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The old scientific-technological instrumentations in the Museo dell' Arte della Lana of Stia

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***Abstract* – The study of the old scientific-technological instrumentations exhibited in the Museo dell'Arte della Lana of Stia in the Casentino Valley in Tuscany, allows to discover interesting connections between textile industry, science and technology. One example is a testing device from the beginning of the 19th century that allows the user to characterize fibers, yarns, fabrics, and other hygroscopic materials. The testing device, permits true and accurate determination of their strength, and well as other properties affected by the moisture content of the fiber/material under study, without the need to refer to moisture *regain* tables and charts. The instrument represents a noteworthy improvement in the art of testing materials and products of hygroscopic nature. The napping machine, known as *ratinatrice*, is an example of technological instrumentation affected by the industrial development. A plate of the *Encyclopédie de Diderot et d'Alambert - Art des textile*, shows a drawing of the *ratinatrice* which can be considered a forerunner of the one of the museum dating back to 19th century. The instrumentation consists of a wooden roller on which hooked iron teeth are fixed in order to maintain the fabric under tension and of a movable table with abrasive material that with different movements (straight, circular, oscillator), gives the fabric passing under pressure, the characteristic curly appearance. The napping machine design and making is shaped by the evolution of the finishing technique of the *panno casentino*, characterized by a curly surface. Differences between the drawing and the artefact may be found in the mechanical parts, in the dimensions of the hooked iron teeth and in the granulometry of the abrasive materials.**

I. INTRODUCTION

Interesting connections between industry and scientific-technological instrumentation can be established examining old instruments utilized for the characterization of textiles, exhibited in the Museo dell'Arte della Lana (Wool Museum) of Stia in the Casentino Valley in Tuscany [1]. The main entrance of the museum is shown in Fig.1. The geographical configuration of the Casentino valley has strongly contributed in keeping away from the Tuscan productive world, the *Lanificio Lombard,* the former wool mill built in 1838, that houses the museum. The first Lanificio di Stia Company was established in 1852, when a modern entrepreneurial activity had been organized in a few decades to concentrate the various phases of wool processing in a single factory. In the early sixties of the 19th century the Lanificio employed about 140 workers and was the first in Tuscany to use machinery imported from abroad. Between 1862 and 1888, under the direction of Adamo Ricci, the mechanization of the entire production process was completed and the complex of plants was rationalized. From the end of the 19th century the Lombard family became the owner of the Lanificio and entrusted the direction to the Venetian Giovanni Sartori, who modernized the factory, bringing it to the levels of the most important Italian mills and worked to create a concrete social security coverage to all workers in difficulty.

Fig. 1 - Museo dell'Arte della Lana), Stia-Arezzo Italy. The entrance of the museum, the Edificio dell'Orologio, on background, with the old restored turbine, in the foreground the Staggia river and the logo of the museum in the bottom (Museo dell'Arte della Lana, Stia).

With the direction of Sartori, the Lanificio reached the peak of its prestige, as evidenced by the fact of being the official supplier of the House of Savoy, and at the highest level of employment.

