucking may be divided into 2 types of motions:

- Whole body movements : Bending forward to reach etc.
- Hand Movements: Sequence of operations

Frame-by-frame time analysis of video footage of manual tea-plucking cycles would reveal interesting insight.

Determining the human limit associated with plucking will enable us to set a safe value for tearing force required to detach tea leaves from the stem. (30% recommended).

Data from previous literature combined with this new ergonomic data would provide a tangible scale to evaluate the products performance.

### PLAN FOR FIELD TESTING:

A strain gauge sensor (placed on the thumb tip) routed via amplifiers through a computer USB to software may be used to quantitatively measure the plucking force required to detach leaves using:

- Traditional hand-plucking
- Tea-plucking aid

Comparison of these 2 plucking forces with respect to time will enable us to predict the mechanical advantage gained from using the product (i.e. its effectiveness). The effect on muscular effort may be analysed on a qualitative basis by interviewing the test subjects.

## 5.1 MOTION ANALYSIS

Fig5.1



Fig5.2



Fig5.3



Fig5.4



Fig5.5



Fig5.6



Fig5.7



Fig5.8



## 5.1 MOTION ANALYSIS

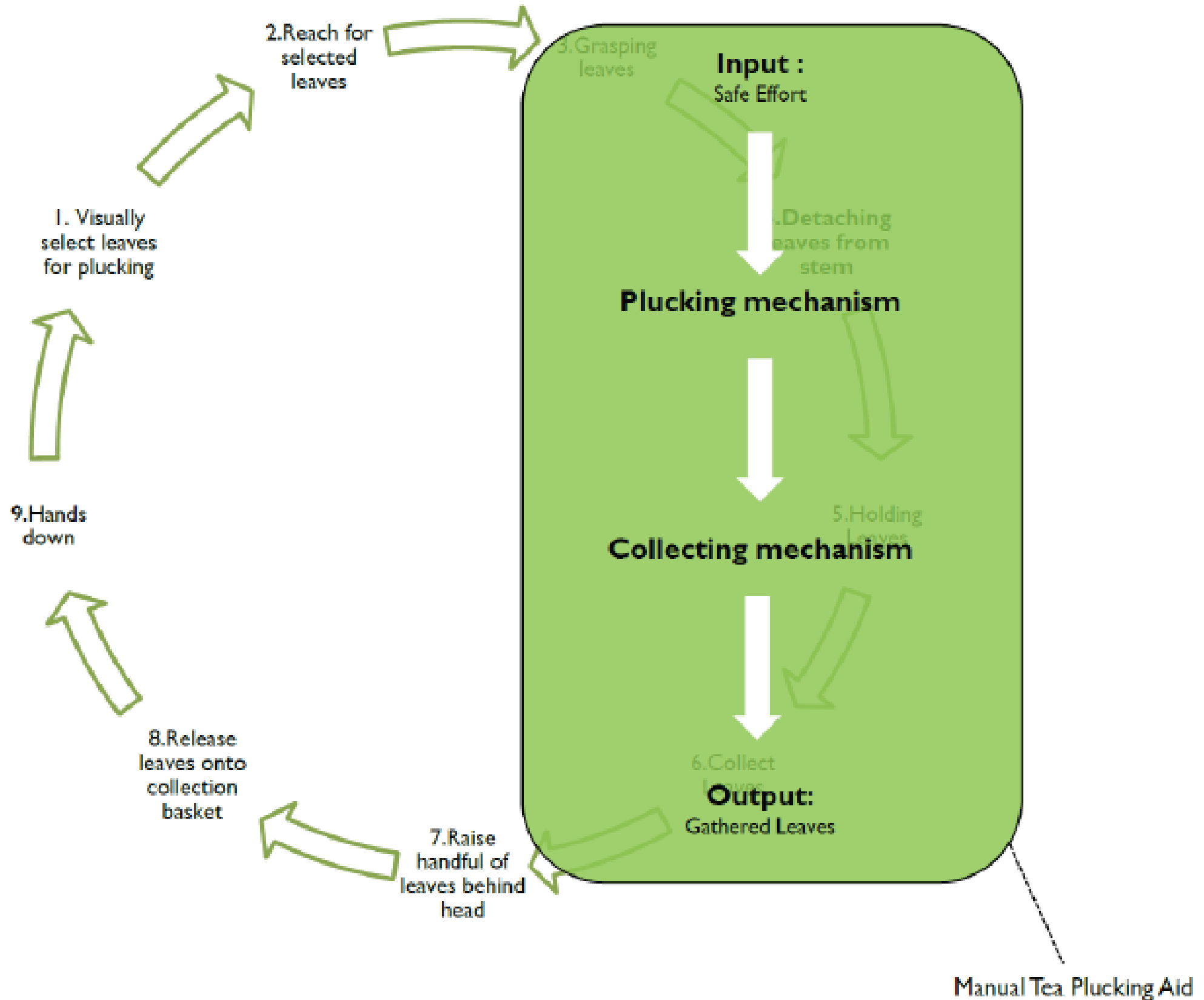


## 5.2 IDENTIFYING MOTION SEQUENCES

Scene	Right Hand Motion	Left Hand Motion	Midriff Motion
A1	Grasping, Pinching leaf stem	Reaching for leaves	Leaning forward,
A2	Twisting wrist ,Raising forearm	Grasping & pinching leaves	Leaning Back,LHS tilt
B1	Shuffling leaves :Index->ring finger	twisting wrist ,raising forearm	Neutral,RHS tilt
B2	Reaching for leaves	Shuffling fingers	Leaning forward
C1	Grasping, Pinching leaf stem	Reaching for leaves	Leaning forward,
C2	Twisting wrist ,Raising forearm	Grasping & pinching leaves	Leaning Back,LHS tilt
D1	Shuffling leaves :Index->ring finger	twisting wrist ,raising forearm	Neutral,RHS tilt
D2	Reaching for leaves	Shuffling fingers	Leaning forward
F1	Twist wrist outwards	Mean Position	LHS tilt
F2	Raising Forearm	Mean Position	LHS tilt
G1	Rolling shoulder back,compressing elbow	Mean Position	LHS tilt ,Leaning Back
G2	Shoulder limit , elbow fully compressed	Mean Position	LHS tilt ,Leaning Back
G3	Bend wrist ,release finger grip	Mean Position	LHS tilt,leaning forward
H1	Lower shoulder ,extend elbow	Mean Position	Neutral
H2-H3	Mean Position	Reaching for leaves	Neutral

Plucking Action	Shoulder Joint	Elbow	Wrist	Fingers
Reaching for leaf	Extends , orients	Extends	Orients	Unclassed , extended
Grasping & Pinching Leaves	Rigid in position	Extended	Oriented	Clasped ,Thumb-index pinching
Twisting Stem to detach	Rigid in position	Radial Displacement	Twists towards body (CW)	Tightly clasped
Shuffling Leaves:Collecting	Loosens Up	Perpendicular to shoulder	Untwists ,relaxes	Slides across to collect leaf
Raising to Basket	Shoulder Joint	Elbow	Wrist	Fingers
Hands full of leaves	Rigid	Rotates	Facing Upwards	Clasped
Raising leaves to basket	Rotates to maximum	compresses	Bends ,orients	Unclassing
Lowering	Rotates back to mean	extends	re-orients	Unclassed

### 5.3 IDENTIFYING KEY COMPONENTS



**ERGONOMIC ISSUES**

**1.Plucking of Leaves:**

- a) Repetitive Strain Injury
- b) Fatigue
- c) Inflammation

**2.Collecting Leaves in hand:**

- Sustained contraction of muscles

**3.Environment:**

- a) Absorption of Alkaloids & pesticides
- b) Insect & snake bites

**DESIGN INSIGHTS :**

**1.Plucking Component**

- Effort distributed over more muscles is advisable.
- Dynamic 2 handed plucking motion is recommended.
- Eliminating unnecessary motions will reduce the effort ,time required.

**2.Collecting Component**

- Should not get caught in the tea bushes
- Should not obstruct device from plucking
- Avoid

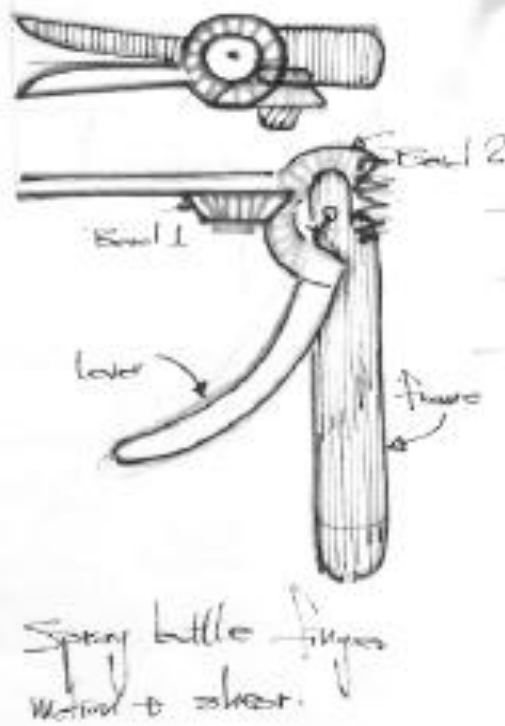
**3.Protective Component**

- Product weight <1 kg per hand
- Must allow for air circulation.
- Protect fingers to elbow.



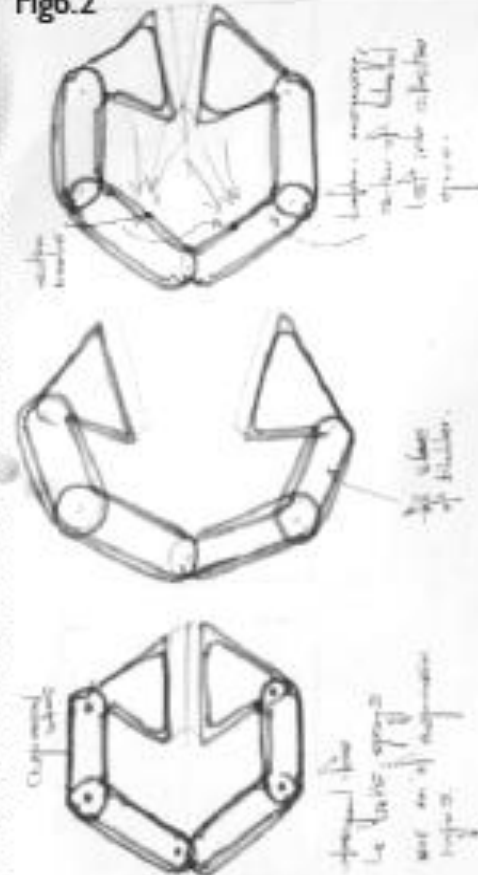
# 6.1 IDEATION – MECHANICAL ASSIST TYPE

Fig6.1



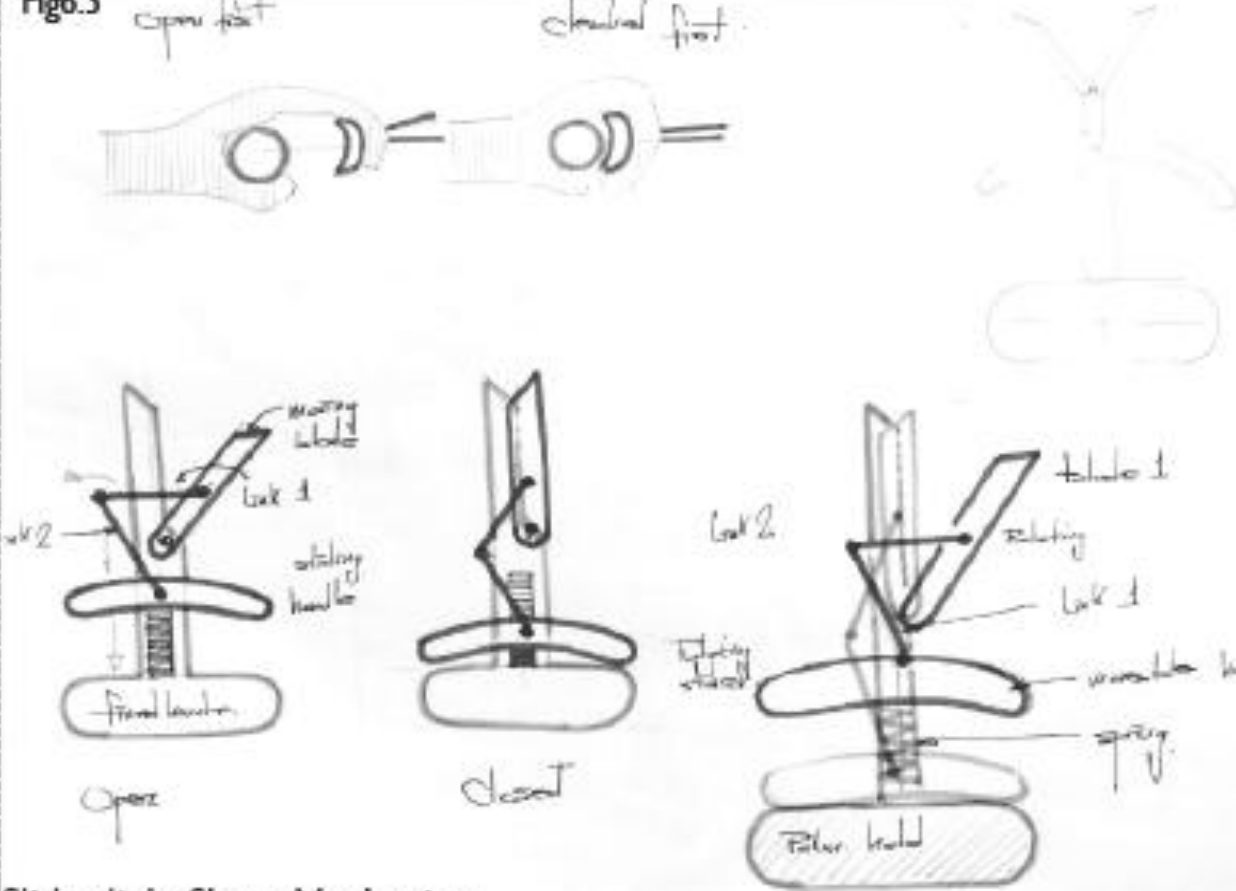
Trigger Shear Mechanism

Fig6.2



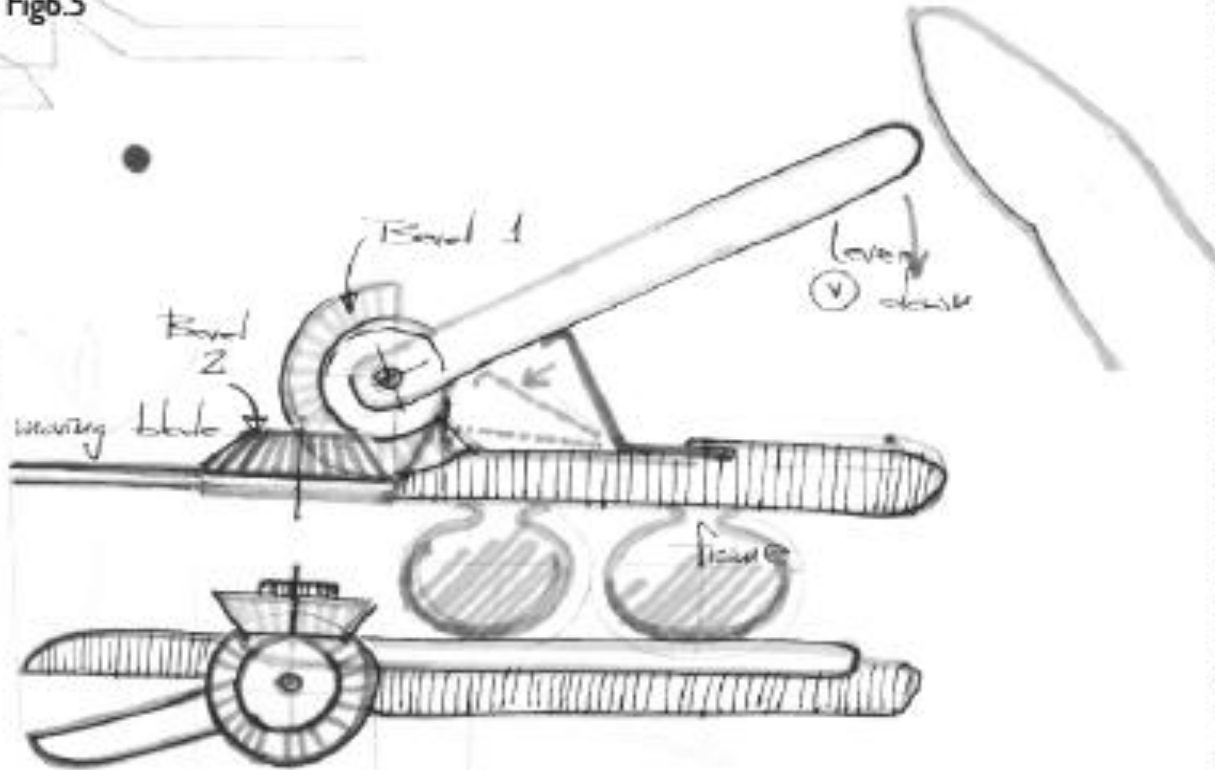
Compressed Bladder Mech.

Fig6.3



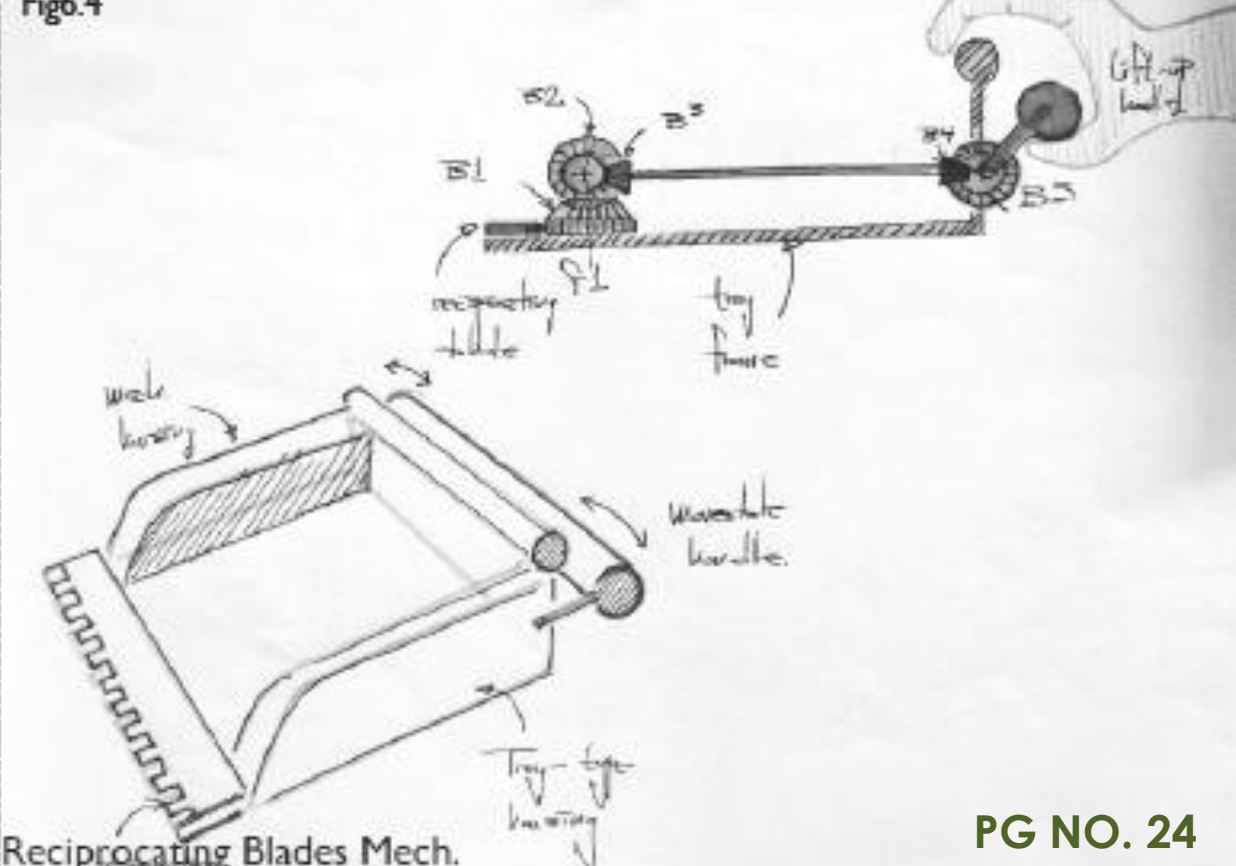
Slider link-Shear Mechanism

Fig6.5



Thumb Tapping Shear Mech.

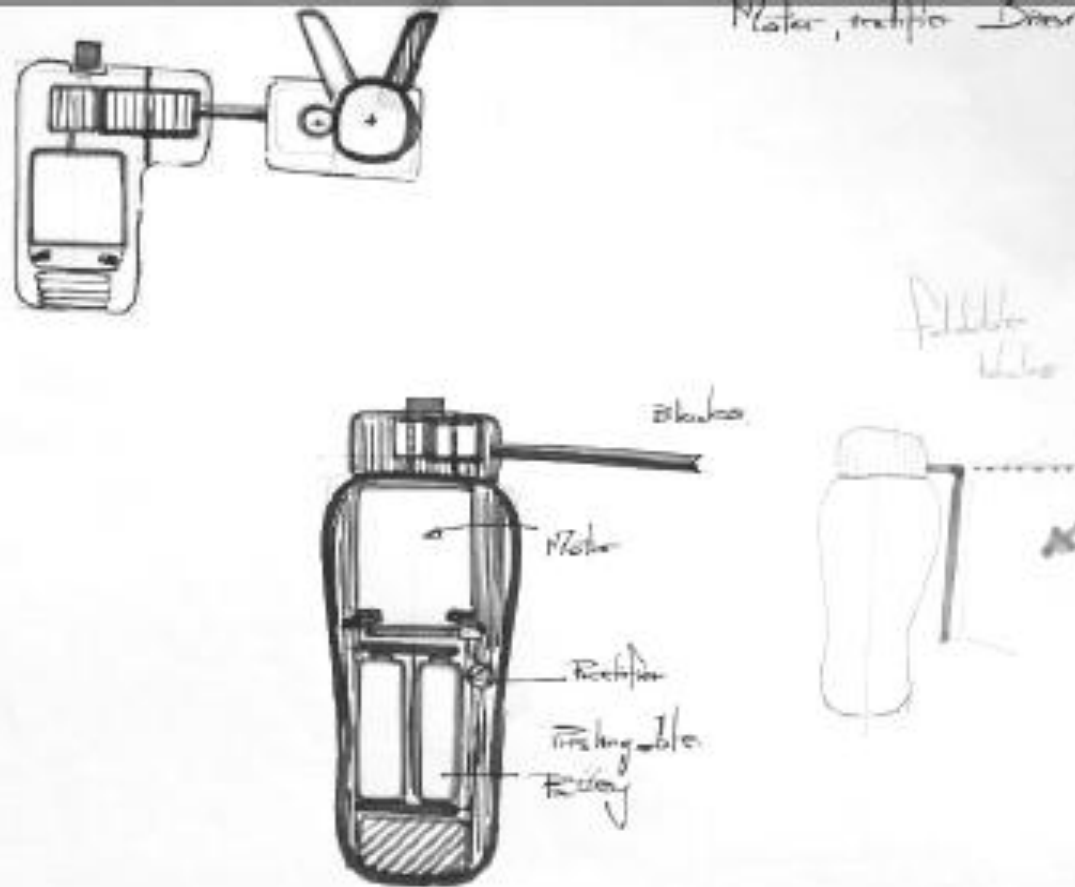
Fig6.4



Reciprocating Blades Mech.

