

DESIGN RESEARCH SEMINAR REPORT ON

DESIGN METHODOLOGY FOR IMPROVEMENTS TO THE TEA-LEAF PLUCKING AID

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Fig1: A typical tea-plucker , Dooars, Darjeeling



Fig2: traumatised hands of a tea-leaf plucker

1.0 INTRODUCTION

At present, India is the second largest producer of tea in the world & accounts for the employment of more than 2 million people *.

At the bottom of the tea industry pyramid are the tea plantation workers, who are prone to various occupational hazards, 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.

1.1 OCCUPATIONAL HAZARDS AFFECTING HANDS OF TEA PLUCKERS

HAND FATIGUE & REPETITIVE STRAIN INJURY

Due to long hours of repetitive motions whilst plucking tea

HAND INFLAMMATION AND STIFFNESS

Due to sustained contraction of muscles.

EXPOSURE TO HARMFUL CHEMICAL RESIDUES

From plucking tea leaves and pesticides

ABRASION OF FINGERS

Due to repetitive plucking motion.

INJURIES

From Leeches, insect & snake bites.

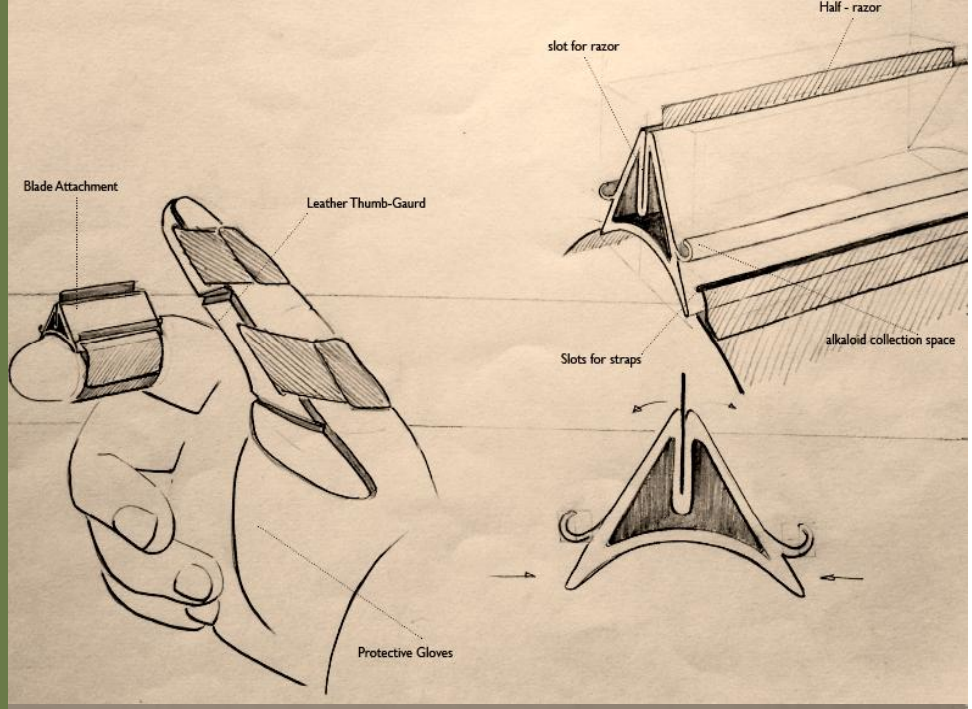


Fig3,4: Tea-leaf Plucking Aid Prototype from P2



1.2 BACKGROUND OF P2 DESIGN DIRECTION

The pre-final design concept from project 2 was rapid prototyped in ABS and tested with tea-pluckers in Dooars , Darjeeling district, West Bengal.

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 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.

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, 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.

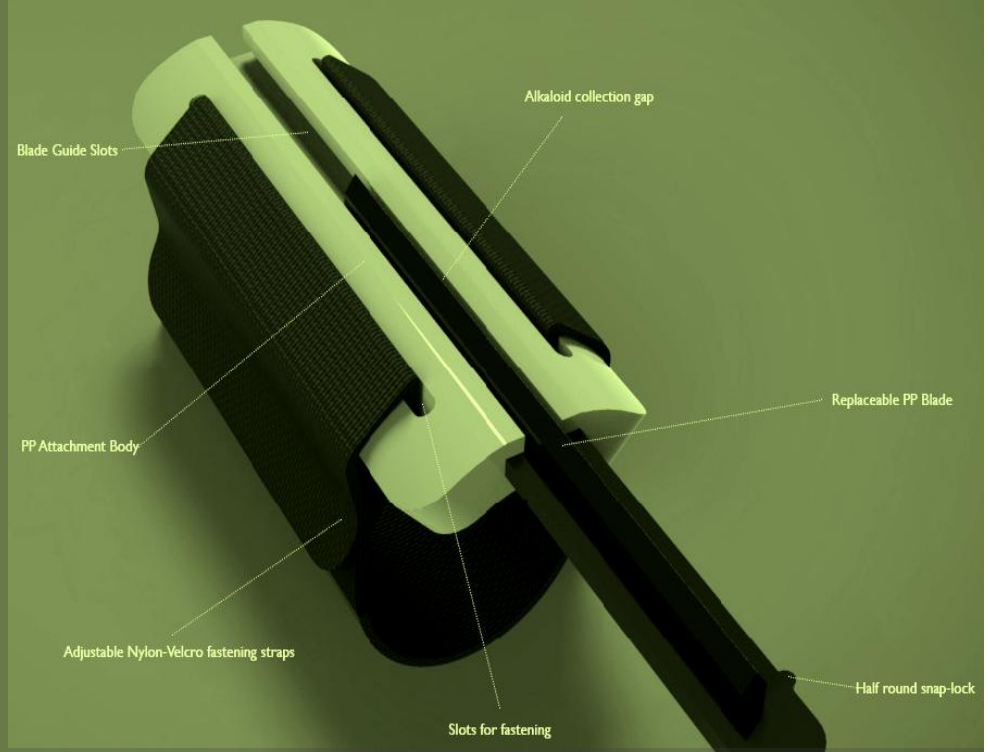
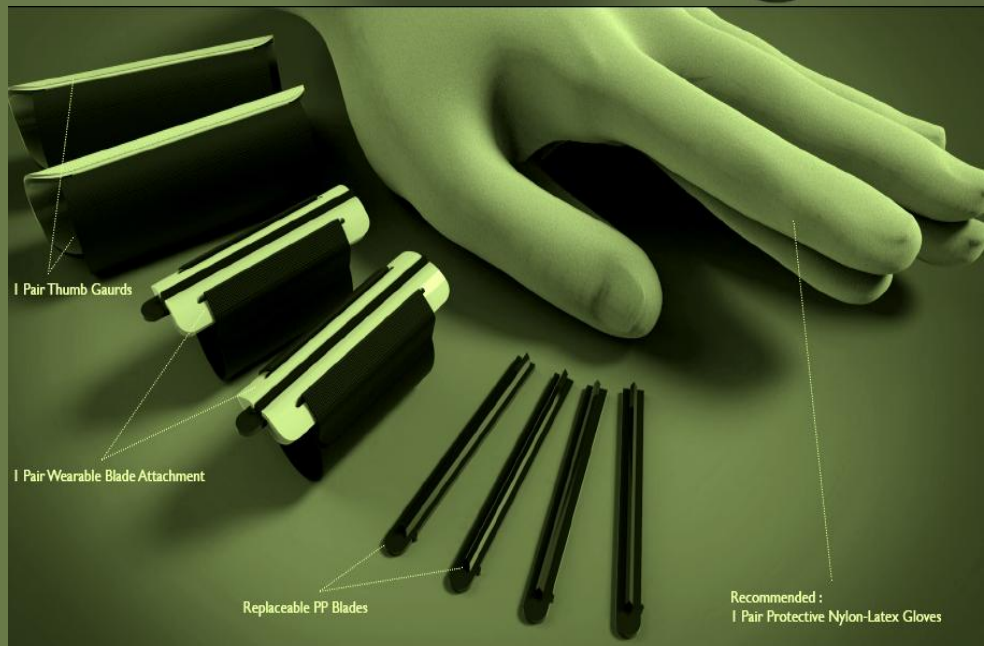


Fig5,6: Tea-leaf Plucking aid design proposal from P2



1.3 DESIGN DIRECTION POST P2 USER TRIALS

Post user-trials with tea-pluckers & stakeholders ,the following refinements were incorporated into the final design proposal (for P2):

1. SS blades may be replaced with disposeable polypropylne blades to prevent injury.

2. Blade attachment height may be reduced to facilitate better approach to leaf.

3. Nylon-fabric bands layered with Velcro strapping may be used to fasten better.

The final design concept at P2 level proposed the following components for the tea-leaf plucking aid.