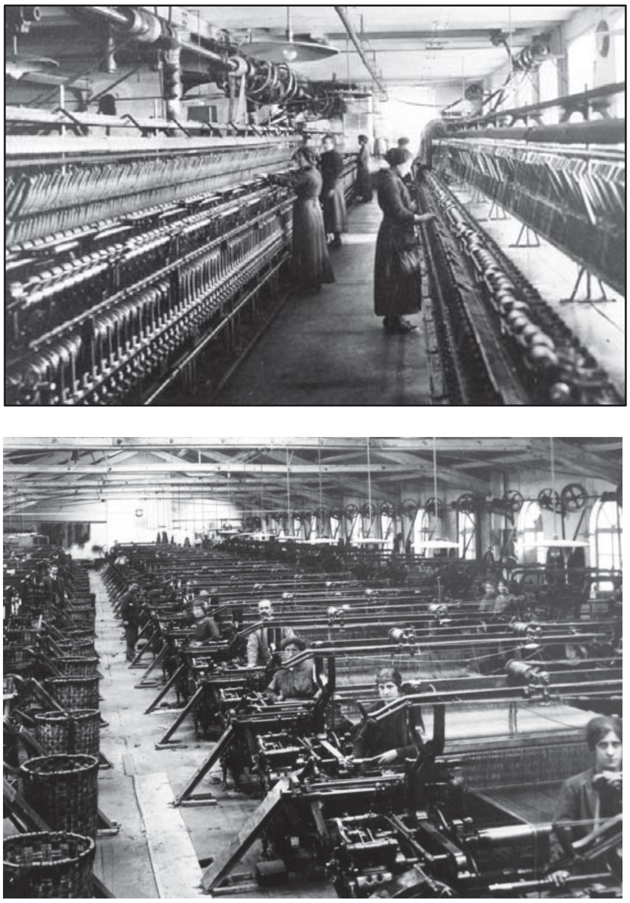

Fig. 2 - Workers in the Museo dell'Arte della Lana, Stia-Arezzo Italy : top -area of the thread twisters in 1914; bottom-the weaving area of with 60 looms (property of Giselda Bresciani, Stia).

Fig. 3 - The testing device utiloized for the moisture absorption evaluation of 20th century (Museo dell'Arte della Lana, Stia).

The prevalence of the workers were women, as shown in Fig. 2. At the end of the first world war the workers employed were 500, the chassis around 136 and the production was over 700.000 meters of cloth. Following the crisis started in the 1960s, the Lanificio failed in 1985 and closed definitively in 2000. Simonetta Lombard, heir of the family who owned the Fabbrica for over sixty years, reacquired the buildings by setting up a foundation for a restructuring project for the creation of a center for the dissemination of the textile culture *Casentino* [2]. This project took shape in 2010 with the opening of the Museo dell'Arte della Lana. Consequently in the *Lanificio Lombard*, a centralized factory in which all the production processes took place, the remarkable theoretical and practical skills locally developed, allowed to shape design, making and reconfiguration of instruments, in a way tailored to the needs of the production of the iconic fabric *panno casentino.* One example is a testing device from the beginning of the 19th century that allows the user to characterize fibers, yarns, fabrics, and other hygroscopic materials. The testing device, permits true and accurate determination of their strength, and well as other properties that are affected by the moisture content of the fiber/material under study, without the need to refer to moisture *regain* tables and charts. The instrument represents a noteworthy improvement, in comparison with past practice, in the art of testing materials and products of hygroscopic nature. The napping machine, known as *ratinatrice*, displayed in the wool museum, is an example of technological instrumentation affected by the industrial development. As a matter of facts, a plate of the *Encyclopédie de Diderot et d'Alambert*, in the volume *Art des textile*, shows a drawing of the *ratinatrice* which can be considered a forerunner of the one of the museum dating back to 19th century. The napping machine design and making is shaped by the evolution of the finishing technique of the *panno casentino*, which has a curly surface. It derives from an ancient rustic cloth known inthe 14th century as *panno grosso di Casentino* [3]. Originally from the first valley of the Arno river, the Casentino cloth was known, from the Middle Ages to the end of the 19th century, as a rustic and firm cloth, obtained with the wool produced by the sheep of the Casentino mountains. The cloth was suitable for the needs of those who were forced to live outdoors or continuously on the road, thus becoming the ritual dress of carriage drivers, farmers, crafty villagers.

II. THE YARN CHARACTERIZATION

Knowledge of the properties of fibers, yarns and fabrics is essential because it helps the manufacturers make appropriate fabrics for specific applications [3]. Fabrics are made mostly from yarns and sometimes from fibers directly. The length of wool fibers is about 5 cm for finest wool and 35 cm for the longest and coarsest wool and vary in the diameter, from 14 to 45 micron.

The properties of textile fibers can be classified in two categories, the physical properties (mechanical properties, moisture absorption characteristics, electrical properties, thermal and optical characteristics) and the chemical and biological properties. Optimum level of properties are essential not only during the service life of the textile product but also to meet processing requirements particularly during spinning, fabric manufacturing and chemical processing [4].

