



The Role Of Crimp In The Textile Process

By Mike Safley

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The term “crimp” has become a very familiar term to Alpaca breeders. Crimp is defined as the natural wave formation of the fiber, expressed as waves or crimps per unit of length. Visually, crimp is most notable in the well organized staples found in the fleece. Crimp also occurs along the shaft of a single fiber. This has been defined by Cameron Holt, of the Melbourne College of Textiles, as crinkle.

In the wool trade, breeders, graders, classers, and manufacturers have traditionally held the view that more crimp meant finer fiber. This misperception has been codified into the various count systems used to classify the fineness of sheep’s wool. One such system is incorporated into the U.S. Standard Grades of Raw Wool, issued by the U.S. Department of Agriculture and is found in Table 1 below.

Grades	Number of Crimps per Inch
Very fine	22 to 30
Fine	14 to 22
1/2 blood	10 to 14
3/8 blood	8 to 10
1/4 blood	5 to 8
low quater	2 to 5
Common	0 to 2
Braid	0 to 1

The measurement of fiber has become a very sophisticated scientific pursuit. With the advent of objective measurement of wool by such instruments as the LASER SCAN, OFDA, or air flow machines, it is now well settled that crimps per inch is only a rough indicator of fiber fineness. Many of the myths surrounding the processing qualities of certain fiber traits have been disproved by employing these new measuring devices.

Today, it is possible to isolate the measurement of crimp and fiber diameter in the raw fleece and to separately assess their impact on the qualities of finished products. Questions, such as how crimp frequency affects the processing of raw wool and the handle of finished cloth are now being answered by researchers in Australia, Japan, and New Zealand.

Sheep’s wool has been the subject of most, if not all, available research with regards to crimp as a processing characteristic. This research is not, by any means, definitive of Alpaca fiber. But understanding the role crimp plays in the textile process could be beneficial to Alpaca breeders.

Many fiber bearing animals produce fleece which is utterly devoid of crimp. Vicuna fiber, from the Alpacas’ original ancestor, has no crimp. Suri Alpaca fiber has no crimp. Mohair from goats and Angora from rabbits has no crimp. These fibers are among the most desirable in the world. In other words, the existence of crimp is not necessary to define the value of fiber or create fine garments.

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Huacaya alpacas often exhibit crimp in their fleece and, if not crimp, then crinkle. The heritability of crimp in Alpacas would appear to be very high. Studies of Merino sheep indicate a heritability factor of 0.46 for Merino flocks selected solely for increased or decreased crimp. If it is proven that a particular type of crimp is a commercially valuable trait, it could easily be selected for genetically, although there may be antagonistic genetic correlations between fleece weight, fiber diameter, and crimp frequency.

Large scale wool processing studies, using a wide range of wool types from different breeds, have demonstrated that 80-90% of the variation in the processing performance, of wool, yarn, and in the quality of fabrics may be explained by variation in the raw fleece characteristics of fiber diameter, crimp, and length. Alpacas have the capacity to produce crimp in their fleece. Assuming that crimp in Alpaca is desirable, just as it is in sheep, leads to an investigation into the nature of crimp and the type of crimp which is most desirable to the textile manufacturer.

THE STRUCTURAL NATURE OF CRIMP

Wool fiber has two cortical cells, para and ortho. In certain coarse fibers a hollow core may be visible (medulla). The cortical cells in Alpaca fiber constitute a variable fraction of the the fiber mass, being the lowest in coarse and the most in fine fibers where the fraction may be as high as 90%

Cortical cells are the load-bearing elements of the fiber. The cuticle, or outer scale, imparts the inherent aesthetic qualities of the fiber, such as softness of handle and luster. The entire assembly is held together by a glue called intercellular cement.