1. 1 PAIR PP BLADE ATTACHMENTS: Disposeable PP Blades
Adjustable Nylon-Velcro Straps

2. 1 PAIR THUMB GAURDS: PP layered with foam leather
Adjustable Nylon-Velcro Straps

3. 1 PAIR PROTECTIVE GLOVES: Nylon-latex gloves (upto elbows)

1.4 INFERENCES FROM P2 TRIALS : IDENTIFYING IMPROVEMENT AREAS

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.

2.0 METHODOLOGY FOR REFINEMENT

INFERENCES FROM P2

- **BLADE ATTACHMENT**
  - Safety
  - Collection Eff.
  - Approach
- **THUMB GUARD**
  - Flexibility
  - Comfort

ALTERNATIVES - DESIGN ,MOCKUPS

- **BLADE ATTACHMENT**
  - Plastic Blade
  - SS Blade w/ safety
  - Thumb Mounted
- **THUMB GUARD**
  - Segmented Plastic
  - Leather ,Fabric
  - Varient 3

EXPERIENCE PROTOTYPING OF MOCKUPS

- **ROLE PLAYING**
- **TEST PARAMETERS**
  - Safety
  - Collection Eff.
  - Ease of Approach
  - Flexibility
  - Comfort
  - Protection

EVALUATION & SELECTION OF FINAL

- Matrix Evaluation

FINAL USER TRIALS

- **PARAMETERS**
  - 5 Tea Pluckers
  - Comparison to
  - Hand Plucking
  - Defined Time & training
- **QUANTITATIVE**
  - Collection Eff.
  - Metric Analysis – expression mapping
- **QUALITATIVE**
  - Plucking Force
  - Safety
  - Ease of Use

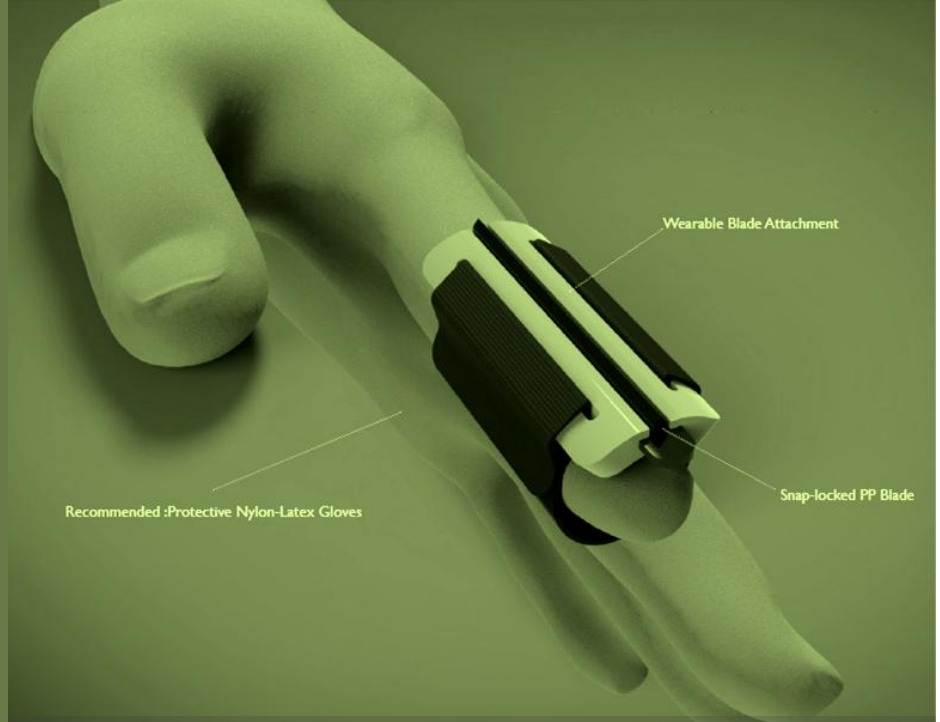
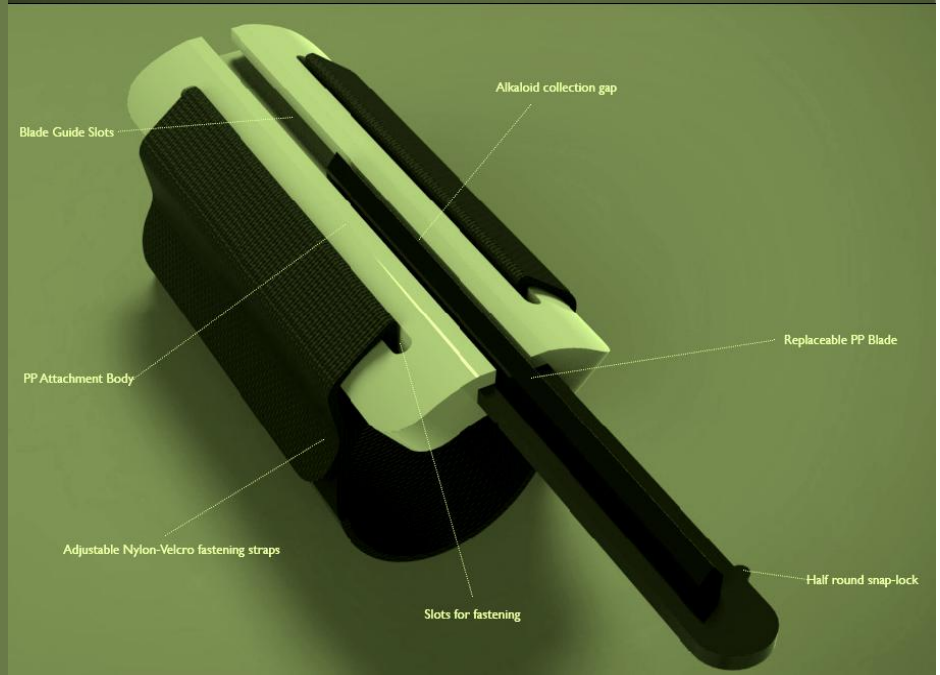


Fig7,8: Tea-leaf Plucking Aid blade attachment from P2



3.0 BLADE ATTACHMENT RE-DESIGN CRITERIA

Post project two user trials , it became apparent that thumb guard needed to be refined to allow for better approach to leaves and consequently higher plucking and collection efficiency. The following refinement criteria was developed for blade-attachment refinement :

▪INCORPORATE SAFETY FEATURES:

Ensuring accidental motions (eg. brushing face) do not result in injury.

▪DECREASE BULK:

Decreasing the volume to allow for better approach to the tea-leaves.

