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felt PET: a material research project

by
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Abstract

felt PET: a material research project

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Susanna Hohmann

Wool has long been used by nomadic Mongolian heros-people as a cladding for their traditional dwellings and as a material for crafting everyday objects. A moldable, lightweight material into which other materials and forms can easily be embedded, wool felt has a distinct aesthetic and an inviting tactile quality. The Felt PET project challenges urban dwellers to see that material/structural innovations and strategic spatial effects can be produced from wool felt.

Contemporary technologies and economies prescribe specific lifestyles and influence individual choices and behaviors. The surrounding physical environment is made up in large part by the cultural artifacts we produce --- petroleum, plastic ware, Prozac, and the Internet, to name a few. In an attempt to shake things up and promote a atmosphere of creativity in our contemporary postindustrial culture, I have extracted felt and the process of felting from both its traditional and industrial economies and inserted it into my own contemporary patterns of use and behavior. To be most potent, my re-contextualization of felt claddings is both integrated and idiosyncratic: produced with recognizable contemporary methods of design and manufacture, while resulting in one-off crafted artifacts that accommodate my idiosyncratic uses and behaviors with singularly different forms.

The claddings I propose are designed around common activities and events. They intentionally shift between addressing the body and the architectural interior spaces the body inhabits. Though handcrafted and idiosyncratic, felting wool can produce claddings whose function and program vary across a continuous surface or landscape. By capitalizing on the enormous potential of wool for producing soft, flexible, portable, innovative, and playful interior environments, I see Felt PET as a viable and critical choice for a contemporary cultural artifact.
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felt PET: a material research project
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ORIGIN

01
Inuit hunter in polar bear skin. A tanned animal hide is the oldest cladding type.

02
This Turkish Shepherd’s coat is a cladding and a shelter, in which to sit, in the event of rain or snow. His flock of sheep provide a constant source of wool from which he can directly produce felt without the technology of weaving.
HOUSE

03
Gedjecondu dwellers in Turkey. The "goods of Life" are draped, and carpets slide from floors onto cushions onto walls. The lines between furniture and room, wall and floor, and object and space are dissolved.

04
A traditional Mongolian Ger in the early stages of construction. The entire construction process occurs over the span of a day.

05
A wooden frame provides the structure of the Ger. All Ger components can be transported by a horse, camel or yak.
INFLUENCE

06
Felt sheets clad the wooden structure and provide insulation for the Ger. Felt can be made so dense as to be nearly impervious to wind and water, yet it is far lighter than other waterproof materials like wood and metal.

07
Felt is used in this context because wool is so abundant in this environment. Along with horse riding, felt evolved with and made the Mongolian nomadic way of life possible.

08
Traditional Mongolian method for producing large felted sheets. Raw wool fibers are laid out on horsehides, wet and rolled around an axel that is then pulled by a horse for up to 18 kilometers.

09
Depiction of Mongolian Felt-making ceremony.
SEAT

The Felti Chair is a contemporary felt chair that combines aspects of both blanket and chair as well as explores structural felt construction techniques. Designed by Geatano Pesce and produced by Cassina the Felti chair is made primarily out of wool felt that has resin embedded in it in a very light-handed way. The resin "frame" registers only on the inside surface of the chair leaving the back to read as a pure felt surface, thus preserving the visual and tactile qualities of felt.
SHEAR

Sheep are usually shorn twice a year, once in the late spring and once in the early fall. The wool is trimmed in one piece and is called a fleece.

FELTING process
RAW

Raw wool comes directly off the animal. Each ton of raw wool contains approximately 150 kg of dirt, 150 kg of Lanolin, 40 kg of sunit, 20 kg of vegetable matter, leaving 640 kg of fiber. Sunit is the natural grease in the sheep’s wool.

SCOUR

Scouring is the process of washing wool fleece in hot water and detergent to remove the non-wool contaminants. Scouring does not always eliminate vegetable matter such as burrs and seeds, and so heavily contaminated wool must go through a process known as carbonizing. If burrs are not removed at this stage they can cling to the wool fibers and not be noticed until processing is complete.