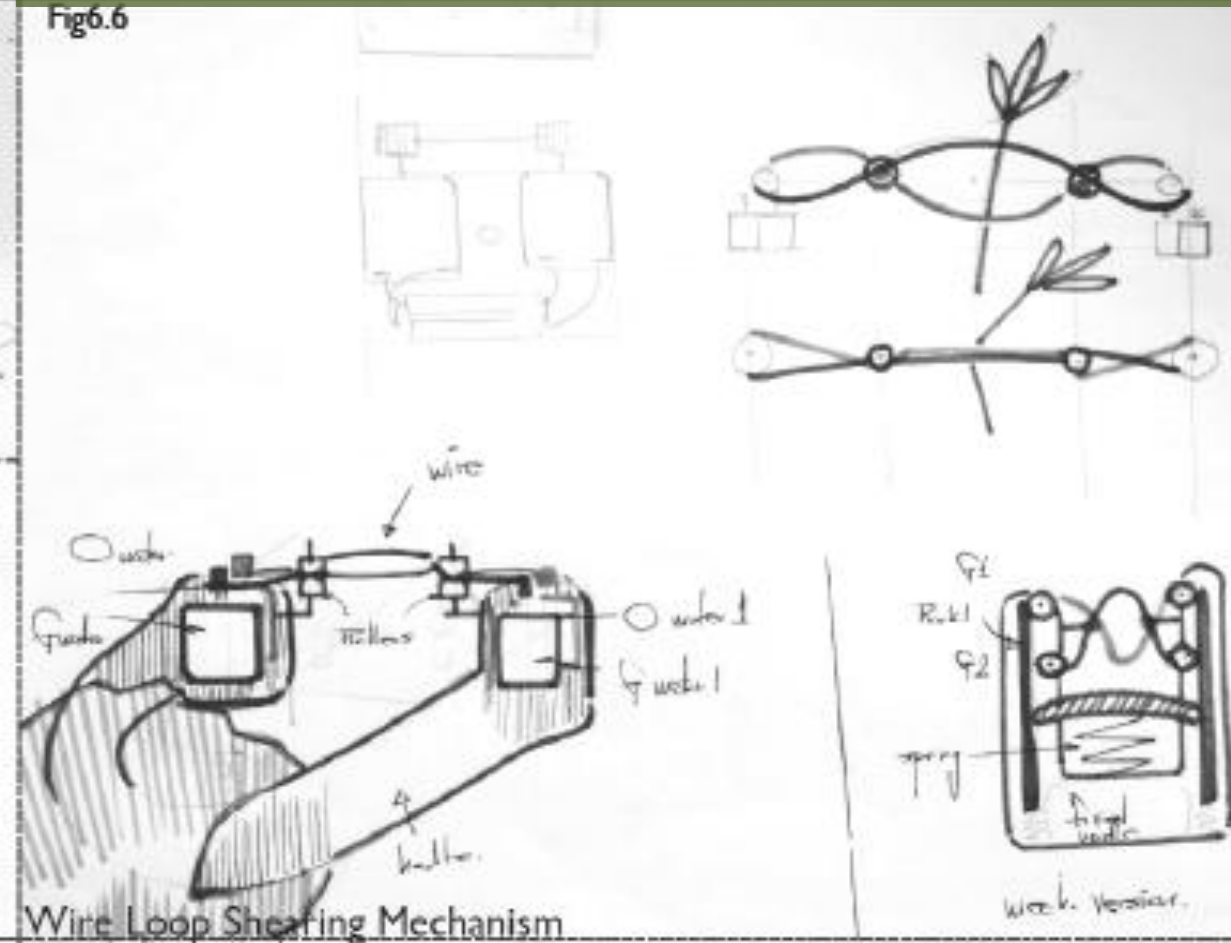
6.2 IDEATION : ELECTRICALLY ASSISTED TYPE