▪PROMOTE EASE OF USE:

Improve usability & fastening methods

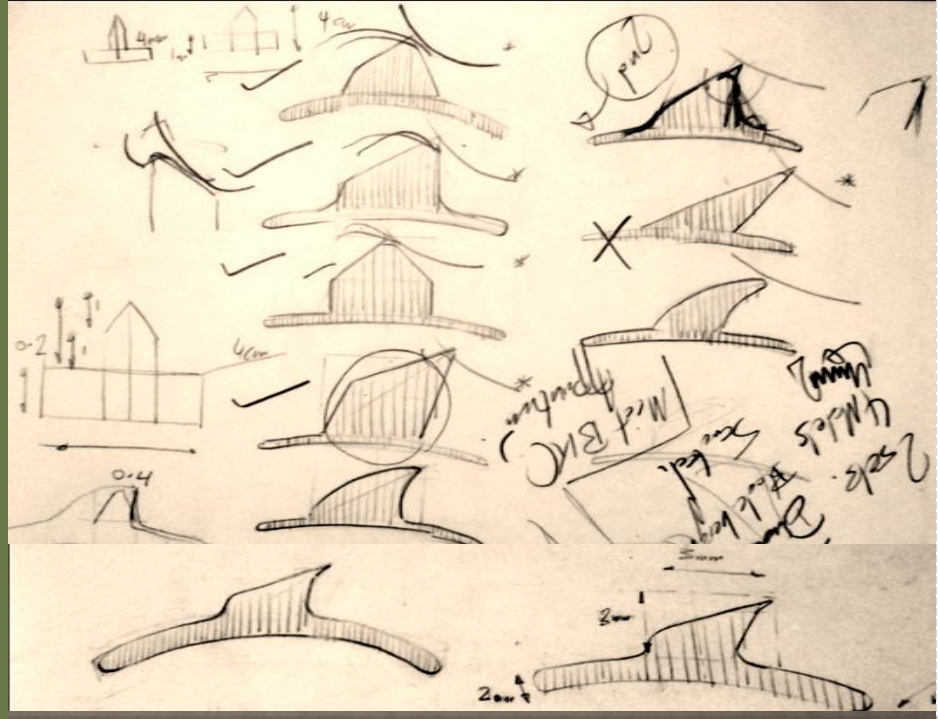
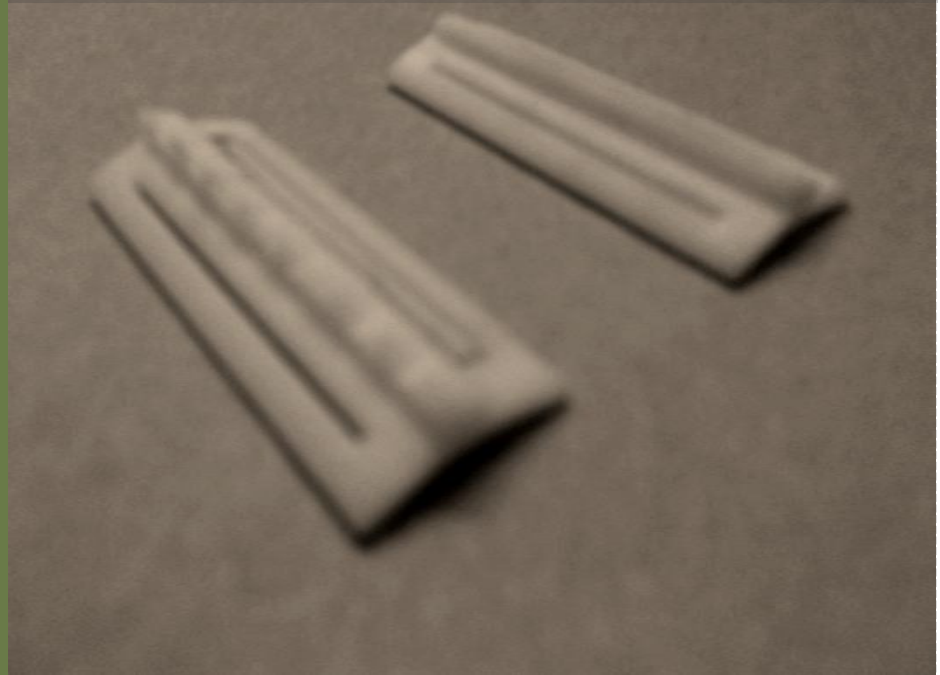


Fig9, 10: Blade attachment refinement – testing blade shapes



3.1 DECISION FOR SINGLE-PIECE PLASTIC ATTACHMENT

During project 2 feedback session, it was highlighted , that instead of having two sets of moulds (1 for the blade attachment , 1 for the disposable plastic blades) , it may be more economical to incorporate a single-piece blade attachment (therefore reducing the number of dies) for mass manufacture.

Omitting the removable blades also ensured that the number of parts and therefore manufacturing complexity is reduced.

3.2 CONCEPTUALIZING POSSIBLE BLADE SHAPES FOR PURPOSE

Various blade shapes were conceptualized for the purpose , the blade shapes chosen for prototyping were slightly inclined away from the thumb. This particular orientation of the plastic blade ensured , plucking force (from the thumb) was imposed on the smallest possible area.

Two variations (straight edge & teethed cutting edge) of these single-piece plastic blade attachments were rapid prototyped in ABS.

3.3 INFERENCES FROM TESTING PLASTIC BLADE

The ABS prototypes were tested on bushes similar to tea-bushes and it was observed that the amount of plucking effort required , in comparison to the previous SS blade prototype, was significantly higher and hence the collection efficiency of leaves was also poor.

We moved away from this design direction as we did not want to compromise on the reduction in plucking force , tested in the pre-final prototype.

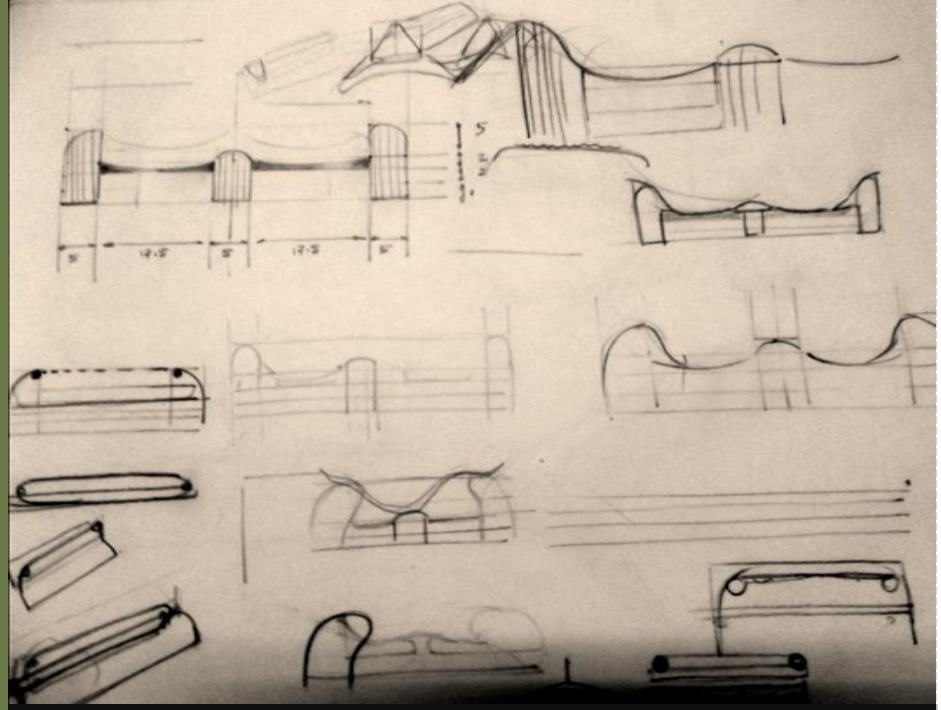
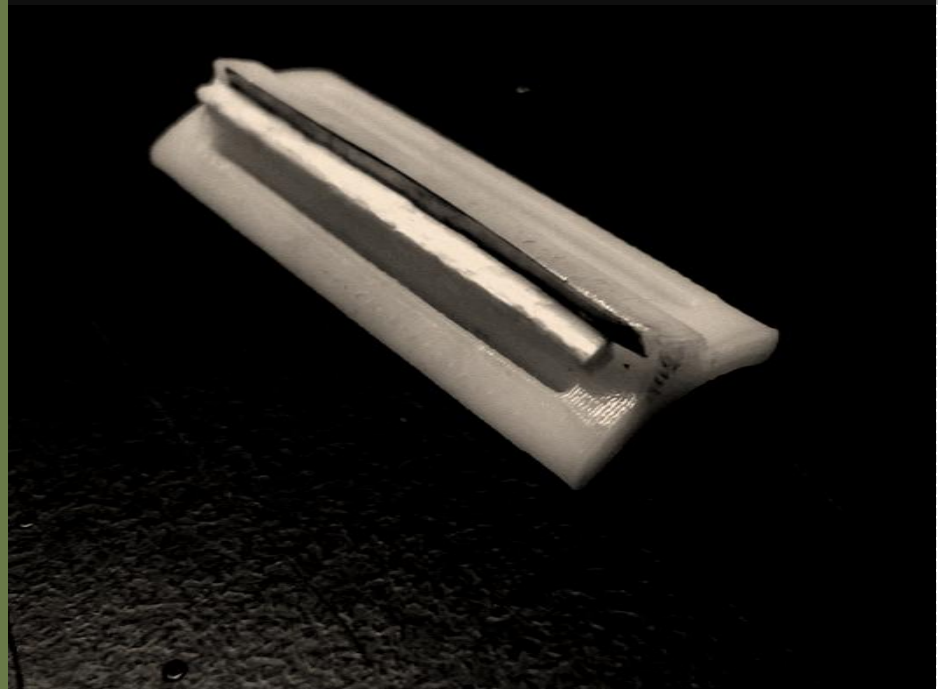


Fig11,12: Blade attachment refinement – SS Blade Insert



3.4 DECISION FOR SS BLADE INSERT

After testing the single-piece plastic blade attachment , it became apparent that the SS blade must be retained to ensure more efficient cutting action of the tea leaves.

