Indigenous Development of Sheep Hair Shearing Machine

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Abstract

A Sheep Hair Shearing Machine is used to cut the woolen fleece of the sheep. In India, this is usually carried out by manual scissors. There are some foreign industries which manufacture motorized sheep hair shearing machines. These machines are imported and used in India. IIT Delhi has developed an indigenous handpiece, including comb and cutter, as an alternative to the costly imported device in 2008 and presently the complete machine is being developed indigenously at mass production level. The machine consists of comb, cutter, handpiece, motor, flexible drive, motor, grinder, etc. The rotational input is provided to the crankshaft of the machine by a flexible shaft connected to the electric motor which converts the rotary motion to the reciprocating one. This relative motion between the comb and cutter causes the shearing action of hair. This paper presents the various manufacturing processes adopted for different parts of the machine. Since the combs and cutters are the most critical parts and are susceptible to frequent wear, hence, heat treatment to these components is also discussed. In addition to the manufacturing processes, this paper also summarizes the results of the field trials recorded during the actual shearing of sheep hair.

Keywords: Sheep hair shearing, Heat treatment.

1. INTRODUCTION

The quality of natural wool depends on the quality of hair received from sheep which further depends on the process of sheep hair-shearing. Globally, sheep hair shearing machine is extensively used by the wool industry to cut hair from the sheep's body. These motorized machines are available in the market from foreign suppliers (e.g., Lister Nova, Heiniger, and Horner Shearing) and are costly. These machines make the process efficient and smooth. In India, sheep hair shearing is mostly carried out manually using blade scissors which require high skill and experience. This method has drawbacks such as slow speed and inefficient cutting as it is not able to cut the hair from the roots.

Fig. 1. Sheep hair shearing

As an alternative, IIT Delhi has taken up the challenge in 2005 [1] to indigenously develop only the hand-held device for the sheep hair shearing machine and to make it available at lower cost to rural India. It's testing and comparison is shown in Fig. 1. Later another project was undertaken in 2015 to develop the complete set-up including the flexible drive, motor, grinder, etc. for mass production. During field testing in 2016 some issues like blunting and more heat generation of comb-cutter, heavier motor drive as compared to the imported one, selection of materials for different components, etc., were noticed. The experience of how to develop the machine and overcome the difficulties are explained in this paper.

2. DESIGN OF VARIOUS COMPONENTS

The first step was to understand the nomenclature and functioning of different parts of the existing machine. So, various components of the sheep hair shearing machine were studied. The chemical composition of the components was also found out using spectroscopy. The design calculations for the major components like barrel, joints, nut, bolt, gear, pressure pin, shaft with crank, etc. were done and the factors of safety of these components were also calculated.

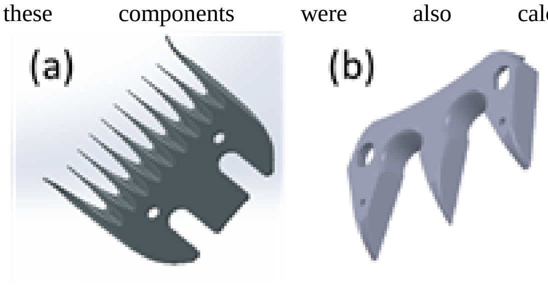

Fig. 2. CAD models of (a) Comb and (b) Cutter

All the components of the sheep hair shearing handpiece were then modeled using NX software. The modeled components including comb and cutter (Fig. 2), were assembled (Fig. 3) and interferences were checked. Before manufacturing any part, the

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required tolerances were also provided and the same were calculated.

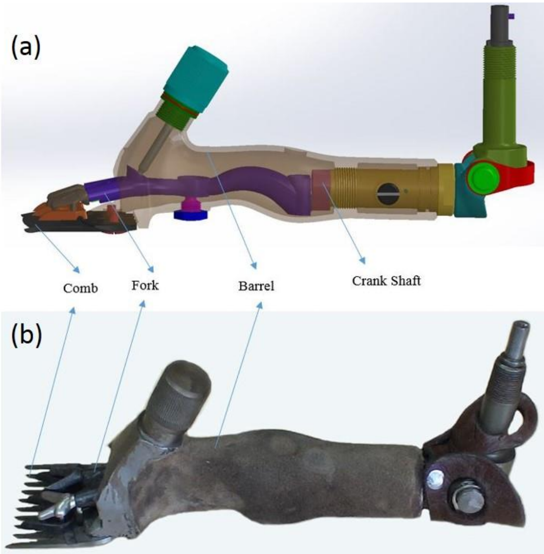

Fig. 3. (a) Assembled CAD model of handpiece and (b) Actual handpiece

3. MANUFACTURING

In this section, manufacturing of different components is explained.

3.1 Combs and Cutters

Combs and cutters are the most critical parts of the machine. They undergo excessive wear and require high hardness and wear resistance to withstand abrasion for longer life. Their brittleness should also be minimized. The material composition (Table 1) and hardness of the imported comb and cutter were tested.