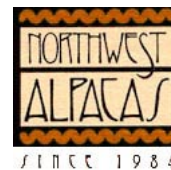
Wool fiber has a bilateral structure. That is, the paracortex and orthocortex grow side by side. It is this structure which is believed to give wool its crimp. Think of a single fiber as a rope made of two independent strands which are twisted together. When twisted ever more tightly, the rope kinks or crimps. Research in 1953 by a Japanese scientist found that the orthocortex was always observed on the outside of the crimp curve as shown in Illustration 1.

Villarroel found that fine Huacaya Alpaca (not Suri), like wool, has a clearly defined ortho-para differentiation in the crimped fiber. The medium to coarse Alpaca fiber (23-35 microns) cortex is less distinct and the two types of cells break up into segments. In coarse fibers the ortho segment is seldom seen. Suri fiber has no visible bilateral demarcation.

CRIMP COUNT - ALPACA VS. SHEEP

The following discussion of crimp's impact on finished textile products in this article focuses on crimp count and, to a lesser degree, fiber diameter. The sheeps wool used in the processing trials discussed herein ranged in diameter from 16.5 to 22.3 microns, with a range of low crimp frequencies beginning at 4 crimps per centimeter and ending at a high crimp frequency of 8 per centimeter. Four (4) crimps per centimeter translates into 10.6 crimps per inch.

To keep in perspective the information contained in this article, please refer to Illustration 2. The five locks of alpaca fleece pictured have crimp counts beginning with A, at 1.97 crimps per centimeter (5 crimps per inch) and ending with E, at 2.76 crimps per centimeter (7 crimps per inch). These counts are considerably less than the Merino fiber used in the processing trials discussed below. To better understand the visual relationship of the crimps per centimeter of the sheep's wool discussed and the Alpaca samples pictured, please review Illustration 3.



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The samples found in Illustration 2 were measured for both micron count and crimp frequency by Yocom-McColl Testing Laboratories in Denver, Colorado. All five of these samples are from male Alpacas. Sample D is from a six month old animal and the balance of the samples are from older breeding males. These tests provide further evidence that crimp count does not accurately predict fineness.

DIFFERENCES BETWEEN SHEEPS WOOL AND ALPACA FIBER

Before discussing the implications of crimp in the textile process, it should be made clear that there are substantive differences between sheep's wool and Alpaca fiber. Alpaca fiber has different scale heights -- approximately .4 microns vs. sheep's wool at .8 microns. The scale frequency of Alpaca is more than sheep's wool -- 9 per 100 microns vs. 4 per 100 microns. Alpaca fiber is also much stronger than sheep's wool.

All of these differences complicate the transposition of information about the processing of sheep's wool to the processing of Alpaca fiber. Some of the information may be pertinent, some may not. Alpaca breeders need to develop research that specifically identifies the commercially valuable fiber traits of the Alpaca. The following discussion helps to identify traits which have the potential to impact the value of Alpaca fiber.

WOOLEN VS. WORSTED

Before reviewing the results of processing trials found herein, it is important to understand the difference between the woollen and worsted spinning systems. Crimp impacts different qualities to yarn made from each of these systems.

Woollen fabrics are characterized as being fuzzy, thick, and bulky. They are made from fibers that are one to three inches in length which have been carded and not combed (worsted yarns are carded and combed). After the carding process is complete, the woollen sliver is twisted by machine into rope-like strands called roving and wound onto reels for spinning. Woollen yarns are fluffy, loosely twisted, and are used in weaving fabrics such as tweeds and blanket cloth. Woollen fabrics and yarns are traditionally made into bulky garments such as coats and sweaters.

Worsted yarns are spun from longer (three inches plus) fibers that have been carded, combed, and drawn. Combing machines further straighten the Alpaca sliver, making the individual fibers lie parallel. The combing process also eliminates noils. The drawing process takes the worsted sliver, doubles it over onto itself and draws it out again to a thinner, more uniform diameter to ensure that all the Alpaca fibers are parallel. Worsted yarns are twisted tighter and thinner in the spinning process and are manufactured into lightweight fabrics, such as gabardine and crepe.