The next concept iteration therefore involved inserting a small SS blade into the plastic blade attachment body. The height of the blade was limited to 3mm , a significant reduction from previous 7mm SS half razors.

Insert moulding , a relatively cheap manufacturing method for directly moulding the metal blade insert with the plastic blade was proposed for this particular iteration.

3.5 INFERENCES FROM TESTING INSERT

As expected , the cutting action of the inserted SS blade was significantly more efficient in comparison with previous plastic blade versions. The much reduced blade height made the leaves easier to approach and pluck.

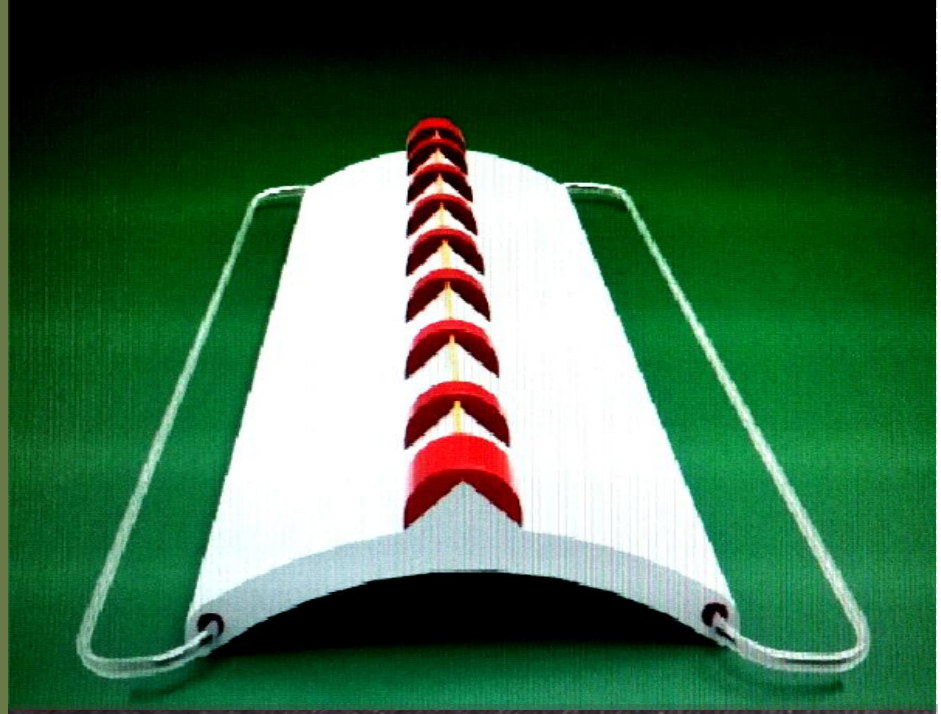






Fig13,14,15: Testing out possible blade safety features

3.6 CONCEPTUALIZING SAFETY FEATURES : CONCENTRIC RINGS

As discussed earlier , retaining the SS blade insert would mean certain safety features would need to be imparted onto the blade attachment to ensure accidental injuries are prevented.

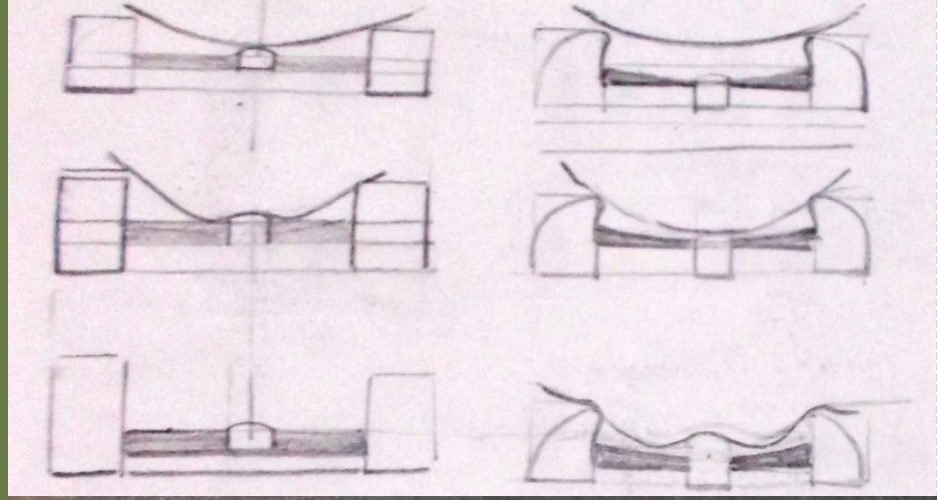
In order to achieve this ,plastic rings linearly arranged at intervals over the sharp SS blade insert were designed and mocked up in styrene to test feasibility for the purpose.

3.7 INFERENCES FROM TESTING

Although the plastic rings avoided accidental injury , it also made it significantly more difficult to cut leaves (due to the reduction in effective blade length).

The intervals between each ring were too small (at 7mm) to allow for effective cutting of tea leaves.

The profile of the rings resulted in leaf shrapnel getting jammed and collected near the rings, making cutting difficult.



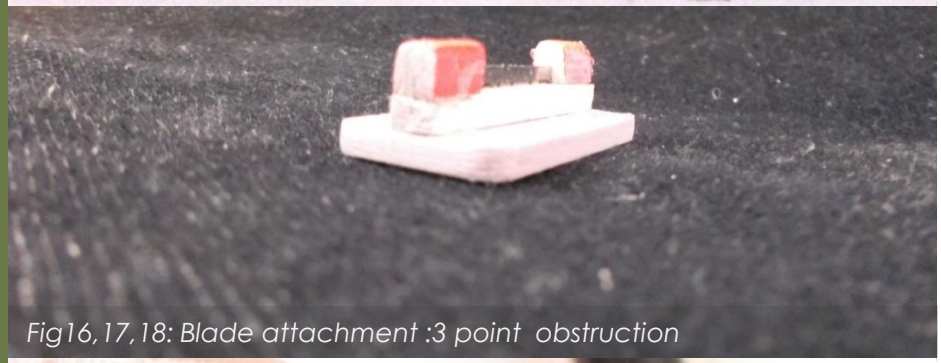


Fig16,17,18: Blade attachment :3 point obstruction



3.8 CONCEPTUALIZING SAFETY FEATURES: POINT CONTACT OBSTRUCTION

In order to overcome the issues associated with the previous safety features , A 3 point contact concept was developed. This involves the use of 2 large ring-like protrusions (about 5mm higher than blade height) on either side of the blade attachment (these act as obstruction to accidentally touching the blade)

The 3rd protrusion is much smaller in size & positioned in the center of the blade attachment , this avoids accidental blade contact , upon pressing. The center nub is strategically placed to allow for 2 finger widths of effective blade length & filleted to avoid leaf shrapnel jamming.

These 3 nubs could either be moulded directly along with the blade attachment body , or snapped onto attachment.

3.9 INFERENCES FROM TESTING SS BLADE W/ SAFETY FEATURE

As the figures along side show , upon mocking up and testing the point contact obstruction concept , accidental injury (eg. brushing hands across the face) was avoided to a significant extent.

The 2 finger widths of effective blade length allowed for effective cutting of the leaves.

