Design and development of single end sizing machine for traditional weavers

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Abstract
Small scale woven fabric manufacturing industries in Ethiopia still use traditional processing, which is complicated warping and sizing. This has lower efficiency and affects the quality of warp yarn. In addition, the current drying of sizing yarn is done using sunlight, which does not give consistency and adequate drying. This work was developed based on the current situation faced by small scale weavers in Ethiopia. The scope includes the design and development of single end sizing machine to provide an effective sizing with lesser time and cost. Two concepts were generated by benchmarking with the existing product and produced with different functions and operating processes for warp yarn sizing machine. The final concept was selected by considering the user's operating environment and maintenance, which could be used in small scale woven fabric manufacturing industries. Considering the users' needs and buying capacity, a prototype was fabricated. After the manufacturing of a single-end sizing machine, a functional run-test was carried out and proved to be an alternative effective method of warp sizing. The properties of a single-end sized yarn was compared with traditional sized yarn and the validation of the machine was carried out by the user group; the feedback was positive.

***Key Words**: Single end sizing, Force analysis, Strength analysis*

I. INTRODUCTION

Ethiopia has a rich heritage of craft skills. Handicraft is considered to be one of the most important and widely spread occupations of most Ethiopians next to Agriculture.[1] As part of the handicraft heritage, Ethiopia has diverse traditional handloom products. This sub-sector provides large-scale employment and is an important source of livelihood for a large number of people working on handloom in clusters[2]. The report revealed that there is high potential for Ethiopian handloom products in the European Union countries, particularly in Germany, the UK and France. In order to sustain the handloom sector, it is essential to put in continuous efforts to upgrade the handlooms, to improve the productivity and reduce the fatigue so that the weavers' earnings are improved. [3] Vital areas include improvements and innovations in process and skill level, which can bring about major changes in the way things are done. It is sometimes forgotten that the handloom sector thrives totally on the skill of the weaver, which provides a technology barrier. [4] The process sequence of traditional weavers starts from warping, sizing, winding, drawing, tying and weaving. These processes are done simultaneously without using any technological knowledge and equipment. In 2013, Jumpei Itagaki at University of Osaka stated that the mechanism of the traditional warping process in Ethiopia for warping thread entails fixing cotton thread (approximately 15 hanks) onto a bamboo tool (Qwoshere). The tips of the thread are taken from each hank and twisted into one strand, and the tool is rotated to create the hank. [5] Normally in Ethiopia, there are two methods of warping thread - pig warping and crisscrossed warping. In the first, two sticks for warping (Denkero, Chahel) and one stick (Ainet) for figure are driven into the ground and the hanks are hung between these sticks to create tension (Fig. 1). The process is repeated until the cloth reaches the desired measurement and it is typical to make 400–420 warp ends for a cloth which has length of 24-36 metres. However, because of the final measurements of the gray cloth that the customer requires, the number of warps threads will vary from time to time. The sample indicated that some types of cloth will require less than 400 warps while some may require more than 450. When warping is complete, the warp thread hanging on the three sticks is rolled into the shape of a hank and tied at the tip. The other method of warping thread involves crisscrossing into the trees [6] and hanging warp over. But these processes inflict problems on the warp yarns, which mostly occur at cross ends, or result in lose warp, snarl formation due to over-tension and unequal length of the yarn. The next process after warping is warp sizing; this sizing process has an impact on the quality characteristics[7], [8] of yarn, which is mainly done to give the yarn enough strength, surface glaze and stiffness so that it can withstand the beating of the reed during the weaving process and also maintain the stiffness necessary for even weaving and a proper look at the warping once the weaving is complete. The sizing process is done only for cotton yarn and is generally done by using a thin paste powder of rice, corn starch or teff. [9]

The traditional sizing process involves first heating a huge container on wood fire; when it reaches boiling point, size paste like corn, teff and rice size paste is added. Once the sizing paste is cooked and ready, the cotton yarn, which is in the hank form, is mounted by two wooden rods to keep the hank hanging over the bath and directly immersed into the vessel. The paste is manually stirred using a wooden frame and after the paste is sticky onto the yarn, the sized yarn will be taken out and dried using sunlight. The complete process of the preparation of warp yarn for weaving takes up to two-three consecutive days as shown in Figure 2. However, this process results in quality problems in the yarn such as loss of strength due to high cooking temperature, tangle, hard size yarn due to oversize, size spot, sandy warp, size dropping and uncontrolled viscosity.