Fig6.5



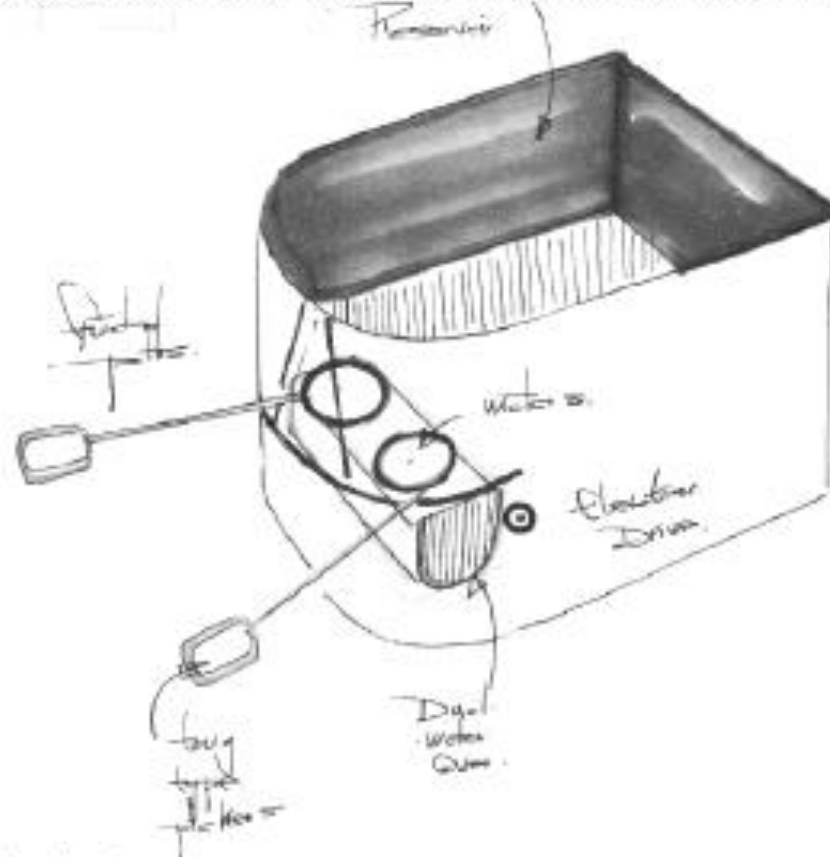
Vertical Axis Electric Shear

Fig6.6



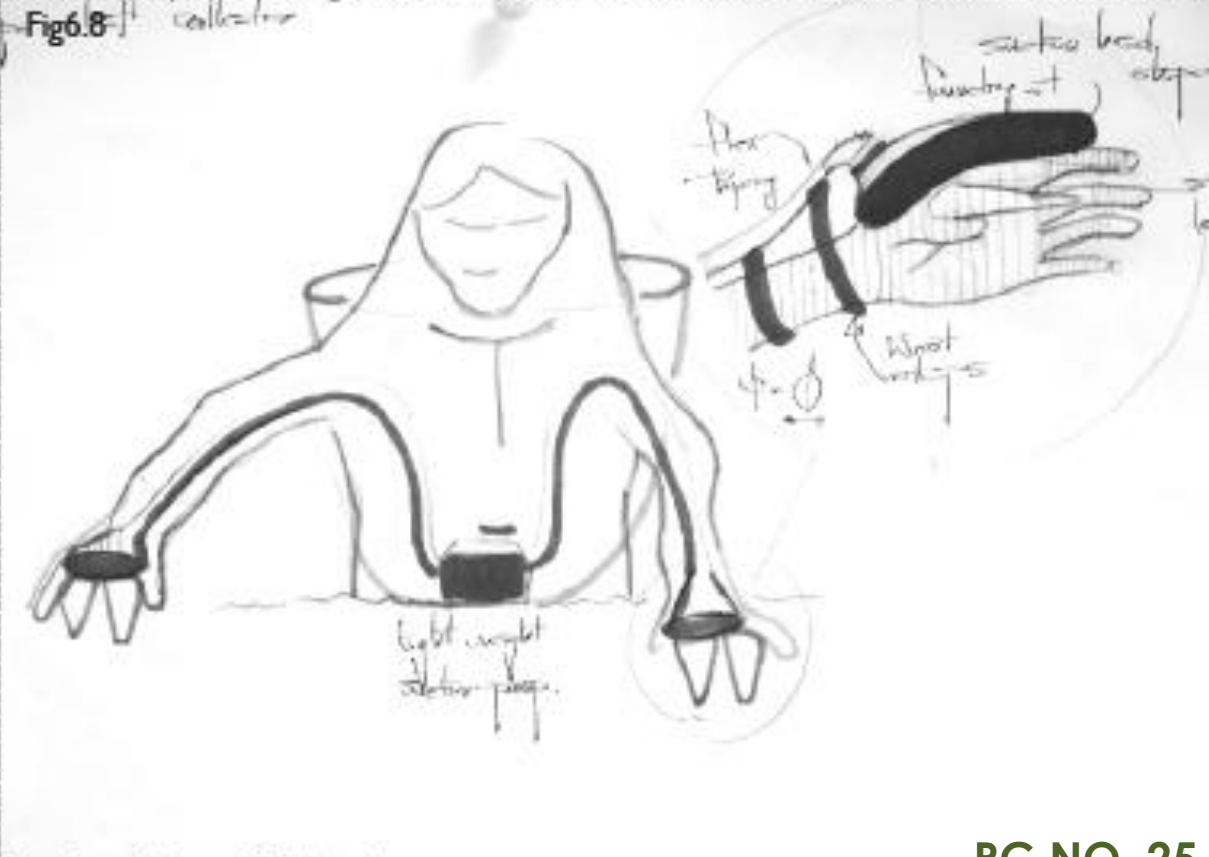
Wire Loop Shearing Mechanism

Fig6.7



Pick & Place Mechanism

Fig6.8



Suction Pump Collection

6.3 IDEATION : SPRING LOADED TYPE

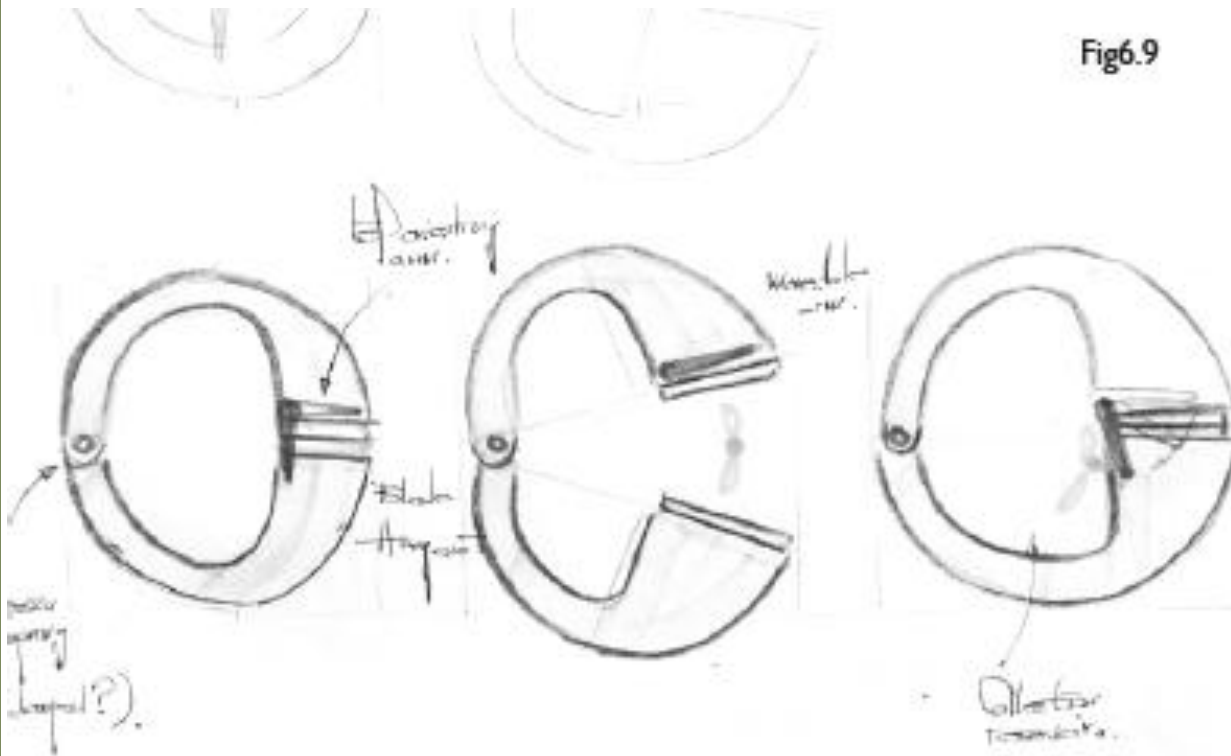


Fig6.9

Hinged Shears – Moving arm Collector

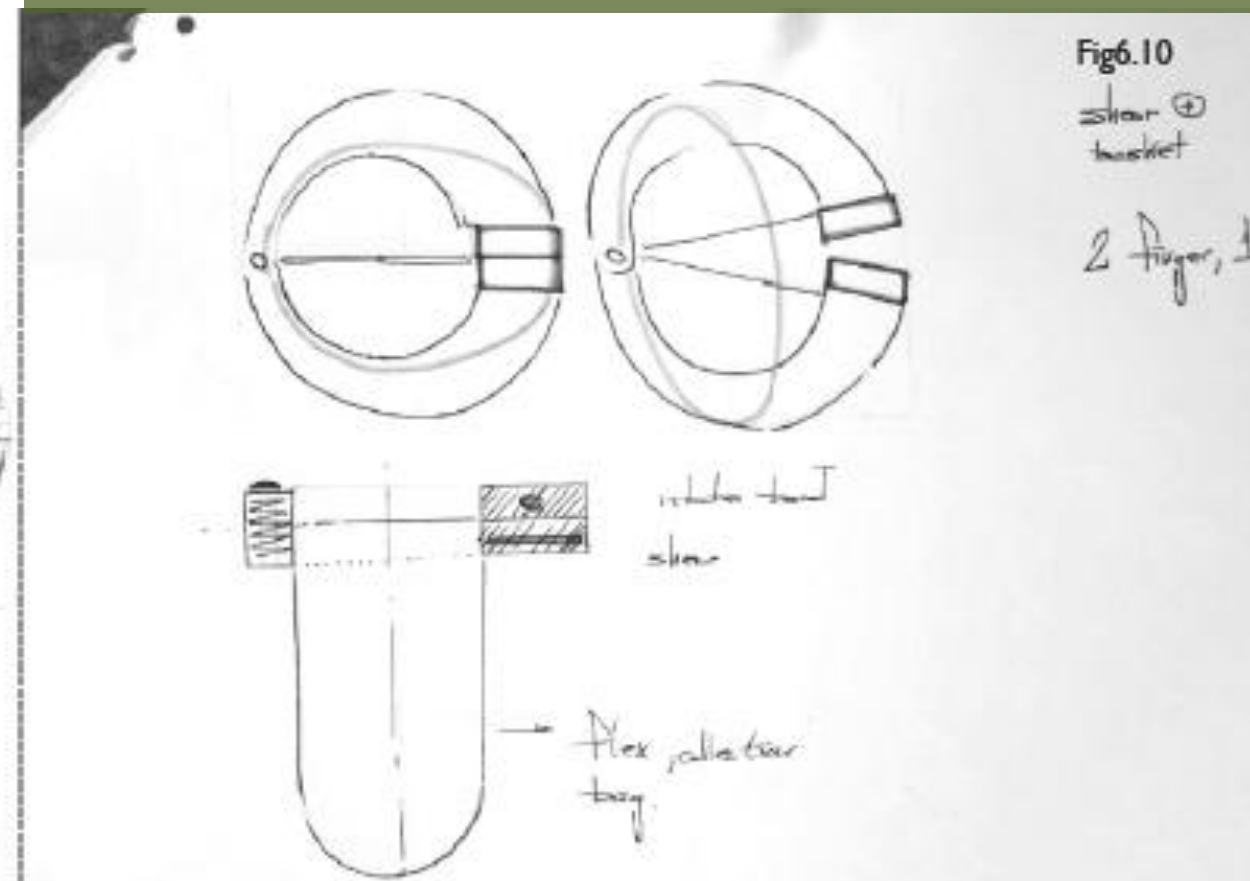


Fig6.10

Hinged Shears – Band Collector

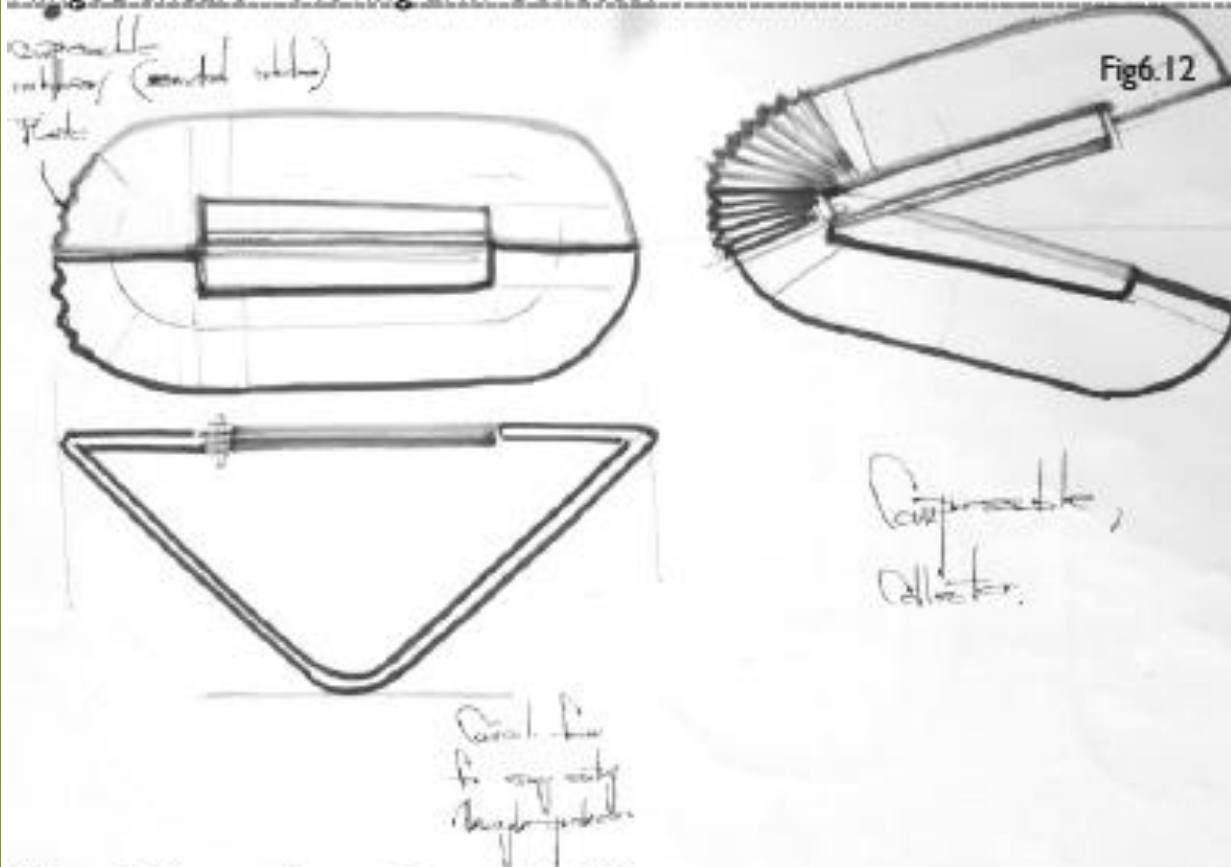


Fig6.12

Hinged Shears -Locus Contour Collector

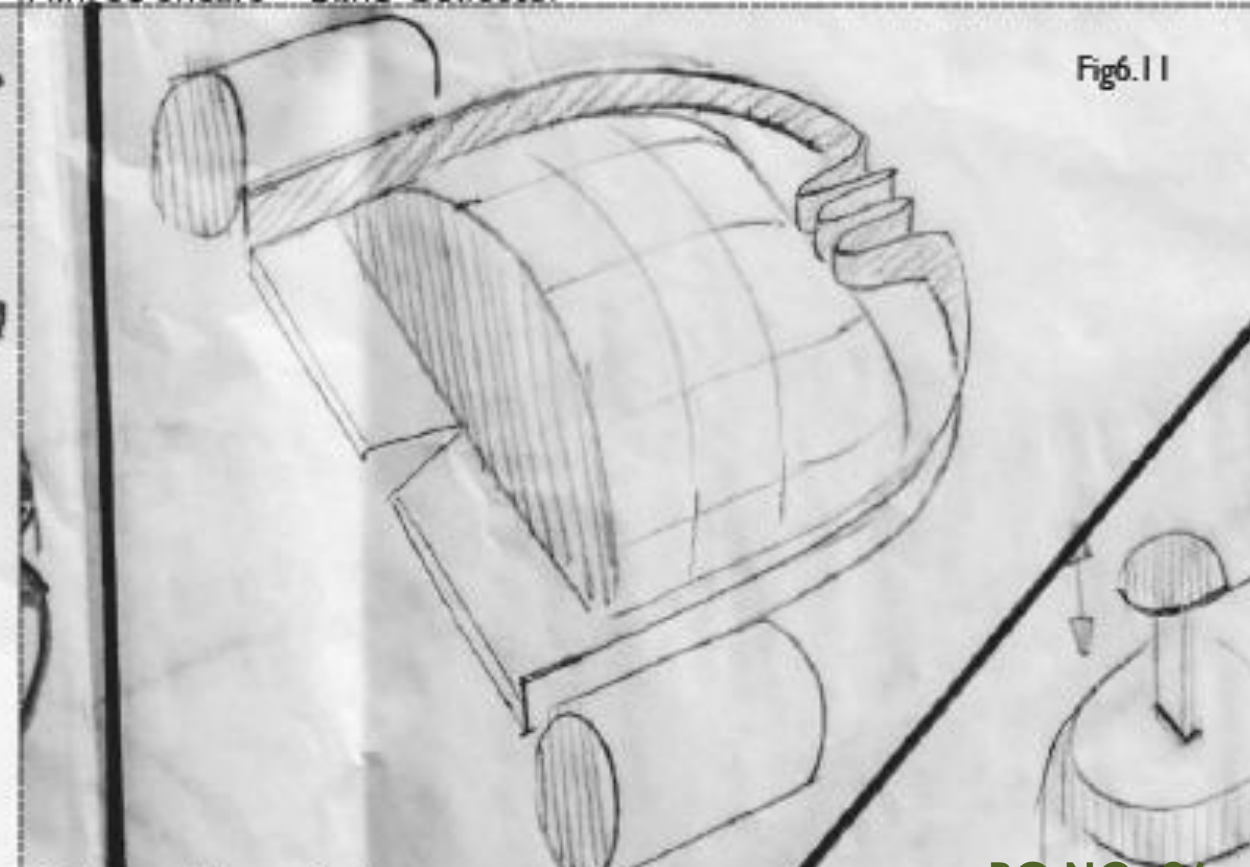
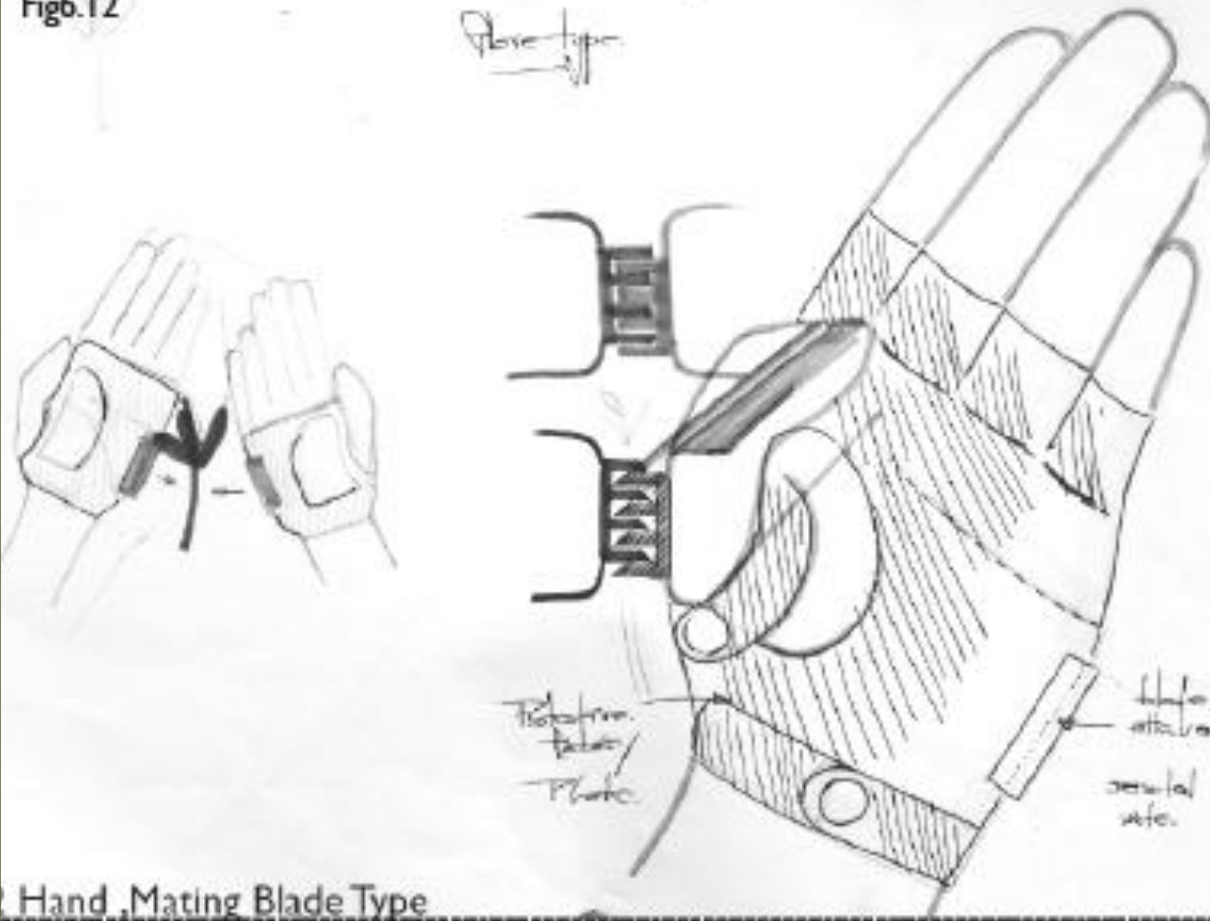


Fig6.11

C Shaped Shear-Collector

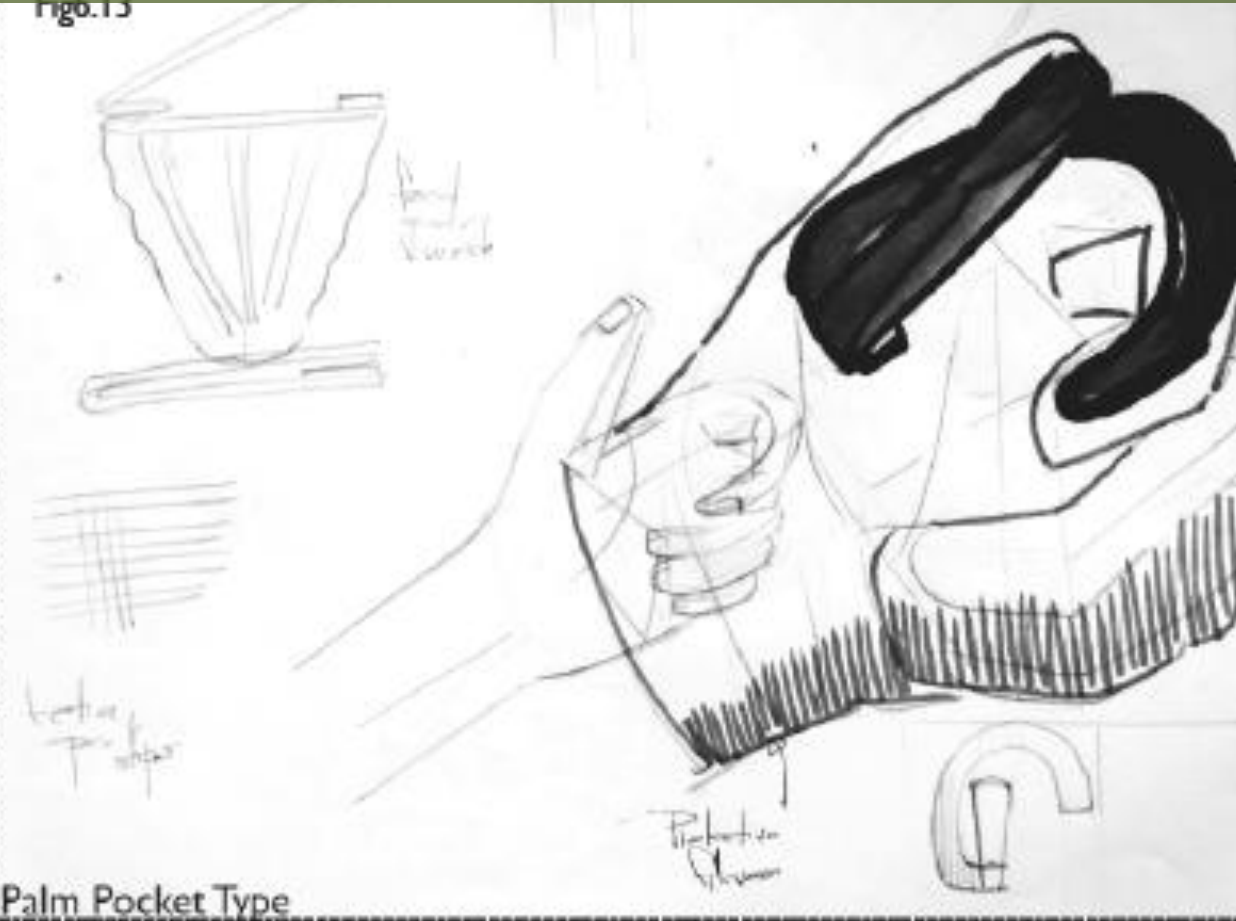
6.4 IDEATION : HAND WORN TYPE

Fig6.12



Hand, Mating Blade Type

Fig6.13



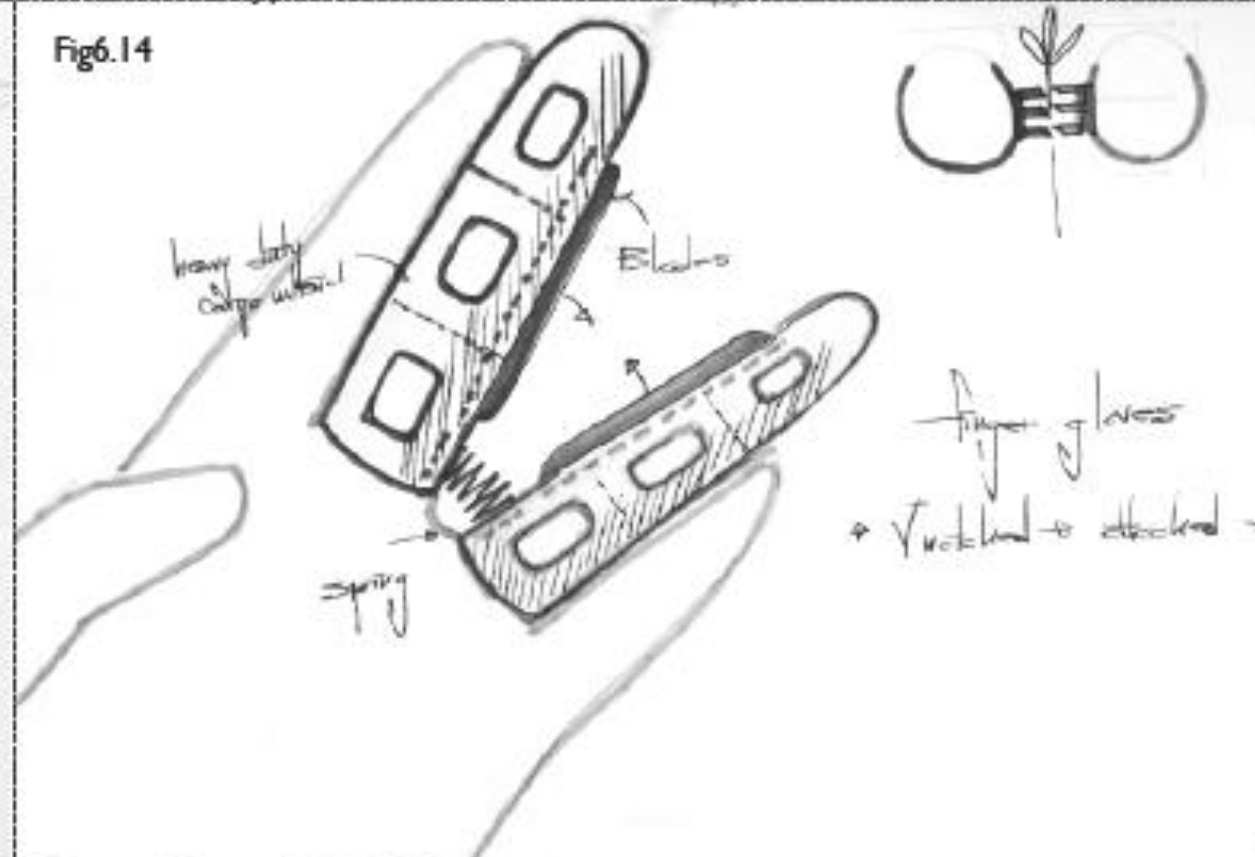
Palm Pocket Type

Fig6.15



Mounted Guitar Pick Type

Fig6.14



2 Finger, Mating Blade Type

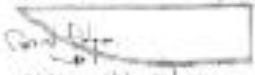
# 6.5 IDEATION : BLADES & COLLECTORS

Fig6.16

① Heavy Chiseling  
② Sharp



① Sharp Blade at angle



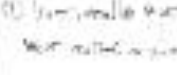
② Allow 2 level one  
③ Strong blade → strong work

① Allow 4 lbs of edge  
to wear, rotating angle



② Not Economy

① Sharp Blade



② Sharp Blade



Fig6.17

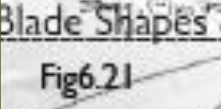
① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



⑦ Sharp Blade



⑧ Sharp Blade

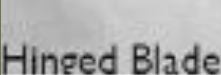
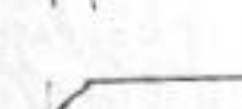
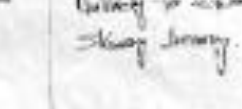


Fig6.18

① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



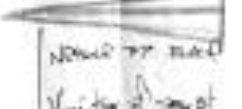
⑦ Sharp Blade



⑧ Sharp Blade

Fig6.19

① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



⑦ Sharp Blade



⑧ Sharp Blade

Fig6.20

① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



⑦ Sharp Blade



⑧ Sharp Blade

Fig6.17

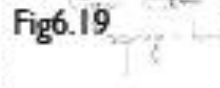
① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



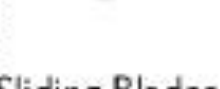
④ Sharp Blade



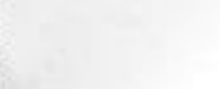
⑤ Sharp Blade



⑥ Sharp Blade



⑦ Sharp Blade



⑧ Sharp Blade



⑨ Sharp Blade



⑩ Sharp Blade



⑪ Sharp Blade



⑫ Sharp Blade

Fig6.18

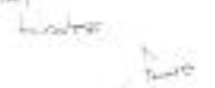
① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



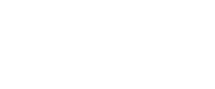
⑤ Sharp Blade



⑥ Sharp Blade



⑦ Sharp Blade



⑧ Sharp Blade



⑨ Sharp Blade



⑩ Sharp Blade



⑪ Sharp Blade



⑫ Sharp Blade

Fig6.19

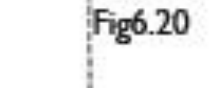
① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



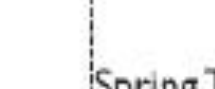
④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



⑦ Sharp Blade



⑧ Sharp Blade



⑨ Sharp Blade



⑩ Sharp Blade



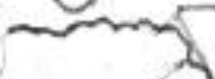
⑪ Sharp Blade



⑫ Sharp Blade

Fig6.20

① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



⑦ Sharp Blade



⑧ Sharp Blade



⑨ Sharp Blade



⑩ Sharp Blade



⑪ Sharp Blade



⑫ Sharp Blade

Blade Shapes & Uses

Wire-Frame Tetrapack

Conical Shaped SS

Fig6.19

Fig6.20

Sliding Blades

Spring Type

Fig6.21

① Heavy Chiseling  
② Sharp



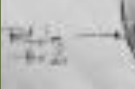
③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



Fig6.22

① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



⑥ Sharp Blade



Fig6.22

① Heavy Chiseling  
② Sharp



③ Sharp Blade at angle



④ Sharp Blade



⑤ Sharp Blade



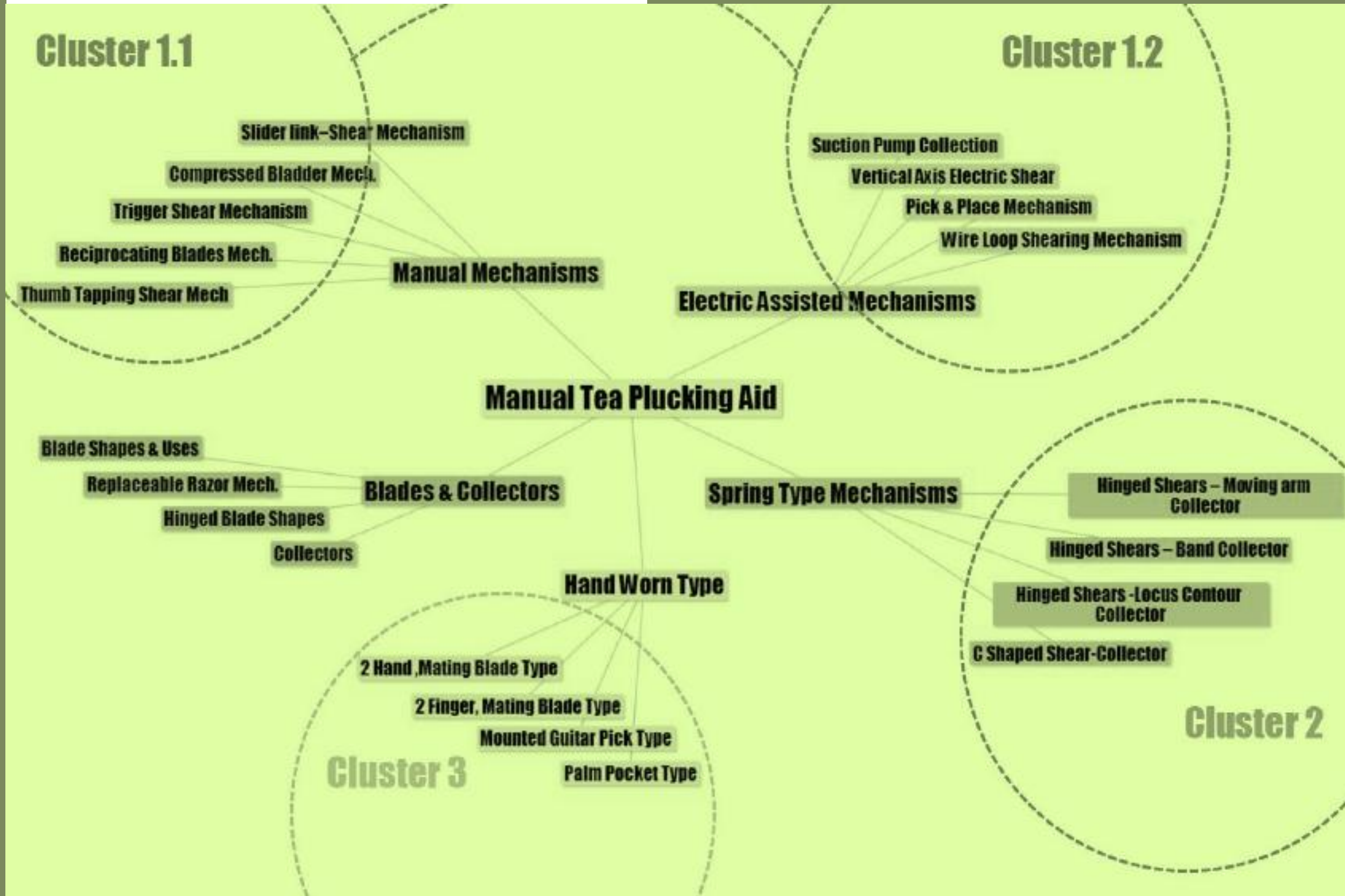
⑥ Sharp Blade



Hinged Blade Shapes

Replaceable Razor Mech.