Table 1: Composition of the imported comb and cutter (% by weight)

Part	C	Mn	Cr	Ni	Mo	V	W
Comb	1.16	0.56	Nil	Nil	Nil	0.08	0.018
Cutter	1.0	0.36	0.46	Nil	0.65	0.05	0.18

Keeping the mechanical and chemical properties of the imported comb and cutter in mind, the literature was explored for the replacement using commercial steels. It was found that D2 tool steel matches with most of the requirements (Tables 2 and 3) and it can be heat treated to obtain the required hardness.

Table 2: Composition of D2 Steel used for comb and cutter (% by weight)

Material	Fe	C	Mn	Si	Cr	Mo	V
D2 Steel	85.28	1.489	0.221	0.288	11.682	0.771	0.793

The parts were made using milling as shown in Fig. 4. Next, vacuum heat treatment was used to increase the hardness of the comb and cutter.

Table 3: Hardness of material in imported machine and D2 Steel

Material	Reading#1 (HRC scale)	Reading#2 (HRC scale)	Reading#3 (HRC scale)	Average (HRC scale)
Imported Comb	67	66	66	66
Imported Cutter	67	67	67	67
D2 steel	58	59	59	58.66

3.2 Heat Treatment

Several steps in heat treatment are explained next.

Choice of Process Parameters

Vacuum heat treatment is a clean process. So the parts do not need to be cleaned afterwards. It also offers a reliable process control with high automation, low maintenance, and environment friendly. All these factors make vacuum technology especially attractive for high-quality parts. The process parameters (Table 4) chosen for the combs and cutters are explained below whereas the parts after vacuum treatment are shown in Fig. 4.

Preheating Temperature
Heat very slowly and preheat between 600°C - 815°C. It was heated to 650° C and held for 10 to 15 minutes.

Austenite Temperature
From the preheat cycle, the furnace was set for 1010° C, which is the austenizing temperature for D2.

The soak time was selected based on 1 hour per inch (25.4 mm) of the smallest cross section of the parts. According to literature [3, 4], parts that are smaller than this should be soaked using the following rule of thumb:

1/8" (3.175mm) 30 minutes
1/4" (6.350mm) 40 minutes
1/2" (12.70mm) 50 minutes
3/4" (19.05mm) 55-60 minutes

Thickness of minimum cross-section of our piece is 1.5 mm. So, soaking time was 30 minutes.

Quenching
For gas quenching up to 6 bars, lower pressure can be used for small parts which have thickness less than 50-60mm. This minimizes excessive distortion.

Tempering
D2 tool steel can be tempered by using two different methods. One way is to single temper at (205° C). This method is used successfully for years where the higher hardness 62 HRc is desired. The more common and preferred method is to double

Table 4: Process parameters used for vacuum heat treatment

Material	Pre-heating temp.	Soaking time	Hardening Temp.	Soaking time	Quenching temp. (medium)	Tempering temp.	Soaking time
D2 steel	650°C	30 min	1010°C	1 hour	65°C Gas quenching up to 6 bars	515°C(1^{st} tempering) 480°C (2^{nd} tempering)	2 hours each

temper the parts for higher tempering temperatures.

First Temper

The first temper was for 2 hours of soak per inch of minimum cross section. The temper time for our part was 2 hours at 515° C.

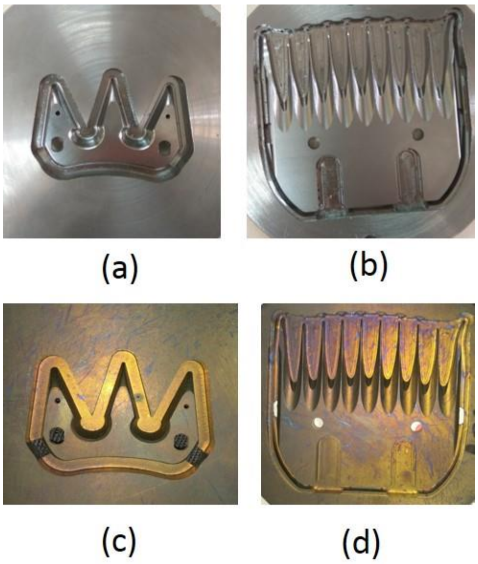

Fig. 4. Fabricated (a) Cutter after milling (b) Comb after milling (c) Cutter and (d) Comb after vacuum heat treatment

Second Temper

The second temper takes place only after the part returns to room temperature. The time can be half an hour to several days. It is very important that it is held at room temperature and not tempered from the 65° C mark like the first temper. The second temper was done at 480° C, for 2 hours per inch of cross section. After the process was complete and the part was cooled, the hardness was 58 HRc.