The moisture absorption will be analyzed because of the presence of the testing device, shown in Fig. 3. As a matter of facts evaluating the moisture adsorbing capacity of textiles is important: in hot and humid weather one can feel very unconfortable if the clothes do not adsorb perspiration and moisture. The discomfort may be reduced if the cloth can adsorb moisture and maintain some equilibrium with the outside atmosphere. Natural fibers absorb water better that man-made fibers. The amount of water in a specimen is generally expressed as moisture regain (mass of adsorbed water /mass of dry specimen x100). Moisture regain data are known for the most common fibers, as shown in Table 1. For example the moisture regain for wool is the highest, and except rayon, the cellulosic and proteic fibers absorb much more amount of moisture that the other categories of fibers because of the presence of moisture absorbing groups in their chemical structures. The testing device, present in the museum, permits true and accurate determination of the moisture content of the fiber/material under study, without the need to refer to moisture *regain* tables and charts. The tests may consist of a simple weighing operation, in order to ascertain the relative proportion of water in a given quantity of wool, or in a breaking test of a yarn or a piece of cloth. The invention consists in producing in a otherwise unchanging atmosphere, a predetermined degree of humidity trough a humidifying agency controlled by variations in the weight of moisture absorbed by a control-element consisting of a known bone-dry weight of material of the same kind as the one to be tested. The instrument represents a noteworthy improvement, in comparison with past practice, in the art of testing materials and products of hygroscopic nature.

Table 1 - Moisture regain (%) at 20°C and 65% of relative humidity

Fiber	*Moisture Regain (%)*
Wool	14-18
Viscose	12-14
Cotton	12
Silk	10
Nylon	4.1

Fig. 4 – The napping machine, ratinatrice, of the company Tilman Essen-Inhabert: Mateheé & Scheiber by Burthexhid bei Aachen, displayed in the Museo dell'Arte della Lana, utilized to produce the curly surface of the Panno casentino , the orange fabric on wooden roller (Museo dell'Arte della Lana,Stia).

III . THE RATINATRICE (NAPPING MACHINE)

First of all some information has to be given on the *Panno del Casentino,* the fabric for which the *ratinatrice* shown in Fig. 4 is used. The first documents on this resistant cloth date back to 1272, in the middle ages, a *panno rusticale* worn by people who, forced to live outdoors, had to protect themselves from the harsh weather. In the 19^{th} century the Panno Casentino became a fabric appreciated by nobles and outstanding personalities as Giuseppe Verdi, Giacomo Puccini and many other characters of the culture and entertainment world, even Audrey Hepburn in the film "Breakfast at Tiffany" wears a coat made with this cloth.

In the traditional orange and green colors, the Panno Casentino is the result of a careful craftsmanship, with thirteen finishing phases. The puncture procedure allows the felting of the wool that compacts and makes the fabric more closed, then it goes to the raising, a machine scratches the surface to pull out the hair. This final stepgives the cloth the classic curly appearance and creates a double layer that allows the fabric a perfect thermal insulation and an efficient impermeability, while maintaining the perspiration of the skin at the same time. From the documentation found in the wool factory, it is difficult to determine the exact date of birth of this eccentric fabric. It must be said straight away that the complexity of the case lies exclusively in determining who and when imported the first machine called *ratinatrice*, (from ratiner: accotonare, make cotton balls) essential to perform the curling finishing that characterizes this cloth. At the end of the 19^{th} century or at the beginning of the 20^{th}

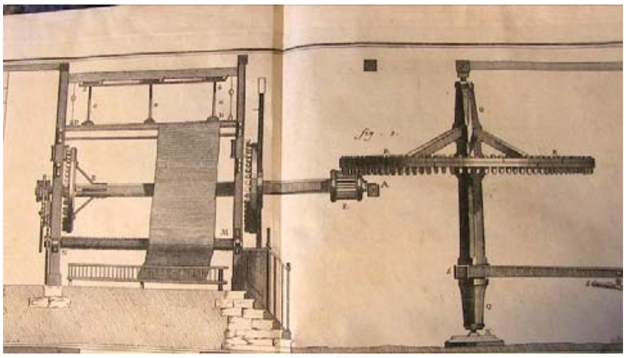

Fig. 5 – Ratinatrice from the Encyclopédie de Diderot et d'Alambert - Art des textile (L'Encyclopédie, 1re éd. Reproduction, Museo della Lana, Stia).