In traditional nomadic felt making practices the wool is generally not washed at this point in the process. Commercial felters make use of this step to extract Lanolin from the fibers. Unrefined Lanolin is a by-product of the scouring process. In its purified state, lanolin is used in creams, soaps, lotions, and cosmetics.
CARDING

Carding is the process, in which the wool is fed between wire brushes on a number of revolving rollers in order to produce batts of fiber. The carding process orients all the fibers in a the batt in the same direction.

Felt is constructed by layering wool batt on top of each other one perpendicular to the next. The thickness of the felt depends on the number of layers of batting that are crosslapped prior to the fiber entanglement phase.
ENTANGLEMENT

Felt is made when the wool fibers are physically interlocked and consolidated by mechanical work. This can be done as a wet process where water, pressure and soap are applied to the fibers, or in a dry process where needles with small barbs on the ends pass through the wool batts and entangle the fibers as they are pulled through.
FILM STILLS

The images above are captured from a short film that recorded two processes of felting. The top row of images are taken during a hand felting class I took at the Mongolian Textile Institute at the Mongolian University of Science & Technology in Ulaan Baatar where I felted a traditional style Mongolian hat and an ornage hand bag. The second row of images are taken from a felt making factory in Ulaan Baatar where felt boot liners and the 1 meter X 5 meter felt sheets used to insulate traditional Mongolian Gers are made.
OBJECT & ACTION

Felt noun: 'A non-woven fabric made from fibers that are physically interlocked and consolidated by mechanical work, chemical action, and moisture without the use of weaving, knitting, stitching, thermal bonding or adhesives to form a compact material that will not ravel or fray.

Felt verb: 'A technique that produces a non-woven sheet of matted material created by the entanglement of a mass of fibers.
FIRST FABRIC

01
Turkish women laying out fibers to be felted.

02
Felt is the oldest known fabric. Preserved in permafrost, felted artifacts were found in a Pazyryk tomb in the Altai region of Russia. This fragment of a wool felt covering for a saddle is dated to the 5th century BC. Felt is most likely the oldest known fabric because the fiber can be made directly into fabric without the technology of weaving.
wool fiber: cross-section through sheep skin

The complex nature of felt is derived from its basic unit: a single wool fiber. While felt is now manufactured out of many types of fiber, it is the particular characteristics of wool that gave rise to the production of felt.

WOOL

Traditionally, the term wool referred to the fibers covering the skin of a sheep. Since the Wool Products Labeling Act of 1939, the term wool includes the fleece of a sheep, angora goat, undercoat of a cashmere goat, yak, llama, vicuna, and guanaco.

A single wool fiber is a complex protein macromolecule. The outer layer of a wool fiber is made up of hard, flattened cells called scales whose surfaces overlap and enclose the fiber cortex. Scale size and shape vary from species to species and is an important characteristic used in fiber identification. The exposed edges of scales point towards the tips of animal fibers and give rise to the friction effect and felting.
Each wool fiber is a molecular coilspring. The cortex of the fiber is divided into the ortho-cortex and para-cortex that coil around one another as they grow and are structured through several orders of bundled spring like fibrous elements. The ortho-cortex and para-cortex are comprised of many macrofibrils.

**STORED ENERGY**

Macrofibrils in turn are comprised of many microfibrils. Microfibrils are comprised of eleven protofibrils. Protofibrils are comprised of three spiral shaped proteins wrapped around one another. Essentially, each wool fiber is a spring-shaped bundle of little rubber bands.

The elastic nature of wool fibers is enhanced by a waviness that runs along the length of each fiber. This wavy property is called crimp. Crimp, along with the coiled fiber structure, allow wool fibers to be stretched up to 50% when wet and 30% when dry, and still bounce back to their original shape when stress is released.
wool felt: 35x, 350x, 1500x magnification

PRIMARY TECTONIC

The primary tectonic of felt is a porous matrix of randomly organized, overlapping and entangled fibers that interact with each other and create air pockets. The effects of sound attenuation, light diffusion, heat insulation, moldability and tactility are all embedded in this surface. Modulating the size and distribution of these air pockets allows these effects to be manipulated.

