Indian Institute of Information Technology Design and Manufacturing Kancheepuram
Department of Mechanical Engineering

Final Report

SUBJECT
Automation in Manufacturing
(MEC319P)

Title of the Project: Automation in Hair Wig Manufacturing
Re"HA- LO" - Relieving Hair Loss Problems for generations to come

Group Number : B

Date: 11/11/2020

Roll Number	Name
MDM18B049	Soorya Sriram
MDM18B063	Khirupasagar R
MDM18B037	Rajendra Prasad
MPD18I002	Anirudh Govindarajan Sampath Kumar
MFD18I003	Ajai Madhavan

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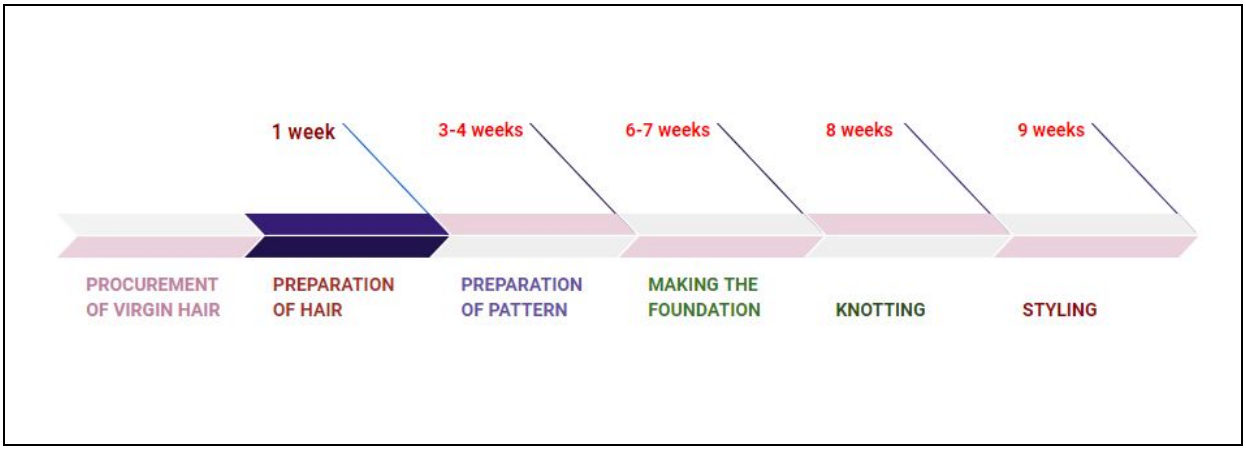
Problem Statement:

The hair wig manufacturing is a cumbersome and time consuming process that involves plenty of pre and post processing activities other than just preparation of the hair bundles.

In the World 4.0 Automation Plays a major role in every form of field to help **Development, Safety, Fast Production** to satisfy heavy demands.

Our Product is to help in Automating the making of Hair Wigs with minimal human intervention . The product is focussed on Faster production and Safety of the Labourers .

However, major effort and labour is being spent in the preparation of these hair bundles since the quality of these samples are integral to the hair wigs being prepared and sold.

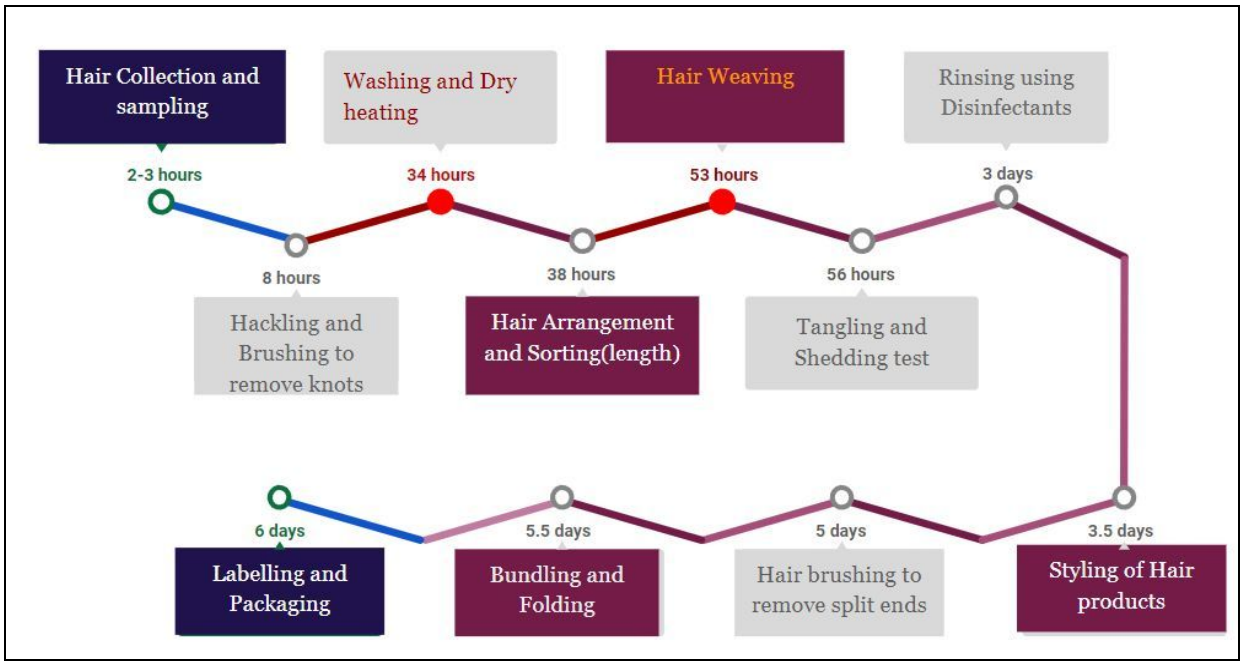


Styling of this hair bundle is post processing activity where wigs are custom made to the buyer's liking.

Primary Focus:

Our primary focus is to reduce the number of hours and labour put in to create these hair samples since hundreds of these wefts are required for one hair wig to be prepared.

The following shows the processes involved to manufacture a single hair bundle:



We plan on doing this activity by integrating industrial robots (Automated Guided Vehicles) and automation with the current structure of using labour without compromising on the quality of the final hair bundle.

Industrial Statistics:

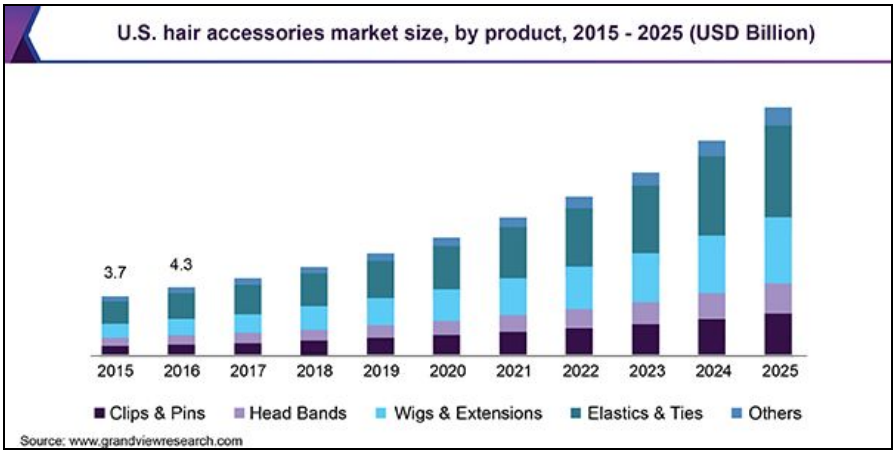
The global hair wigs and extension market is expected to grow at a **CAGR** (Compound Annual Growth Rate) of over **8% during the period 2018–2024**. The urge to improve the physical appearance is another major factor driving the hair wigs and extensions market worldwide.

The rise in income levels has pushed people to increase spend on personal grooming and beauty products, which, in turn, is boosting the end-user confidence to invest in personal grooming, including hairs wigs and extensions. The hair care segment accounted for 18% of the total revenue of the global beauty market in 2017 and was the second-largest segment after skincare.