century only two textile factories of Stia and Soci were able to import machines like the rating machine from abroad in the Casentino valley. The documents show that in 1890 the Casentino cloth with the curled part had not yet appeared on the markets, while, in 1916, it was proven the presence in the Lanificio di Stia of a German-made machine, coming from Aachen, on the border between Germany-Holland-Belgium, shown in Fig 4. This napping machine improperly called r*attina*, is made up of two sides, from the body of the machine and two large long and narrow horizontal boards through which the fabric to be treated advances well; the lower fixed axis is tightly wrapped with a good cloth, the upper one, normally lined by a rubber horn, exerts an adjustable pressure on the fabric; this is called ratinator table because, due to the effect of electric controls, which give it a circular movement, it causes the curly rat effect on the hairy surface of the fabric.

In the wool factories of the Casentino valley, some minor but substantial changes were made to the gaskets, mainly to those of the table of the napping machine, which had to work on ordinary wool, thus needing a greater rating effect to force the fabric to assume and stabilize in the desired effect. In 1916 the napping machine was already supplied to the Stia plant, not necessarily purchased in that year, due to the critical period of the First World War when all the productive efforts of the Lanificio were concentrated on military supplies. On the other hand the line of the machine, the design of the sides, some wooden gears existing in its mechanisms, allow to qualify the ratinatrice as an ancient artefact. Around the seventies the ratinatrice disappeared, neglected due to the commercial vicissitudes of the Lanificio. Thanks to Italo Radini, the owner of the Ramtex company of Lonate Ceppino, it returned back to the Lanificio after decades. The interest of the study of the ratinatrice is in the connection between technology and materials science. As a matter of facts this machine was essential in textile finishing, the last step in fabric manufacturing, when the final fabric properties are developed adding to the textile several functional characteristics [5]. Finishing, performed generally on every kind of textile with chemical compounds and/or with mechanical devices, changes the fabric's aesthetic and/or the physical properties, the texture or surface characteristics. Textile finishing gives a textile its final commercial character with regard to appearance, shine, handle, drape, fullness, usability, etc. Chemical finishing or 'wet finishing' involves the addition of chemicals to textiles to achieve a desired result. In this finishing process water is used as the medium for applying the chemicals. Heat is used to drive off the water and to activate the chemicals. Meanwhile, mechanical finishing is considered a dry operation even though moisture and chemicals are often needed to successfully process the fabric. The mechanical finishes include calendering, emerising, compressive shrinkage, raising, brushing and shearing or cropping. Some finishes combine mechanical processes along with the application of chemicals.

In another classification typology, the treatment carried out with the ratinatrice can be considered among the physical finishing methods, as optical finishing, brushing and napping, softening, shearing and compacting of the textile structure. Physical delustring of a fabric, as well as bulking and lofting of the fabric can be achieved by treatments which roughen the fiber surface or raise fibers to the surface. Fiber raising processes, such as brushing and napping, involve the use of wires or brushes which catch yarns in the textile structure and pull individual fibers partly from the yarn structure. The resulting fabric is warmer, softer and more comfortable. During calendering or beating of a fabric interaction between individual fibers within yarns may be lessened and the textile structure softened. When a smooth textile structure free of raised surface fibers or hairiness is desired, the fabric may be sheared by passing the fabric over sharp moving blades or by passing the fabric over a series of small gas jets which singe and burn away raised fibers [5]. It is interesting to observe the ratinatrice present in the museum is similar to the one found in the *Encyclopedie de Diderot et d'Alambert*, in the volume *Art des textile,* shown in Fig.5. The plate shows a drawing of the *ratinatrice* a forerunner of the one of the museum dating back to 19th century. It consists of a wooden roller, known as *scardasso*, on which hooked iron teeth are fixed and of a movable table that with different movements (straight, circular, oscillator), gives the fabric passing under pressure, the characteristic curly appearance.

