NC STATE UNIVERSITY
COLLEGE OF Textiles NC STATE UNIVERSITY
JTATM
Journal of Textile and Apparel, Technology and Management
Volume 8, Issue 1, Spring 2013

Cryogenics - An Engineering Tool for Textiles and Apparel

M. Parthiban, M.R. Srikrishnan and S. Viju
Department of Fashion, Textile Technology
PSG College of Technology

ABSTRACT

Cryogenics is the study of the production of very low temperature (below −150 °C, −238 °F or 123 K) and the behavior of materials at those temperatures. The word cryogenics stems from Greek and means "the production of freezing cold"; however, the term is used today as a synonym for the low-temperature state. A person who studies elements under extremely cold temperature is called a cryogenicist. Rather than the relative temperature scales of Celsius and Fahrenheit, cryogenicists use the absolute temperature scales. These are Kelvin (SI units) or Rankine scale (Imperial & US units). It is not well-defined at what point on the temperature scale refrigeration ends and cryogenics begins, but most scientists assume it starts at or below -150 °C or 123 K (about -240 °F). The National Institute of Standards and Technology at Boulder, Colorado has chosen to consider the field of cryogenics as that involving temperatures below −180 °C (-292 °F or 93.15 K). This is a logical dividing line, since the normal boiling points of the so-called permanent gases (such as helium, hydrogen, neon, nitrogen, oxygen, and normal air) lie below −180 °C while the Freon refrigerants, hydrogen sulfide, and other common refrigerants have boiling points above −180 °C.

Keywords: cryogenics, material freezing, refrigeration

Introduction

Cryogenics is low temperature physics: "The branches of physics and engineering that involve the study of very low temperatures, how to produce them, and how materials behave at those temperatures". Cryogenics is important because rocket fuel (oxygen and hydrogen) must be loaded in as liquids at cryogenic temperatures. Cryogenics is also important for attaining super-conduction and for cryogenic tempering of metals for hardening. Even with good preservation of body tissues by cooling and vitrification, future science will be required to cure presently incurable diseases and to rejuvenate elderly people to a youthful condition[1]. Aging, disease, and damage due to cooling low temperature are all potentially things that can be repaired by nanotechnology and other future molecular repair technologies. Cryonics will work only when future medicine has mastered these repair technologies. It seems inevitable, with the progress of science, that these repair technologies will come to exist. Cryonics is important for people who want to live much longer than is possible in the current world of medicine. Cryonics is a "lifeboat to the future" from the current "primitive" state of medicine. Cryonics is no so important for people who are happy to live to be 70 or 80 and want no more of life, even with the potential of rejuvenation and perfect health.

When people say "cryogenics" what they often really mean is "cryonics", which is "The emerging medical technology of cryopreserving humans and animals with the intention of future revival." Cryonics is important insofar as it can provide a means for people who are living today to live very long lifespans -- perhaps hundreds of thousands of years. *DEEP CRYOGENIC* processing is different from conventional cryogenic processing and requires cooling the parts to more than 300° below zero compared to about 120° for conventional cryogenic processing[2]. *DEEP CRYOGENIC* processing is a microprocessor controlled dry process, which includes cooling the parts at a programmed rate. Soaking the parts for up to thirty-six hours, and then an additional tempering operation to relieve any stress that may remain. During heat treating, steel's micro-structure transforms from austenite to martensite, which makes the steel much more wear resistant. However, some small pockets of austenite may not transform and this does not allow the knives to perform as well as they can. DEEP CRYOGENIC processing helps change retained austenite to martensite, completing the transformation process[3].

Cryogenic processing

Cryogens, like liquid nitrogen, are further used for specialty chilling and freezing applications. Some chemical reactions, like those used to produce the active ingredients for the popular statin drugs, must occur at low temperatures of approximately −100°C (about -148°F)[4]. Special cryogenic chemical reactors are used to remove reaction heat and provide a low temperature environment. The freezing of foods and biotechnology products, like vaccines, requires nitrogen in blast freezing or immersion freezing systems. Certain soft or elastic materials become hard and brittle at very low temperatures, which make cryogenic milling (cryomilling) an option for some materials that cannot easily be milled at higher temperatures.