Fig 1. Warping process in traditional weavers

Fig 2. Warp yarn sizing - (a) squeezing (b) drying (c) in traditional weavers

In 2007, researchers Hyunyoung Ok and Heungsup Park [10] developed a single end sizing yarn with slot applicator [10], and they stated that a single-end sizing process was developed to solve the problems associated with the conventional method.

II. METHODOLOGY

The methodological approach of this research contains five phases which include a combination of prior concept design consideration, i.e. type of load and stresses caused by the load, motion of the parts or kinematics of the machine, form and size of the parts, convenient and economical features, use of standard parts, safety of operation, cost of construction and ergonomic considerations of full machine, material selection, design of machine parts, manufacturing of the parts and assembling.

After the machine was manufactured, a test run was done by sizing a cotton yarn, which has 21 Ne and using of corn size paste with MLR of 1:12 at a temperature of 90^{O}C. Finally mechanical strength, elongation and abrasion of the yarn was carried out, which was sized by traditional and single end sizing which has the same size paste, MLR and cooking temperature. It was tested by universal yarn strength tester and yarn abrasion testers and then analyzed by STATA Ver.14.0 software.

III. CONCEPTUAL DESIGN

The single end sizing machine is proposed to design and manufacture a combination of four different processes - warping, sizing, drying and winding, which is held in preparation of the weaving process at continuous, and at the same time, which is the motion of moving parts driven by chain and sprocket mechanism.

IV. MATERIAL SELECTION

The selection of proper materials for engineering purposes is based on the objectives of minimum cost, availability of the materials, suitability of the materials for the working conditions in service, and cost of the materials. [11] Based on the above factors, the selected materials for manufacturing of creel frame, sizing box frame, drying section frame and winding section frames are mild steel, which has a rectangular shape and standard mechanical properties of modulus of elasticity of 182.5Mpa, ultimate tensile strength of 165Mpa, endurance limit of 68.75Mpa and hardness Brinell of 180. Additionally, the selection of immersing roller in the size box and winding roller in winding machine is also mild steel which has a round cross sectional shape.

1. Design of machine parts

1.1. Analytical design of Creel

These machine parts have included two basic machine elements - the vertical and horizontal creel frame and vertical cone holder frame that arrange in a "V" shape and has an angle between 35^{O}, creel height of 240cm which carries 300 ends of cones of 2.5kg each with 25 top-to-bottom and 20 cm side-to-side apart and total creel length of 300 cm each (A).

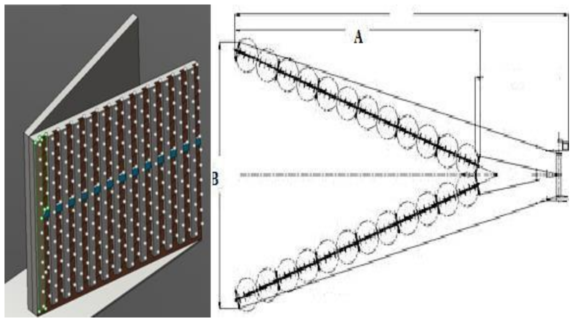


Fig 3. V-creel

The analytical design of the creel is done by using detailed calculations and force analysis of the vertical creel frame and vertical cops holder. All parts are subjected to compression forces and the strength analysis of parts are done by using shear stress and bending stress of the vertical creel frame and vertical copes holder, which determine the bending moment and shear force as shown in Figures 4, 5 and 6.