THE ASSOCIATION BETWEEN CRIMP AND COMPRESSION PROPERTIES IN CARDED WOOL AND WOOLEN-SPUN YARNS

Understanding the influence of fiber crimp on the processing properties of wool fiber has been hampered by the lack of appropriate fiber crimp measurement techniques. Today, there is a scientific method for the routine measurement of the curvature of short snippets of fiber, as reported by P.G. Swan, T.J. Mahar, and J.P. Kennedy from the Division of Wool Technology, CSIRO, Australia. As a result of this new technology, scientists have determined that there is an association between the crimp, thickness, and compression properties of carded wool.

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To study these relationships, eight low-twist, woolen-spun yarns of two different micron counts were spun and analyzed. These samples used blends of crimped and crimpless Merino wools of two average fiber diameters. Crimpless fiber was added to crimped fiber in six of the samples. Three samples had 20% crimpless fiber, three had 40% crimpless fiber, and two contained 100% crimped fiber.

This trial has shown that the thickness and compressibility of the carded fiber assembly and the resultant yarns are strongly related to the amount of crimp in the wool. The bulk of carded fiber decreases as the percentage of crimpless fiber is increased. There was also a strong relationship between the average curvature (crimp) of short sections of raw fiber and the yarn fiber assemblies. (See Table 2.)

TABLE 2: Measured average carded wool properties for the 8 lots (D = average fiber diameter [19]; K05 = normalized fiber curvature [10]; bulk = core Bulk [18]; RC = Resistance to Compression [17]). Standard deviations are enclosed within parentheses

Lot	D (um)	Crimple Fiber ((%)	K05 (mm-05)	Bulk (cm)	RC (N.gm-1)
1	19.0	0	1.43 (0.27)	4.24	6.93
2	19.0	20	1.30 (0.34)	3.82	6.43
3	19.0	40	1.15 (0.39)	3.27	5.89
4	22.3	0	1.22 (0.29)	3.88	6.43
5	22.3	20	1.11 (0.33)	3.45	6.13
6	22.3	20	1.12 (0.28)	3.40	6.05
7	22.3	40	1.06 (0.33)	3.11	5.70
8	22.3	40	1.04 (0.29)	3.12	5.66

The study results demonstrate that fiber crimp persists throughout woolen system carding and spinning operations, although the amount of crimp is reduced as fibers react to the strains imposed during the yarn making process. These results presented in Swan, Hara, and Kenneday's paper show that the average curvature (crimp) of fibers was reduced by approximately 10% when making woolen yarn.

The study also found that the remaining residual curvature (crimp) exerts a substantial influence on the bulk density of unrelaxed low-twist woolen yarns. This means that yarn manufacturers may, by the sourcing of wools of high crimp alone, reduce the weight of woolen yarns while maintaining an increase in the yarn bulk without a corresponding increase in weight.

The study makes the case for the economical use of high crimp frequency wool in the woolen process. But before jumping to the conclusion that breeding for highly crimped Alpaca fiber is the ideal, consider the following discussion of the value of low crimp frequency wool in the worsted process.

The findings of the studies below may provide a glimpse as to why alpaca is considered to have superior handle over wool of a similar diameter. These studies illustrate the complexity of the contribution that crimp makes to the final textile product. The impact of crimp frequency on the values of woolen yarn is different than it is on worsted yarn.

THE BENEFICIAL EFFECTS OF LOW FIBER CRIMP IN WORSTED PROCESSING AND ON FABRIC PROPERTIES AND FABRIC HANDLE

Studies on the fiber factors which are associated with soft handle in unprocessed wool (greasy wool or clean carded wool) have shown that softness increases with decreasing fiber diameter and with decreasing fiber crimp. Considerable variation in crimp can be found in wools of the same mean fiber diameter. The textile trade's preference has been for higher crimp frequency. This traditional view holds that higher crimp in finer apparel wools produces softer and smoother finished fabrics.