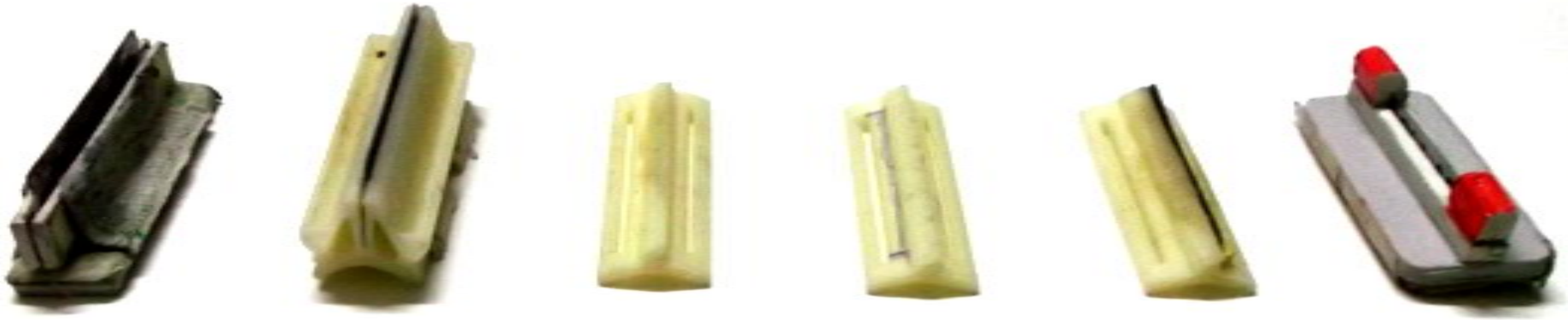


Fig19,20: Blade attachment refinement – evolution of mock-ups



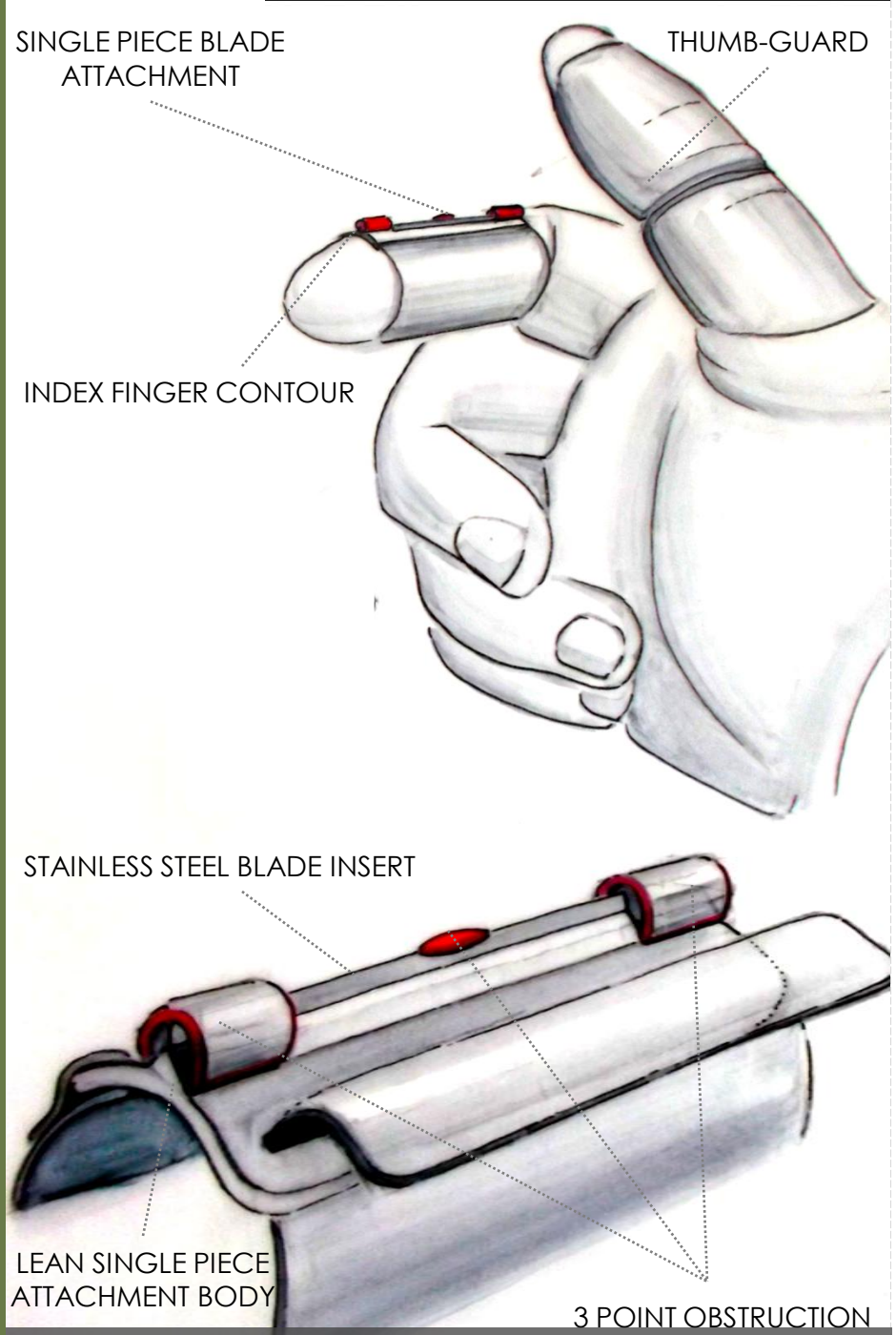


Fig21: Final Design – Blade attachment for tea-leaf plucking aid

3.10 FINAL BLADE ATTACHMENT DESIGN FEATURES

The refined blade attachment concept for the tea-leaf plucking aid incorporated the following additional features:

✓ STAINLESS STEEL BLADE INSERT

SS blade insert was finalised as the cutting edge for the attachment as it resulted in the least amount of plucking effort required to detach leaves from the stem in comparison with other tested blades.

✓ 3 POINT OBSTRUCTION SAFETY FEATURE

As discussed earlier the 3-point obstruction feature ensures that there is significant protection from accidental injury despite using a sharp stainless steel blade insert.

✓ 50% REDUCTION IN VOLUME

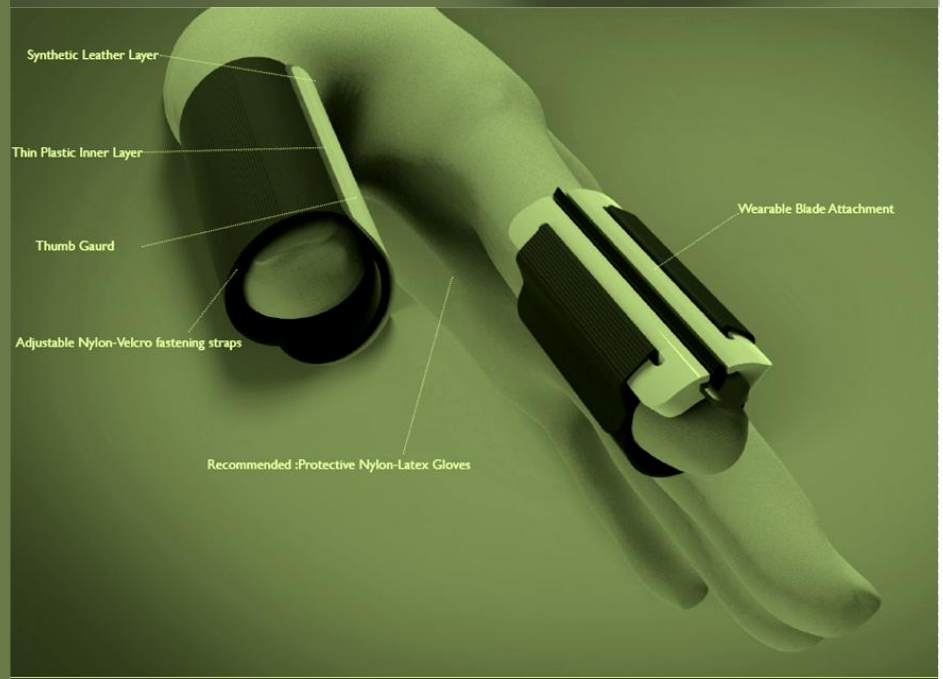
Overall thickness of the blade attachment was stream-lined to a minimalistic 4mm (compared to about 8mm in earlier versions).The blade height was also significantly reduced in an effort to make approach to the tea-leaves easier.