Poll Average industry growth 2015–2020: 1.8%

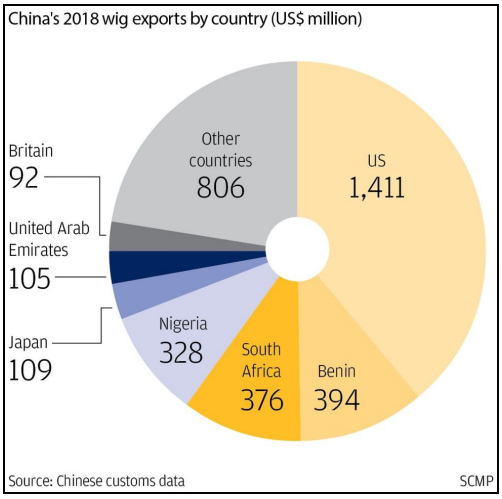
The Wig and Hairpiece Stores industry represents a niche product retailer within the hair-care sector. Over the five years to 2020, industry revenue is projected to grow at an annualized rate of **1.8% to $390.6 million.**

The global hair wigs and extension market is estimated to reach revenues of more than **$10 billion by 2023**. The hair wig industry has been growing at a faster rate as compared to other grooming products. The below is an estimation of Growth of the hair wig market in the USA till the year 2025:

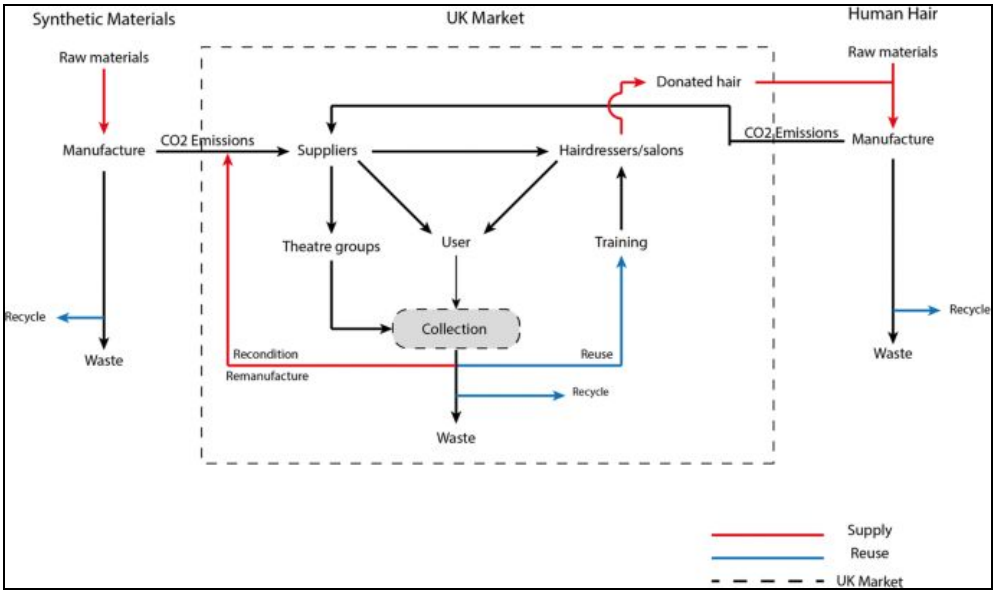


Africa is the second-largest destination for wigs, making up **37%** of the overall market, just behind the **US's market share of 39%**.

There exists alternatives to hair wigs including surgical and non-surgical transants. When compared to these alternatives, demand for hair wigs have garnered higher revenues in the recent past because of its easy application and less cost.
India and China are major exporters of Hair to the rest of the world. The below is the statistics of how the Chinese exported their Hair wigs to various other countries in the World.



Thirumala-Thirupati is one major contributor along with many other small organizations that plays a major role in the supply chain from India's side.
The **Supply Chain for Hair Wigs in the UK Market** is :



Natural Virgin Hair vs Synthetic Hair:

Human Hair

Synthetic Hair

Synthetic Hair	Human Hair
Pros:	
Synthetic wigs are easy to take care of. Because synthetic wigs have something called "style retention," they never have to be styled. You simply wash, dry and then shake them out, and the wig will return to its initial style.	Many human hair wigs can be colored, permed and styled just like your own hair. Keep in mind that it is important to take your wig to a stylist who is experienced in dealing with human hair wigs if you wish to alter the style.
Synthetic wigs hold their style regardless of the weather.	Human hair wigs come in a variety of textures, so you can match your own hair texture very closely.

You can try out various colors and styles without the need to see a hair stylist by purchasing multiple synthetic wigs.	With proper care, human hair wigs can last a year or more when worn daily.
You can choose from an array of natural colors, as well as several fantasy colors. Recoloring is not recommended for synthetic wigs and traditional hair color will not adhere to the fibers.	Human hair wigs feel great and can look incredibly natural.
Cons:	
Synthetic wigs cannot be straightened or curled with heated styling tools unless it is a specifically designed "heat friendly" synthetic wig.	Human hair wigs are more labor intensive and require more effort and skill to style. The hair will incur damage if subjected to harsh brushing, back-combing or overuse of heated styling tools.
Some economy or budget synthetic wigs (typically those low priced ones) may have an unnatural shine.	Just like real hair, human hair wigs need to be washed, deep-conditioned and re-styled frequently.
Synthetic wigs and toppers do not last as long as human hair wigs. They typically last about 4-6 months with daily wear.	It is difficult to replicate an exact color when you replace a human hair wig or wish to purchase a backup of the same

	style. Human hair wigs of the same color will vary slightly from wig to wig because each wig contains hair harvested from multiple people.

Current Method of Hair Wig Preparation:

There are **two methods** of attaching hair to wigs.

The first and oldest is to weave the root ends of the hair onto a stretch of three silk threads to form a sort of fringe called a "weft". The wefts are then sewn to a foundation made of net or other material. In modern times, the wefts can also be made (a warp is the vertical thread of a weave, the weft is the horizontal thread) with a specially adapted sewing machine, reducing the amount of hand labour involved.

In the 19th century another method came into use. A small hook called a "ventilating needle" or "knotting needle", similar to the tambour hooks used for decorating fabric with chain-stitch embroidery at that period, is used to knot a few strands of hair at a time directly to a suitable foundation material.

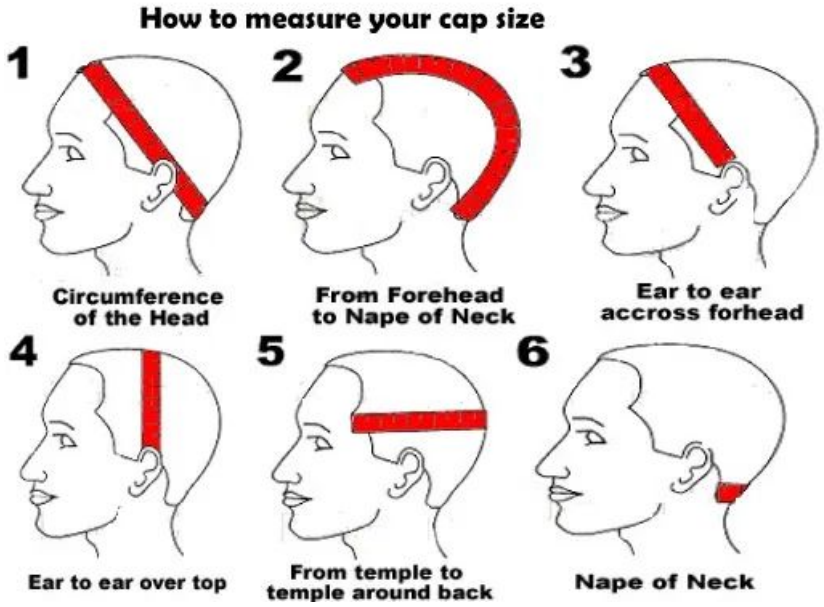
This newer method produces a lighter and more natural looking wig. High quality custom wigs, and those used for film and theatrical productions are usually done this way.

It is also possible to combine the two techniques, using weft for the main part of the wig and ventilating hair at the edges and partings to give a fine finish.

Processes involved in the Current Hair Wig manufacturing:

1. **Measurement:**

Making custom wigs starts with measuring the subject's head. The natural hair is arranged in flat curls against the head as the various measurements are taken. It is often helpful to make a pattern from layers of transparent adhesive tape applied over a piece of plastic wrap, on which the natural hairline can be traced accurately. These measurements are then transferred to the "block", a wooden or cork-stuffed canvas of the same size and shape as the client's head.