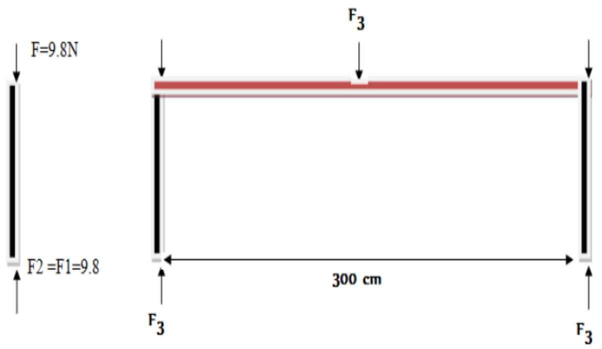


Fig 4. Force analysis of vertical creel frame

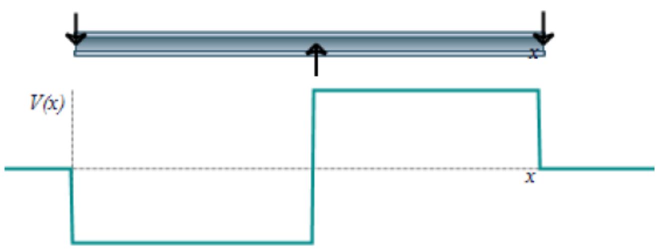
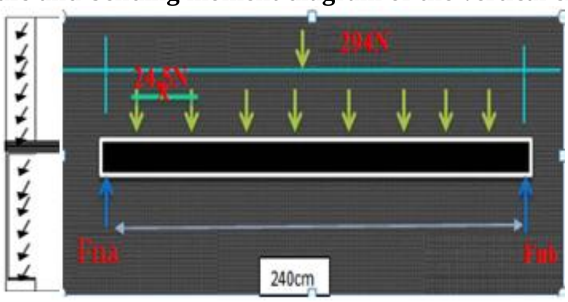


Fig 5. Shears and bending moment diagram of the vertical creel frame



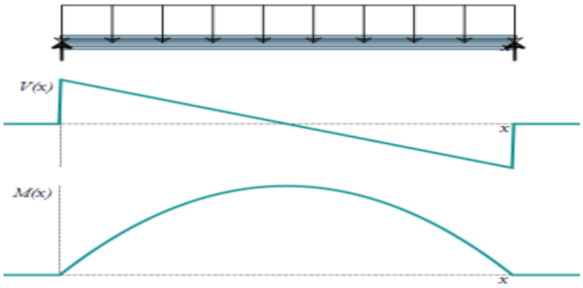


Fig 6. Bending stress on the vertical cops holder frame

The result of force, stress and ultimate strength of the individual machine parts are summarized in Table 1.

Table 1: Summary of analytical design of machine parts

Machine Zone	Machine part	Result analysis of			
		Force (N)	Strength (Ncm)	Heat (Watt)	
				Q_C	Q_E
Creel	Vertical Creel frame	$F_{na}=F_{nb}=9.8$	$1.47*10^3$		
	Vertical Cop holder	$F_{na}=F_{nb}=147$	$5.88*10^3$		
Sizing box	Size box frame	$F_{na}=36.35$, $F_{nb}=27.35$.	6614		
Drying zone	Drying Stove			$10*10^3$	$0.646.*10^3$
Weaver beam	Weaver beam frame	F_{na}=Fnb=14			

1.2. Analytical design of size box

Size box is the zone, which warp yarn is immersed into the boiled size paste and this machine has four main parts,. are size box frame, guide roller, immersing rollers and squeeze rollers which have 0.5, 0.5, 0.5 and 5kg respectively applied on to the size box frame.

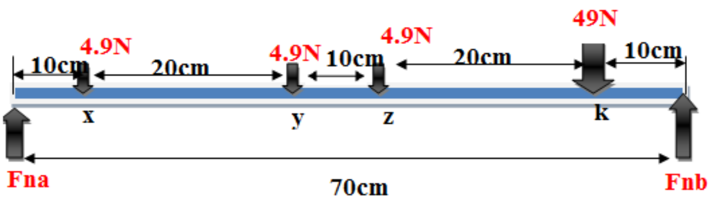


Fig 7. Compression stress on the size box frame

The size box frame is subjected to compression stress due to compression load applied to the frame. Also the size box frame is subjected to compression and bending forces and the movement at each node is calculated and based on its allowable bending stress and its ultimate bending stress, the length and strength of the machine are determined.