In contrast to this long held view, controlled experimental trials, which trace the softness of wools in the raw state to finished fabric, highlight the persistence of softness due to lower fiber crimp, in addition to softness as a result of finer fiber.

Eight samples of cloth were manufactured using higher and lower crimp wools in the fine (20.5 μm) and superfine (18.5 μm) Merino. This fabric was used to determine the handling properties that result from processing wools of different diameter and crimp combinations. The average staple crimp frequencies were 5 crimps in the low crimp cloth and 8 crimps in the high crimp cloth. These crimp styles represent differences normally occurring in commercially available fine wools.

The study came to the following conclusions about the difference between the various samples:

- 1) The higher crimp wools were not as soft, in the raw and scoured state, as the lower crimp wools of the same diameter.
- 2) The lower crimp wools had increased hauteur (length) in the top produced, which was 2-3 mm longer than the higher crimp wools of the same diameter, staple length and strength.
- 3) The 18.5 μm wools produced tops about 3 mm shorter than the 20.5 μm wools of the same crimp, staple length and strength.
- 4) During spinning, the lower crimp wools were easier to draft and produced slightly more even yarns.

The subjective assessments of the various pieces of cloth (see Table 3) which were manufactured demonstrated that superior fabrics were made from wools of lower crimp and/or finer diameter. In particular, twill fabrics made from the higher crimp wools were thicker and rougher than the equivalent fabrics from the lower crimp wools. The difference in surface smoothness was evident in the handle tests. The higher crimp fabrics were stiffer in shear and generally less elastic. At the same crimp frequency, fabrics made from higher diameter wools were rougher, stiffer, less extensible, and less resilient in compression than the lower diameter fabrics.

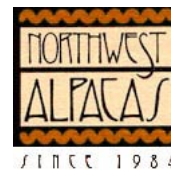
TABLE 3: Distribution of preferences in subjective comparisons of fabric pairs differing in diameter (D) and/or crimp (C). Low diameter indicates 19 um or less; low crimp indicates staple crimp frequencies <6 crimps.cm-1. Significance in chisquare test of independence (P<0.05, p<0.01, p<0.001).

	Preference	Softer	Thicker	Smoother	More Resilient
CRIMP only comparison (n=8 subjects x 11 fabric pairs)					
Low C	59	42	20	54	33
High C	29	45	59	33	48
No Choice		1	9	1	7
DIAMETER only comparison (n=8 subjects x 9 fabric pairs)					
Low D	61	46	33	55	23
High D	11	24	34	15	43
No Choice		2	5	2	6
MIXED comparison (n=8 subjects x 7 fabric pairs)					
Low D + High C	37	35	38	32	20
High D + Low C	19	18	14	22	29
no choice		3	4	2	7
ADDITIVE comparison (n=8 subjects x 4 fabric pairs)					
Low D + High C	28	23	9	27	9
High D + Low C	4	8	20	5	21
no choice	1		3		2

Some of the judges who assessed the fabrics commented on the coolness of feel of the lower crimped fabrics. The thinner and, therefore, more dense fabrics made from the lower crimped wools may have a greater degree of fiber to skin contact when touched, thus allowing for a faster exchange of heat.

Fabrics made from higher crimp wools were perceived as thicker, less smooth, and possibly more resilient than equivalent fabrics from lower crimped wools. Similarly, finer wools produced fabrics which were perceived as softer, smoother, and less resilient than equivalent coarser wool fabrics. These subjective results which indicated preference for the handle of the low crimp cloth were supported by mechanical measurements of fabric bending, shear rigidities, and fabric surface friction.

The study demonstrated the preference in overall handle for fabrics made from lower crimp wools over fabrics made from higher crimped wools. The results also demonstrate that the character which crimp imparts to fabric handle is different than the character contributed by fiber diameter. Fabrics made from finer wools are preferred because of their softness and smoothness, whereas lower crimp imparts smoothness and leanness, and perhaps coolness, to fabric handle. Knowledge of these effects can be used by textile manufacturers to design and engineer fabrics with particular handle characteristics and mechanical properties.