The evolution of the finishing led to develop processes in which raising is achieved using bristles (natural teazles), or bent metal wires, to catch and lift fibers out of the plane of the fabric surface and make the fibers protrude as a pile or nap. Since damp wool fibers are more pliable, and less fiber loss is suffered, the majority of wool fabrics are raised while damp. The typical wool regain employed would be 60-70% and lubricants may be also be used to reduce friction. Some fabrics may be pre-raised under damp conditions and then given a second brushing after

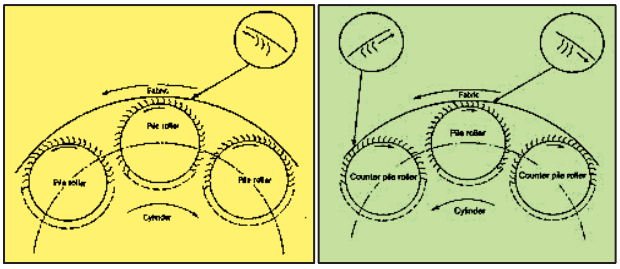

Fig. 6 – Scheme of the planetary raising machine: single action(left) , double action (right).

drying. In raising, fabric surfaces are subjected to a tearing action that pulls fibers from the surface yarns and from within the fabric to form a raised surface or pile.
The fabrics passed over rollers covered with strips of rubber-backed fabric in which bent wires are embedded, similar to those used in carding machines. The wire surface travels faster than the fabric and so tears at the fabric surface. In raising, fabric surfaces are subjected to a tearing action that pulls fibers from the surface yarns and from within the fabric to form a raised surface or pile. When raising knitted fabric made from continuous filament yarns, the action is controlled so that filaments are lifted out to form loop pile, which is not broken. In wool and cotton fabrics, raising generally lifts up and breaks the fibers to make the pile. Knitters sometimes use the term brushed for raised knitted fabric. Raising machines may be either single action or double action planetary machines. Fig. 6 shows the operation of a single action planetary raising machine. Pile rollers mounted around a large cylinder rotate very fast so that the surface speed of the wire is faster than the movement of the fabric. In a single action machine the orientation of the hooks of the metallic wires is the same, and the pile rollers rotate in the same direction, being anticlockwise. In the single action raising machine, the cylinder on which the planetary pile raising rollers are mounted rotates in the opposite direction (clockwise) to the anticlockwise fabric movement. Single-action machines have 24 to 36 pile raising rollers mounted on the main drive cylinder. In the double action planetary raising machine, alternate rollers have the metallic wire pointing in opposite directions. The cylinder and counter pile roller speeds are much faster than the fabric feed and pile roller speeds. The cylinder rotates in the same direction (anticlockwise) as the fabric movement. Double-action machines have a total of 24 to 36 pile and counter pile raising rollers mounted on the main drive cylinder. Fabric tension and the relative speeds of the fabric, rollers, and raising cylinder are varied to produce different effects.

III. CONCLUDING REMARKS

This paper deals with the Museo dell'Arte della Lana located in Stia, in the Casentino area, in the complex of the ancient wool mill, an example of industrial archeology which has been recovered as a center for spreading textile culture. The exhibition path is a real sensory experience, where you can touch, smell, listen, learn, experiencing first-hand the craftsmanship of some gestures linked to the Art of wool. Moreover several scientific-technological instrumentations are exhibited as the ones described in the paper. As a matter of facts the visit is divided into the following sections : An art as old as man; Nature and fibers; The Art of Wool; The craftsmanship of wool; The Stia Wool Mill; Industrial processing of wool. The museum itinerary begins with a jump back over time, up to the dawn of civilization human, when weaving was a central activity in the life of man. The natural textile fibers are then presented more widespread and older, such as wool, silk, cotton, linen and hemp, which are exhibited to be touched, illustrating the plant or the animal from which they derive. The wool processing cycle is then illustrated The cycle of wool processing is then illustrated, arriving to the description of the period in which the processing steps were mechanized: the wool mill was born as an industry.

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