1.3. Analytical design of drying section

This section contains two main parts - drying section frame and drying parts. The function of the drying section frame is to carry the drying unit and the force and strength of the drying section frame are also analyzed by bending movement and compression stress.

Also the function of drying yarn is based on the methods of producing a rounder yarn. Non-contact methods were investigated by using a round stove which produces from clay and gypsum layered of radius of heat emitting is 30cm and this will convert direct electrical energy of 220 Volt and a current 4.54A to conduction, convection and radiation heat.

The amount of heat generated by the direct electrical energy source is calculated by,

$$Q_C = \frac{KATo}{X} \text{---}1$$

Where $Q_{C=}$ Conduction heat, K= The thermal conductivity which is directly read from standard table chromium is 11.3W/Mk, A= The contact area of the resistance wire, T^o= The changing temperature between the two surfaces and X= The layer between resistive coil wire and gypsum which is 1 mm.
Therefore the charge of the electric which have 220 voltage with 4.54 ampere is equal to

$$Q= I*V \ldots\ldots\ldots 2$$
$$4.54A*220V=1000W$$

And the area of heat emitting device which has 60cm radius,

$$A=\Pi r^2 \ldots\ldots\ldots 3$$
$$3.14*0.3^2m=0.286m^2$$

So the heat radiation transferred from the surface of the emitting circular stove to the air is heated by radiation.

$$Q\ emit=\Sigma*\alpha*T^4 \ldots\ldots\ldots 4$$
$$Q_{Emit} =1.567*10-8*0.3m2*4484$$
$$645.78W$$

Where Σ= Emissivity of the gypsum, which is equal to one, α= The Boltzmann constant which has a value of $5.67*10^{-8}$, A= emitting surface area which has $A = \pi r^2$, T= emitting surface temperature, which has 448K.
And the deference between the heat, which generated by the electrical restive wire and the surface of gypsum layer equal to 354.22Watt, i.e. (1000W-645.78W).
As a result, the mass of yarn that will dry in the drying section without contact is latent heat, which is generated on the surface of the round stove and can be calculated by,

$$QL = M * L \ldots\ldots\ldots 5$$
$$\mathrm{M(g)} = \frac{QL}{L} = \frac{0.645KJ}{2260\mathrm{KJ/Kg}} = 285.7\ g/s$$

Where Q_L is latent heat of vaporization, M=Mass of yarn and L= is the specific heat of water which is 2260KJ/Kg.

1.4. Analytical design of weaver's beam

The warp beam holds many thousands of individual warp yarns and this yarn winding machine contains two main parts - winding box frame and winding roller. The winding frame is subjected to stress by the winding roller and the number of yarn accumulated on the weaver's beam.
The motion driving parts of winding roller is directly attached to the tips of winding roller, which directly drive manually by hand and it is attached and connected by a chain and sprocket mechanism from the guide and squeeze roller in the size box frame.

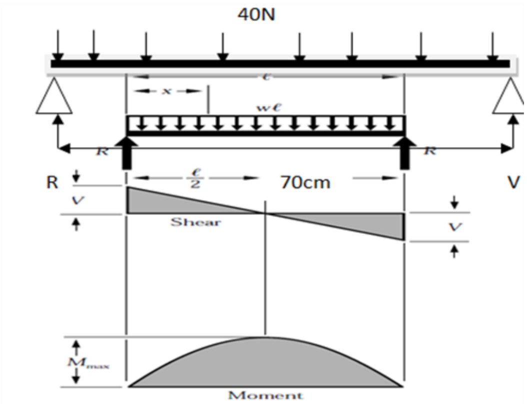


Fig 8. Shear stress and bending moments of winding section

V. PREPARATION OF AUTOCAD DESIGN OF MACHINE

Based on the analytical design, each part of the machine was designed and drawn by AutoCAD software as shown in Figure 9.