✓ IMPROVEMENTS IN USABILITY

Nylon-fabric bands layered with Velcro may be used to fasten the blade attachment onto the index finger and arrest motion whilst plucking. The velcro straps allow for effective fastening to variable finger diameters.



Fig22,23: Thumb Guard detailing from P2



4.0 THUMB GUARD REDESIGN CRITERIA

4.1 INSIGHTS FROM P2 USER TRIALS

Post project two user trials , it became apparent that thumb guard needed to be refined to allow for better approach to leaves and consequently higher plucking and collection efficiency. The following refinement criteria was developed for thumb-guard refinement :

- **IMPROVE MANEUVERABILITY:** Ensuring thumb movement & dexterity of the guard by designing for flexibility
- **DECREASE BULK:** Decreasing the volume to allow for better approach to the tea-leaves.

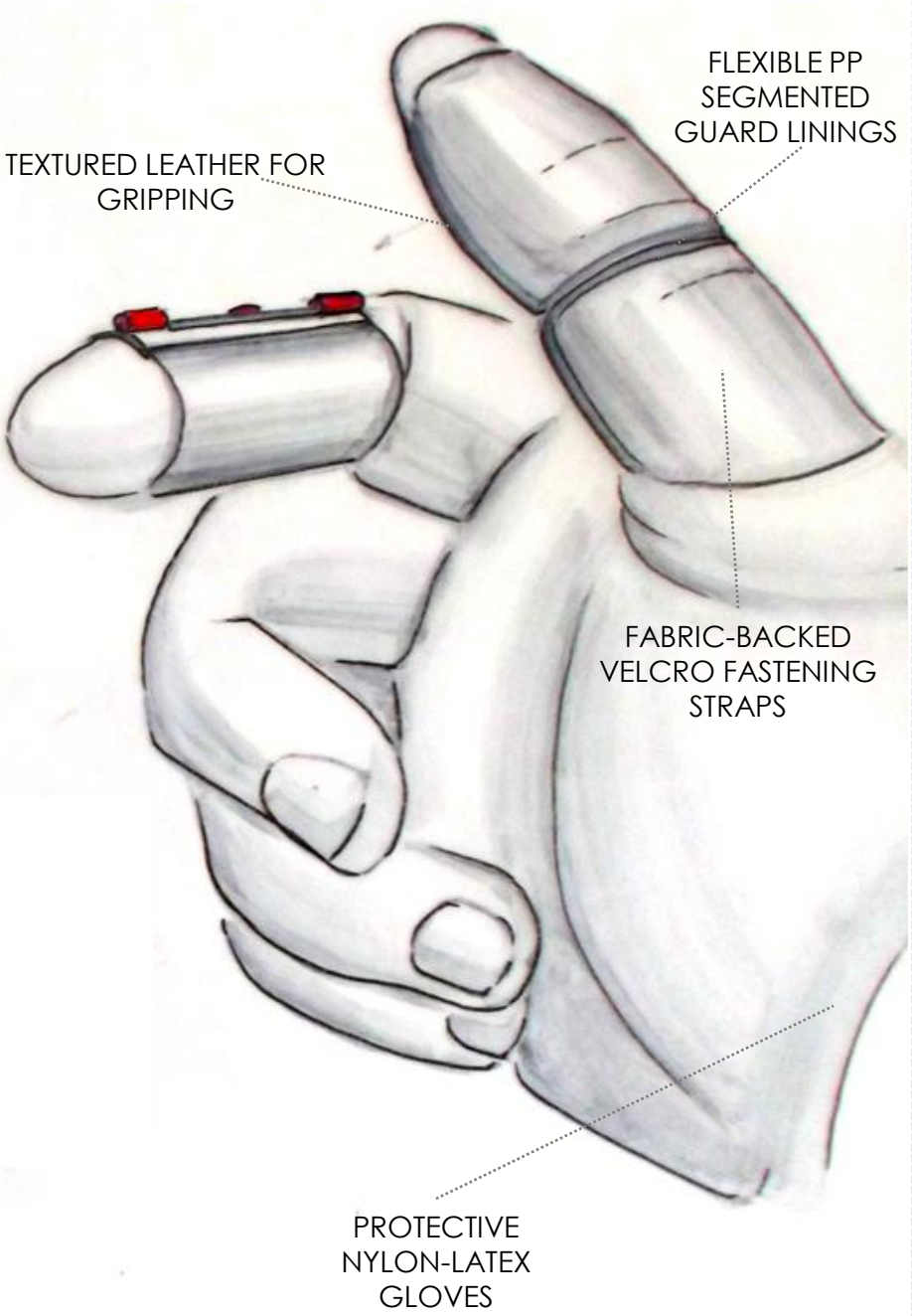


Fig24: Final Design –Thumb Guard for tea-leaf plucking aid

4.2 FINAL THUMB GUARD DESIGN CONCEPT FEATURES:

The refined thumb guard concept for the tea-leaf plucking aid incorporated the following additional features:

✓FABRIC BACKING LAYER

Interiors of the thumb-guard are layered with thick canvas fabric as a secondary measure to avoid slash injuries from the blade.

✓FLEXIBLE POLYPROPYLENE LAYER

Polypropylene < 1mm wall thickness is proposed to impart flexibility onto the thumb-guard. Varying wall thicknesses have been incorporated in the thumb joint region to allow for more bending.

✓ ABRASIVE GRIPPING SURFACE

In the front-end ,a loop-like pattern inspired by finger prints has a sandblasted texture to allow for better gripping of the tea-leaves during plucking.

✓FASTENING

Nylon-fabric bands layered with Velcro may be used to fasten the blade attachment onto the index finger and arrest motion whilst plucking. The velcro straps allow for effective fastening to variable finger diameters.

5.0 FINAL DESIGN SPECIFICATIONS

5.1 MATERIALS & MANUFACTURING

1. **Blade attachment body** Injection moulded polypropylene with ss blade insert
2. **Blade attachment fastening** Stitched fabric backed velcro straps
3. **Thumb guard body** Textured leather-fabric layer with pp backing
4. **Thumb guard fastening** Stitched on fabric backed velcro straps

5.2 DIMENSIONS & ANTHROPOMETRY

All dimensions were determined as per the hand anatomy of a 95th percentile female adult. All subjects with hand dimensions between 5th-95th percentile would be able to fit into the dimensional wire-frame shown alongside.