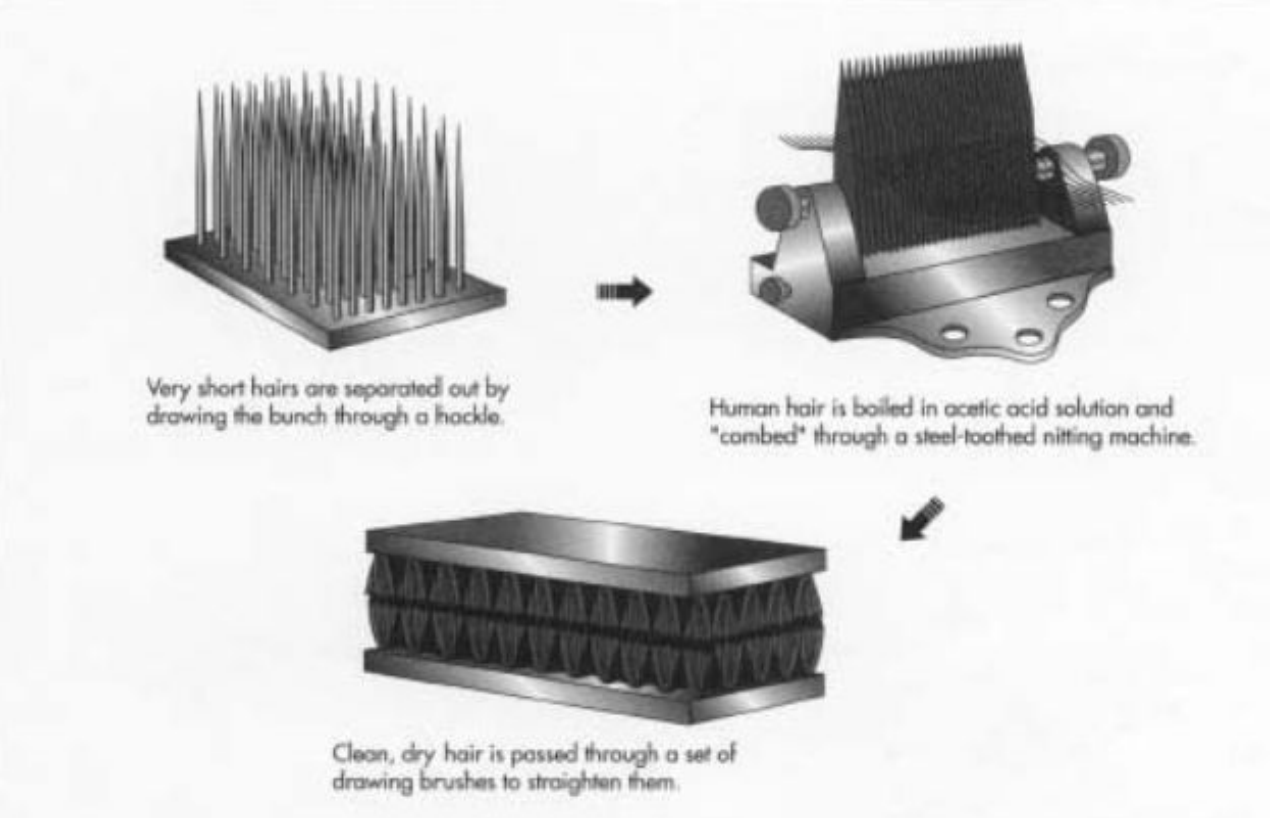


2. Foundation:

Depending on the style of the wig, a foundation is made of net or other material, different sizes and textures of mesh being used for different parts of the wig. The edges and other places might be trimmed and reinforced with a narrow ribbon called "galloon". Sometimes flesh colored silk or synthetic material is applied where it will show through the hair at crown and partings, and small bones or elastic are inserted to make the wig fit securely. Theatrical, and some fine custom wigs, have a fine, flesh colored net called "hair lace" at the front which is very inconspicuous in wear and allows the hair to look as if it is coming directly from the skin underneath. These are usually referred to as "lace front wigs".

3. Hair preparation:

Natural hair, either human or from an animal such as a goat or yak, must be carefully sorted so that the direction of growth is maintained, root to root, and point to point. Because of the scale-like structure of the cuticle of a hair shaft, if some hairs get turned the wrong way, they will ride backwards against their neighbors and cause tangles and matting. The highest quality of hair has never been bleached or colored, and has been carefully sorted to ensure the direction is correct. This process is called "turning". For less expensive wigs, this labour-intensive sorting process is substituted by "processing" the hair. It is treated with a strong base solution which partially dissolves the cuticle leaving the strands smooth. It is then bleached and dyed to the required shade and given a synthetic resin finish which partially restores the strength and luster of the now damaged hair. Synthetic fiber, of course, is simply manufactured in the required colors, and has no direction.

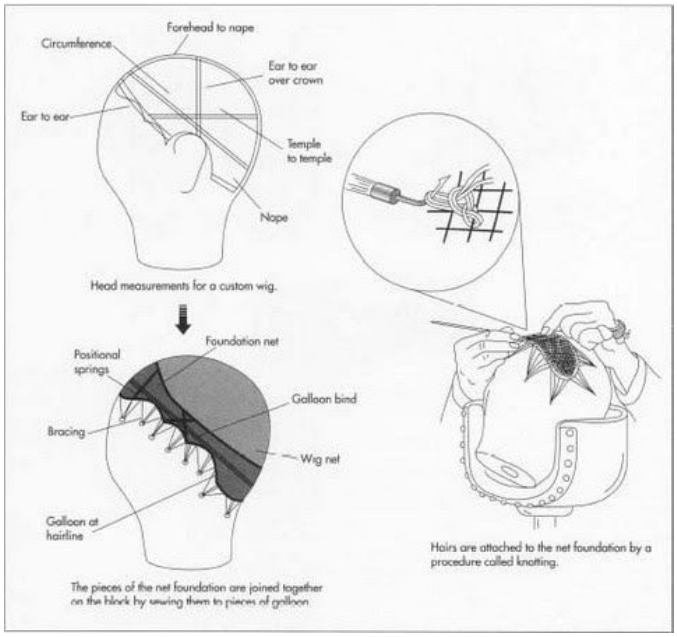


The wigmaker will choose the type, length and colors of hair required by the design of the wig and blend them by pulling the hair through the upright teeth of a brush-like tool called a "hackle" which also removes tangles and any short or broken strands. The hair is placed on one of a pair of short-bristled brushes called "drawing brushes" with the root ends extending over one edge; the edge facing the wigmaker (or properly called, boardworker), and the second brush is pressed down on top of it so that a few strands can be withdrawn at a time, leaving the rest undisturbed.

4. Adding the hair

Weft structured wigs can have the wefts sewn to the foundation by hand, while it is on the block or, as is common with mass-produced wigs, sewn to a ready-made base by skilled sewing machine operators. Ventilated (hand knotted) wigs have the hair knotted directly to the foundation, a few strands at a time while the foundation is fastened to the block. With the hair folded over the finger, the wigmaker pulls a loop of hair under the mesh, and then moves the hook forward to catch both sides of the loop. The ends are pulled through the loop and the knot is tightened for a "single knot", or a second loop is pulled through the first before finishing for a "double knot". Typically, the bulkier but more secure double knot is used over the majority of the wig and the less obvious single knot at the edges and parting areas. A skilled wigmaker will consider the number of strands of hair used and the direction of each knot to give the most natural effect possible.

It takes generally six heads of hair to make a full human hair wig.



5. Styling

The completed wig is pinned to a soft block for styling. The hair is gently dampened by combing through with a wet comb. Curls are formed as pin curls or on rollers or cotton forms. The wig is covered with a net and dried in a warm oven. The curls are then unpinned, and the hair is combed and styled. A net is carefully placed over the finished style, and the wig is returned to the oven to set the style.

6. Fitting

The subject's natural hair is again knotted tightly against the head and the wig is applied. Any remaining superfluous wig lace is trimmed away. Hairpins can be used to secure the lace to the hair and occasionally, skin-safe adhesives are used to adhere the wig against bald skin and to better hide any exposed lace. Finishing touches are done to the hair styling to achieve the desired effect.

1.Preparation: Pour a moderate amount of neutral shampoo in warm water and mix well.

2.Cleaning: Turn the wig outwards, put into the water and gently washed, then rinsing it.

3.Care: Water and the care solution in 50 : 1 soak the product for 8-10 minutes then rinsing it.

4.Finishing: absorb the moisture by towel, and put it on the bracket to sort out the hairstyle.

5.Dry: Put it in a ventilated place to dry naturally, then put it in the box, save in a dry place.

Cleaning And Maintenance

Disadvantages in Current Hair Wig manufacturing:

- ❏ Wigs, especially those made out of human hair, can also be styled and treated the same way with your natural hair. So for whatever occasion, it would no longer be necessary for you to find another wig. Instead you can use those artificial tresses by curling, straightening, or teasing it.
- ❏ Before, one of the common fears most wearers have is that their wigs might come off at any chance. Fortunately nowadays, manufacturers developed wigs that can be adjusted in order to fit snugly on your head.
- ❏ In addition to this, adhesives are also available to securely attach this hairpiece to your scalp. However most complain that it can be uncomfortable and it makes your hair difficult to clean.
- ❏ The major disadvantage of the current method is its time consuming process. Most of the processing is manual. Segregation of proper hair , brushing , knitting is a major time consuming process and it would take days to do the process.
- ❏ Another disadvantage is that hair being knotted needs to be precise and well knotted because the knots made are small. Skilled labour needs to be taken and would cost more.
- ❏ Price is a disadvantage for some people. But many understand that because they are made of real hair, cost will be more than synthetic wigs.

About Our Product:

We have focused on the preparation of hair sample and have split the procedural works into “8 BOOTHS” which are as follows:

Booth 1: Hair Collection, Sampling and Sorting
Booth 2: Hackling,Brushing and Sorting according to the Length
Booth 3: Washing and Dry Heating
Booth 4: Hair Weaving – Manual
Booth 5: Tangling, Shedding test and rinsing with disinfectants
Booth 6: Rinsing and basic styling of Hair samples
Booth 7 :Bundling and Folding- Manual (mainly for Quality Inspection)
Booth 8: Packaging