## 6.6 CLUSTERING OF IDEAS



7.0 THREE CONCEPT DIRECTIONS

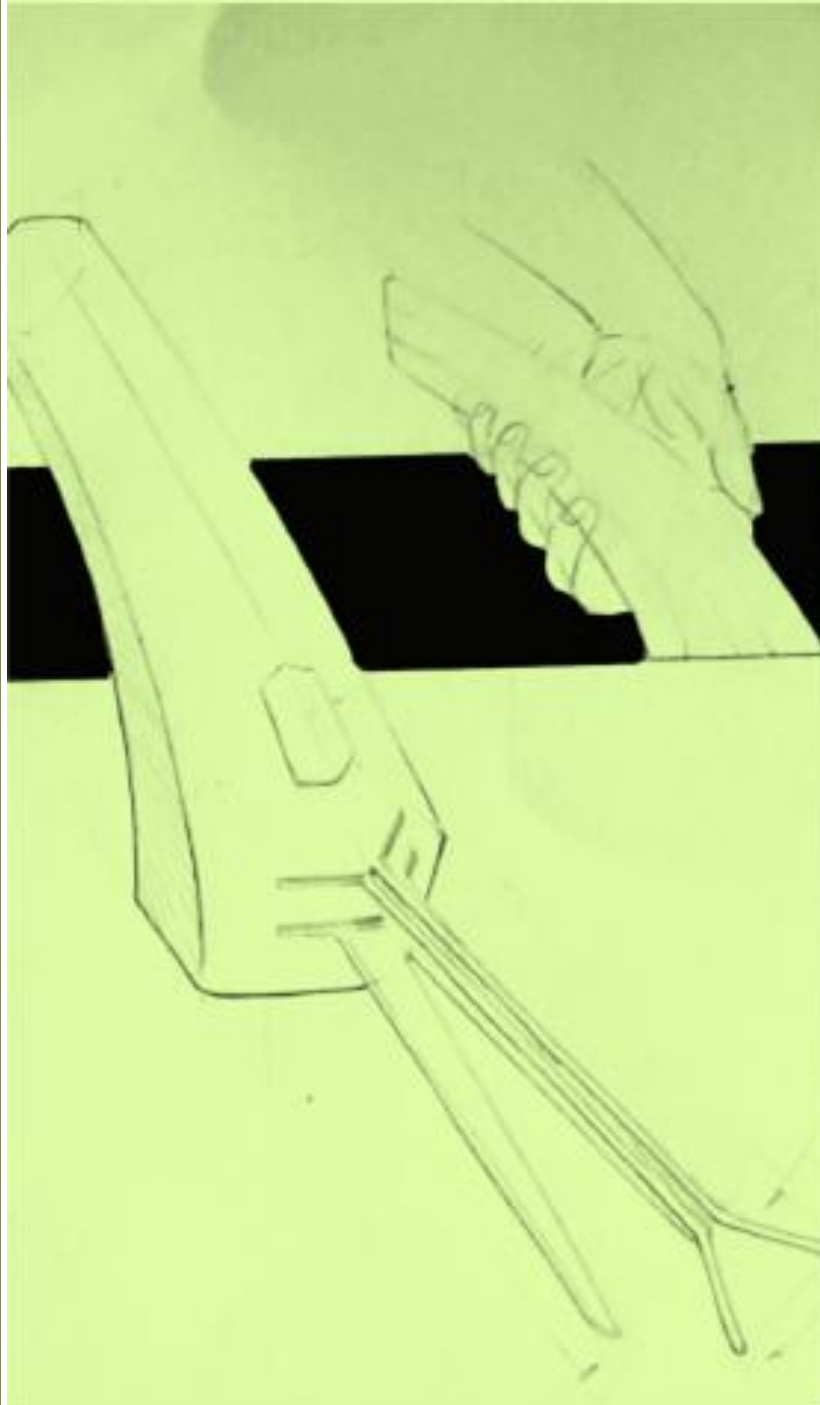


Fig7.1 Concept Direction 1: Top Collector Type



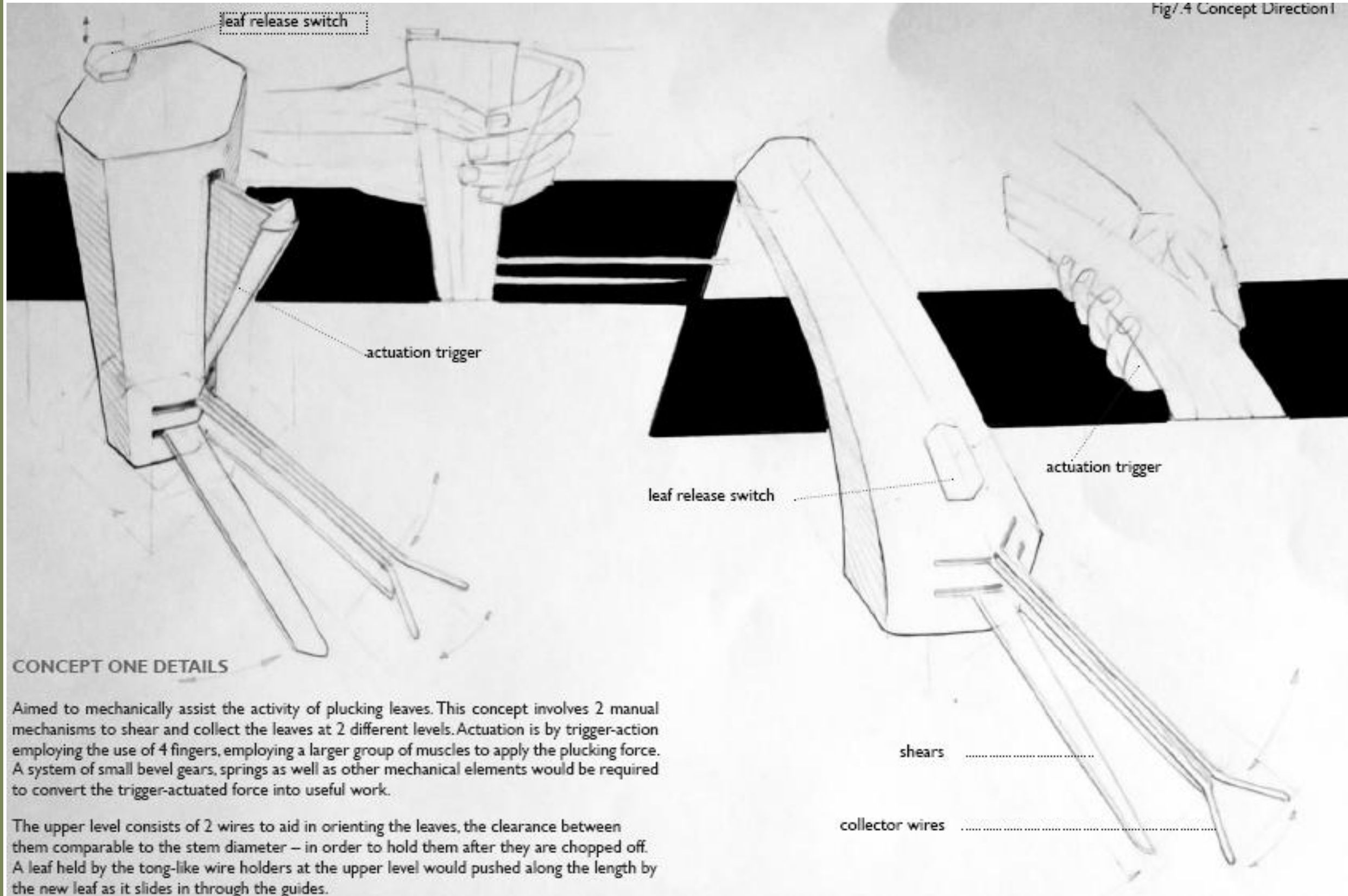
Fig7.2 Concept Direction 2: C-Shaped Type



Fig7.3 Concept Direction 3: Hand-worn Type

## 7.1 CONCEPT DIRECTION 1

Fig/4 Concept Direction 1



### CONCEPT ONE DETAILS

Aimed to mechanically assist the activity of plucking leaves. This concept involves 2 manual mechanisms to shear and collect the leaves at 2 different levels. Actuation is by trigger-action employing the use of 4 fingers, employing a larger group of muscles to apply the plucking force. A system of small bevel gears, springs as well as other mechanical elements would be required to convert the trigger-actuated force into useful work.

The upper level consists of 2 wires to aid in orienting the leaves, the clearance between them comparable to the stem diameter – in order to hold them after they are chopped off. A leaf held by the tong-like wire holders at the upper level would be pushed along the length by the new leaf as it slides in through the guides.

# 7.1 CONCEPT DIRECTION 1

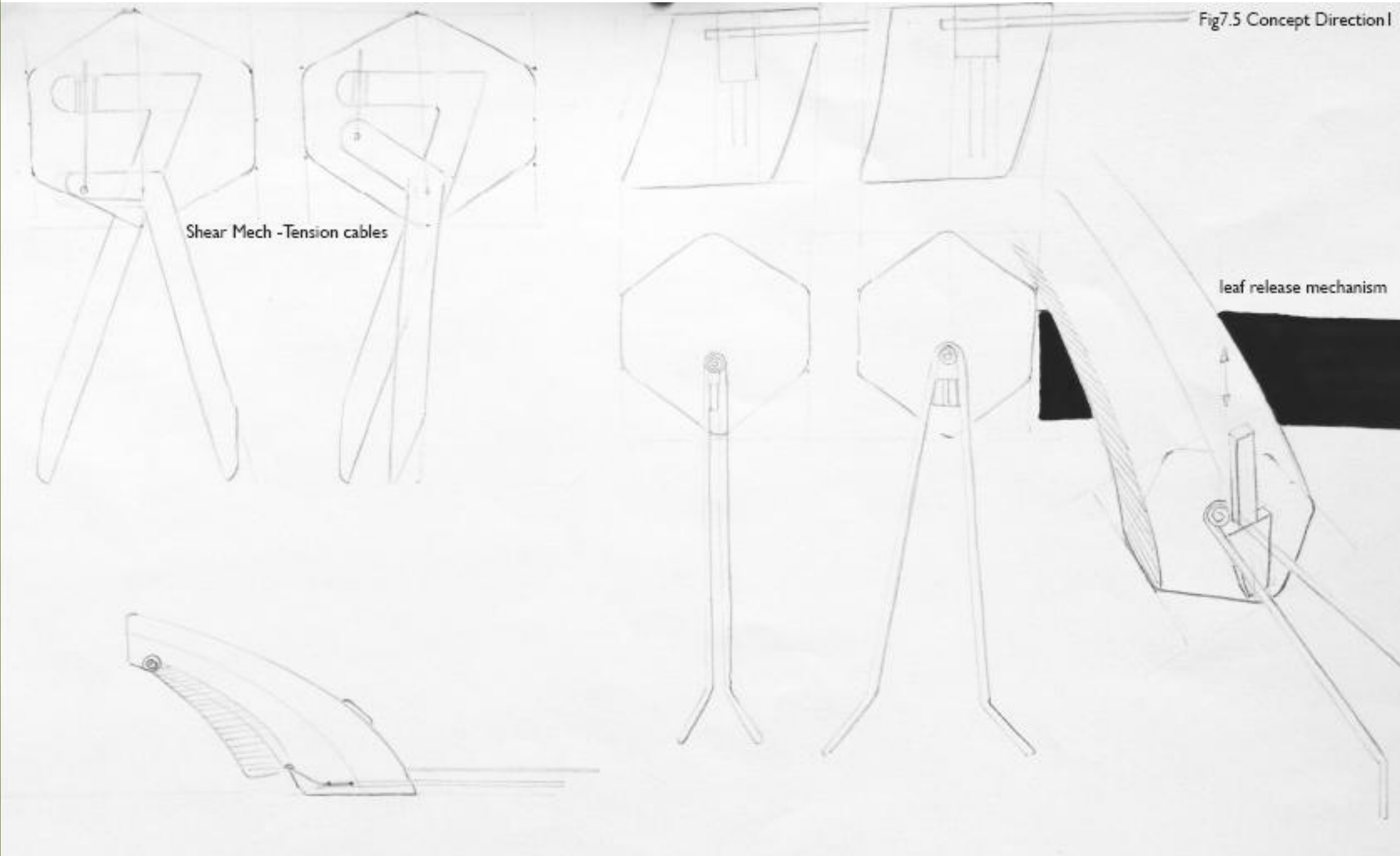


Fig7.5 Concept Direction I

Shear Mech - Tension cables

leaf release mechanism

## 7.1 CONCEPT DIRECTION 1 TESTING



### CONCEPT 1 TEST INFERENCES

- An unacceptable amount of time is required to orient the leaves through the collector before shearing.
- Orienting leaves through the collector require very precise movements.
- Length of collector wire used in the test was insufficient for consistent & reliable collection of leaves.
- Complexity due to mechanism and no. of moving parts would increase cost.

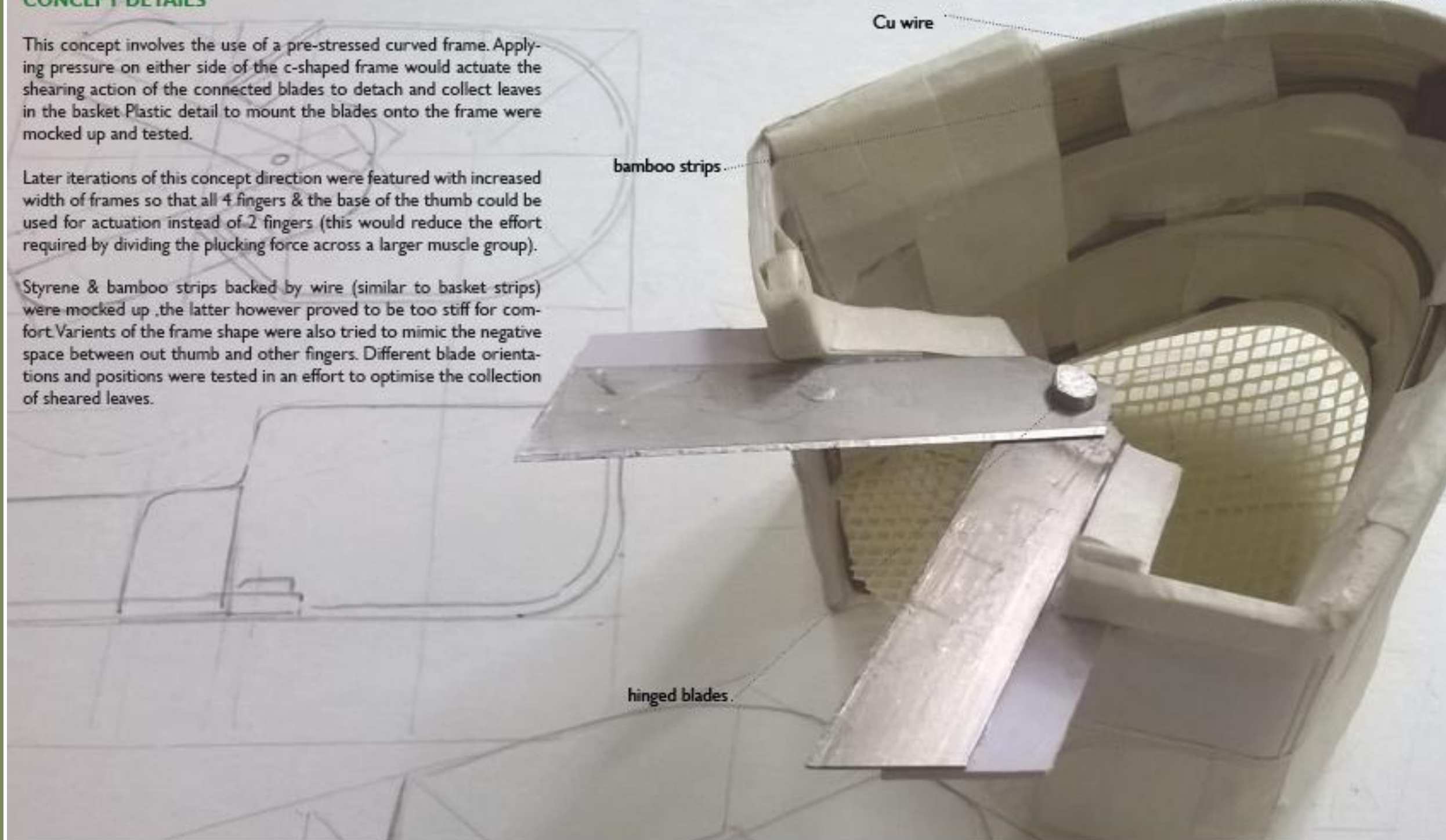
### CONCEPT DETAILS

This concept involves the use of a pre-stressed curved frame. Applying pressure on either side of the c-shaped frame would actuate the shearing action of the connected blades to detach and collect leaves in the basket. Plastic detail to mount the blades onto the frame were mocked up and tested.

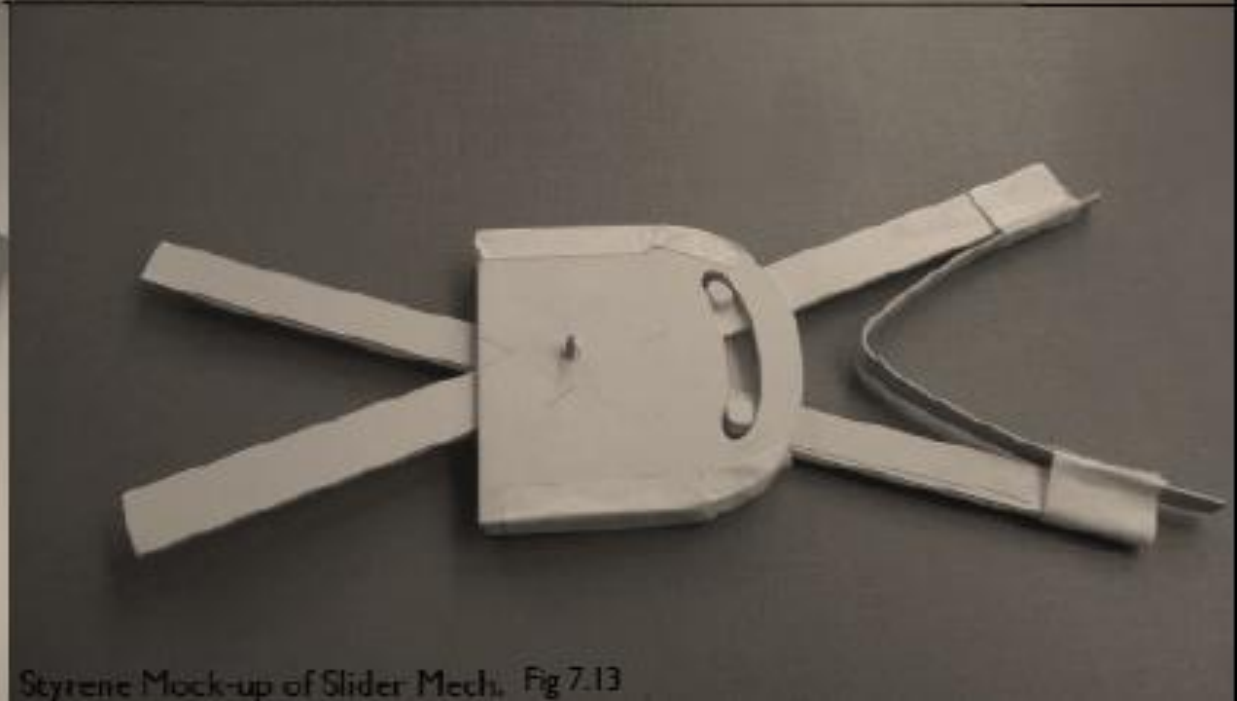
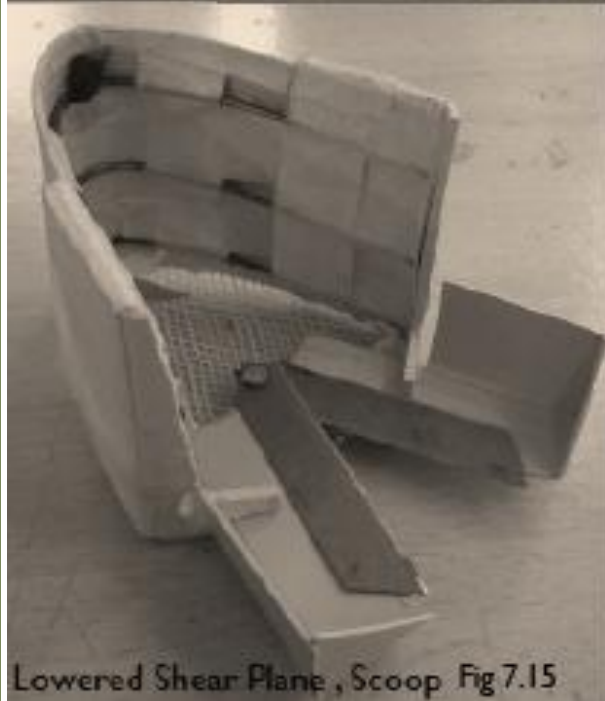
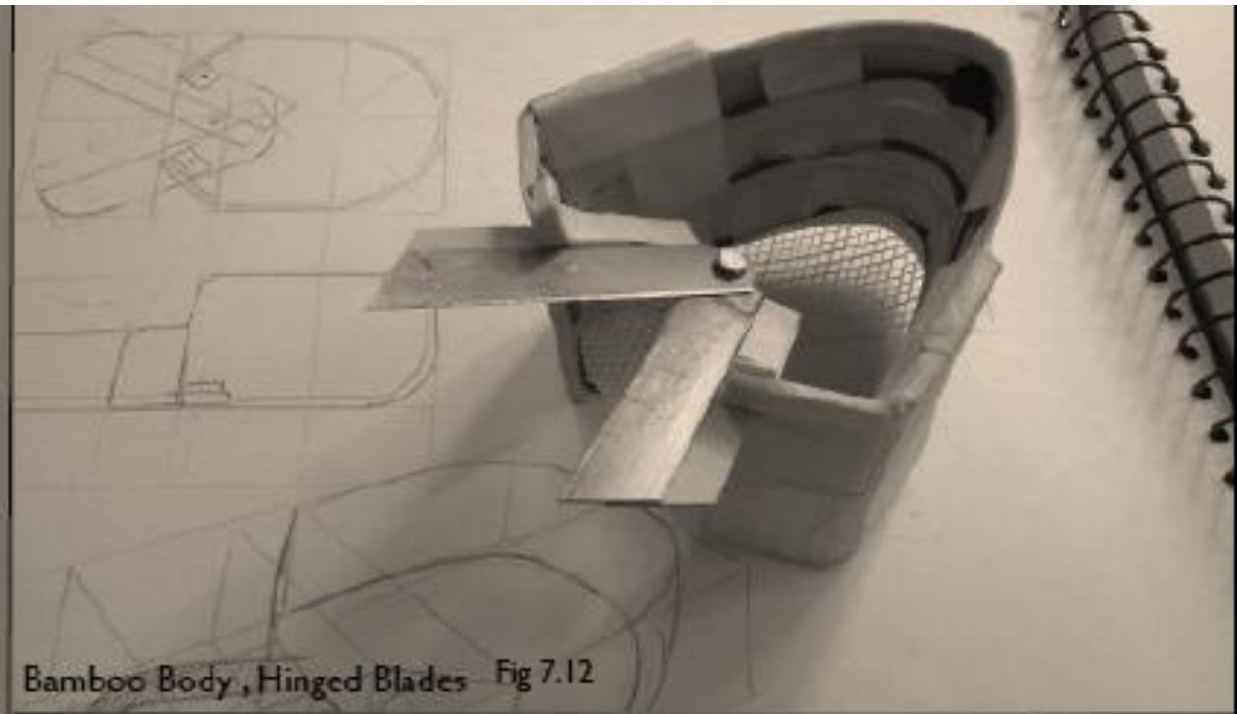
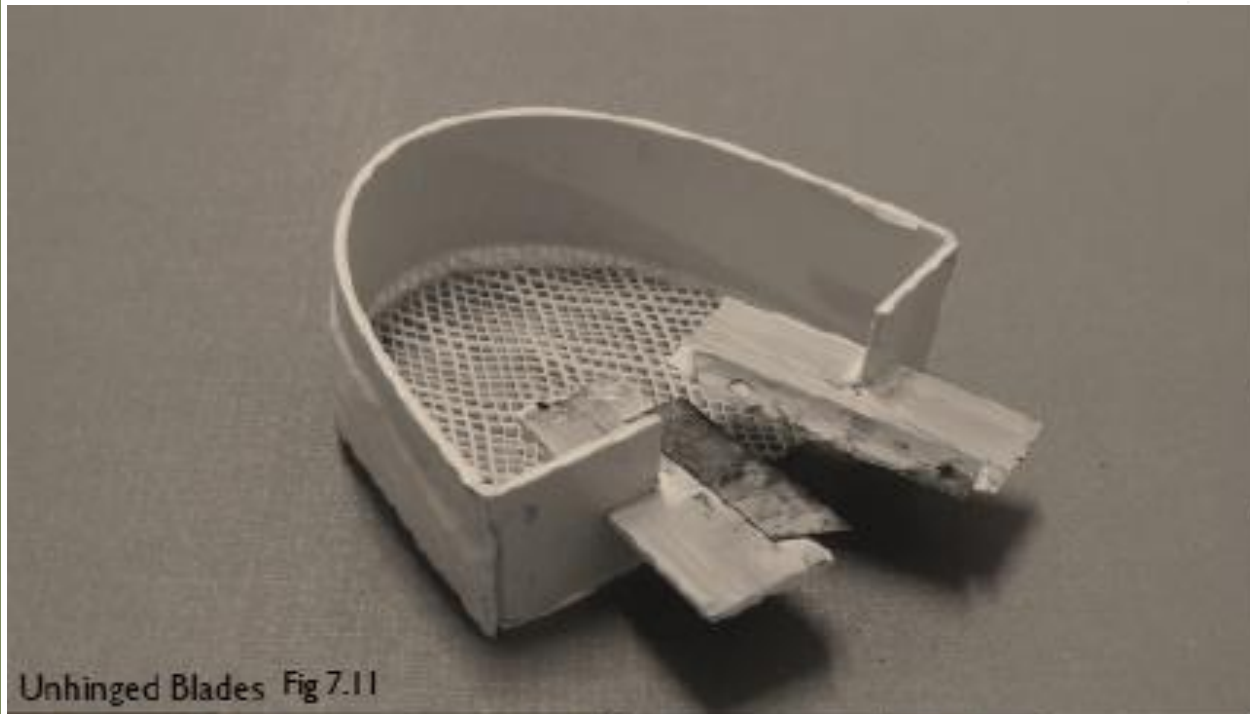
Later iterations of this concept direction were featured with increased width of frames so that all 4 fingers & the base of the thumb could be used for actuation instead of 2 fingers (this would reduce the effort required by dividing the plucking force across a larger muscle group).