Unlike more technically advanced woven fabrics the interactions of felted fibers are local. The addition or subtraction of any particular fiber or fibers does not affect the over all performance of the fabric.
This chart describes the performance criteria that exist for industrial felt. Industrial felt is engineered for use in the automotive industry primarily as sound dampener, in the oil and gas industry as a wicking and gasket material, and in the paper making industry as a homogenous wicking surface. Most industrial felt engineering is concentrated on varying the density and stiffness of felt sheets to enhance sound or fluid absorption.
Shape memory in felt is a function of its resilient properties as well as its ability to be molded into and retain a series of particular shapes.

Felt's resilient qualities allow it to recover its original shape from compression deformation as long as the compression force is not greater than the compression force applied during the act of felting. The denser the felt, the more resilient it is in the face of compression deformation and the higher its rate of recovery from deformation.

SHAPE DYNAMICS

Shape memory in metal alloys is a function of a fluctuating molecular conformation that occurs when the temperature of that material reaches a specific point. That is, metal alloys with shape memory abilities can move between two positions based on a change in temperature. Felt can be rendered plastic and moldable with heat and water and can then locked into a shape with dry heat. If deformed, this locked shape can be reactivated with the addition of water and heat. In this manner felt can be reworked into any number of conformations because the shape of the felt fabric is due to a particular mechanical arrangement of fibers not a chemical reorganization on the molecular level. A wool fiber and thus felt is very durable and can be bent back on itself more than 20,000 times without breaking.
Resiliency: the physical property of a material that can return to its original shape or position after a deformation that does not exceed its elastic limit. In felt, resiliency is measured by the ability of the wool fibers to push back after flexing.

The ability of the fibers to push back after flexing is a function of the complex molecular structure of the wool fiber.

Borsalino felt hats are rolled up for ease of transport. The resiliency of the wool fiber allows the hat to resume its unrolled shape once out of the transport tin.

SHAPE MEMORY

Wool fibers enmeshed as felt inherently “want” to stand up straight, as if on the back of a sheep. The entangling of fibers during the felting process restricts their movement and stores the latent potential energy that the coiled fiber possesses. The entangling of the fibers causes air spaces to form in between the fibers. The amount of air space determines the amount of room the surrounding fibers have to flex. The denser the felt, the smaller these air spaces are and the less flexible the material is; at the same time, the more resilient it is due to the increased amount of “trapped” potential energy.

Resiliency of individual fibers also gives rise to insulating quality of felt. Air is trapped in the spaces that the crimped wool fibers generate when felted together.
Wool absorbs moisture from the atmosphere of greater humidity and releases it to the drier environment. Both heating and cooling are achieved through wool’s ability to create a balance in moisture conditions.

Shivering: In cold and damp climates wool textiles act as heat generating insulators. As wool fibers absorb atmospheric moisture through pores in the epicuticle, the hydrogen bond of water is broken and chemically reacts with amino acid molecules in the cortex of the fiber to generate heat. This interaction keeps a layer of warm dry air between the garment and the wearer, which holds in body heat. Wool can absorb up to one-third of its weight in atmospheric moisture without feeling damp. In cold and dry climates felted wool textiles are insulators because the felt matrix creates millions of air pockets. Air trapped in those pockets retains body heat and forms a warm and dry buffer zone between the body of the wearer and the cold ambient air.

Sweating: The body cools itself naturally with the evaporation of perspiration. Wool expedites this process by absorbing perspiration and keeping dry air next to the skin.

Touregs wearing wool jubbahs: These garments provide a cooling moisture wicking surface during the heat of the day and a warm insulating layer at night.

**SHIVERING & SWEATING**
RAIN SCREEN

Wool has the unique characteristic of being hydrophilic (absorbent) towards water vapor but hydrophobic (water repellant) towards liquid water. The cuticle layer of wool fiber has a hydrophobic epicuticle, off which water runs, while water vapor diffuses into the fiber through microscopic pores in the surface of the epicuticle. This is because the molecular structure of the epicuticle is smaller than that of liquid but larger than that of water vapor.