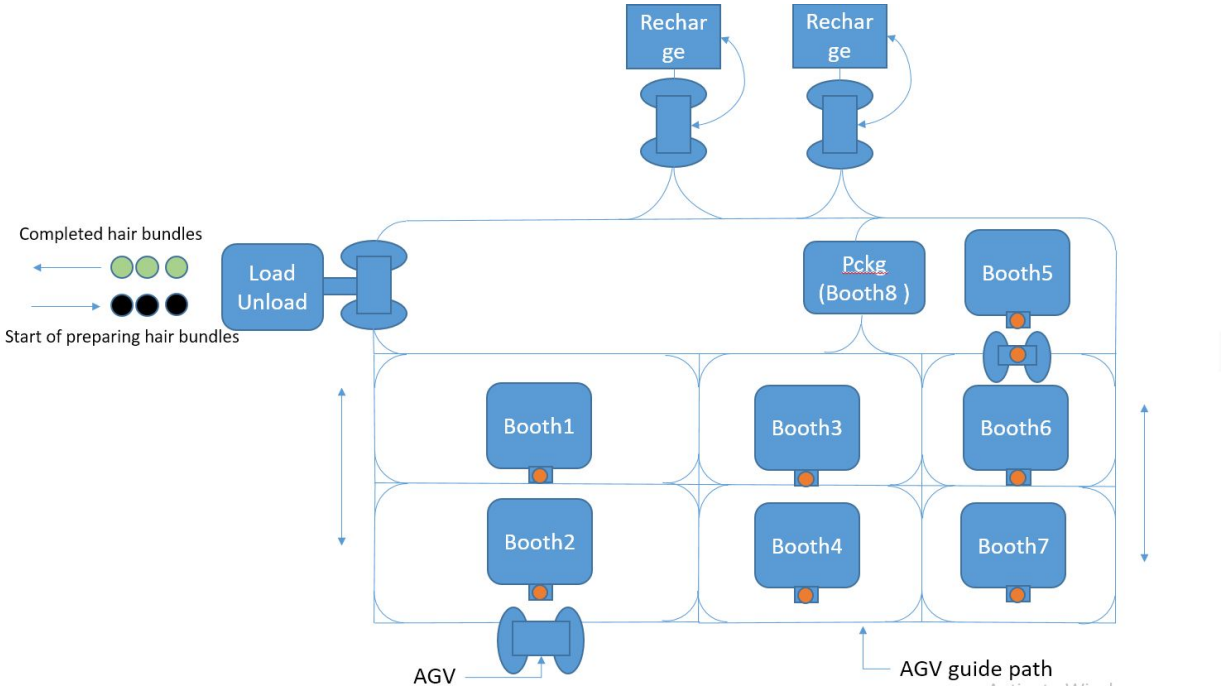
(We took the reference of procedures from the existing methods of Hair wigs manufacturing)

The existing methods are done manually which reduces the production and dealing with hair direct contact could be allergic or infectious and some of the process involving dying , using disinfectants could be hazardous too.

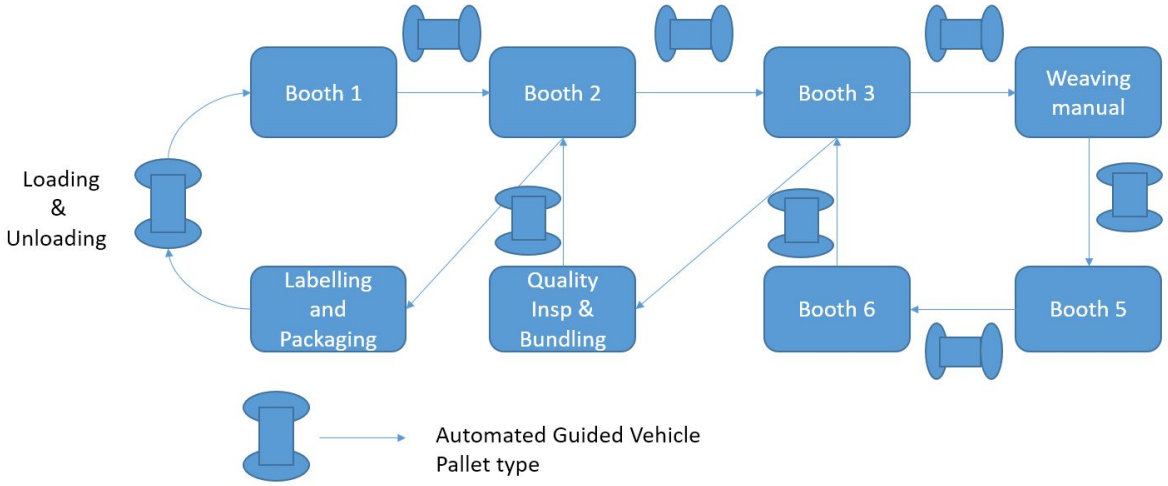
Manufacturing Layout:

The manufacturing system we intend to create consists of nearly 8 processing systems interconnected by an Automated material handling system which is controlled by a distributed computer system (mostly manually).
So, this comes under the Flexible manufacturing system as the manufacturing assembly is capable of processing a variety of part styles(different) simultaneously at various work stations , and the mix of part styles and quantities can be adjusted to demand and customer patterns.
It is more like a dedicated FMS as the variety of hair bundle styles(based on hair color, styles like body wave, curl and straight) is limited and the complete population of hair bundles to be manufactured is known in advance.

The detailed classification of our assembly would be **DETAILED - MULTI CELL FLEXIBLE MANUFACTURING SYSTEMS** as there are more than one group of cnc or part making booths or processing workstations.
The manufacturing layout of the plant is **OPEN FIELD LAYOUT** as AGVs are used Unloading and Loading are at the same end and parts are routed to different machines based on the availability.



The process of manufacturing/ preparing hair bundles in the proposed manufacturing layout



Automated Guided Vehicle:

Pallet trucks are being used to move palletized loads along predetermined routes
As the weight to be carried by the AGVs are **less than 35 kg**, the type of AGV used is **SSI Schaefer Weasel**.
Some Agvs are accompanied with evaporator roller rods so that the wet hair is heated or dried while transporting.
The type of **Navigation** used is **RFID tags**
The **Operating time** for the AGV is nearly **18Hrs**
Turning radius of Weasel is **600mm**
Speed of the weasel is a max of **1m/s**
Due to its **high scalability**, it can be easily extended and used in Industry 4.0.

Our Manufacturing Line:

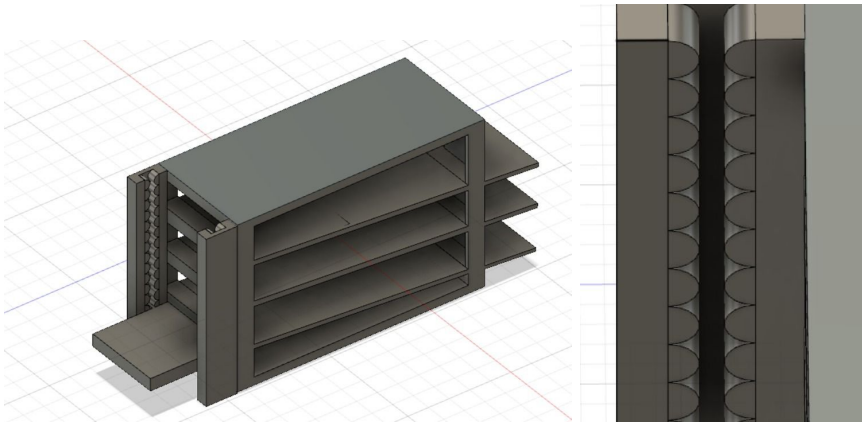
The entire manufacturing process has been divided into 8 major departments/booths where the process involved will be explained and described in the following:

Booth 1: Hair Collection, Sampling and Sorting

- The manufacturing line begins here. Once the hair bundles have been acquired from the supplier, it is important the hair is sorted according to the colour, texture and quality of the hair. It is important to maintain the consistency and source of the hair when creating the final bundles for uniformity.
- A specifically manufactured tray is used where there will be 15 partitions (Batches of 15 have been selected for explanation purposes).
- Once the manual labourer is happy with the quality of the input raw hair, he is to identify the head of the hair bundle and place a specially made attachment ring (plastic ring that does not corrode or affect the hair when heated or washed) that allows the hair bundle to be clamped in Booth 2.
- He is to place the hair bundle lengthwise in the partition of the tray.
- A shelf has been specially made and let's say it has 3 rows. The labourer is to place the tray on the ledge at the bottom.

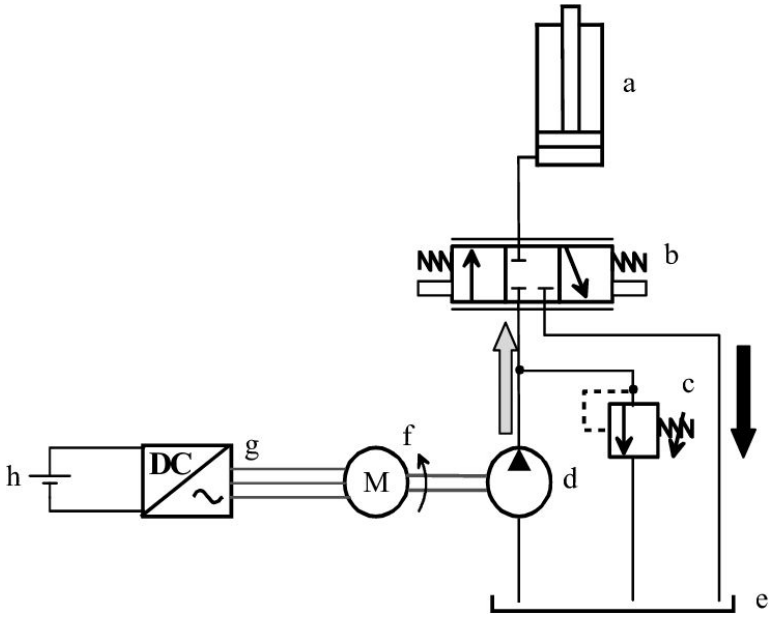
- Each row of the shelf is given specific code depending on the colour of the hair that is placed.
- These rows are inclined at an angle of 30 deg - 45 deg where the left end is higher than the right end.