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The New Zealand Ag Research, Invermay Agricultural Centre, and the Wool Research Technical Division, Nippon Keori Kaishi Ltd, Osaka, Japan carried out similar studies looking at the effect of crimp frequency at the early stages of processing worsted yarn. The second stage of this study points out the complexity of crimp's role in the handle, feel, and look of garments made of similarly constructed worsted yarn when used in knitted versus woven goods.

EVALUATION OF NEW ZEALAND LOW AND HIGH CRIMP MERINO WOOLS

I. WOOL CHARACTERISTICS AND EARLY STAGE PROCESSING ATTRIBUTES

These tests used shorn fleeces from 98 ewes which were assigned to four processing lots, namely: Ultrafine (16.5 microns) high crimp (UH), ultrafine (16.5 microns) low crimp (UL), superfine (19.4 microns) high crimp (SH), and superfine (19.4 microns) low crimp (SL). The low crimp lots average 5.7 crimps/cm (range 4.6-6.1) and the high crimp lots averaged 8.0 crimps/cm (range 7.7-9.1).

These fleeces were tested as they were carded, combed, drawn, and spun. The following processing traits were attributable to the different crimp frequencies:

- 1) The percentage of short fibers in tops was markedly lower for low crimp wools than high crimp wools.
- 2) Neps formation was less in superfine and lower crimp wools (SL).
- 3) Fiber crimp was closely correlated with staple crimp which indicates that staple crimp may be used to class fleeces into different fiber crimp categories.
- 4) Superfine and low crimp groups produced more clean wool than ultrafine or high crimp groups.
- 5) Clean yield was higher in low crimp groups.
- 6) Lower crimped wools created tops with more hauteur than high crimped wools of equal staple length.

Wools with different crimp frequency were shown to have a similar carding performance. But, low crimp wool had better combined performance and produced stronger and softer yarns. This study also noted that most subjective grade and style assessment systems favor high crimp wools. But most scientific textile trials indicate that high crimp is associated with a deterioration in early stage processing properties, such as yarn irregularity, extension and breaking strength.

The New Zealand study on early stage processing attributes concluded with the following observation. Unless there is widespread acceptance in the textile processing industry in favor of either low or high crimp wools, selection for the trait in Merinos is unjustified. However, objective measurements which assist with the identification of low or high crimp wools in different styles of fleeces would seem to be of practical benefit to wool processors.

EVALUATION OF NEW ZEALAND LOW AND HIGH CRIMP MERINO WOOLS

II. WOOL CHARACTERISTICS AND PROCESSING PERFORMANCE OF KNITWEAR AND WOVEN FABRICS

The second section of the study dealt with the wool characteristics and processing performance of knitwear and woven fabric made from worsted yarn with different crimp frequencies. The following characteristics of the finished products were attributable to crimp frequency.

- 1) Yarns spun from low crimp frequency wools had higher extension and elastic modulus scores which, when knitted, were smoother and softer handling than high crimp frequency wools.
- 2) High crimp frequency wools, however, resulted in better yarn evenness and fluff index, but evidenced greater yarn shrinkage.
- 3) Fiber diameter was not significantly related to yarn shrinkage.
- 4) Hand evaluation values were higher for both low fiber diameter and low crimp frequency. Rankings for total hand values decreased in order of UL >UH >SL >SH, with low crimp frequency lots in each fiber diameter group having a higher handle score than the high crimp frequency lots.
- 5) Yarns spun from low crimp frequency wools are easier to process, could be spun finer with fewer end-breaks and have less wastage.

For the yarn and fabric specifications used in this trial, the results showed that fiber diameter and crimp frequency had competing effects on the quality assessments of both the knitted and woven fabrics.