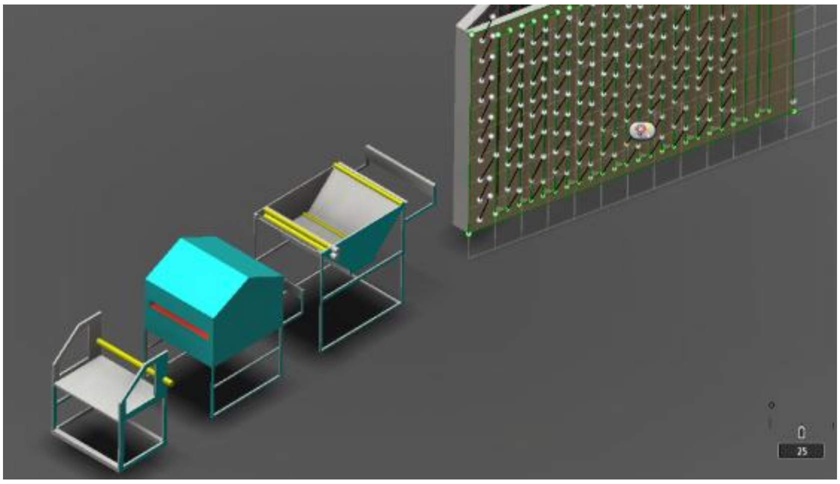


Fig 9. Final design of machine with Auto CAD

VI. MANUFACTURING AND ASSEMBLING MACHINE

After design of each part of the machine based on design and analysis, each individual part was manufactured by cutting the metal parts, drilling metal hole parts, sheet metals are trimmed by shearing machine, electrode welding by welder machine and assembling and surface finishing of all parts.

VII. MECHANISM OF OPERATION

Single threads are taken from the cone packages and passed through a tension control guide at the front of the creel and passed into yarn separating dents of a comb. After passing the comb, the yarn is passed above the guide roller in the size box and directly immersed into the size box by two immersing rollers for predetermined size pick-up. Then the yarn is squeezed by one set of squeezing rollers and it goes to the third zone which is non-contact drying; this is actuated by the electrical stove installed in the drying zone.

After the yarn is dried, it will pass to the winding zone. Winding is performed on the weaver's beam, which is driven by a sprocket chain mechanism. Finally, the winding yarn on the weaver's beam is directly used by the weaver to manufacture the required cloth.

VIII. RESULTS AND DISCUSSION

Thirty samples of 21 Ne cotton yarn were examined for tensile strength, elongation and abrasion resistance before sizing and after sizing imparted by traditional and single end sizing methods by using the universal strength tester and a yarn abrasion tester respectively. The mean tensile strength, elongation percentage and abrasion resistance of each yarn are shown in Table 2.

Table 2: Mechanical property of yarns before sizing and after - both single end sizing and traditional sizing methods

Strength (CN/Tex) Elongation (%age)	Obs.	Mean	Std. Dev.	Min	Max
Strength before sizing	30	367.055	10.85	345.7	387.8
Elongation before sizing	30	4.633333	.13	4.28	4.9
Strength after traditional sizing	30	408.15	7.17	388	423
Elongation % after traditional sizing	30	5.155667	.40	4.28	5.8
Strength after SES	30	432.4833	10.1	400	450
Elongation after SES	30	6.090667	.93	4.45	8.8

Table 3: Abrasion resistance (rev) of unsized, traditional sized and single end sized yarn					
	Obs	Mean	Std. Dev.	Min	Max
Unsized yarn	30	12.13333	2.648791	7	18
Traditional sized yarn	30	13.56667	4.099481	8	22
Single end sized yarn	30	16.533	4.56	10	24

The maximum and the minimum value for tensile strength, elongation and abrasion resistance of each yarn with different sizing methods are shown in Figure 10.