- The rows are not flat surfaces but are instead made of metallic stainless steel rollers similar to rollers available at bag checks at airports.
- The right end of the shelf which is generally closed allows these trays to roll out when it is opened.
- Let's say the first top row contains only 'black hair bundles', second middle row contains only 'brown hair bundles' and the third lowest row contains only 'blond hair bundles'. The hair bundles being prepared at the manufacturing plant on a specific day might be only brown.
- By inputting the code that is specific to the row having brown hair samples trays, the opening of the right end of the shelf occurs when an AGV arrives at the booth.
- Once the alignment sensors provide a green signal, the right end opens and one by one the trays start sliding out along the slide onto the input basket placed at the bottom of the slide.
- Let's say the basket has a capacity of 1 tray containing 15 hair bundles. There is a **Photoelectric sensor** that keeps count by counting the number of times the light was obstructed. When the capacity is reached input is given to slide to realign its mouth and the opening of the row's right end of the shelf.
- The right end closes by realigning the slide to its lowest/highest position, the alignment sensors get switched off and the extendable boxing glove retracts.
- The AGV at the booth lifts this tray to the next booth of the manufacturing line.
- It is a continuous process where AGV's are used to transport 1 tray of 15 hair bundles to the next booth at regular intervals.
- **Hydraulics mechanism** is used to transport the carton or tray from the bottom to the top of appropriate shelves



Concepts Implemented:

Hydraulic Circuit:



Components used:

3/3 way valve - Solenoid
Pressure relief valve ar pump
Electric motor
Single acting Cylinder
Battery
Tank

Working Principle:

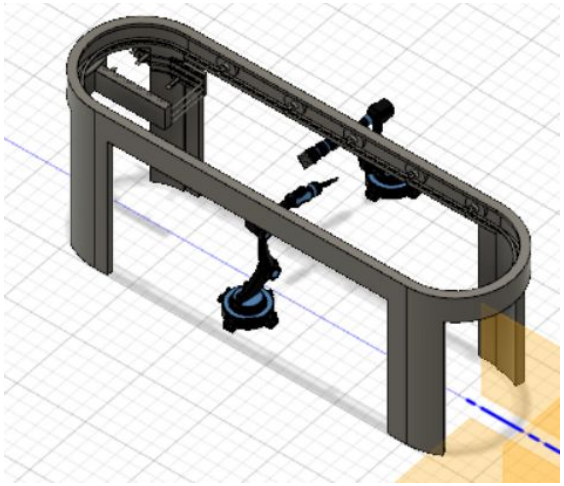
When the left envelope of the 3/3 way valve is activated using solenoid, the flow from the pump is directed to the cylinder and extension stroke is achieved and the ledge attached to the piston is moved upwards. When the middle envelope is activated, the piston movement is locked and the movement of the ledge is stopped. When the right envelope is activated, the flow is from the piston to the tank and the piston retracts and the ledge moves downwards.

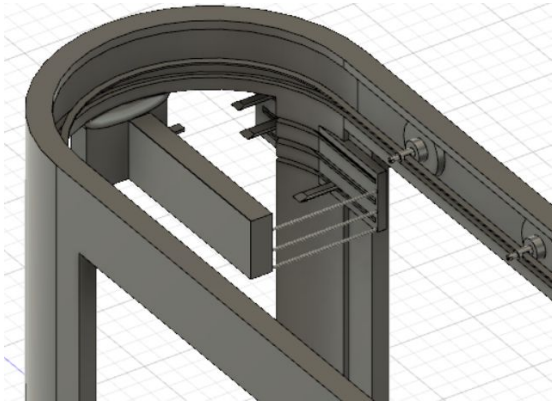
A **photoelectric sensor** is an equipment used to discover the distance, absence, or presence of an object by using a light transmitter, often infrared, and a photoelectric receiver. They are largely used in industrial manufacturing.

Booth 2: Hackling,Brushing and Sorting according to the Length

- The AGV now places this partitioned tray onto the input platform of Booth 2 and returns to Booth 1 in a continuous fashion.
- There is an overhead rotary belt drive that consists of 5-6 clamping robotic hands.
- The input platform is a conveyor belt that starts its step wise operation once the AGV leaves the booth. The tray is placed in such a manner on the conveyor belt that the 1st partition is aligned when the rotary belt stops at regular intervals.
- This robotic hand is made to stop above the tray placed on the conveyor belt at a specific position.
- It automatically clamps the specially attached ring at the of each hair bundle of the first hair bundle.
- Once a hair bundle is clamped, using a stepper motor, input is given to the conveyor belt to move the tray in such a manner that the 2nd partition is aligned with the next robotic clamping hand at the same position.
- This process occurs in a periodic fashion and when all 15 hair bundles have been clamped by the robotic arms, the empty tray slides off the conveyor belt onto the previously waiting AGV which travels back to Booth 1.
- Once the first hair bundle is clamped, the overhead rotary belt drives starts its motion along the x axis. It travels a certain distance ie. 60 cm and then stops. At this time the next hair bundle is being clamped by the next robotic arm.
- Simultaneously at the 60 cm mark, 2 industrial robotic arms with ends shaped into edges similar to a comb are placed on opposite sides to the vertically oriented hanging hair bundle.
- Brushing is done only in a top to down fashion. This is done by the preprogrammed computer controlled robotic arms. One comb edge of one robotic arm is at the top about to start brushing, the robotic arm opposite has its brush at the bottom of the combing cycle.
- As the robotic arm at the top starts executing its brushing, the robotic arm at the bottom moves back along the z axis and up to the top of the hair bundle along the y axis where it is clamped and moves forward along the z axis ready to start brushing.
- Now as the 2nd arm starts brushing from top to bottom, the 1st arm at the bottom of the combing cycle executes a similar motion as mentioned above.

- This alternate brushing is done for approximately 10 times and till the hair bundle is sufficiently straightened and the hair pulled out falls on the floor sweeped off later.
- Now the rotary belt starts its motion again and stops at 60 cm again. While the 2nd hair bundle undergoes brushing and the 3rd hair bundle gets clamped, the first hair bundle is now the length/height measurement part of the process.
- According to the specific height given as input to the console, say 14 in, the **displacement sensor** placed along a vertical height measuring rod precisely identifies the height at which the hair bundle is to be cut.
- A robotic arm with an edge similar to a scissors wide enough to cover the entire hair bundle is extended along the z axis at exactly the 14 in mark and cutting mechanism is executed by this arm.
- The extra hair that falls is collected in an empty basket and once all such 15 bundles of hair have been trimmed to specified height, an AGV transports this basket back to Booth 1.
- When the rotary belt moves or rotates another 120 cm, the first trimmed bundle is released by the robotic clamping arm and is now collected in a collection basket and in due time, this robotic arm is back at the starting of the process clamping its next hair bundle.
- Since the hair wig manufacturing is a small scale manufacturing industry, a small rotary belt of just 5 clamping arms is sufficient to execute this operation in a continuous and timely manner.
- An AGV transports the collection basket once all 15 hair bundles of 1 tray have been collected. This operation is maintained using a **Photoelectric Sensor** that increases its count every time its light path is interfered or crossed. Once the tally reaches 15, input is given to the AGV to transport it to Booth 3.





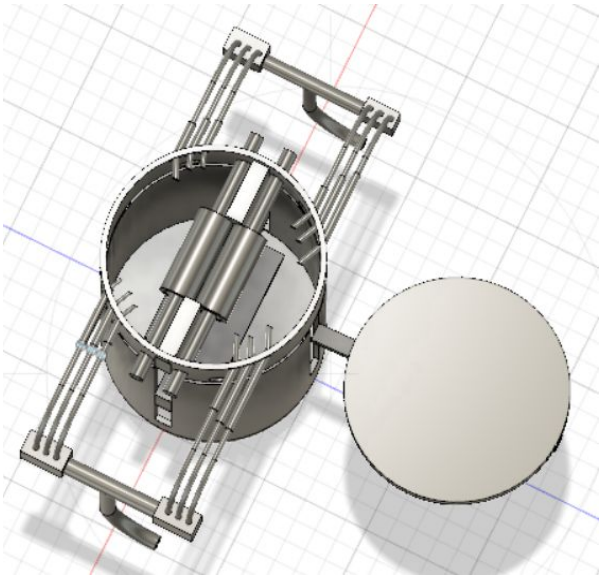
Concepts Implemented:

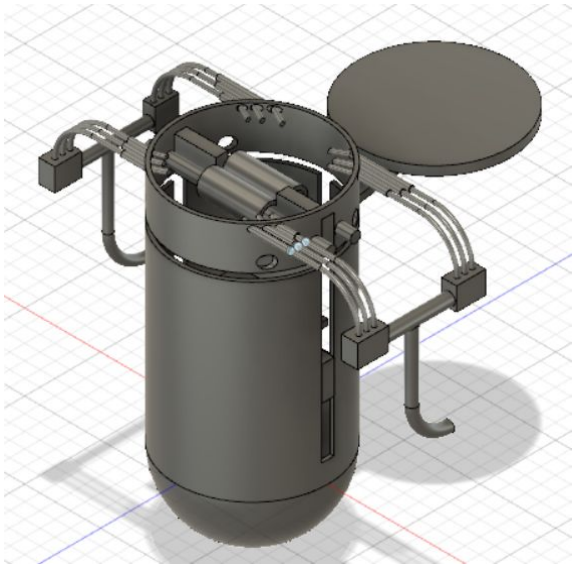
A mechanism similar to a milling machine has been used for brushing. A **Displacement Sensor** is a device that measures the distance between the sensor and an object by detecting the amount of displacement through a variety of elements and converting it into a distance.