A Mongolian wool rain coat takes advantage of wool's ability to shed water and retain heat.
FIREFIGHTER

Wool’s high moisture content and protein constituents provide a natural flame retardant. The moisture retained in each fiber makes wool difficult to set alight under most conditions, and then it burns only weakly, forming a cold char which tends to extinguish burning when it is removed from the source of fire.

Wool’s fire retardant nature allow it to be used as insulation in buildings. Wool insulation meets all building regulations for installation in the UK and New Zealand.

Laser etched wool felt burns while in contact with the laser beam and self extinguishes when the laser moves.
Wool does not conduct electrical current. There is virtually no measurable current flow through dry or pre-soaked wool at any of the voltage settings from 100 DCV to 5000 DCV. This suggests that wool has extremely high electrical resistance and does not appear to conduct DC or AC current even under very high voltage potentials.

This glass insulator used in high-voltage power lines has an equivalent electrical resistance to wool felt.

A LED bulb is felted into the felt fabric. The wool felt acts as an insulator between the leads on the bulb.

Two layers of copper fibers are felted into the felt fabric when current is applied across those layers an LED bulb (with some added insulation on the long prong) can be “plugged” in anywhere on the felt.
01
These extremely dense felt balls are used as the heads on timpani drum sticks. These are industrially manufactured and turned on a lathe to achieve the final rounded shape.

02
Mongolian felt “vase” is an example of a 3-D felting technique. It is incidentally not watertight.

03 + 04
Initial experiments designed to test if a felt tube or series of tubes could be made to support themselves.
CASTING
STRUCTURE

05+06+07
These experiments test the casting of 3-D shapes into a felt sheet during the process of felting. In these experiments raw fibers were felted over plastic cups. Image 07 shows these cast shapes reinforced with various hardness of resin.

08
In this experiment a sheet of wire mesh was felted into a sheet of felt. The result was a felt sheet that was dominated by the language of the wire and not the soft tactile nature of the felt.
MOLDING

This experiment was designed to see of industrial sheet felt could be moulded into a 3-D surface. In this case a positive and a negative mold is made, the felt is soaked in water and then clamped in the mould and dried. The molded shape stays intact until it is wet again.
SURFACE

These jacket making experiments deal with felt's ability to produce complex seamless garments. In “casting” these felt jackets I learned that during the process of felting the fibers have the characteristics of both clay and fabric. These material characteristics allow for complex seamless felt construction as well as differing fiber densities across a continuous surface. The first jacket was a seamless construction experiment that I cast directly on to Sharen and then cut off of her.
The second jacket I cast on to a paper mannequin that I molded form a cast of my torso. This jacket was designed with a thick cushioned collar/pillow so that as I nodded off I would have a place to rest my head and take a short nap. The density of the felt is greater at the collar than through the rest of the jacket.
DENSITY

The design of the Sharen Bidasee Sleep-sleeve arises from the common event of Sharen falling asleep on her arm in front of her computer. The sleeve would be part of a felt garment that she would wear to stay warm in studio that she could also use as a headrest. This design allowed me to explore both felt construction techniques as well as the idea that a body and its habits was the architecture that was being clad.
The surface of the sleeve is engineered to have areas of different densities of fiber. The more dense areas providing cushion for resting. A mold is needed to fabricate these different densities.
GLOW

Light diffused by felt produces a soft glow. In this jacket constructed out of SAE-5 grade felt, the felt is too dense for very much light to pass through it. A pattern has been laser etched into the surface to reduce the density of the felt in a particular pattern that glows when light is applied.

LIGHT JACKET
OPV (Organic Photo-Voltaics) absorb solar energy that can be stored in batteries or used directly for lighting. OPV is a polymer coating combination that could be printed directly on a felt surface.

TFB (Thin Film Battery), a high efficiency battery that could be embedded into the felt during the process of felting.

OLED (Organic Light Emitting Diode), emit photons of light when excited by an electric current. They may be deposited like ink on the surface of the felt or embedded into a sheet of felt during the process of felting.