Fig 1. Cryogenic valve

Cryogenic processing is not a substitute for heat treatment, but rather an extension of the heating - quenching - tempering cycle. Normally, when an item is quenched, the final temperature is ambient. The only reason for this is that most heat treaters do not have cooling equipment. There is nothing metallurgically significant about ambient temperature. The cryogenic process continues this action from ambient temperature down to −320 °F (140 °R; 78 K; −196 °C). In most instances the cryogenic cycle is followed by a heat tempering procedure. As all alloys do not have the same chemical constituents, the tempering procedure varies according to the material's chemical composition, thermal history and/or a tool's particular service application. The entire process takes 3–4 days.

Cryogenic production

Cryogenic cooling of devices and material is usually achieved via the use of liquid nitrogen, liquid helium, or a cryocompressor (which uses high pressure helium lines). Newer devices such as pulse cryocoolers and Stirling cryocoolers have been devised. The most recent development in cryogenics is the use of magnets as regenerators as well as refrigerators. These devices work on the principle known as the magnetocaloric effect[5]. Cryogenic temperatures, usually well below 77 K (−196 °C) are required to operate cryogenic detectors.

Cryogenic Treatment

A cryogenic treatment is the process of treating work pieces to cryogenic temperatures (i.e. below −190 °C (−310 °F)) to remove residual stresses and improve wear resistance on steels. The process has a wide range of applications from industrial tooling to improvement of musical signal transmission. Some of the benefits of cryogenic treatment include longer part life, less failure due to cracking, improved thermal properties, better electrical properties including less electrical resistance, reduced coefficient of friction, less creep and walk, improved flatness, and easier machining[6].

Cryogenic hardening

A cryogenic treatment is the process of treating work pieces to cryogenic temperatures (i.e. below −190 °C (−310 °F)) to remove residual stresses and improve wear resistance on steels. The process has a wide range of applications from industrial tooling to improvement of musical signal transmission[7]. Some of the benefits of cryogenic treatment include longer part life, less failure due to cracking, improved thermal properties, better electrical properties including less electrical resistance, reduced coefficient of friction, less creep and walk, improved flatness, and easier machining.

Major Industrial uses

Liquefied gases, such as liquid nitrogen and liquid helium, are used in many cryogenic applications. Liquid nitrogen is the most commonly used element in cryogenics and is legally purchasable around the world. Liquid helium is also commonly used and allows for the lowest attainable temperatures to be reached. These liquids are held in either special containers known as Dewar flasks, which are generally about six feet tall (1.8 m) and three feet (91.5 cm) in diameter, or giant tanks in larger commercial operations. Dewar flasks are named after their inventor, James Dewar, the man who first liquefied hydrogen[8]. Museums typically display smaller vacuum flasks fitted in a protective casing. Cryogenic transfer pumps are the pumps used on LNG piers to transfer liquefied natural gas from LNG carriers to LNG storage tanks, as are cryogenic valves.

Cryogenic application in textile and apparels

(a) Liquid ammonia mercerization

Stable shaping process technology opens the doors to fashion, a transitory fantasy determining the form, color, design and new effects of textiles and clothing. This process, presently, is typical in fashionable cotton industry products and is also one of the mature technologies developed in textile and fiber industry. The features such as fitness, comfort, easiness to stretch, etc., are highly desired today. New purified cotton is a quality product material made using this high technology, that overcomes the traditional flaws of shrinkage, wrinkled clothes, and improves dramatically the natural properties of softness, comfort of cotton.

Liquid ammonia finishing (or) liquid ammonia mercerizing' refers to the process that truly revives the cotton through the expansion of liquid ammonia at an ultra-low temperature inside the fiber. When the cotton fiber is treated at -33ø C liquid ammonia, ammonia at ultra-low temperature will permeate immediately into the crystallographic structure of the fiber. Stress will be released through interior expansion, which makes the fiber cavity round and smooth and rearranges the molecular structure, thus the crystallographic structure becomes slack and stable. This physical change makes the surface of the entire fabric smooth and bright, with solid and soft feel, so elasticity and wash-and-wear is fully achieved.

The benefits of liquid ammonia mercerizing lies in the following effects that can be achieved simultaneously**:** The superb appearance, feel and brilliancy of dyed shades, make the buyer select the ammonia mercerized garment/fabric rather than the regular caustic mercerized one.