Booth 3: Washing and Dry Heating

- The most important booth of the Hair preparation line is Booth 3 since the cleanliness and quality of the hair bundle is of utmost importance.
- The hair bundles will be full of oil, grease and bacteria/lice not visible clearly to the naked eye.
- Once the forklift AGV drops a tray of unorganized 15 hair bundles on a portable conveyor belt made of metal rollers at one end. The height of the belt is increased till the one end of the conveyor belt is on the same line as the opening of the boiler.
- One end of the belt is increased further causing the tray to slide into a boiler(cylindrical drum) placed at the other end of the belt.
- The tray lands perfectly on the ledges provided and the cleaning process begins.
- 3hoses and 4 pipe openings are placed at strategic positions at 10, 2, 4 and 8 o clock.
- With the tray of 15 bundles in the middle, the opening of the hoses faces towards the tray.
- The 3 hoses start rotating about a vertical axis similar to a washing machine, the water ejected at a powerful force thoroughly cleans all the bundles of hair.
- There are 2 vertical robotic arms with rotating brushes at the ends that mixes up the hair bundles while cleaning and helps to remove the oil in the hair.
- There is a computer controlled metallic lid that gets slotted below the ledges when the hoses start revolving.
- By the time the rotating hoses gain sufficient speed and water starts gushing out, the metallic lid would have completely slid out covering the lower parts of the boiler (Cylindrical drum).
- Once the metallic lid completely covers the boiler opening below the ledges, openings along the sides of the boiler above the metallic lid for drainage of the water are used for cleaning.

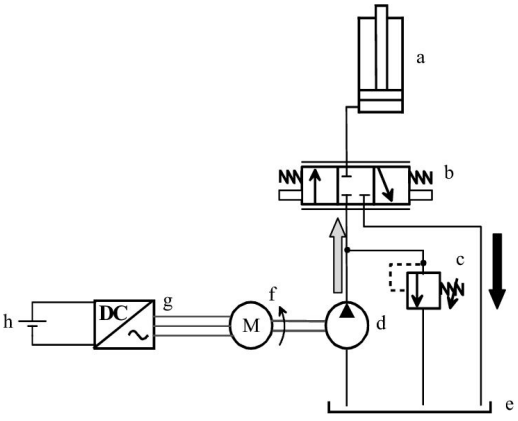
- This cleaning process is currently done manually by stirring a large cylinder for an hour. Our process reduces the stirring time by considerably and increasing the quality of cleaning.
- When the cleaning process is completed say 20 mins, the water is drained out completely and channeled to the water treatment plant in the manufacturing plant.
- The metallic lid retracts back and using a hydraulic system, the ledges are made to fall down into the lower regions of the boiler.
- The boiler having a capacity of 5 such trays first completes the cleaning process using the mechanism mentioned above every time.
- Once 5 such trays have been cleaned and placed at equally spaced heights by the hydraulic powered ledges, the metallic lid retracts and closes the boiler permanently.
- The lower region of the boiler has a heat blowing water evaporator system where similar to a dry cleaning machine, the heat inside the lower region is increased to a high temperature that the 5 trays of 15 hair bundles undergo a drying process for 18- 24 hrs.
- The vapour generated is channeled out via the bottom of the bottom where it is recooled and this recollected water is sent to the water treatment plant in the manufacturing layout.
- The oil and grease collected at the bottom of the boiler and above the metallic lid has to be periodically cleaned and maintained by a supervising labourer.
- The drying process is now completed. The hydraulic arms are computerised to pull the ledges back up one at a time where the vertical robotic pushes the tray outward towards the inclined portable conveyor belt which is aligned and slides the tray of 15 hair bundles to its other end where a forklift AGV is waiting to collect it.
- Now the AGV transports a tray of clean tray of 15 hair bundles to the next booth.

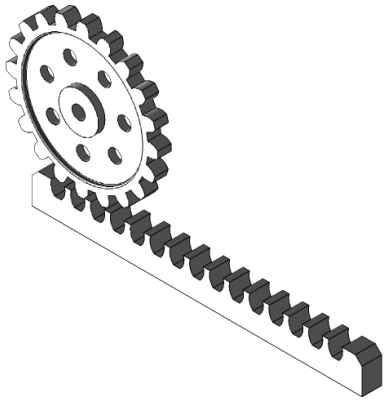




Concepts Implemented:

Hydraulic Circuits are used for the functioning of the ledges/ movement gears to help in the vertical movement of the tray. Bearings/ rack and pinion motion may be also employed for easy translation.



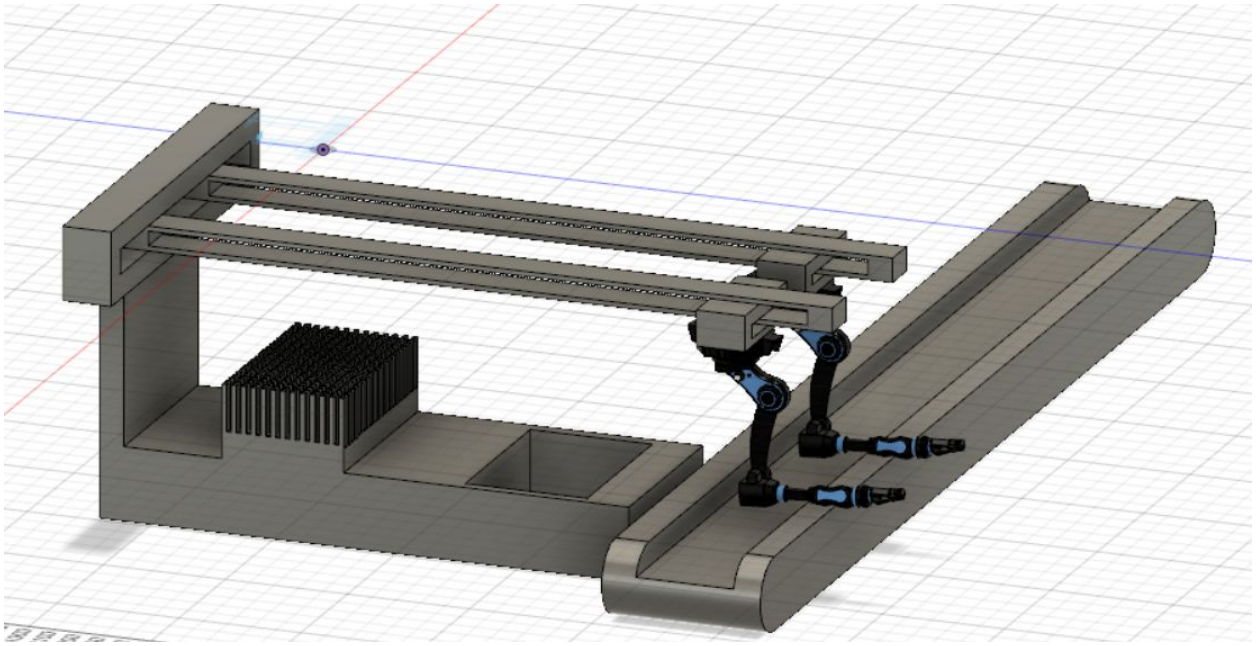


Booth 4: Hair Weaving - Manual

- Hair weaving is a process which requires personal and careful attention to the quality of hair being sewn into wefts.
- Hence manual labour is used to organize the bundles of hair.
- Three sewing machines placed in order where the labourer carefully provides the bundles of hair as input to create a durable triple weft which is a sewn hair bundle composed of 3 - 4 smaller hair bundles.
- Once the required length of hair has been sewn, say 120 cm, the long hair bundle is carefully placed on a tray with 2 clamping safety pins placed at its ends.
- When 15 such hair bundles of length 120 cm are placed on a tray, the tray is transported by an AGV to booth 5.

Booth 5: Tangling, Shedding test and rinsing with disinfectants

- 2 robotic arms with clamping ends move along the negative X Axis to the input station. These 2 robotic arms are connected in the middle by a rod.
- The width between the 2 arms can be varied but is kept constant to the length of the hair bundle sewn previously (in this case 120 cm)
- The 2 clamping ends of the robot move down along the negative Y axis to clamp onto the end of the hair bundle with safety pins, the robotic arms lift one hair bundle at a time in the tray. The position of the clamping pins are aptly identified using **cameras** and **tactile sensors**.
- The hair bundle as well the robotic arms simultaneously move along the positive X Axis say 120 cm.
- At this position there is a bed of needles placed where the tangling and shedding test occurs.
- The hair bundle clamped lengthwise between the two is lifted above and behind the bed of needles.
- The robotic arms then descend along the negative Y axis to an extent that the entire hair length is exactly covered by the bed of needles.
- In one swift motion, the robotic arms move along the negative X axis and the hair bundle along with it.
- This process occurs for 3 times to prevent any tangling or shedding later.
- Now the robotic arms move back along the negative X axis say 50 cm where a wet soap bath with disinfectants is present.
- The robotic arms descend in the Y axis such that the entire hair sample is dipped into the water bath using a **force sensor**. There is a **laser sensor** on the side of the rod at a height such that the robotic arms do not get wet.
- This dipping process into disinfectants is done 5 times in a continuous fashion before being dropped in the conveyor belt 50 cm away from the water bath placed at a right angle.
- After this process is completed the robotic arms move back to the input tray to collect its next sample.
- Once this process occurs 15 times and the entire input tray has passed the tangling, shedding and rinsing test, the input tray is brought back to Booth 4 by the AGV.