Although dependent on construction and finishing, low crimp frequency wool woven fabric appeared to be more suitable for summer attire or in women's garments, while high crimp frequency wool woven fabrics would be more suitable for men's winter clothing.

In conclusion, the authors of the study observed that wool growers should continue to produce a range of wool types which differ in the interrelationships between key fiber characteristics which are of importance to processing. This diversity will enable designers to be innovative in developing new wool products, and also allows processors to select the type of wool best suited to their particular production specifications.

A SUMMARY OF THE VARIOUS PROCESSING TRIALS

The studies reported here are all highly technical in nature and the conclusions understandably varied in some instances, but the results of each study were generally consistent in the following regards:

- 1) Higher crimped wools may be more commercially valuable when used in the woolen process.
- 2) Low crimp, low micron wools generally demonstrated better handle characteristics.
- 3) High crimped wools were better suited for use in heavier winter garments.
- 4) Low crimped wools were better suited for light weight clothing.
- 5) Low crimped wools were generally easier and more efficient to process than high crimped wools.

Many of these conclusions are contrary to popularly held beliefs.

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AN ALPACA BREEDERS LOOK AT CRIMP

Alpaca has far less crimp than Merino wool. Based on the conclusions in the above studies, the low crimp frequency in Alpaca fiber may partially explain why Alpaca is thought to have superior handle when compared to sheep's wool of a comparable micron count. Suri, which has no crimp, is thought to have a smoother handle than both the high crimp Merino and the low crimp Huacaya of a similar micron count.

Alpaca breeders who select for fineness in their breeding programs may also be automatically selecting for crimp or crinkle, due to the increased presence of orthocortex in finer fibers. Crimp has benefits for the breeder in addition to those valued by textile manufacturers. For instance, crimp may visually indicate fineness, density, and uniformity in the raw fleece.

As alpacas age, their crimp tends to broaden and disappear. The fleece also becomes coarser each year. This can be explained by Villorreal's observation that the cortex of coarser fiber is less distinct. The orthocortex tends to disappear as micron count increases. Breeders should understand this phenomenon and be more reliant on genotype than phenotype when assessing the crimp producing capacity of Alpacas, particularly males.

Crimp in Huacaya fiber definitely adds to its processing efficiency. Crimpless fiber, such as Suri, is often artificially crimped during processing to improve its performance. Suri and other crimpless fiber, such as mohair, are often blended with sheep's wool to add such qualities as bulk and resilience.

Dr. Jim Watts, a researcher from Australia, has spent several years studying Alpaca fleece characteristics. He had this to say about crimp as a characteristic. Because Alpaca fiber crimps or waves at regular time intervals, faster growing fibers automatically display bolder crimp or wave frequencies. Do not assume that bolder crimp equates to stronger fiber diameter. Bold deep crimp is a highly desirable fleece characteristic of the Huacaya. From recent textile research of Merino wool it is now known that bold, deep crimping wools are the softest, finest (for their genetic type) and best processing fibers. In the Huacaya we should be looking for and breeding these bold, deep crimping wools.

ALPACA FIBER RESEARCH

It is clear that high tech measurement devices and scientific know how could be of benefit to breeders in researching the processing qualities of Alpaca. For instance, it may enhance the value of Alpaca fiber to articulate the benefits of its low crimp style fleece to fabric designers and manufacturers. Fleece qualities are highly heritable. Once breeders can determine which traits textile manufacturers value, they can easily select for them.

Today we know that fiber diameter, staple length, color, and density all impact the value of an Alpaca's fiber production. Tomorrow, with the proper research, we may determine whether we should be selecting for a particular crimp style or frequency.

One thing is for sure, Alpaca breeders will continue to hear about crimp. Judges talk about crimp in the show ring and many Alpaca purchasers are searching for highly crimped Alpacas. Maybe one day soon we will determine what kind of crimp is our best style.