- Low shrinkage post washing
- Increase in wrinkle resistance

- Increase in fiber elasticity
- Softer to touch and brighter
- Enhanced tensile strength
- Dimensional stability
- Resistance to abrasion
- Dyeing uniformity, dyestuff affinity, color solidity
- Wash and wear properties

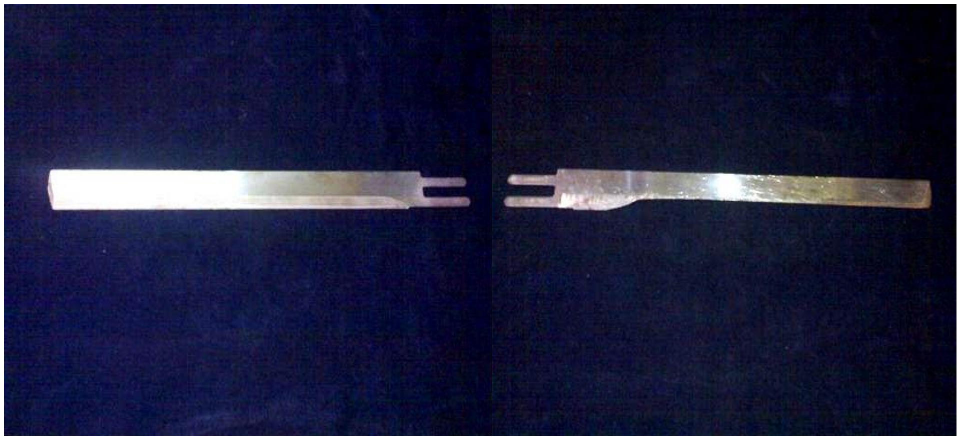
(b) Cryogenic treatment in garment manufacturing

The technique starts from the purchase of cutting knives and sewing needles. Thematerials were given cryogenic treatment. Cryogenic treatment is the process of converting the austenite state (malleable) of the materials to the martensite state (tough). Such that the processed materials have increased wear resistance, increased toughness, and reduced brittleness, but are not too much harder[9] This results in the extension of the durability of cutting knives and sewing needles. The estimated life extension is measured for cutting knives and sewing needles by comparing the treated and untreated knives and the treated and untreated sewing needles were used in the garment industry.

(c) Cryocooling application in garment cutting knives

To explain the theory behind the improvements found on cryogenic cooling it is necessary to explain the process by which tempering produces hardened steel alloy components. The problem of "Retained Austenite‟ has been with us from the beginnings of the development of steel components. Austenite is a soft allotropic form of iron that forms at high temperature. During cooling it gets transformed to other structures of which martensite are the desirable harder phase. But rate of cooling plays a major role in the formation of martensite. If martensite is not formed during cooling, other softer structures may result or austenite itself may remain unconverted. This is unstable at lower temperatures and is likely to transform into martensite spontaneously under certain conditions. However such spontaneously formed martensite tends to be brittle unlike the acceptable tempered martensite. The cryogenic process can be applied on garment cutting knives and sewing needles[10].

The straight knife cutting machine consists of a base plate, an upright stand the hold the vertical blade, motor, a handle for moving assembly, a sharpening device and a handle to transfer the whole assembly from one place to another. Two kinds of power are required to operate a straight knife. Motor power drives the reciprocating blade and operator power drives the knife through three ways. Normally, the available blade vary from 10 cm to 33 cm and normally available strokes vary from 2.5 to 4.5 cm. the greater the blade movement the faster the blade cuts the fabric and more easily the operator can move the machine.



Before Use **After Use**

Fig 2. Cryogenically Treated Garment Cutting Straight Knives

(d) Cryogenic treatment on sewing needles

Sewing needles are classified by their length and thickness. The usual types are “standard” and “long”. The numbering system is not directly related to the length or thickness of the needles; it serves only to distinguish one needle from another. These sewing needles are cryogenically treated and their ratings are elaborately discussed in following data tables.

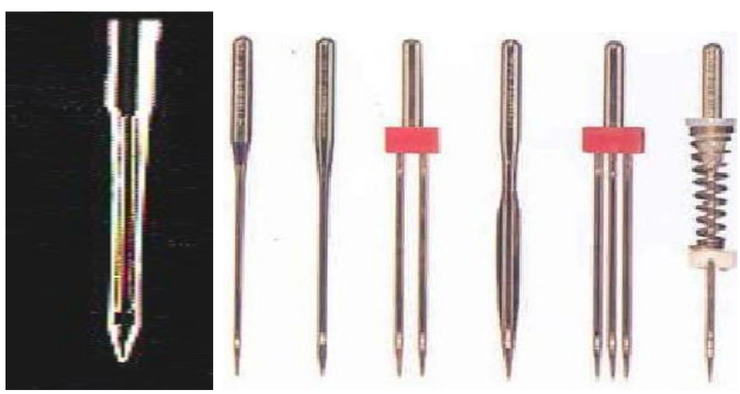


Fig 3. Cryogenically Treated sewing & various types of sewing needles

It has been found during the present scenario that wear resistance of garment cutting knives and sewing needles improve when they are cryogenically treated[11]. Two interpretations of the mechanisms underlying the cryogenic process emerge based on the observed results.