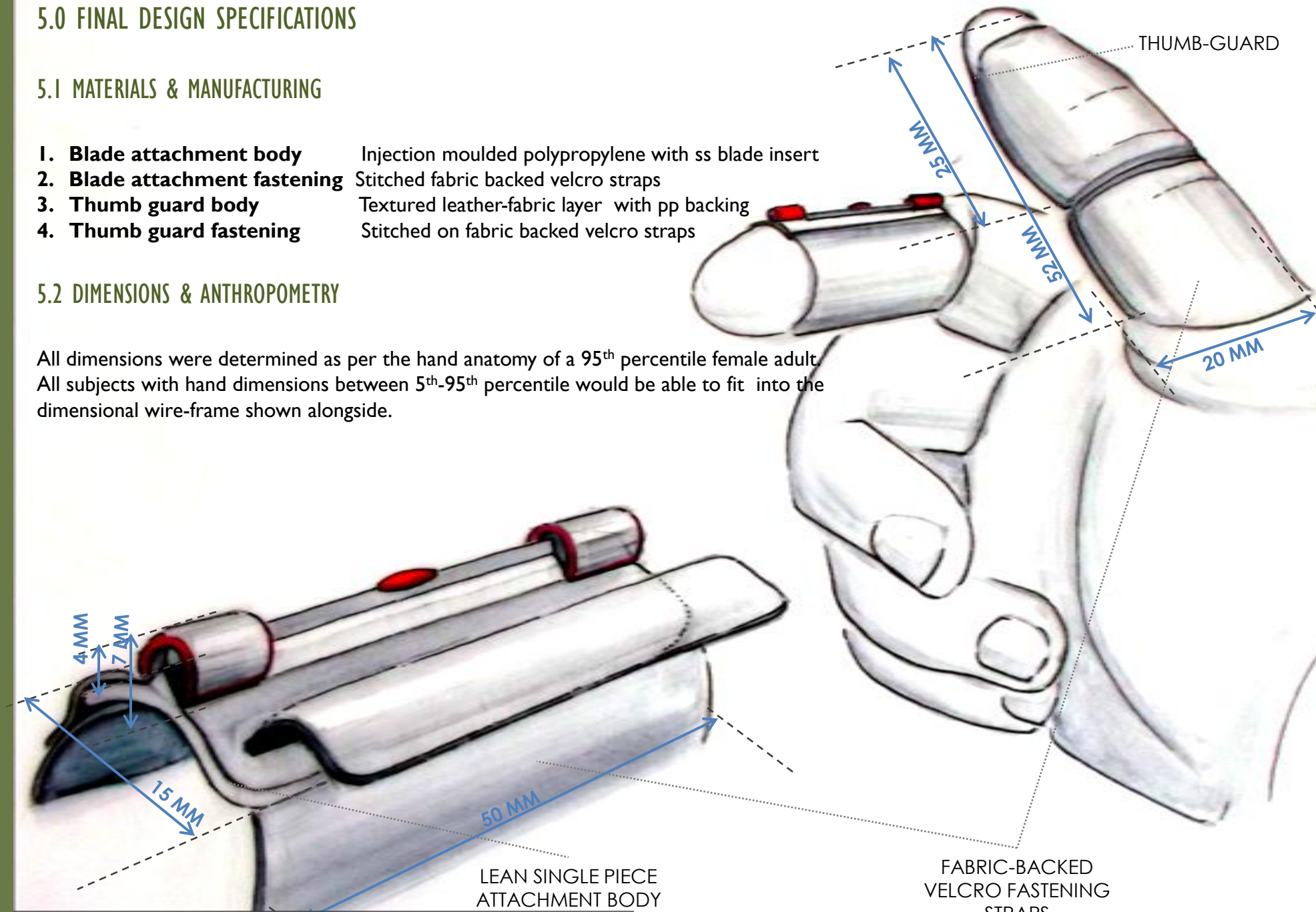
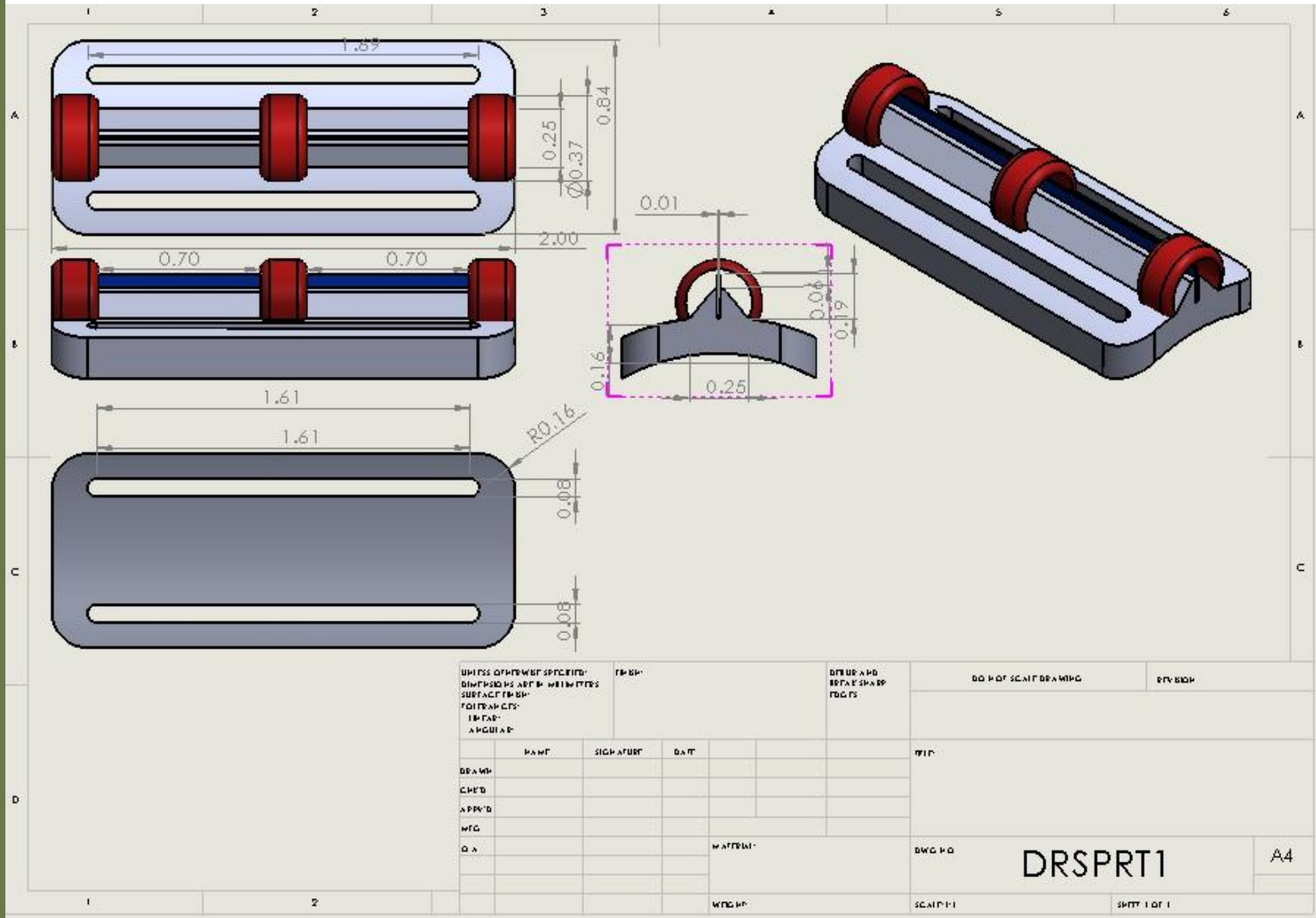


