Cryogenic treatment on cutting tools

For several decades there has been a debate about how effective is the cryogenic treatment on the life of cutting tools.
Right now there is not complete uniformity of opinion on this type of treatment, because of the unclear and definitive interpretation of the major causes of good cutting tools performance , and of the contradictory results obtained in various tests of tool life in different laboratories.
But what is cryogenic treatment ?
Literally it is a heat treatment at low temperatures: many degrees below zero.
In practice there are substantial differences between the treatments performed with different temperatures and with different cycles, and just to give an example, the treatments performed at -84 °C gives a much smaller improvement in wear resistance of the processing performed at -196 °C .
In any case, the scope of these treatments is to increase the surface hardness, wear resistance and toughness of the cutting tool made in High Speed Steel.

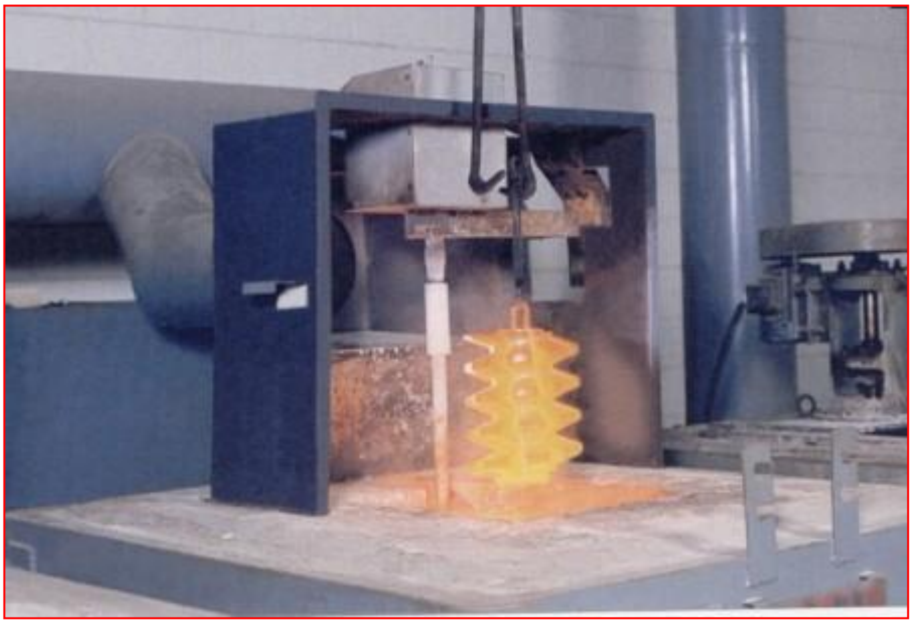

Figure N°1 – *Heatrtreatment of a hob.*

There is already a considerable literature on this subject, but as already said, some scientific reports give for sure that the effectiveness of the treatment is great, but other studies resizing these amazing results.
For example, in the Technical Report KPC-613-5955 (October 1996) of the U.S. research organization, "Allied-Signal Aerospace Co. Kansas City, MO (USA)" states that the tests performed on seven tools have the following results: 5 of tools there has been no increase of tool life while the other two increase the performance was very low.
On the other hand it was found that the coatings with TiN take greater benefit if the support is treated cryogenically.
The above study also draws the conclusion that the cryogenic treatment increases the tool life if they were treated improperly and that the best results are obtained on unsophisticated HSS.
But also other studies, although confirming significant improvements of tool life, they say that the results are often conflicting and recommend to approach the subject with caution.