1. The transformation of retained austenite to martensite,
2. Precipitation of fine alloying carbides,

With the recently done technique, it has been proven that the life of the cutting knives and sewing needles has been extended around 47 % and 15-25% respectively. After the cryogenic process the cutting knives and sewing needles are used in the machines for cutting and sewing operations.

Specific application of cryogenic tool in textiles and apparel

Nowadays the developments in the textile scenario, focuses on the production of a better quality product at lower cost. With the above theme the industry people compete among themselves for a better return on their investment. The technique also demonstrates the savings obtained by the industry with the implementation of cryogenic treated knives and sewing needles in garment machinery parts. As regards the quality at lower cost concept mentioned above, we are at the halfway point with regards to this technology. That is, the lower production cost by the increased life of knives and sewing needles parts has been demonstrated. And the statistical analyses about the performance of machinery parts were installed in a garment industry with cryogenic treated knives and needles. Further our study can move towards the application of this process to other textile machinery parts; which can be cryogenically treated to extend their life and also to enhance their working life. With this in view, sewing machine and metallic parts used in the garment industry have been brought into the preview of this treatment as a second part of this technique.

Major End uses in textile field

As such it can be implemented in various textile fields like,

- Spinning (travelers, rings, mote knives, carding wire points, etc.)
- Weaving (temple rollers, picker, etc.)
- Garments (other types of cutting knives, others types of needles, etc.)
- Knitting (latch, spring beard & compound needles, etc.).

Conclusion

Cryogenically treated materials show a marked increase in wear resistance without any desirable change in dimensional or volumetric integrity. Redressing or regrinding treated tools removes less stock material resulting in longer tool life. The material shows little or no change in yield or tensile strength. The treated material becomes less brittle, without a change in original hardness. The most significant and consistent change is the increased toughness, stability and wear resistance. Almost any kind of tool steel or dynamic part, for whatever application, will exhibit some kind of life increase. As less tools or parts are needed, there is substantial savings in dollars. Additional savings include less downtime and short runs, less maintenance and change-over, which allows for lower production costs.

References

1. Alexandru, Ailibeai G. and Baciu C. (1990), Influence of Cryogenic treatment on life of high speed steels, Materials science and Technology. pp 203-206.
2. Barron R.F. (1982), Cryogenic treatment of metals to improve wear resistance, Cryogenics, August. pp 409-413.
3. Catherine C.Fay, Diane M. Stoakley, Anne K. St. Clair, NASA Langley research center (1998), “Molecularly oriented polymeric thin films for space applications”.
4. Chrysler (1986), Cryogenic immersion enhances wear resistance, Metal Progress, Vol.129, pp64.
5. Collins D.N. (1996), Deep cryogenic treatment of tool steels, Heat treatment of Metals, pp 40-42.
6. Paramasivam S. (2005, Cryogenic treatment on the extension of life of textile machine parts, *project thesis.*
7. Meng, fanju, etal (1994), Role of Eta - carbide precipitations in the wear resistance improvements of Fe - 12Cr - Mov - 1.4C Tool steel by cryogenic treatment, ISIJ International, Vol 34, No. 20 pp 205 - 210.
8. Ronald C. Lasky (2003), The effects of cryogenic tempering on tool steels, *www.nitrofreeze.com.*

9. S.Y. Fu, L.F. Li, Y.H. Zhang, C.J. Huang, Y.F. Xiong (2002),Mechanical properties of SGF reinforced PA66 / PP blends at RT and cryogenic temperature, Proceedings of the 19th cryogenic engineering conference, France.

10. Satish kumar. S (2004), Effect of ultra-cooling on the useful life of rings & travelers, *project thesis*

11. Mr. D. Vasanth Kumar & Mr. C. Sivaraman, “Extension of the durability of garment cutting knives and sewing needles”, *fibre2fashion.com*