Styrene & bamboo strips backed by wire (similar to basket strips) were mocked up, the latter however proved to be too stiff for comfort. Variants of the frame shape were also tried to mimic the negative space between out thumb and other fingers. Different blade orientations and positions were tested in an effort to optimise the collection of sheared leaves.

Fig 7.10 Concept Direction 2



## 7.2 CONCEPT DIRECTION 2



### CONCEPT 2 TEST INFERENCES

- Significant obstruction from neighbouring leaves make approach to top 2.5 leaves difficult with the test blade length.
- Collection of leaves into the reservoir is inefficient in the tested orientations.
- Hand motion involved with device use may have a significant learning curve.
- Blades require precise alignment for successful & consistent shearing of leaves.



### REFINEMENT DETAILS

In an attempt to reduce the learning curve associated with the previous level, handles were incorporated – being stereotypically used in garden tools for decades. A torsion spring actuated slider mechanism was devised to convert the clenching motion of the hands into useful shearing force.



The blade now mounted at the bottom of the collection space is intended to reduce the difficulties related to approaching leaves in a bush. The curved shape blade shape was utilised in an attempt to guide the sheared leaves into the collection space. Red & white are used to enhance visibility of the product contrasting the environment (bush green).

Fig 7.20

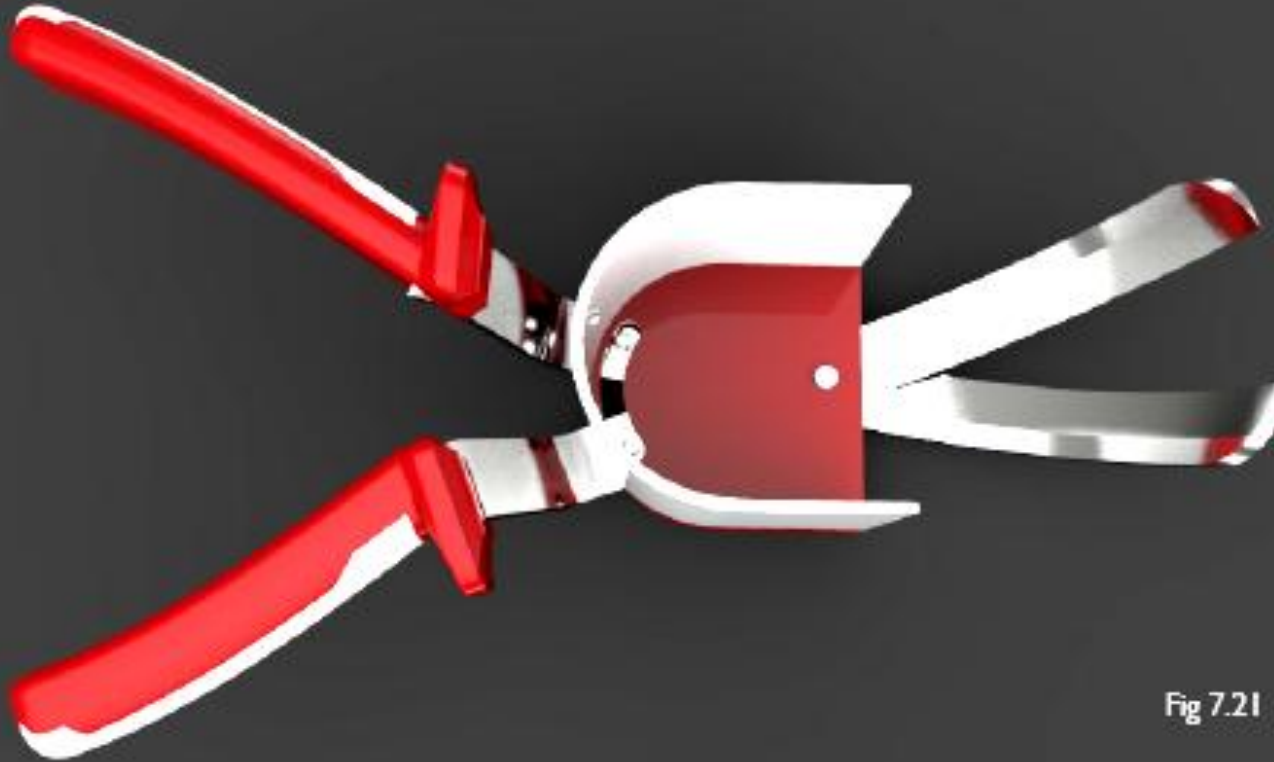


Fig 7.21



Fig 7.22



Fig 7.23

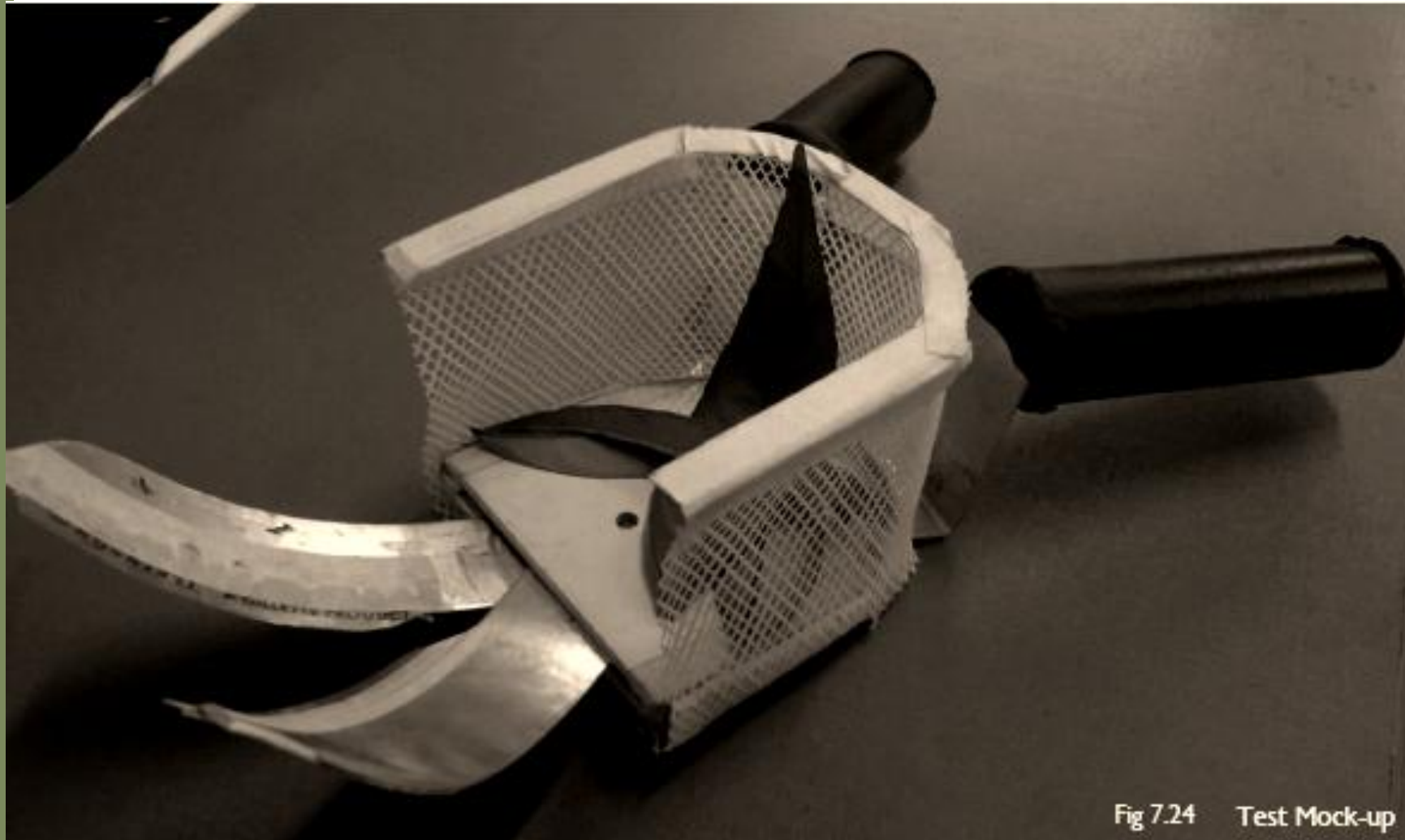


Fig 7.24 Test Mock-up

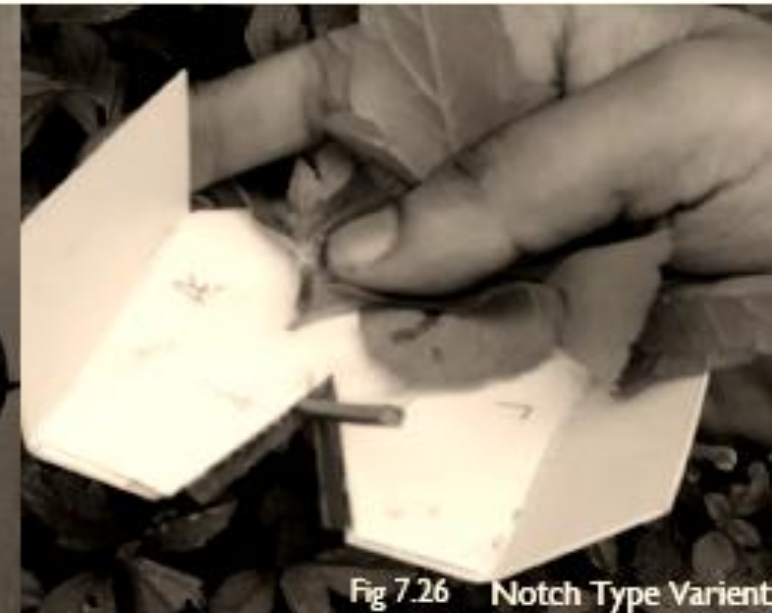


Fig 7.26 Notch Type Variants



Fig 7.25 Blade Profile Variants

### REFINED CONCEPT 2: TEST INFERENCES

Very precise hand motions were required manoeuvre mockup to selectively pluck top 2.5 leaves therefore the productivity was unsatisfactory in comparison to manual hand plucking.

Blade shape and orientation ensures Collection of leaves into the reservoir with about 60 % efficiency under the test conditions.

Blades require precise alignment for successful & consistent shearing of leaves.



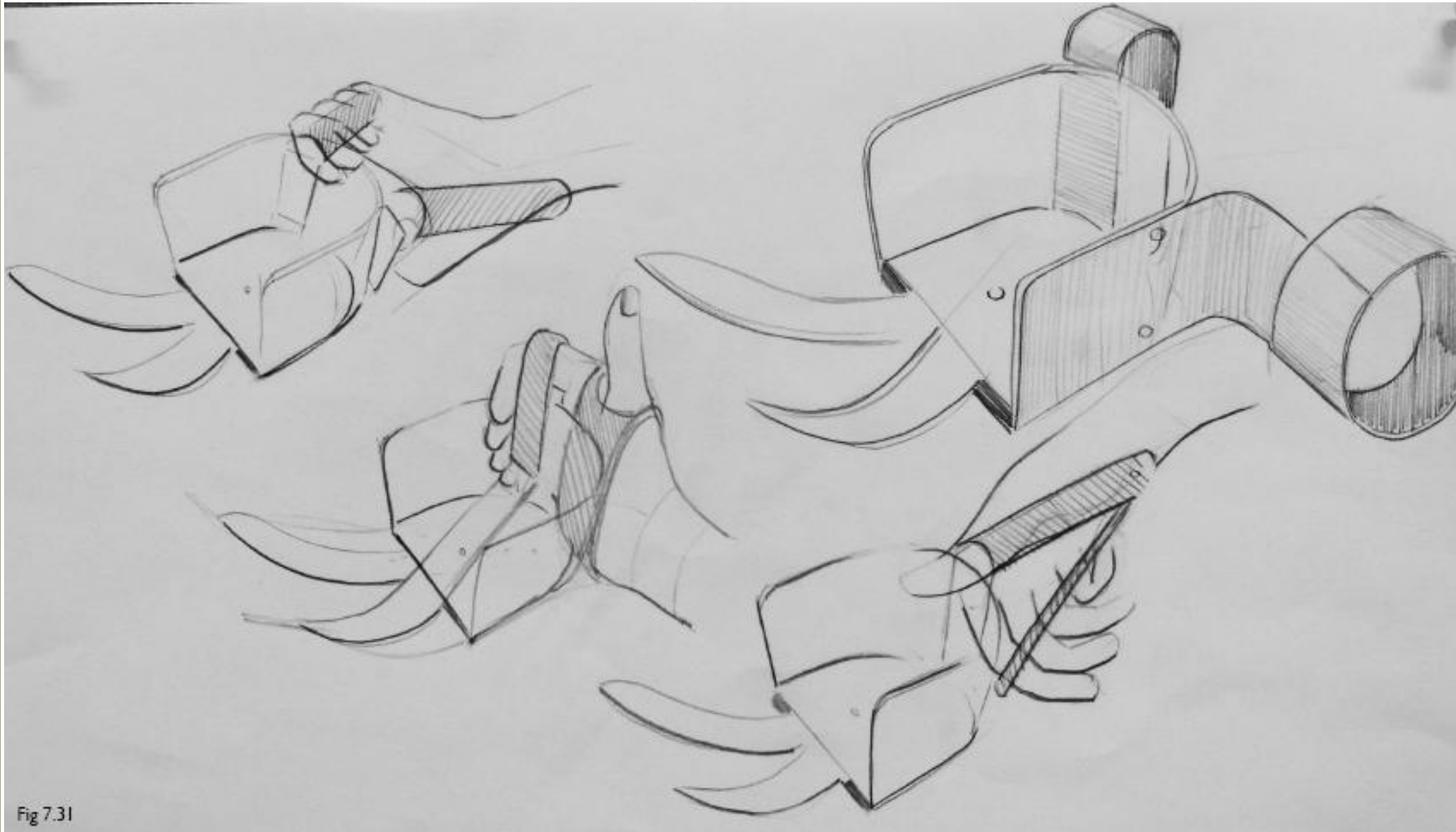
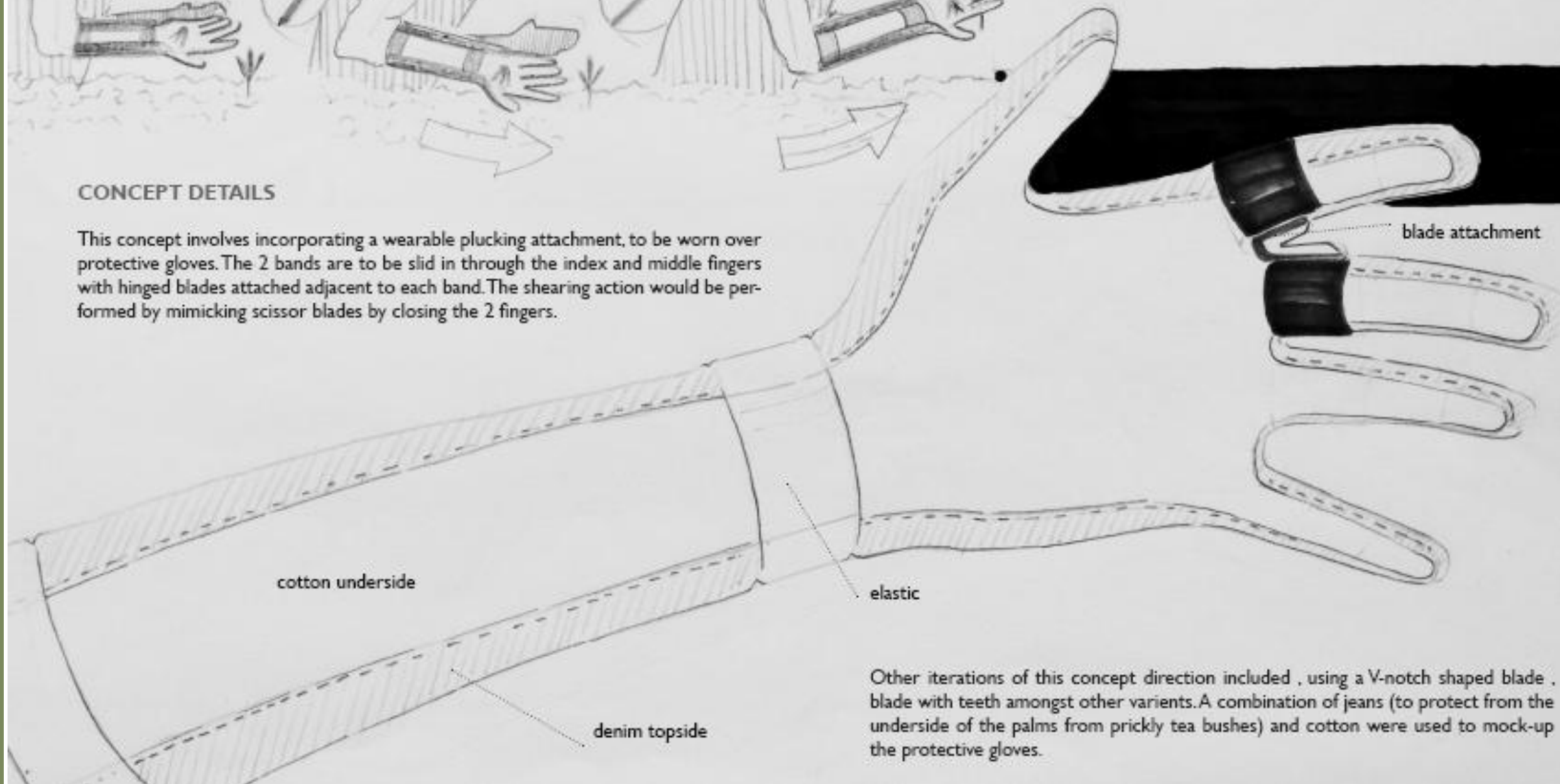


Fig 7.31



#### CONCEPT DETAILS

This concept involves incorporating a wearable plucking attachment, to be worn over protective gloves. The 2 bands are to be slid in through the index and middle fingers with hinged blades attached adjacent to each band. The shearing action would be performed by mimicking scissor blades by closing the 2 fingers.



Other iterations of this concept direction included , using a V-notch shaped blade , blade with teeth amongst other variants. A combination of jeans (to protect from the underside of the palms from prickly tea bushes) and cotton were used to mock-up the protective gloves.

7.3 CONCEPT DIRECTION 3 VARIANTS



Separated Finger Blades Fig 7.33



Fig 7.34 DIY Jeans-Cotton Glove



Curved Blade with teeth Fig 7.35



V-Notch Blade finger straps Fig 7.36



Fig 7.37 Hinged V-notch blade

## 7.3 THREE CONCEPT DIRECTIONS

### TEST INFERENCES

- A significant amount of plucking force is required to completely detach the leaf from the stem.
- Constrained finger positions ( for strapping blades) are uncomfortable.
- Introducing teeth onto the blades may result in incorrectly plucked leaves (half torn leaves )
- Secondary intervention from the thumb is necessary to pull back plucked leaves.



## REFINEMENT DETAILS

This concept was devised to make the use of the product as similar to the manual hand plucking motion as possible. It involves the use of a wearable blade on the index finger and a thumb guard to apply pressure against the blade to detach and collect the leaves to be plucked. It uses the standard SS disposable shaving razor blade that may be replaced when blunt.