We could do another observation that justifies the inconsistency of the results.
Analysts of tools, which have a long experience of the workshop, they know how difficult it is to repeat exactly the same conditions in different tests with the same tools.
Even small differences of rake angles obtained during the various sharpening, or different conditions of re-sharpening, difficult to control, such as different stock removal, different cooling conditions, different types of wheels, or perhaps just different intervals of dressing themselves, can cause local overheating of the steel structure with damage.
And then the working conditions during the tests: cutting speed, feed, stock removal, refrigeration, machine condition, etc. of the workpiece clamping. Each different parameter may distort the final result and therefore is not so strange that you have data that sometimes differ.
But it seems now, however, confirmed that the extensive use in the production of certain types of tools with cryogenic treatment, gives a much better average results than the standard tools.
The cryogenic treatment consists of a slowly cooling, about 2.5 °C/min from room temperature to liquid nitrogen temperature of -196 °C.
Then the parts to be processed are kept in immersion in liquid nitrogen for times that can range from 24 hours to 60 hours, then very slowly return to the room temperature.
It is essential that both the cooling and subsequent return to room temperature follow a slow cycle. In fact the first attempts to cryogenic treatments were done by immersing the tools directly in liquid nitrogen causing thermal shock that caused large internal stresses and damage of the tool.
It is evident that the long time required for this type of treatment is a big problem, but new methods have already been introduced in order to reduce the time of treatment. For example, immersing the piece slowly in liquid nitrogen can reduce the total time to about two hours (Pennsylvania State University and NU-Bit Inc.).
There are several theories about the effects of this cryogenic treatment .
One of them says that you have the complete transformation of austenite to martensite, which is harder.
This phenomenon has been verified by both with the micrographic examinations that with the method of X-ray refractive.
Another theory says instead that the greatest benefits arise because there is a precipitation of sub-microscopic size carbides generated by very low temperatures.
These micro-carbide reduce the internal stress by eliminating the tendency to micro-cracks. Probably in reality it has the combination of the two phenomenon.
However, there is no doubt that in most cases you get a significant improvement of the properties of tool steels.
BOC Gases Division (UK) has published tables in the past that indicate how much to increase the efficiency of various types of tools after the treatment with a system called Cryotough.
The data to be taken with caution, are shown in the following table:

Type of tool	Increase of performance
Saw blades	33%
Taps	300%
Drills (diameter 25 mm)	350%
Hobs	140%
Broaches	185%
Reamers	200%

Figure N°2- *Group of gear cutting tools*

But there is an important observation to be done.
Although these increases in efficiency were consistently confirmed, they would still be obtained on uncoated tools with TiN.
It should be noted that the increase of efficiency of coated HSS tools are far greater than those reported in the table.
Should be investigated deeply of what advantage it would have on tools and then covered with a cryogenic treatment and then coated.
We have already said that some advantage has already been verified, but the real question is whether this is sufficient to say that the process considered economically.
In recent times it has started to talk about this treatment for those tools which have not yet obtained a benefit from the TiN coating. We speaking in particular of shaving cutters.
This type of tool in fact cannot be coated in an effective manner in the most important points, that is, inside the serrations, because these surfaces are finished by tools and are not ground after heat treatment.
In addition, the shaving cutters are usually constructed of steel M2, and almost never in super alloyed steels.
From laboratory tests, as already mentioned, was found that the steel M2 receives more benefit from cryogenic treatment, however, you must also change the hardening treatment.
The classic treatment of hardening the steel M2 may be the following:

- *a)- 1st preheat to 600°C (10 – 20 minutes)*
- *b)- 2nd preheat up* to *800°C (10 – 20 minutes)*
- *c)- reaching austenitizing temperature*, *about 1180°C (6 - 12 minutes)*
- *d)- drastic cooling to 500°C*
- *e)- slow cooling to room temperature*
- *f)- heating for 1st tempering at about 550 °C*
- *g)- heating for 2nd tempering at about 560 °C (according to desired HRC)*
- *h)- heating for 3rd tempering at about 540°C*

If you want to do cryogenic treatment should only perform a tempering, usually the first one, at highest temperature.

We easy in this way the transformation of austenite to martensite.
Tests carried out on shaving cutters on which the treatment was performed on the liquid nitrogen had a higher average performance compared to those treated with the traditional method and this was also confirmed by statistical measurements over long periods of use in production.
Even in Japan currently uses the practice of treating with liquid nitrogen shaving cutters.
One of the advantages of this type of treatment compared to other surface hardening (coatings, nitriding, etc..) Is that you do not have a deterioration of the metallurgical properties of steel after of subsequent sharpening.
Any coating of TiN could hardly keep its characteristics for the entire tool life.
Finally it remains to point out that the tools in hard metal (carbide) get benefits if they receive the cryogenic treatment.
This is despite not contain austenite to transform to martensite.
The major problems associated with wear of carbide tools are due to detachment of carbides that are removed by chips as the binder has not enough force to restrain them.
Well, it seems that the cryogenic treatment process improves the resistance of the binder and then slows down the formation of wear.
In addition, the cryogenic treatment reduces the internal stress caused by high pressure during sintering.