Fig25: Final Design Specifications – Tea-leaf Plucking Aid

5.0 FINAL DESIGN SPECIFICATIONS : ENGINEERING DRAWINGS



5.0 FINAL DESIGN SPECIFICATIONS : PRODUCT RENDER

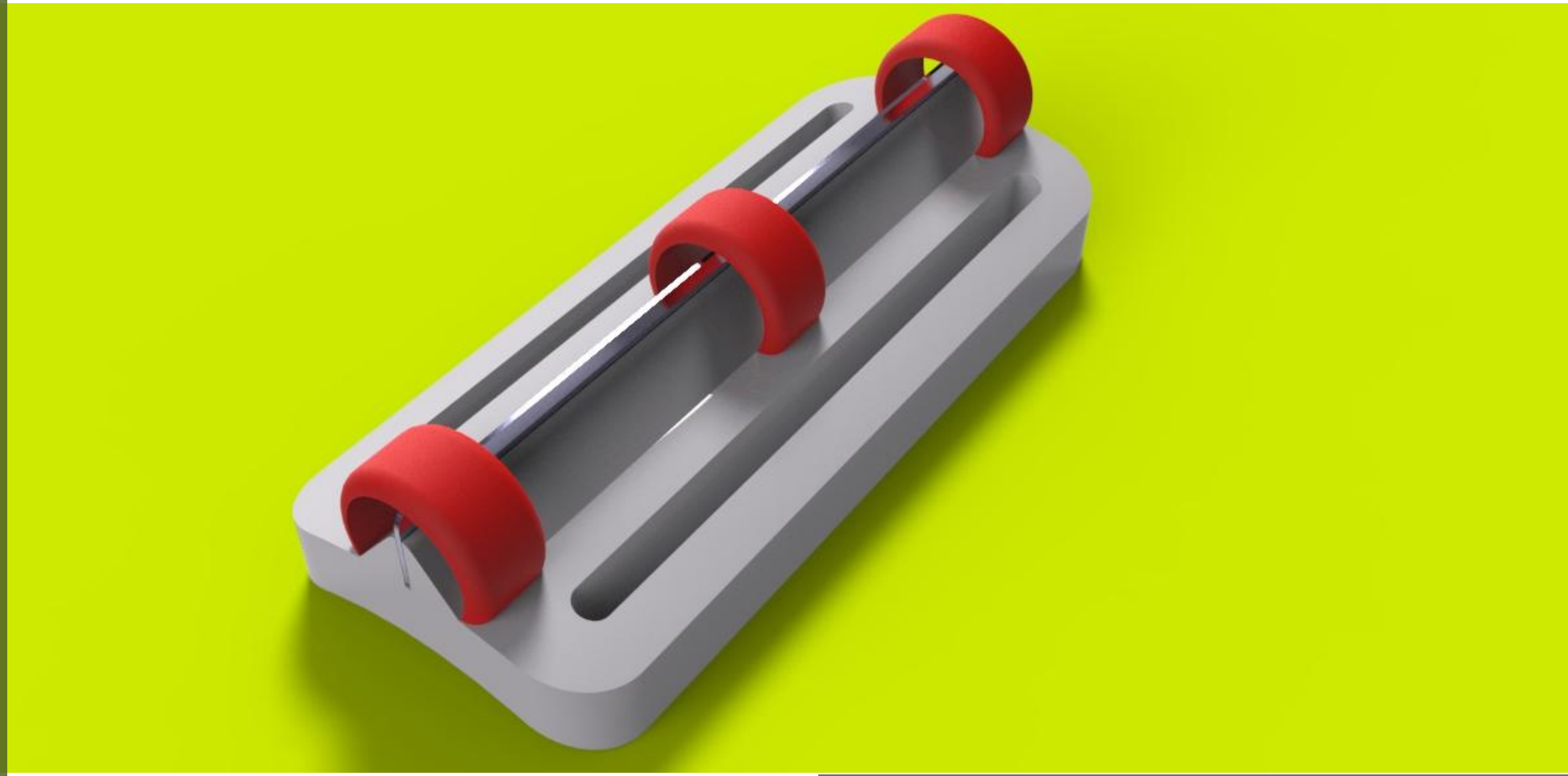


Fig 26 : Final Design :Tea Leaf Plucking Aid with safety

5.0 FINAL DESIGN SPECIFICATIONS : PRODUCT RENDERS

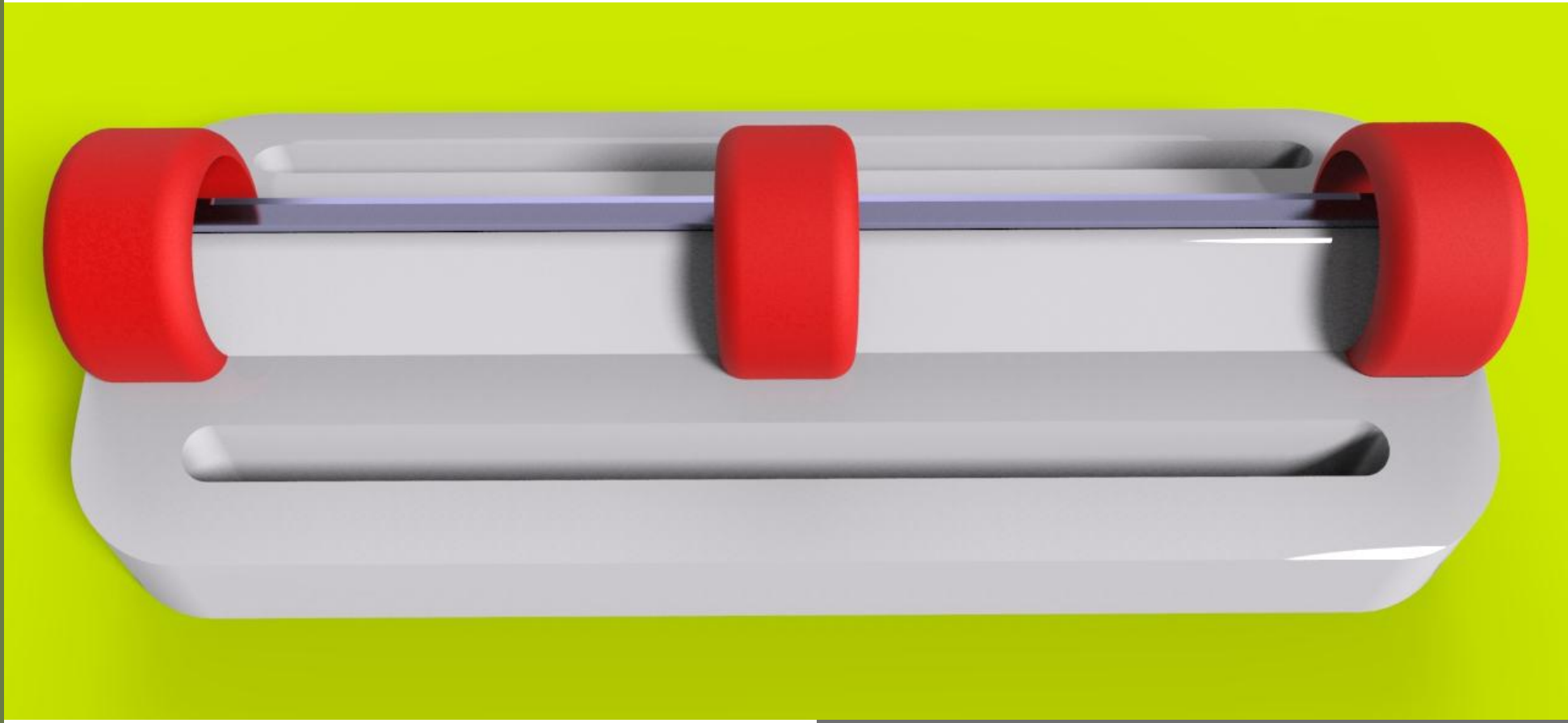


Fig 27 : Final Design :Tea Leaf Plucking Aid with safety



Fig26: A typical tea-leaf plucker ,Dooars ,Darjeeling

SECTION 6.0 PLAN FOR USER TRIALS:

A user trial was planned for January 2015 ,however due to off-season for tea plucking commencement of the pruning cycles, the user trial was rescheduled for a later date.

The user trials for the final design at DRS stage was planned along similar lines to that done at P2 incorporating a mixture of qualitative & quantitative parameters as shown below:

1.NO. OF TEST SUBJECTS :

10 tea pluckers recommended

2. DURATION OF TRAINING WITH PROTOTYPES:

1 week recommended

3. COMPARISON :

1hr hand plucking v/s 1hr proto-plucking

4. QUANTITATIVE DATA:

Plucking Efficiency -> Weight of Plucked leaves (Grams)

5. QUALITATIVE DATA:

- Plucking Effort required (Scale of 5)
- Safety Concerns (Scale of 5)
- Ease of Use (Scale of 5)



SECTION 7.0 CONCLUSIONS:

The iterative industrial design process was utilized to improve upon the design of the tea-leaf plucking aid. Role-playing & experience prototyping using mock-ups ended up being key driving factors in designing better safety features for the tea-leaf plucking aid.

Initial testing of the mock-ups confirmed that the newly incorporated safety features would significantly reduce the risk of accidental injury from the blade during its use for plucking tea leaves.

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

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

DESIGN RESEARCH SEMINAR ON

IMPROVEMENTS

TO THE TEA LEAF PLUCKING AID

SUBMITTED BY: GAURAV SAHA 134130006

GUIDED BY: PROF. PRERNA JOSHI PROF. G. G. RAY

REFINEMENT D-BRIEF:

INCORPORATE SAFETY FEATURES:
Ensuring accidental motions do not result in injury.

DECREASE BULK:
Allow for better approach to the tea-leaves

PROMOTE EASE OF USE:
Improve usability & fastening methods

IMPROVE MANEUVERABILITY:
Ensure thumb movement & dexterity of the guard

EMPLOYED METHODS

TECHNOLOGY

PLUCKING EFFICIENCY

SAFETY FEATURES

MOTION ANALYSIS

ROLE-PLAYING

EXPERIENCE PROTOTYPING

STAKE-HOLDERS

TEA PLUCKERS

TEA ESTATE MGMT.

MANUFACTURING PERSONNEL



1 P2: INITIAL MOCK-UP



2 P2 RAPID PROTOTYPED



3 DRS: SINGLE PIECE PLASTIC BLADE



4 DRS: SERRATED PLASTIC BLADE



5 DRS: INSERT-MOULDED SS BLADE

6 DRS: SAFETY FEATURES



Fig28 : Design Research Seminar Poster Presentation

END