Adjustable straps could be used to arrest the motion of the blade during use. Different blade positioning and number of blades were also mocked up and tested. The thumb guard would be made of layered SS steel fiber mesh and strapped across the base (commonly used in butchering gloves) to protect the thumb from razor slashes.

blade attachment

thumb-guard

half razor

protective gloves

Fig 7.41



Fig 7.42-Side oriented blade

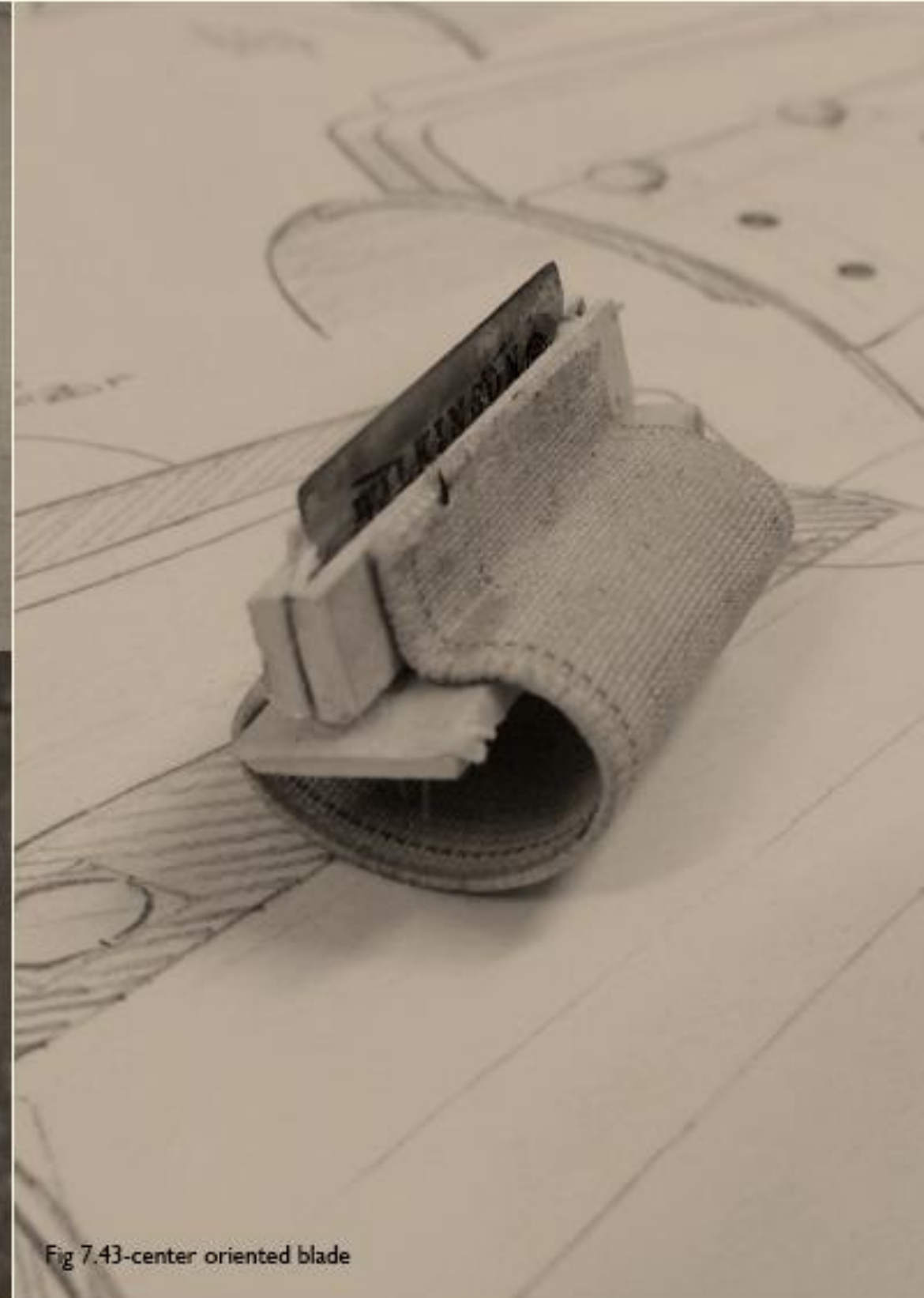


Fig 7.43-center oriented blade



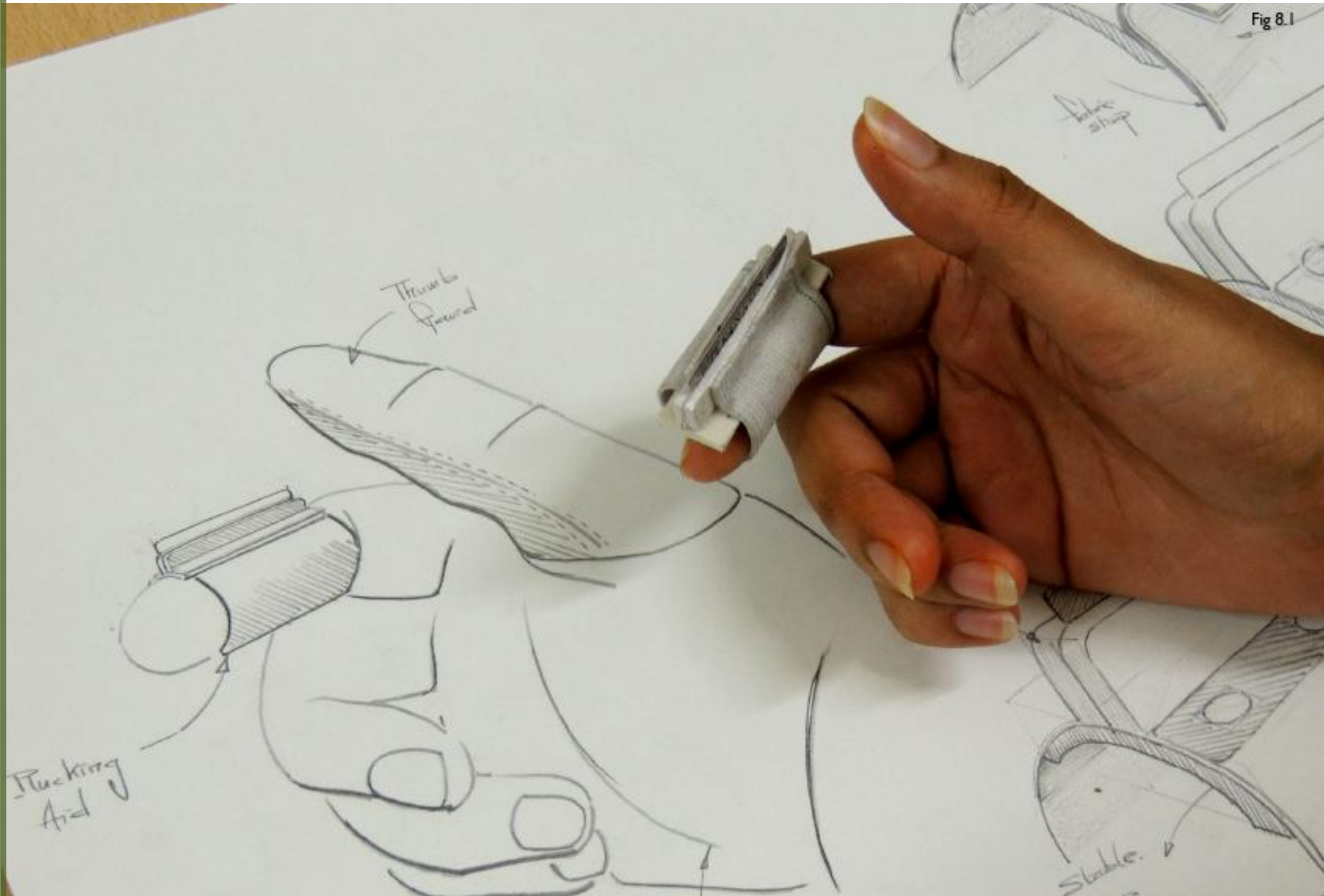
Fig 7.42-double blade variant



### TEST INFERENCES

- Very little force was required to detach the selected leaves from the stem. The productivity in terms of no. plucked / time was similar to hand plucking.
- Quality of plucked and collected leaves were satisfactory, no torn or slashed leaves were observed.
- Learning curve was the easiest in comparison to other mock-ups tested

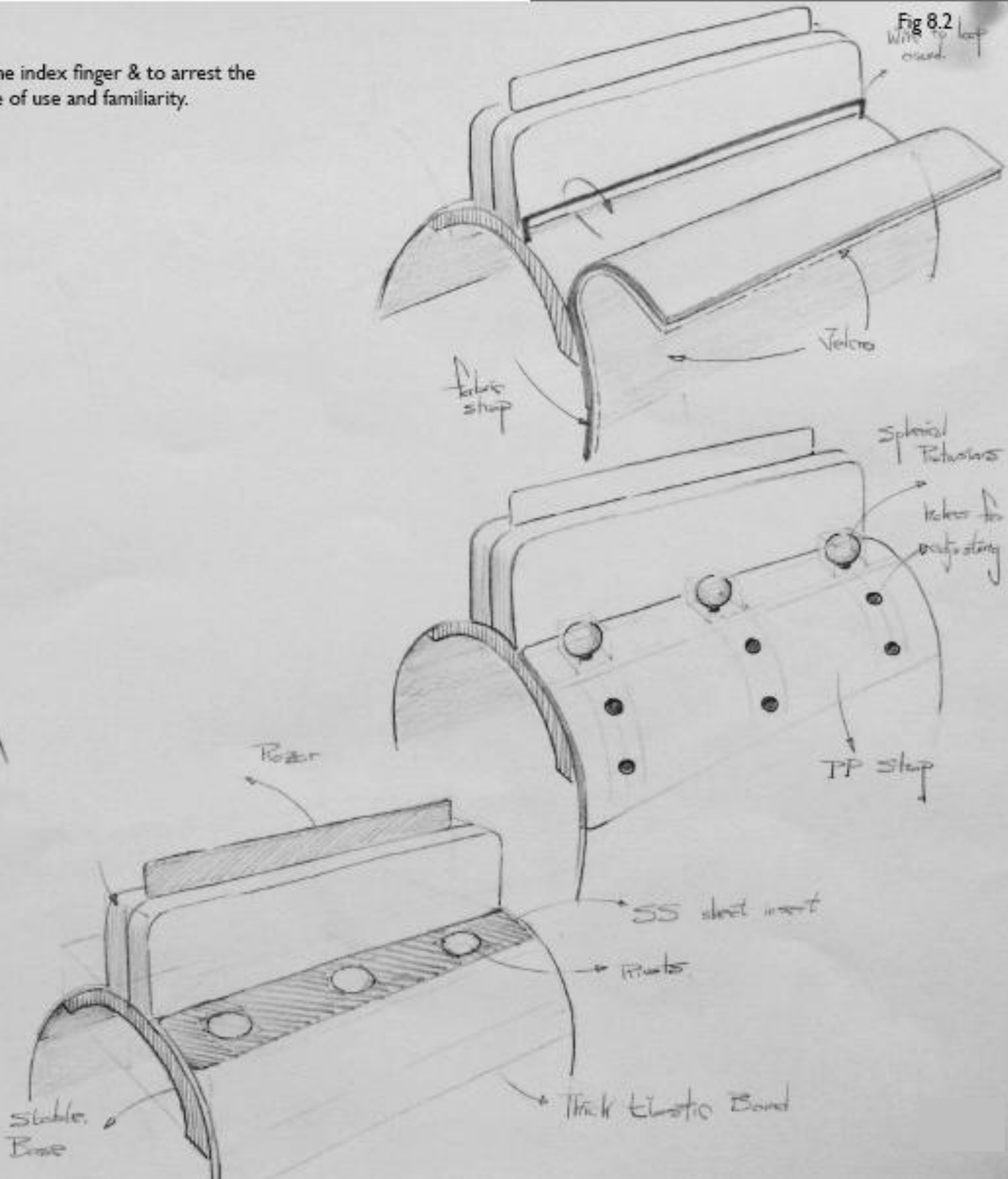
## 8.0 FINALISING CONCEPT DIRECTION



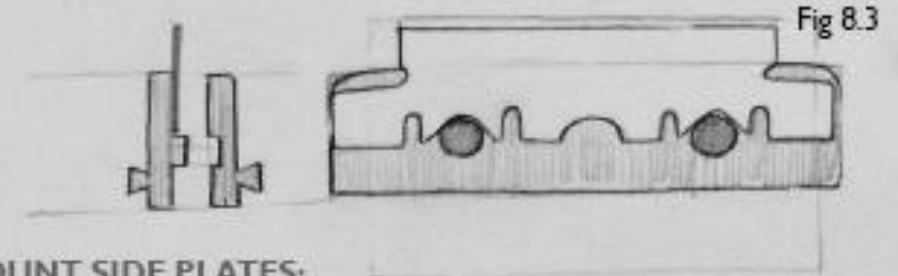
## 8.1 FASTENING METHOD DETAILING

### FASTENING

Nylon bands layered with Velcro is used fasten the blade mounting onto the index finger & to arrest the thumb-guard onto the thumb. The choice was made to accommodate ease of use and familiarity.



## 8.2 INCORPORATING REMOVABLE SS BLADE

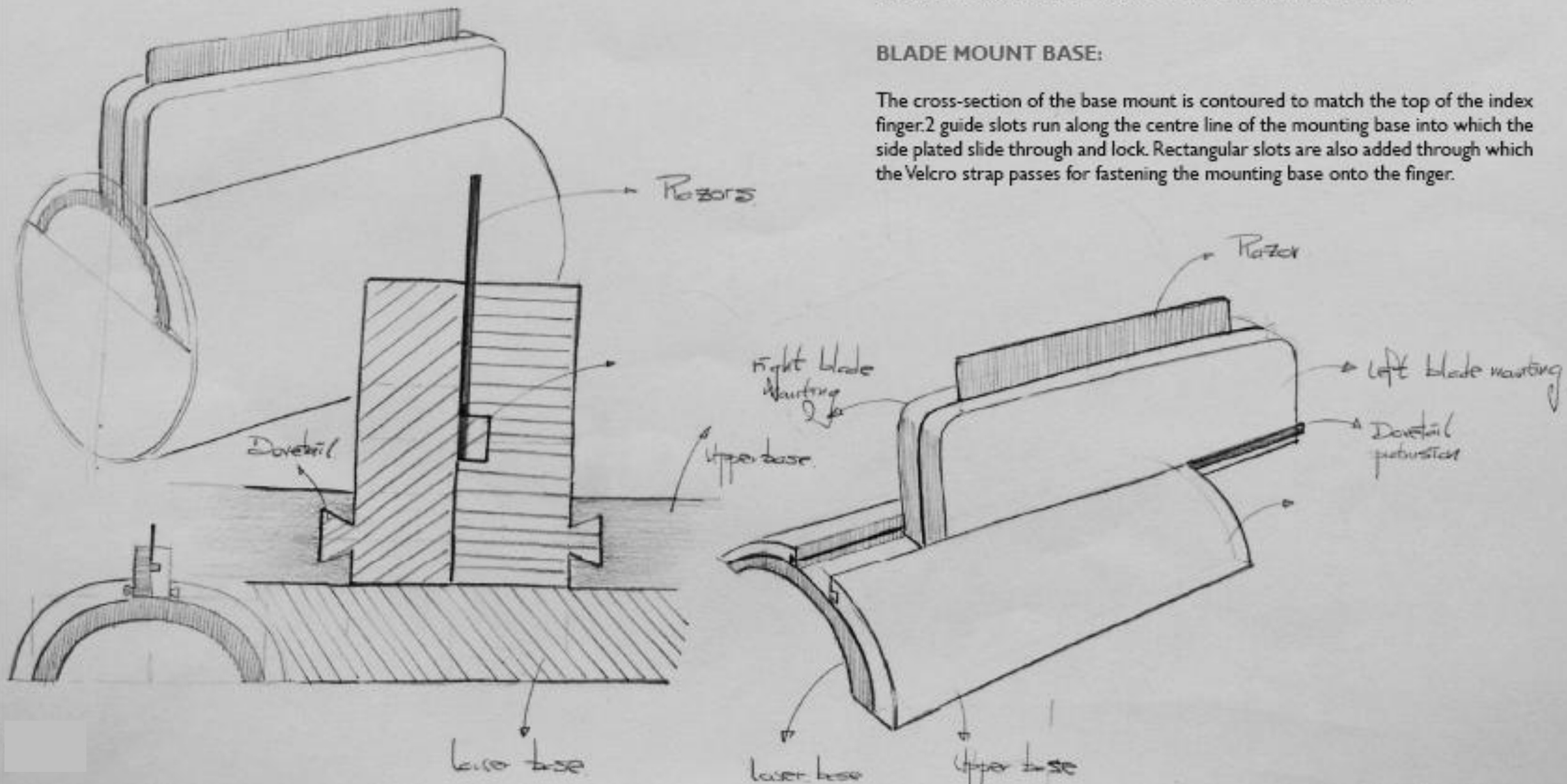


### BLADE MOUNT SIDE PLATES:

In this variant, the blade mount plates are a 2-piece assembly designed for easy dis-assembly using snap joints to allow for replacing razor blades when blunt. Ribs are added to support the razor blade whilst in use. 2 semi-circular protrusions provide reaction force to the blade during use. The protruded lower portion on the side mount plates are designed to slide underneath the base.

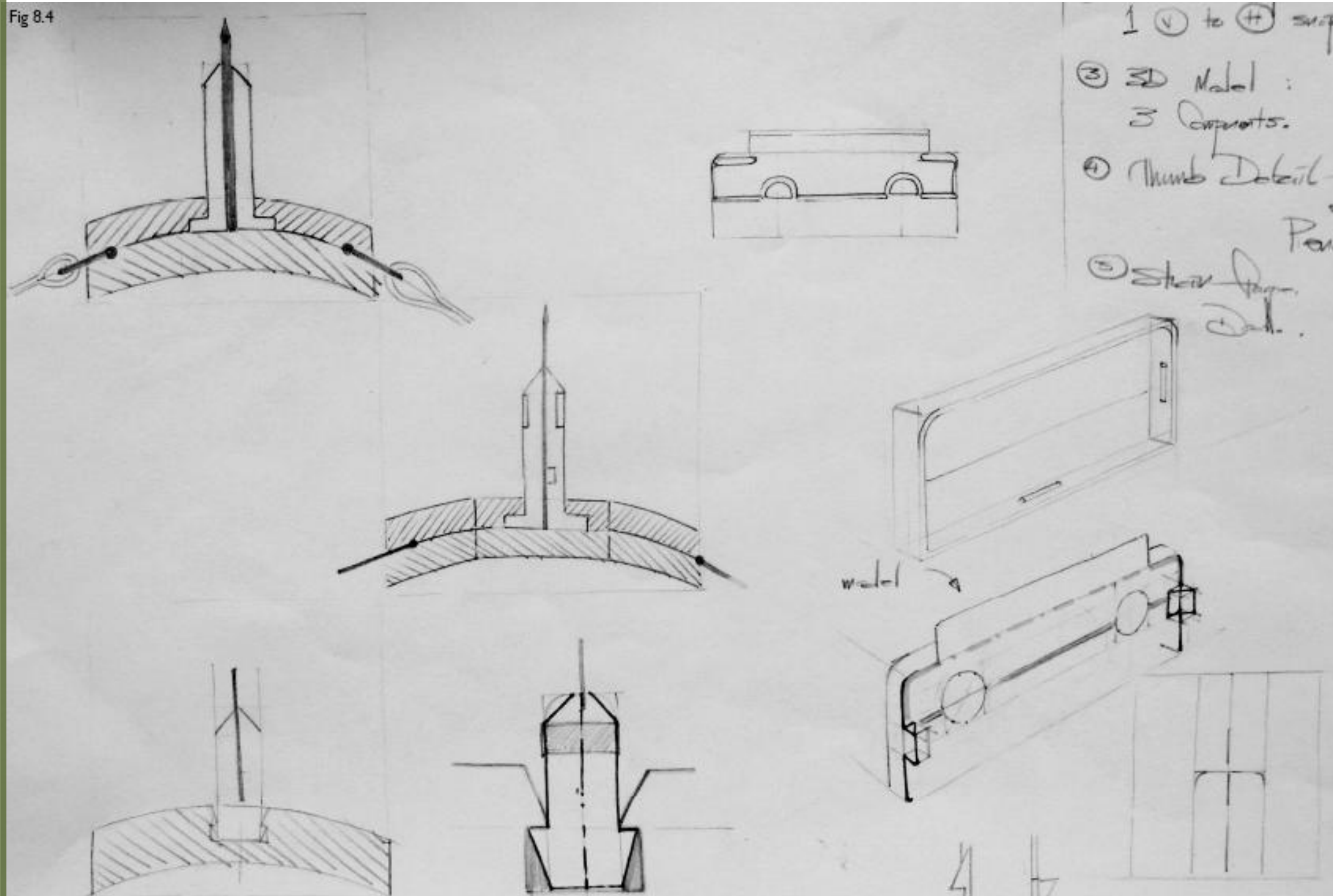
### BLADE MOUNT BASE:

The cross-section of the base mount is contoured to match the top of the index finger. 2 guide slots run along the centre line of the mounting base into which the side plates slide through and lock. Rectangular slots are also added through which the Velcro strap passes for fastening the mounting base onto the finger.