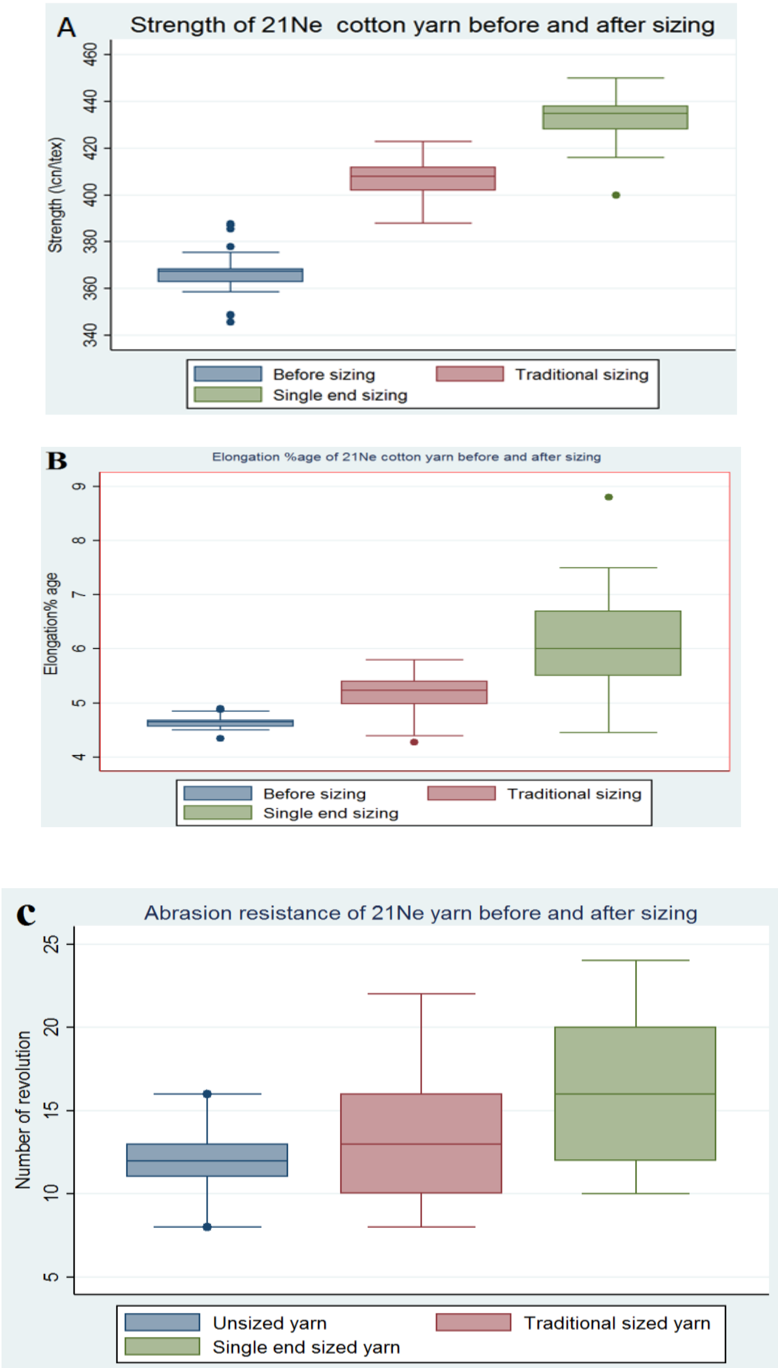


Fig 10. Strength (A) elongation (B) and abrasion resistance (C) of yarn before and after sizing

Figure 10 shows that the yarn, which is sized by single end sizing methods have higher tensile strength than yarn, which is sized by the traditional sizing system. These increments are due to the even and adequate sizing in the size box and even drying by the single end sizing system. In addition, the elongation percentage has also increased due to controlling of over sized yarn. Also the abrasion resistance of the yarn in single end sized has a greater value than the traditional sizing methods due to high size add on and size takes up percentage.

IX. CONCLUSION

Single-end sizing machine is designed and manufactured with cost effective available material. Single-end sizing process sizes the cotton yarn in a scientific method and achieves high productivity of weavers. The yarn, which is treated with single end sizing machine, has 5.96% greater tensile strength than traditional sized yarn and the elongations of single end sized yarn have 18.25% better elongation percentage and 21.9% greater abrasion resistance than that of traditional sized yarn.

X. REFERENCE

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