Concepts Implemented:

A **tactile sensor** is a device. It measures the coming information in response to the physical interaction with the environment. The sense of touch in humans is generally modeled, i.e. **cutaneous sense and the kinesthetic sense**.

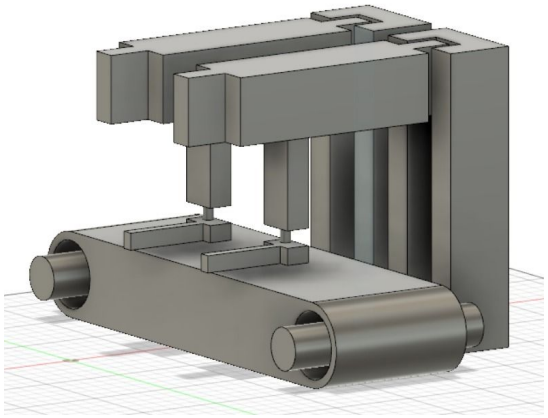
The working principle of a **force sensor** is that it responds to the applied force, as well as converts the value to a measurable quantity. Most force sensors are created with the use of **force-sensing resistors**. Such sensors consist of electrodes and sensing film. Force-sensing resistors are based on contact resistance.

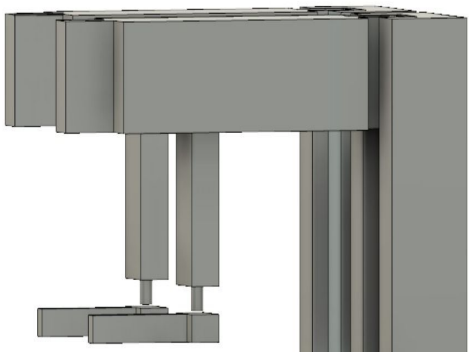
Booth 6: Rinsing and basic styling of Hair samples

- The 120 cm long hair bundle extended lengthwise is placed on a moving conveyor belt along the Z axis orientation.
- It passes over an evaporator plate so as to allow the moisture content to reduce and for easier handling of the hair bundles.
- At a distance after the hair bundle has been placed on the conveyor belt, three robotic arms with clamping ends are placed.
- When the clamping end of the hair bundle is aligned with the robotic arms, the bottom end of the hair bundle is clamped and stationary.
- This arm is connected to the 2nd arm by a link and this arm identifies the midpoint of the length of the hair bundle and holds it firmly against the conveyor belt surface.

- The third arm clamps the top end of the hair bundle and is connected to the 2nd arm by a revolute joint in such a manner that allows this arm to rotate about the vertical axis.
- Now the top end robotic arm rotates about the middle arm and reduces the length to 60 cm. Just as the 2 arms are about to collide the the 1st and 3rd clamping drop the ends synchronously and are placed above each other.
- Now the top arm rotates back, alignment occurs by the middle arm to identify the new midpoint and the 3rd arm clamps back the new end of the folded bundle.
- This process is done so as to get a thicker hair bundle of lesser length of about 8-10 cm.
- Once the required length has been achieved, 2 metallic plates get inserted on either sides of the hair bundle, both the free and clamped ends below the hair bundle.
- The conveyor is a horizontally flipped L shaped belt where once the hair bundles reach the bend, the belt stops.
- 2 robotic arms pick the hair bundles by clamping onto the metal plates, move along the X axis a bit further away from the belt where a vertical rod drops onto the metallic plate ends.
- The vertical rod starts executing rotation in Simple harmonic motion such the thick hair bundle is thoroughly rinsed.
- The water collected in the basin below has to be manually cleaned and removed at the end of the day.
- The robotic arms place the rinsed hair bundle back on the conveyor belt in the same orientation as before along the Z axis.
- The hair bundle has hair overlapping one over the other. Hence along the Z axis while the belt is moving, after a certain distance say 40 cm there is a robotic arm executing brushing similar to the ones in Booth 2 but along a different X-Y plane.
- This brush is to have more bristles, made of stronger material like steel and have a smaller density so as to effectively brush the hair sample and remove the shed hair.
- This process is executed 10- 15 times in a periodic manner and can be increased depending on the manufacturer.

- This straightened hair can be further curled by using an overhead 4 link mechanism with small rod-like ends where the hair is shaped into a curl using the concept of constraints of links.
- This curling process is an additional preparation process and is generally done so as to further customize it manually after the preparation of the hair sample in the post process.
- The conveyor belt completes its responsibility by dropping off this hair sample onto the output tray where the samples are collected similar to how they were provided as input to Booth 2 in an organized manner.
- An AGV carries this output with 15 hair weft bundles to the next booth 7.





Concepts Implemented:

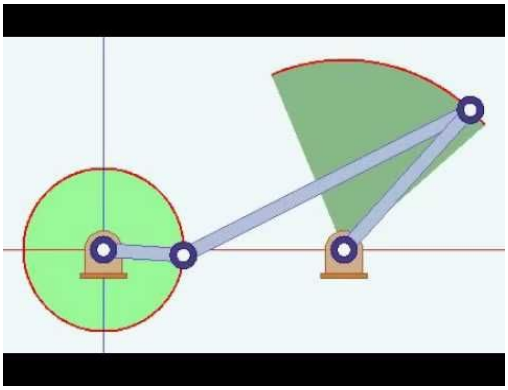
A four-bar linkage, also called a four-bar, is the simplest movable closed-chain linkage. It consists of four bodies, called bars or links, connected in a loop by four joints. Generally, the joints are configured so the links move in parallel planes, and the assembly is called a planar four-bar linkage restricted by the **Grashof Equation**.

One link of the chain is usually fixed, and is called the ground link, fixed link, or the frame. The two links connected to the frame are called the grounded links and are generally the input and output links of the system, sometimes called the input link and output link. The last link is the floating link, which is also called a coupler or connecting rod because it connects an input to the output.

Assuming the frame is horizontal there are four possibilities for the input and output links.

- A crank: can rotate a full 360 degrees

- A rocker: can rotate through a limited range of angles which does not include 0° or 180°
- A 0-rocker: can rotate through a limited range of angles which includes 0° but not 180°
- A π-rocker: can rotate through a limited range of angles which includes 180° but not 0°



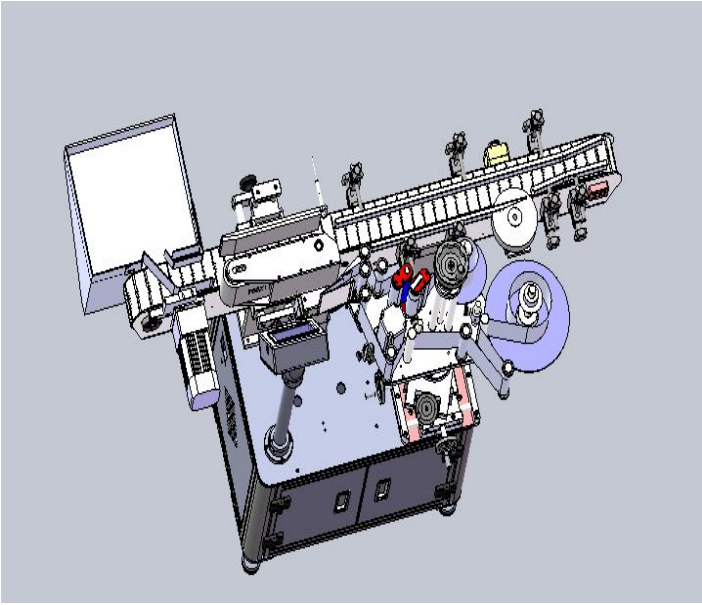
Booth 7:Dry Heating and Bundling - Manual

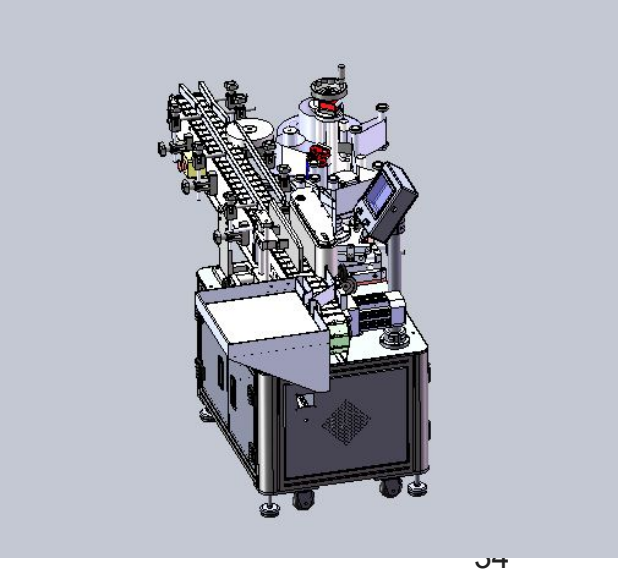
- Multiple such trays organised with 15 such wefts are manually once checked, clamps are removed and placed in a dry heating oven for 6-12 hrs.
- This high temperature oven has a capacity to hold 10-15 such trays placed in a vertical manner separated by wooden planks or placed on ledges.
- This is done manually since it is important to place the trays in an orderly manner and temperature has to be continuously monitored.
- Once the hair wefts have dried up, the trays are sent for visual inspection and felt.
- Split ends are checked for by manual brushing before bundling up the hair wefts using a machine that converts the linear input into rotary output.
- A rubber band is tied around the hair weft, 15 such wefts are placed on a tray and an AGV transports the tray to the packaging booth.