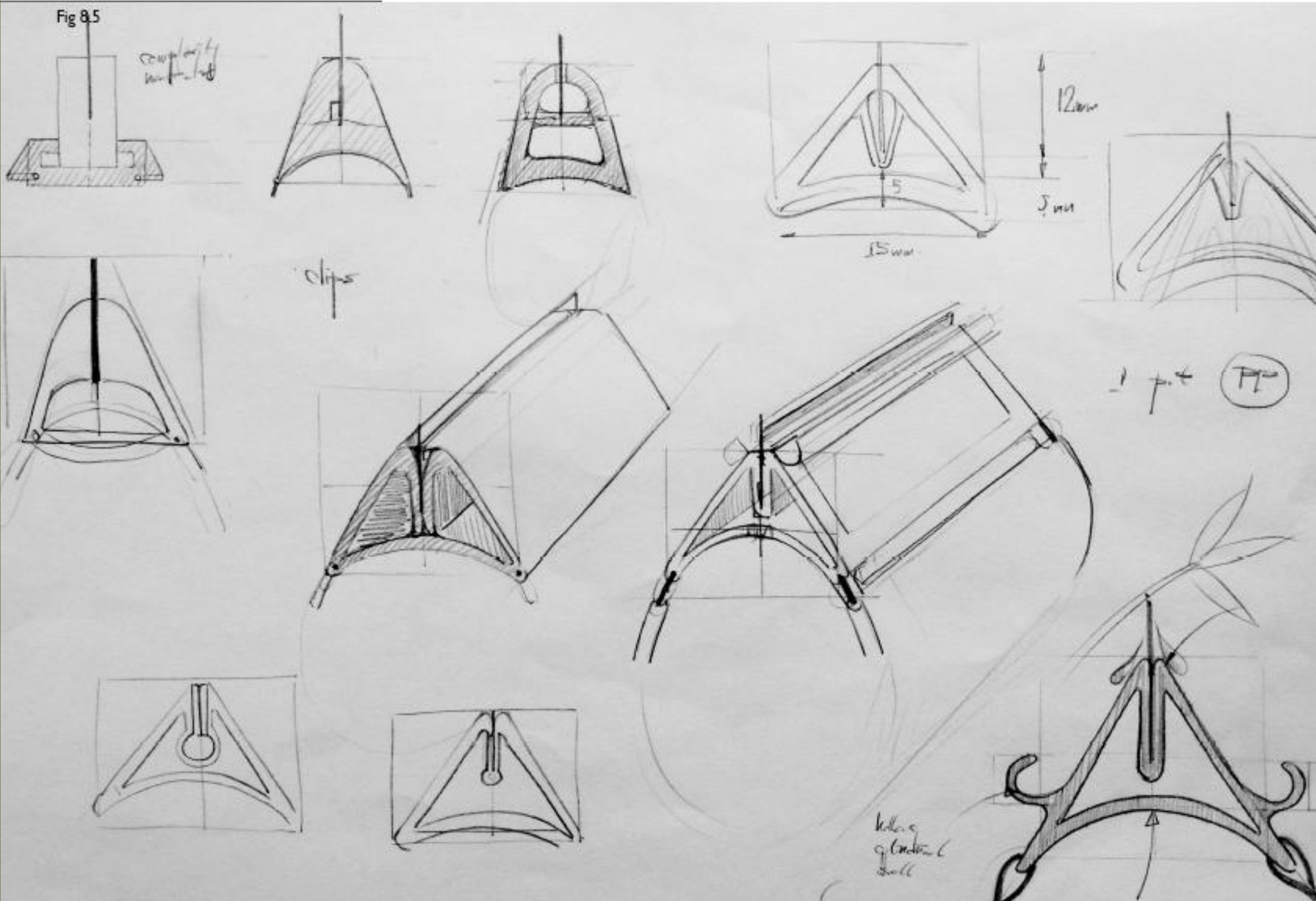


## 8.3 POSSIBLE PACKAGING ALTERNATIVES

Fig 8.4

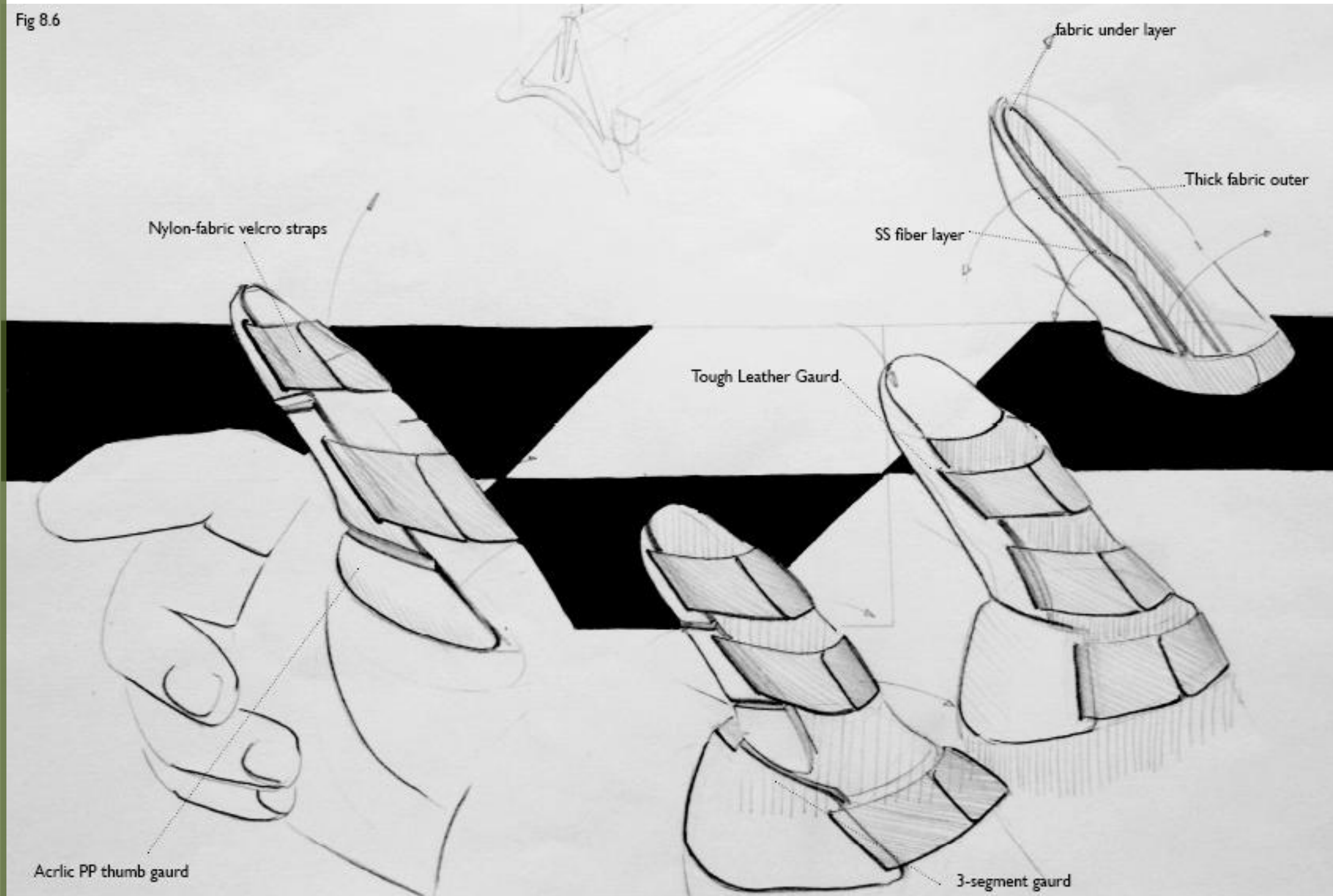


# 8.4 SINGLE-PIECE BLADE ATTACHMENT



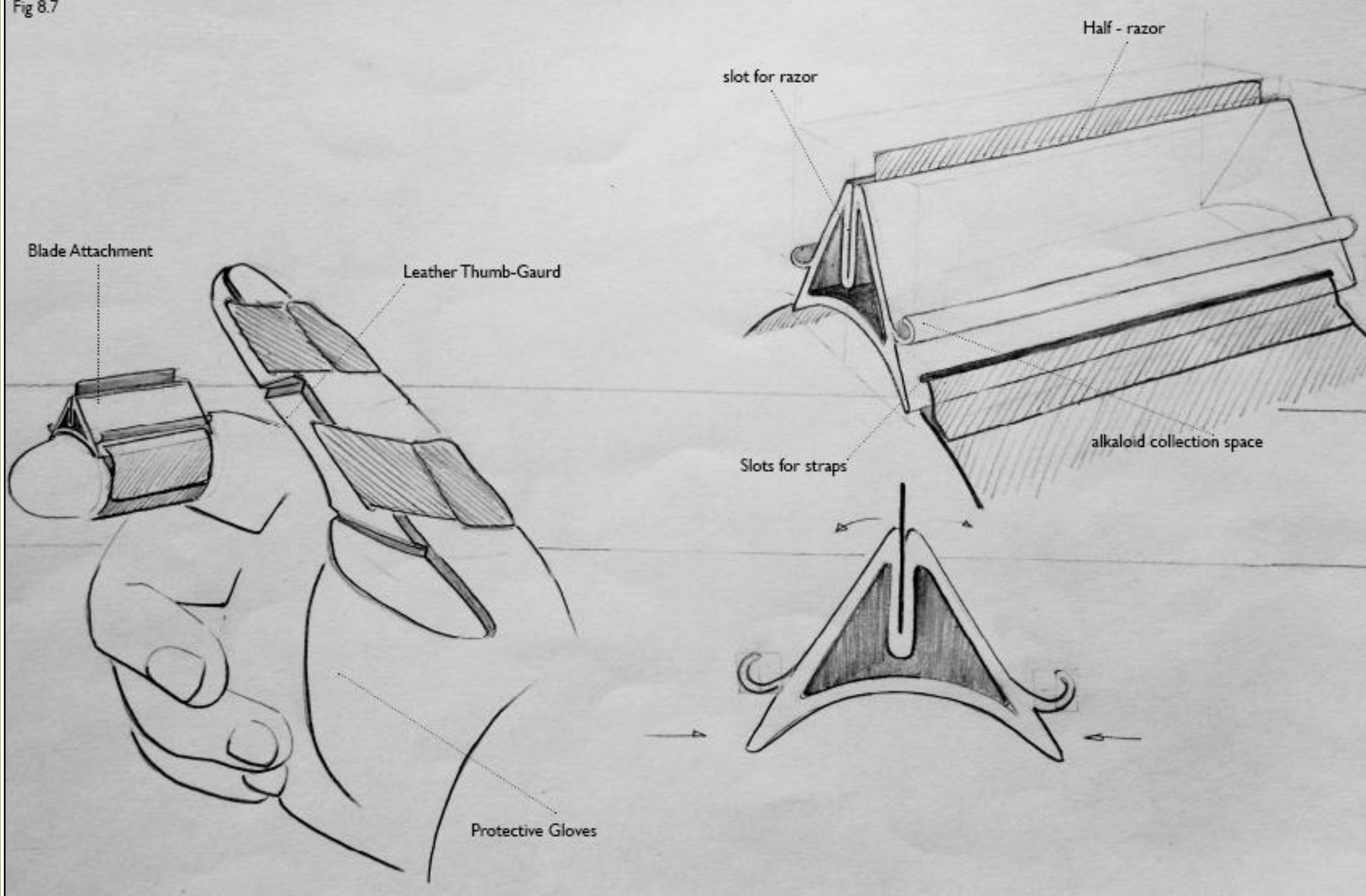
## 8.5 DETAILING THE THUMB GUARD

Fig 8.6



8.6 FINAL CONCEPT SKETCH : TEA-LEAF PLUCKING AID

Fig 8.7



The final design concept involves the following 3 components:

### 1. BLADE ATTACHMENT

This attachment was designed to be strapped onto the index finger over the protective gloves. Nylon-fabric bands layered with Velcro is used to fasten the attachment onto the index finger. These fastening bands pass through the 2 slots (on either side) near the bottom of the attachment. The cross-section of the base is contoured to match the top of the index finger.

Upon lightly pressing near the bottom on either side of the attachment (similar to a clothing peg), the half-razor blade may be released and replaced. Polypropylene is proposed as the material for manufacture due to its fatigue strength, semi-rigidity & reasonable cost for mass manufacture.

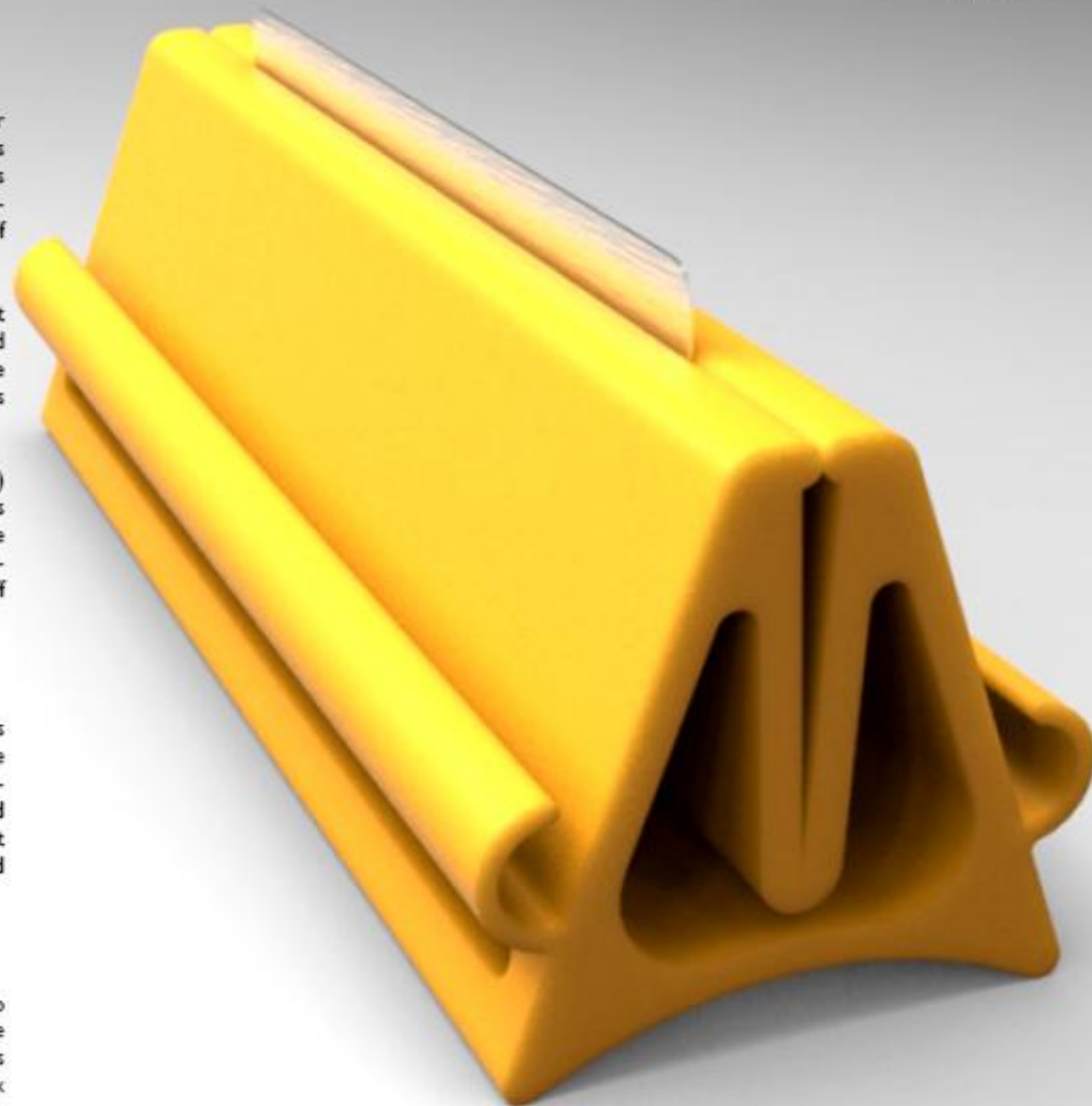
Plucking tea-leaves would result in harmful alkaloids (sap-like liquid) to seep down towards the bottom of the attachment where it is collected, hence avoiding hand-contact with the plucker's hands. The 2 semi-circular protrusions on either side of the attachment are designed to facilitate this. A quick spray of water may be used to wash off the alkaloid when full.

### 2. THUMB GUARD:

In the current design, the thumb is used to press the tea-leaf stems onto the blade to perform the cutting action. In order to protect the worker's thumbs from blade slashes, a leather thumb guard which extends to the base of the thumb was devised. Nylon-fabric bands layered with Velcro may be used to fasten the guard onto the thumb to arrest its motion while in use, these straps may directly be machine-stitched onto the leather.

### 3. PROTECTIVE GLOVES:

Thick breathable nylon-latex gloves (reaching the elbows), similar to those used by edema patients are recommended for use along with the blade attachment & thumb guard- in order to protect the tea worker's hands and fore-arms while they reach over prickly tea-bushes to pluck leaves.



8.8 FINAL DESIGN CONCEPT FOR PROTOTYPING



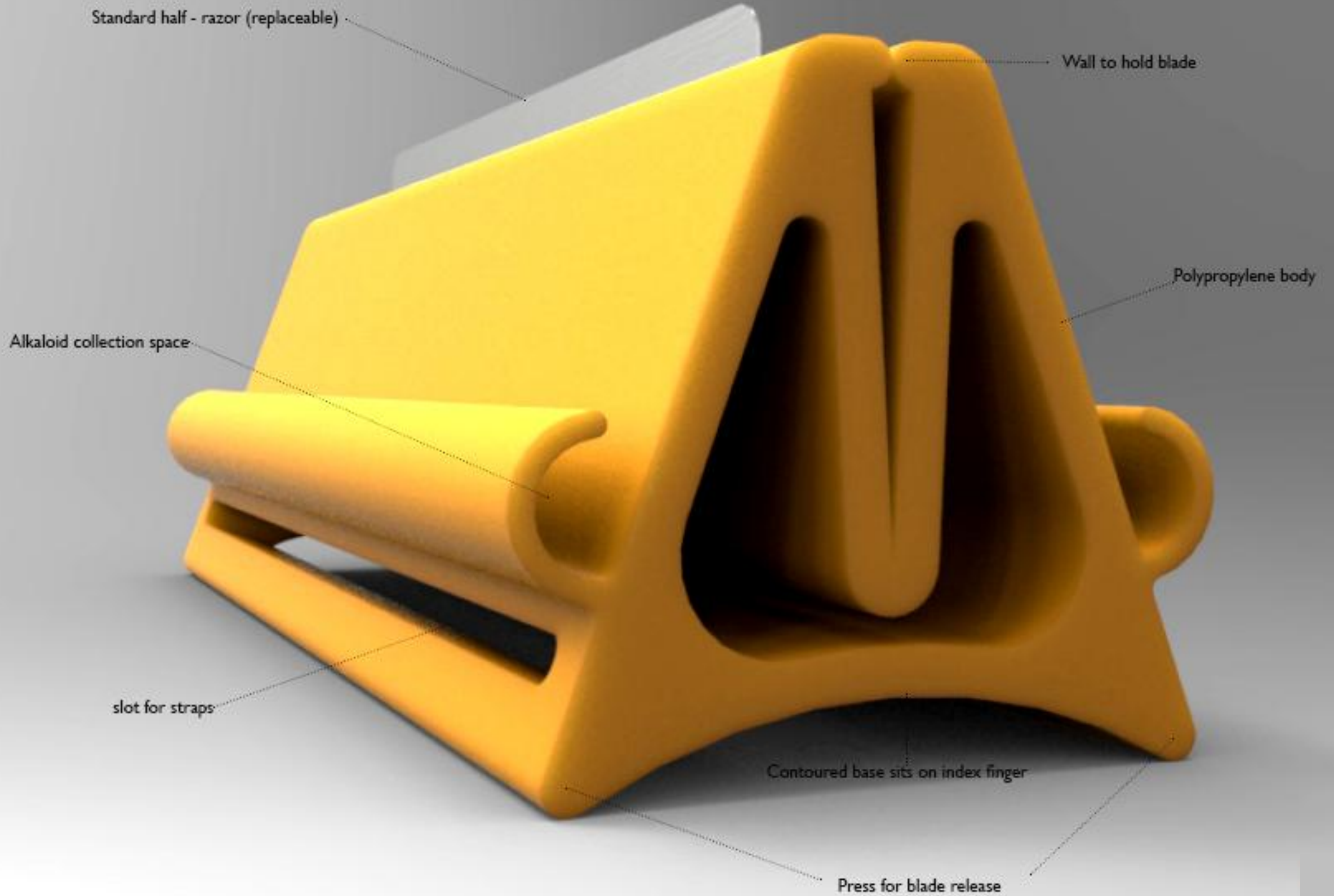
Fig 8.9



Fig 8.10

## 8.9 FINAL DESIGN CONCEPT FOR PROTOTYPING

Fig 8.11





<b>1. No. of test subjects :</b>	5 tea pluckers
<b>2. Duration of training with prototypes:</b>	30 minutes / subject
<b>3. Comparison :</b>	20 min hand plucking v/s 20 min proto-plucking
<b>4. Quantitative data:</b>	Weight of Plucked leaves (Grams)
<b>5. Qualitative data:</b>	Plucking Effort required (Scale of 5) Pain Experienced whilst plucking (Scale of 5) Quality of plucked leaves (Scale of 5)

10.0 USER TRIAL TEST GROUP



10.0 USER TRIALS AT DOOARS, DARJEELING



## 10.0 USER TRIALS AT DOOARS, DARJEELING



## 10.1 USER TRIALS DATA TABULATION

SI #	Name (M/F)	Age	Experience	HAND-PLUCKING (20 MINUTES)				
				Weight of Plucked Leaves (grams)	Average Plucking Rate (grams/min)	Plucking Effort (Score/5)	Pain Experienced (Score/5)	Leaf Quality (Score/5)
1	Kirpa Hasda (F)	27	5 Yrs	1200	60	4	3	4
2	Nancy Khardiya (F)	24	6 Mns	2000	100	3	4	3
3	Anima Indwar (F)	22	4 Mns	1200	60	5	3	4
4	Hasina Sheikh (F)	35	17 Yrs	1500	75	4	5	4
5	Anand Sheikh (M)	21	2 Mns	1500	75	4	3	3

SI #	Name (M/F)	Age	Experience	PROTO-PLUCKING (20 MINUTES)				
				Weight of Plucked Leaves (grams)	Average Plucking Rate (grams/min)	Plucking Effort (Score/5)	Pain Experienced (Score/5)	Leaf Quality (Score/5)
1	Kirpa Hasda (F)	27	5 Yrs	500	25	2	1	4
2	Nancy Khardiya (F)	24	6 Mns	500	25	1	1	4
3	Anima Indwar (F)	22	4 Mns	400	20	2	1	4
4	Hasina Sheikh (F)	35	17 Yrs	500	25	1	1	4
5	Anand Sheikh (M)	21	2 Mns	600	30	1	1	4

## 10.2 USER TRIAL RESULTS

Sl #	Name (M/F)	Age	Experie	HAND-PLUCKING <i>Plucking Effort (Score/5)</i>	PROTO-PLUCKING (20 MIN) <i>Plucking Effort (Score/5)</i>	PERCENTAGE DECREASE
1	Kirpa Hasda (F)	27	5 Yrs	4	2	50.00%
2	Nancy Khardiya (F)	24	6 Mns	3	1	66.67%
3	Anima Indwar (F)	22	4 Mns	5	2	60.00%
4	Hasina Sheikh (F)	35	17 Yrs	4	1	75.00%
5	Anand Sheikh (M)	21	2 Mns	4	1	75.00%
<b>AVERAGE REDUCTION % =</b>						<b>65.33%</b>

### LEGEND FOR SCORES -PLUCKING EFFORT

Score/5	Represents
1	Minimal effort required to pluck leaves
2	Lesser effort required to pluck leaves
3	Fair amount of effort required to pluck leaves
4	More effort required to pluck leaves
5	Maximum effort required to pluck leaves

## 10.3 USER TRIAL RESULTS

SI #	Name (M/F)	Age	Experier	HAND-PLUCKING (20 MIN)	PROTO-PLUCKING (20 MIN)	PERCENTAGE DECREASE
				Pain Experienced (Score/5)	Pain Experienced (Score/5)	
1	Kirpa Hasda (F)	27	5 Yrs	3	1	66.67%
2	Nancy Khardiya (F)	24	6 Mns	4	1	75.00%
3	Anima Indwar (F)	22	4 Mns	3	1	66.67%
4	Hasina Sheikh (F)	35	17 Yrs	5	1	80.00%
5	Anand Sheikh (M)	21	2 Mns	3	1	66.67%
					<b>AVERAGE REDUCTION % =</b>	<b>71.00%</b>

LEGEND FOR SCORES -PAIN EXPERIENCED	
Score/5	Represents
1	Minimal pain or discomfort experienced
2	Lesser pain or discomfort experienced
3	Fair amount of pain experiences
4	More pain or discomfort experienced
5	Maximum pain or discomfort experienced

## 10.4 USER TRIAL RESULTS

Sl #	Name (M/F)	Age	Experience	HAND-PLUCKING (20 MIN) <i>Leaf Quality (Score/5)</i>	PROTO-PLUCKING (20 MIN) <i>Leaf Quality (Score/5)</i>	PERCENTAGE INCREASE
1	Kirpa Hasda (F)	27	5 Yrs	4	4	0.00%
2	Nancy Khardiya (F)	24	6 Mns	3	4	33.33%
3	Anima Indwar (F)	22	4 Mns	3	4	33.33%
4	Hasina Sheikh (F)	35	17 Yrs	4	4	0.00%
5	Anand Sheikh (M)	21	2 Mns	3	4	33.33%

**AVERAGE IMPROVEMENT % = 20.00%**

### LEGEND FOR SCORES -LEAF QUALITY

Score/5	Represents
1	Poor leaf quality
2	Below average leaf quality
3	Satisfactory leaf quality
4	Good leaf quality
5	Very good leaf quality

## 10.5 USER TRIAL RESULTS

SI #	Name (M/F)	Age	Experience	Manual Plucking (2 handed) 20 min	Manual Plucking (1 handed) 20min
				Weight of Plucked Leaves (grams)	Weight of Plucked Leaves (grams)
1	Kirpa Hasda (F)	27	5 Yrs	1200	600
2	Nancy Khardiya (F)	24	6 Mns	2000	1000
3	Anima Indwar (F)	22	4 Mns	1200	600
4	Hasina Sheikh (F)	35	17 Yrs	1500	750
5	Anand Sheikh (M)	21	2 Mns	1500	750

SI #	Prototype Plucking (1 handed) 20min	Percentage Decrease 1	Percentage Decrease 2
	Weight of Plucked Leaves (grams)	(Comparison Vs 2 Handed)	(Comparison Vs 1 Handed)
1	500	58.33%	16.67%
2	500	75.00%	50.00%
3	400	66.67%	33.33%
4	500	66.67%	33.33%
5	600	60.00%	20.00%
<b>AVERAGE REDUCTION % =</b>		<b>65.33%</b>	<b>30.67%</b>

### SAFETY HAZARDS

- Extremely sharp SS razors would slash through their skin if the pluckers absent-mindedly brush their face or body to remove insects.