3.2 Other components of the machine

For the remaining parts of the machine, machining processes like turning, milling, drilling, grinding, etc. were adopted except for some components like barrel, fork, fork yoke, and joints. Barrel was manufactured by shell mold casting since its thickness is very low and its shape is complex. For manufacturing of the barrel, SG (Spheroidal Graphite) iron was used using shell mold casting technique. The die for shell mold casting is shown in Fig. 5.

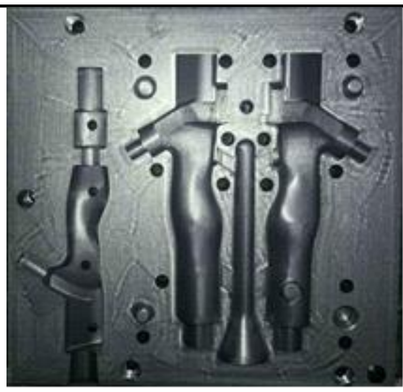

Fig. 5. Die for shell mold casting of barrel

Fork, fork yoke, and joints are manufactured by investment casting followed by machining whose wax models are shown in Fig. 6.

Fig. 6. Wax models for investment casting of (a) Joint, (b) Fork yoke, and (c) Fork

4. FIELD TRIALS

The testing of indigenously developed handpiece, motor with flexible drive, and combs and cutters (Fig. 7) was done in Una, Himachal Pradesh during Feb. 28 – Mar. 01, 2017. The results are shown in Table 5.

Fig. 7. Trials of indigenous motor, improved flexible drive and handpiece with comb and cutter

upto 2

Table 5: Field trial of sheep hair shearing device

Sl. No.	Starting Time	End Time	Working Duration (mins.)	Heating of Comb and Cutter	Heating of Handpiece Body	Vibration	Remarks	Duration of comb use	Duration of cutter use
1	9:36	9:41	5	No		-	New Comb & Cutter		
2	9:42	9:46	4	No					
3	9:48	9:53	5	Comb Heating					
4	9:54	9:57	3	Comb Heating	Little Heating				
5	10:00	10:04	4	Comb Heating		Yes			
6	10:15	10:19	4				Cutter Changed		
7	10:20	10:24	4						
8	10:24	10:28	4						
9	10:44	10:48	4				New Comb and Cutter		
10	10:50	10:54	4						
11	10:54	10:59	5						
12	11:01	11:05	4				Comb was cleaned		
13	11:06	11:11	5	Little					
14	11:12	11:16	4						
15	11:20	11:26	6						
16	11:27	11:35	8				Cutter Changed		
17	11:36	11:39	3						
18	11:40	11:43	3						
19	11:44	11:48	4						
20	11:51	11:55	4						

The motor and indigenous light weight flexible drive were working well. The feedback and problems that were faced are listed below:

a. Entry of wool in the comb was not proper.

b. Due to problem in entry of wool, rubbing of cutter over comb was more. Hence, there was slight heat generation.

c. Motor toggle switch was required for ease of frequent ON/OFF.

Taking the inputs from the first field trial, the machine was improved. A team of Rural Technology Action Group (RuTAG) IIT Delhi went to Barot, Himachal Pradesh to test the modified comb, cutter, handpiece, flexible drive, and motor. The changes were incorporated that are as follows:

1. To facilitate the entry of comb in the wool, the comb was modeled again in NX software by modifying the geometry. From literature, it was found that the thickness between two corresponding teeth of the comb should be less. Accordingly, the comb was re-modeled as shown in Fig. 8.
2. After modifying the geometry, the comb was again manufactured.
3. Incorporation of toggle switch in indigenous motor.

To evaluate the design and to test 5 combs and 7 cutters from two different suppliers more than 60 sheep were sheared (Fig. 9) in Barot, Himachal Pradesh. One comb was shearing 10 sheep (on average) and one cutter was shearing 5 sheep (on average) before the need for regrinding. This is almost equivalent to imported combs and cutters. Data was recorded regrinding of comb and cutter. The cutting was smooth with indigenous combs and cutters and the shearers were happy to work with indigenously developed device.

Fig. 8. Modified geometry of comb

Fig. 9. Smooth cutting using indigenous machine

From field testing it is clear that the indigenously developed sheep hair shearing device and its accessories like flexible shaft, motor, etc. are performing satisfactorily. However, a few modifications are still required in our handpiece which are likely to be rectified and then again they will be tested in actual filed.

5 CONCLUSIONS

Based on the field trials of the developed sheep hair shearing machine, following conclusions can be drawn:

i. It is possible to indigenously develop the improved and economic (~ Rs. 50,000 – 60,000) sheep hair shearing machine.
ii. The performance of the machine depends upon the dynamics and materials of comb and cutter.
iii. The hardness of comb and cutter can be tuned by designing suitable heat treatment process.
iv. The life and regrinding time for comb and cutter are different from each other which further can be optimized by suitable material selection and heat treatment.

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