OTTFT (Organic Thin Film Transistor), a variant of the microcircuit controlling liquid crystal display in laptop computers. OTFTs are made up of printed circuits and could be embedded into a sheet of felt during the process of felting.

This light jacket looks and performs like any other jacket while it is on the body. Once the body is removed and the act of hanging the jacket up is transformed into a spatial opportunity. By taking it off the body, hanging it up and lighting it a softly lit space is defined. It would be great if the jacket glowed while you were wearing it. This could be done by using the technology that Kerin and Timberlake Architects applied to their Smartwrap design. Felt is not a conductive material and circuits can be printed directly on to sheets of felt using conductive inks.

Image 03 shows jacket panel with the laser cutter char washed out, 04 shows the same panel prior to being washed.
PROGRAM

Sitting
Leaning
Laying on my back
Laying on my side
Resting my head
Lounging

The felt Pet Design System generates a felt topography in response to a range of activities related to the body through precise methods of construction. Interior felted landscapes are produced through the combination of felts material effects, a range of programmatic requirements, and the combination of industrial and hand-felting techniques.
Effects

Ambient Effects:
- Soft light
- Sound attenuation
- Thermal insulation

Material Effects:
- Tactility
- Color
- Softness
- Hardness
- Mould-ability

Technologies

- Needle felting
- Pressure felting
- Milling
- Die cutting
- Laser cutting
- Dyeing
- Mold making
- Printing
- Conductive fibers
- Sewing
MIGRATION

Fiber arrangement is manipulated when forms are cast into very dense industrial felt sheets. A seat is defined with a positive form made of cut and stacked sheet felt is placed under the cast form.

FELT PET _ ITERATION.01
PROGRAM / POSITION

PLAN FIBER DENSITY KEY

FIBRE DENSITY

NEGATIVE MOLDING FORM

SAE - 1 GRADE INDUSTRIAL
1/8" FELT SHEET 5' X 7'

POSITIVE MOLDING FORM
TENSIONING PEGS
MOLD BASE

CONSTRUCTION
CONCENTRATION

Fiber density is manipulated by adding more fibers strategically in particular areas in relation to a wide range of sitting and laying positions of a body.

FELT PET _ ITERATION.01
PROGRAM / POSITION

PLAN FIBER DENSITY KEY

FIBRE DENSITY

CONSTRUCTION
EXTRUSION

Fibers are prepared for felting by laying them up on vertical molds so that tube like extrusions can be seamlessly felted into a flat surface.

FELT PET _ ITERATION.01
PROGRAM / POSITION

PLAN FIBER DENSITY KEY

FIBRE DENSITY

CONSTRUCTION
COLUMN

The hypothesis of the Column Experiment was that a tube of felt with a mid section of thick felt and ends of thinner felt could be folded into itself and hold itself up. This turned out to be true but, required 6 lbs of fiber and 12 hours of production time.

A second version of the felt column experiment incorporated through felting a tube of industrial felt with circular punctures into a felt extrusion. Felted joints hold the two types of felt together. Industrial felt is inherently denser than hand felted felt and can be folded and sewn into a tube in minutes to achieve a stability that it takes hours to achieve in hand felt.

FELT PET _ ITERATION.01
WORK SPACE
ORAL DEFENSE
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www.birkelandwool.com

Zeilinger Wool Co
1130 Weiss St.
Frankenmuth, Michigan 48734-1926
www.zwool.com

Oregon Flock & Fiber Festival
www.flockandfiberfestival.com

SuDan Farm
Dan and Susie Wilson
32285 S.Kropf Rd.
Canby, OR 97013

www.CopperMoose.com

**Felt:**
Duro-Felt Products
#6 White Aspen Court
Little Rock, AR 72212-2032
www.durofelt.com

Texas Gasket & Packing Co.
1255 Lathrop
P.O. Box 15698
Houston TX
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American Packing and Gasket Company
6039 Armour Dr.
Houston TX 77020
www.callapg.com

www.mcmaster.com

**Tools:**
Celtic Moon Fiberworks (felting machines)
26289 96th Ave
Maple Ridge, B.C. V2W 1K3 Canada
lavell@telus.net

www.louet.com (carders)
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