### BLADE ATTACHMENT

- Makes approach to leaf difficult hence yielding a low collection efficiency - it is difficult to grip the leaves once they are cut.
- Decreasing height would ensure more plucking force applied at shear junction.

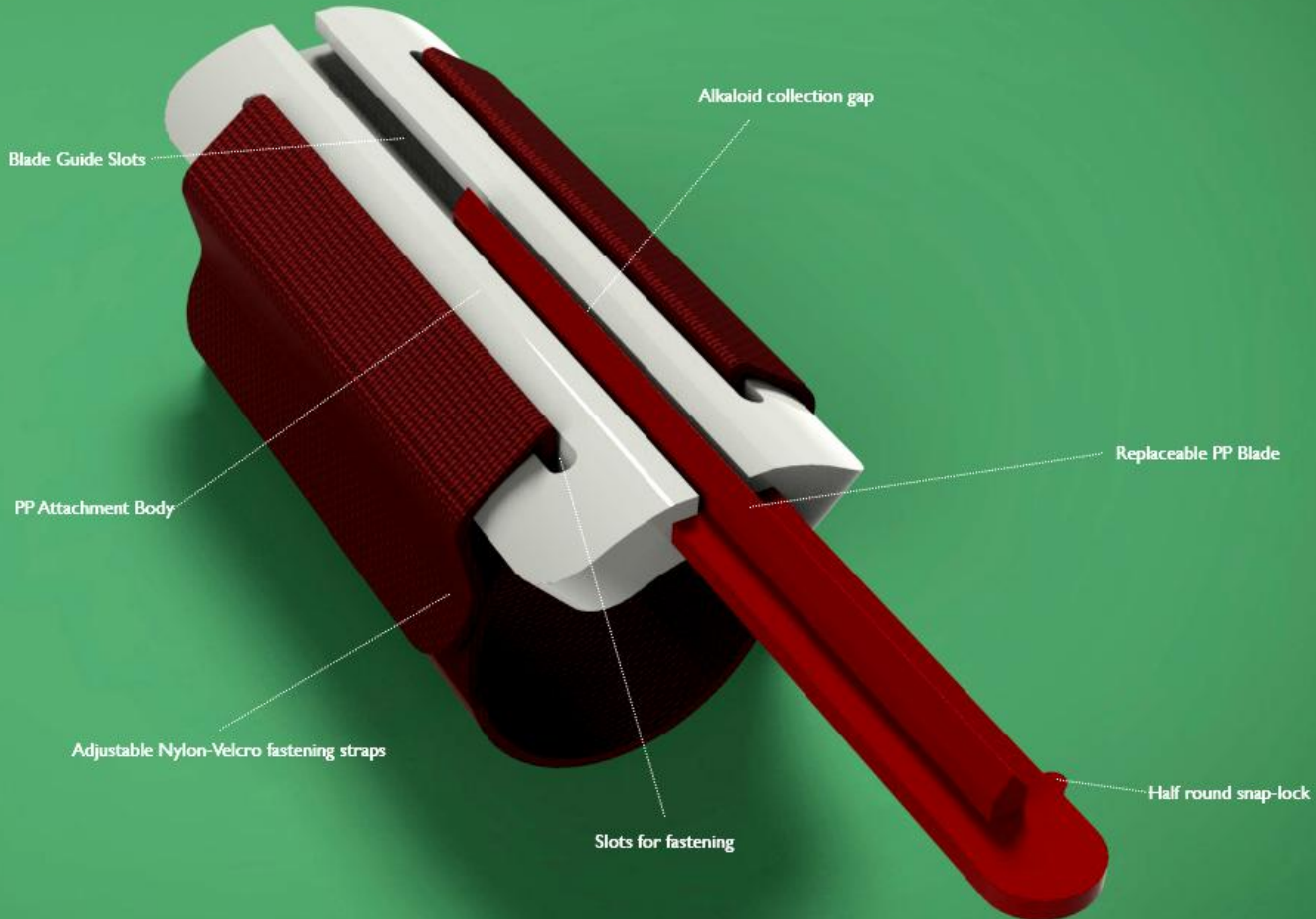
### FASTENING BANDS

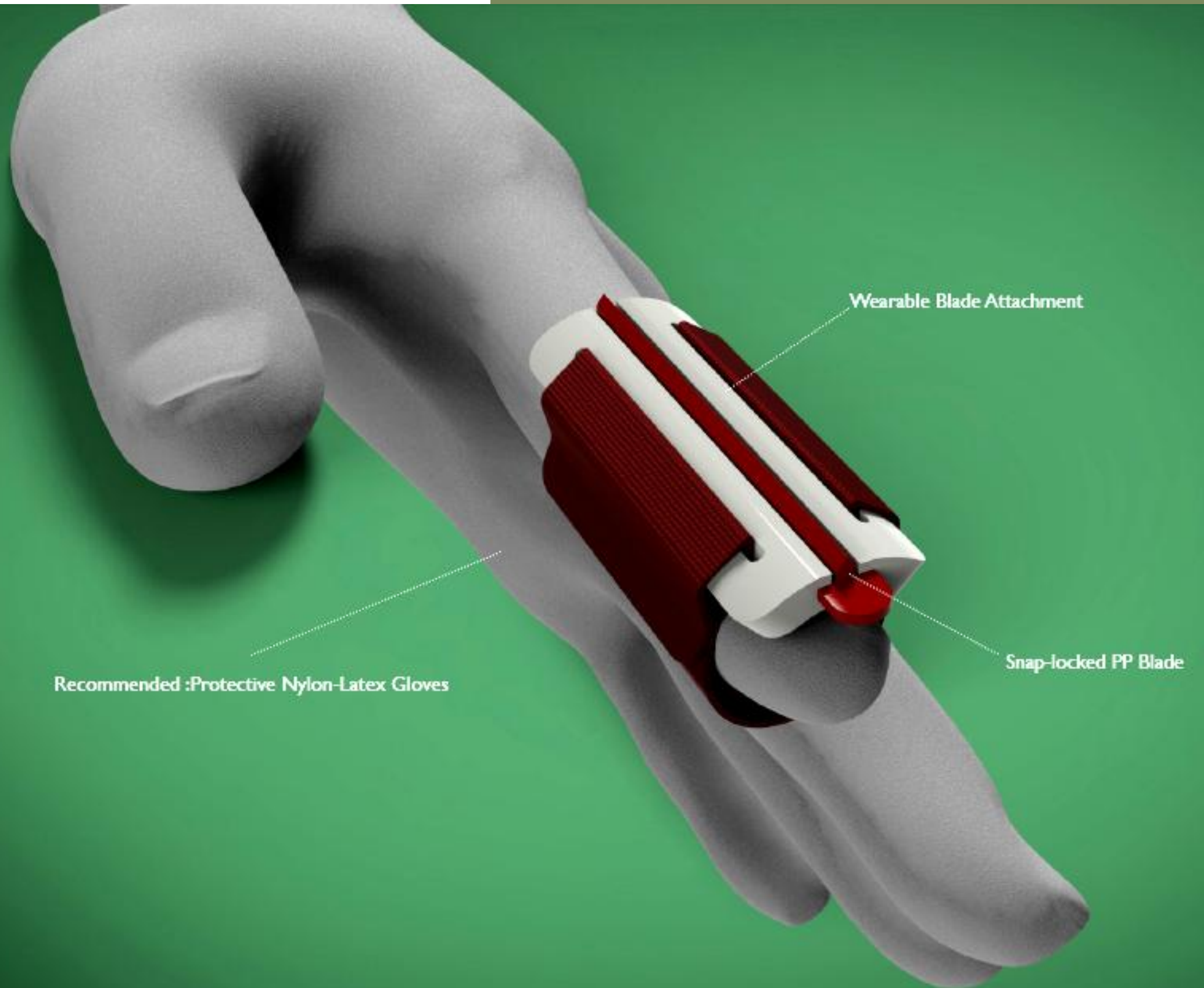
- Elastic straps taken for the field test eventually loosen and rotate about the index finger and thumb.

### TRAINING TIME

Workers need to get accustomed to the aid , prototypes could be deployed for 30 days for deeper insights & more accurate data on usage patterns.

## 11.0 FINAL DESIGN PROPOSAL



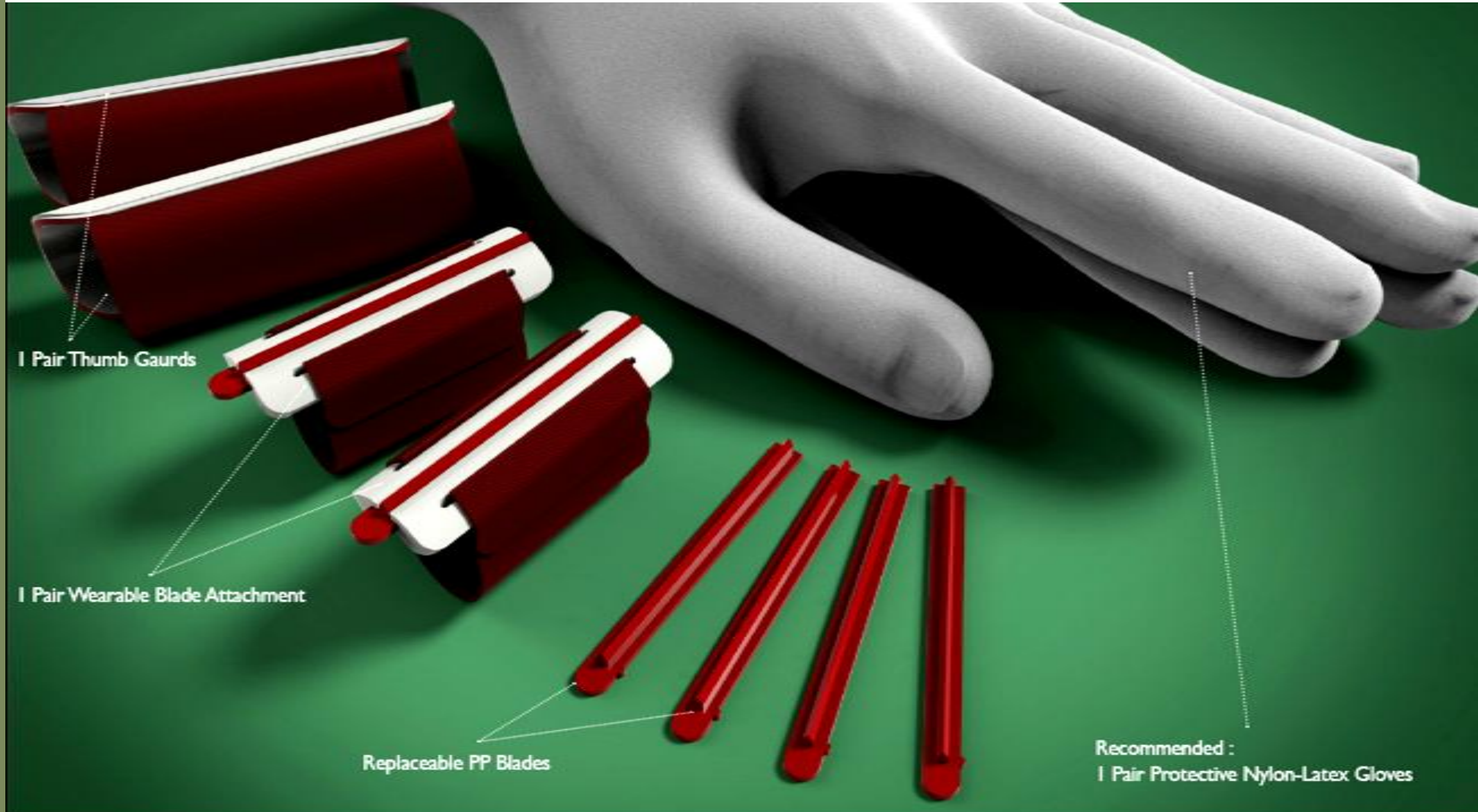


Recommended :Protective Nylon-Latex Gloves

Wearable Blade Attachment

Snap-locked PP Blade



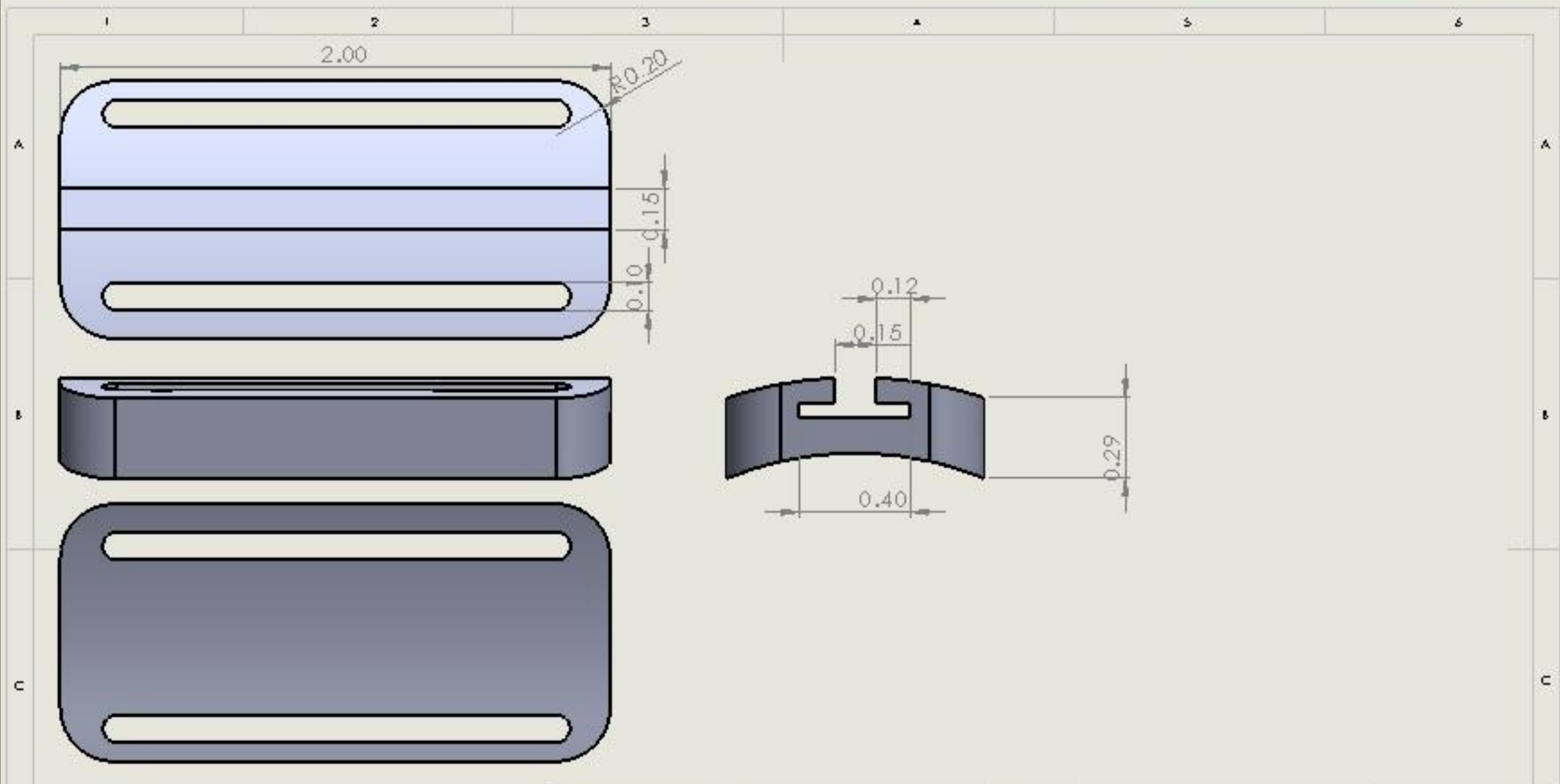


1 Pair Thumb Gaurds

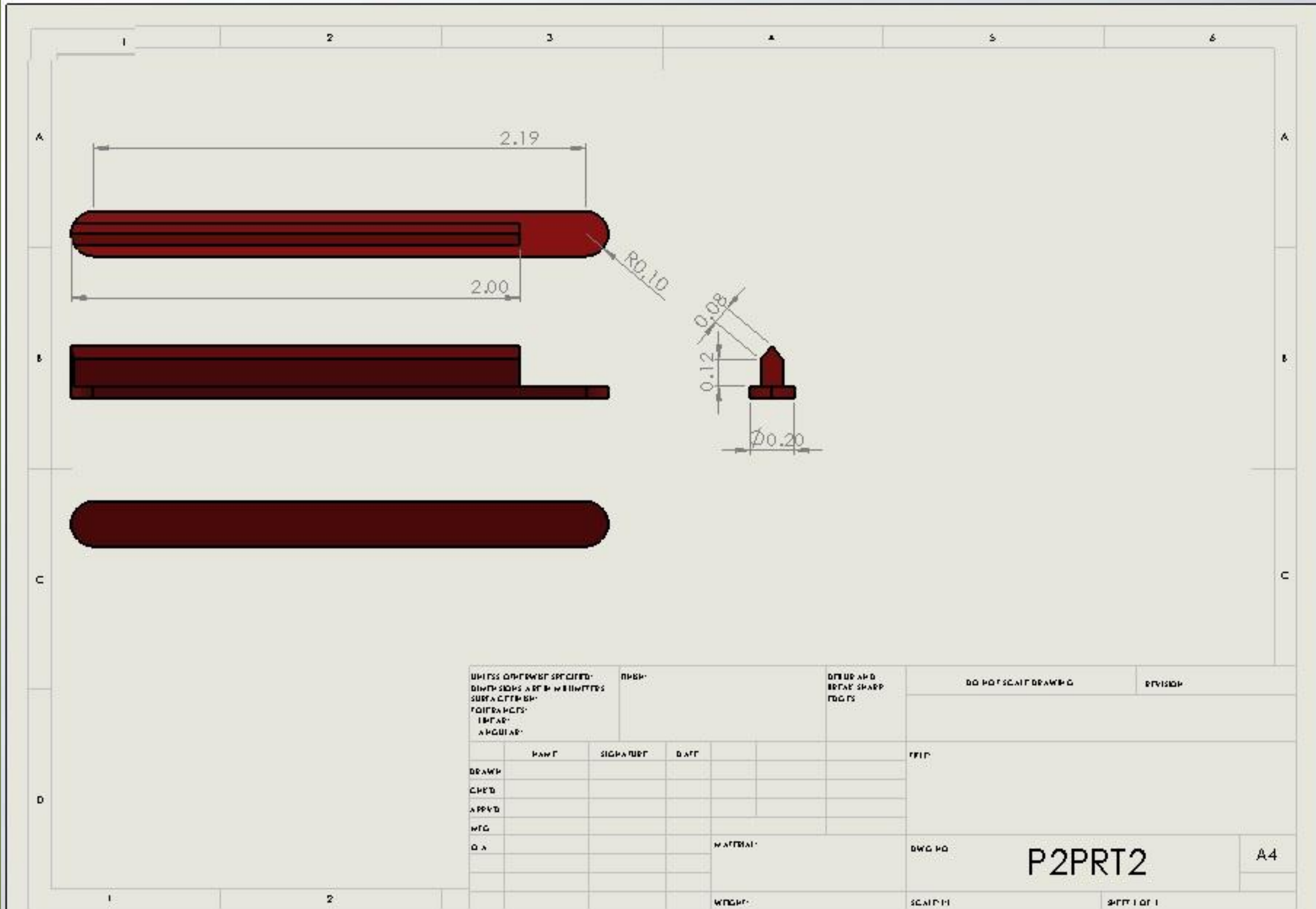
1 Pair Wearable Blade Attachment

Replaceable PP Blades

Recommended :  
1 Pair Protective Nylon-Latex Gloves



UNLESS OTHERWISE SPECIFIED - DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH - FOR DETAILS - TEMPER - ANGLE -		TOLERANCE		DIMENSIONS AND EDGE SHARP EDGES		DATE OF SCALE DRAWING		REVIEWER	
NAME		SIGNATURE		DATE		TITLE		PROJECT	
DRAWN		CHECKED		APPROVED		MATERIAL		DWG NO	
DATE		MATERIAL		DWG NO		SCALE 1:1		SHEET 1 OF 1	
						P2PRT1		A4	



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: FOLLOWING UNLESS OTHERWISE SPECIFIED		PAPER		DIMENSIONS ARE GIVEN UNLESS OTHERWISE SPECIFIED		DO NOT SCALE DRAWING		REVISION	
NAME	SIGNATURE	DATE							
DRAWN									
CHECKED									
APPROVED									
MFG									
Q.A.					MATERIAL		DWG NO	P2PRT2	
									A4
					WEIGHT		SCALE	SHEET 1 OF 1	



## 11.0 CONSLUSIONS

Use of the prototype significantly reduced the plucking effort required to detach tea-leaves as well as pain experienced during tea-leaf plucking. The slight improvement in the quality of plucked leaves may be accounted for due to the slower, more careful sequence of operations whilst using the prototype.

The weight of plucked leaves in comparison to hand plucking is expected to rise once the tea-pluckers are allowed to familiarize themselves with using the prototype for a longer duration and more training.

Although no-one was injured during the user-trials, further refinement of the prototype could incorporate safety considerations to avoid accidental injuries.

## REFERENCES

Sen R.N., Ganguli A.K. , Ray G.G. , Chakrabarti D. 1981

"Ergonomics study of tea-leaf plucking operations : Criteria for selection & categorization." Applied Ergonomics 07/1981

Sen R.N., Ganguli A.K. , Ray G.G. , Chakrabarti D. 1983

"Tea-leaf plucking – workloads & environmental studies." Applied Ergonomics 10/1983

Eliminate blade safety concern completely.  
Designing for better collection efficiency.  
Address static contraction of muscles.  
Strain-gauge testing for plucking effort.  
Business model & Branding.