Booth 8: Packaging

This booth is a standard packaging booth where the input tray is placed on a conveyor belt powered by a stepper motor.

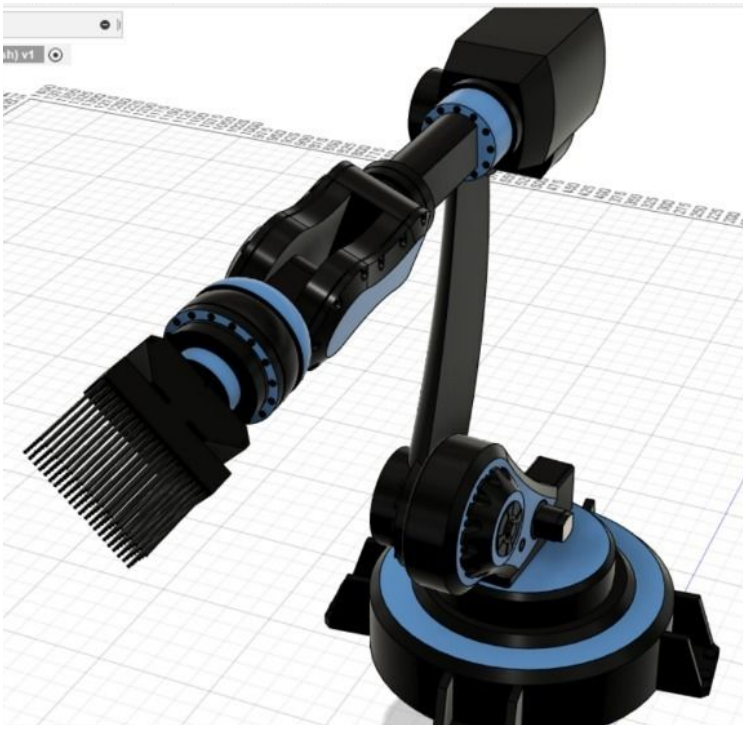
- Hence a single arm picks up the 1st weft and places it on a longer conveyor belt.
- While the conveyor belt moves along the X axis, the belt is stopped at appropriate positions where a robot arm drops down with a plastic cover, in a horizontal position with the direction of motion as same as the conveyor belt, at an angle of 15 degrees.
- Due to the horizontal motion of the conveyor belt, with the given momentum, the bundled hair fully goes into the plastic cover.
- This plastic cover used has the company logo imprinted on its surface or has the company label sticked on the surface.
- After the bundled hair moves further, the conveyor belt stops and a robotic arm drops down , clamps the packaged cover in the middle and rotates it in a clockwise direction of 90 degrees.
- Then a high pressure is applied on both the sides of the cover , at the end of cover, such that there is a gap between the end and the tail of the hair.
- After the cover is sealed, using high pressure, the cover is dropped on the conveyor belt. As the conveyor belt moves the packaged hair bundle is dropped in a carton.
- After a sufficient amount of bundles are placed in the carton, an AGV collects the cartons and moves it to the OUTBOUND LOGISTICS space.





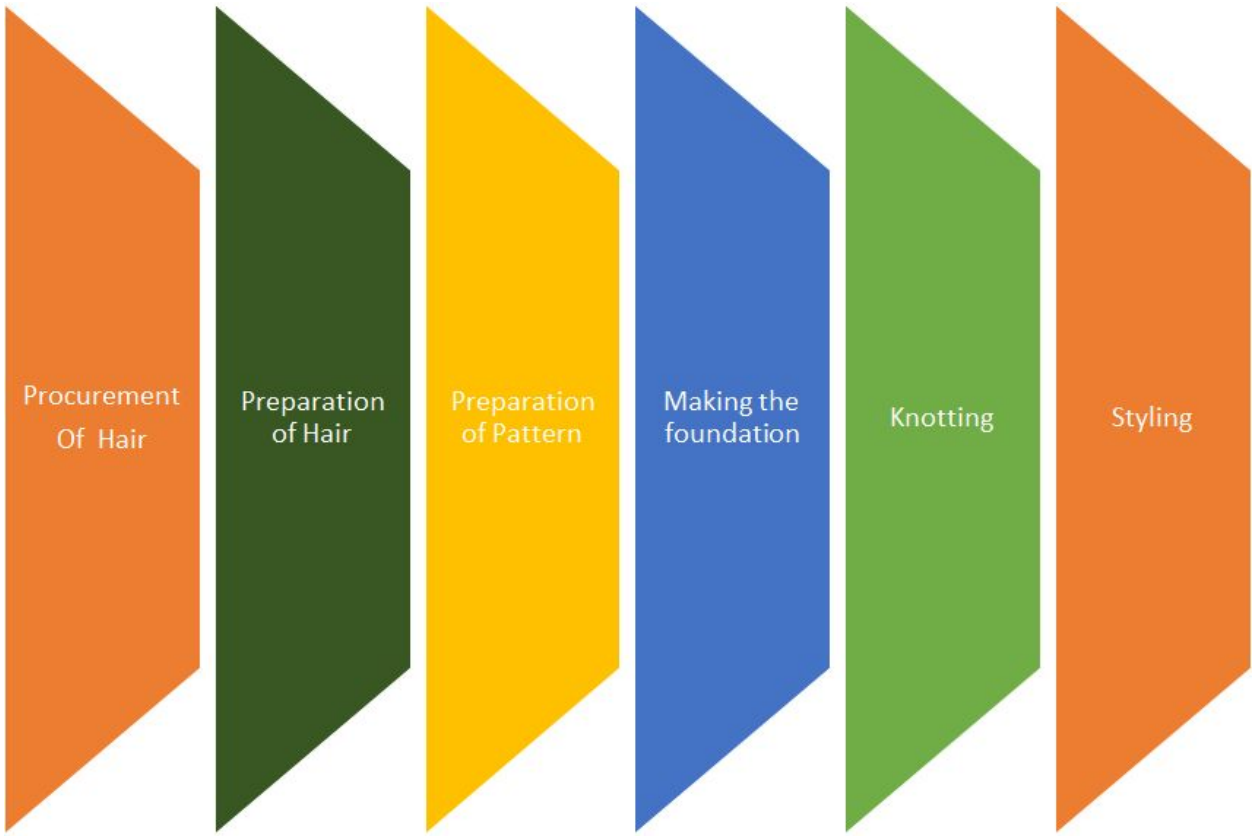
Satisfying Customer Needs - The New Manufacturing

- Automation of this hair preparation process drastically reduces the manual preparation time from 1 week to 3 days.
- Number of batches prepared per week through automation is higher as compared to manual.
- Large number of manual labourers employed of around 400 is drastically reduced to 40 labourers.
- However the cost of acquiring these automated robotic arms with 3rd generation sensors will be expensive. The capital investment for this manufacturing system is high but since this industry has increased demand over the last few years, return of investment is about 4 years.
- Appropriate sensors have been utilised to improve the accuracy and precision of the cleaning process.
- The final hair bundle is prepared mimicking the manual labour process to the tee increasing the efficiency and quality of the final product ready for industry and customization.



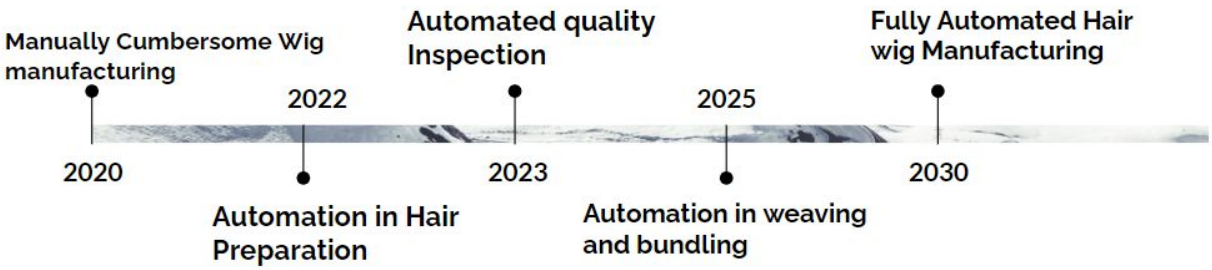
Future Expansion:

In the current manufacturing layout, processes like Bundling and Dry heating, Weaving are done manually because the quality inspection has to be done once in every three processes before continuing the next processes. We are trying to create a robotic quality inspection system so that the quality of the hair bundles are checked every three processes before moving on to the next processes. Then, the weaving process which is currently manual is made automatic using industrial robot technology. This can increase the productivity and quality inspection.



Currently, we are automating preparation of hair. In near future we would automate Preparation of Pattern, making the Foundation, Knotting and Styling of hairs.

VISION for the next 10 Years:



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