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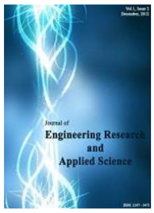

The examination of the effect of deep cryogenic treatment on performance of AISI D2 carpet cutting blades

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Abstract

Commonly AISI D2 tool steel is used to carpet cutting blades in the carpet produce. Recently cryogenic treatment is performed to improve the mechanical response of various steel components. To investigate the effect of the deep cryogenic process on D2 tool steel, D2 tool steel samples and carpet cutting blades were cryogenically treated at -145 °C. The D2 tool steel specimens and the blades were treated in two different groups such as referans, conventional heat treatment and cryogenic process at -145 ºC for 36h after conventional heat treatment. The analyses were made for the purpose of determine the changes in the microstructure and mechanical properties caused by deep cryogenic treatment. The cryogenic treated and non-treated carpet cutting blades were conducted on acrylic, cotton and wool materials blended machine made carpets which were machine carpet with a pile height of 10 to 13 mm. The weight losses of each blade were measured as 2000, 3000, 4000, 5000, 7500 and 10000 m at the end of the cutting also the flank wears of blades were obtained by the microscope images. The cryogenic treatment of D2 tool steel has shown significant improvement in their properties. This improvement enhanced uniform distribution of carbide particles, reduces retained austenite, increase in hardness, increase in tensile strength. The cryogenic process showed that carpet cutting blades reduced weight losses. In addition, the wear of the cutting surfaces were seen to be less than non-treated blades. Consequently, the use of deep cryogenic treatment significantly improved D2 blades life and performance

Keywords: Criyogenic treatment, AISI D2, Tool life, Carpet blades, Performance, Retained austenite.

1. Introduction

The textile industry, which has been growing from the first human beings to the day-to-day needs of dressing, has experienced technological developments and production methods everyday, and at the same time, competition has increased with the speed of production reaching high levels. One of the locomotives of employment in our country is the textile and garment sector. Approximately 3% of the total number of establishments in our country constitutes the number of establishments in the textile sector. Carpet production in textile sector has an important place. Carpet is one of the most used products in the world and it is benefited from many places such as the hospitality, accommodation and automotive sectors. While there are 213 machine carpet producers registered in the TOBB industry database, annual production is 400 million m^2 [1]. The first mechanical system developed for carpet weaving is the brilliant system, also known as wilton wedge or brussels wilton. In 1539 the first carpet was touched in Europe with a vertical hand loom. With the developing technology in the late 19th century, carpet weaving machines started to be used in the textile industry (Figure 1). Machine carpets are made of carpet weaving machines that are similar to hand carpets. The greatest feature of these carpets is their high production speed and low cost of ownership [2].

The production of machine carpets is now ending with the introduction of the likes of the consumer after being performed in integrated facilities in general. Machine types are classified according to production methods. Machine castings have a wide range of different raw material and raw material combinations used in production. These carpets are produced mechanically, and natural fibers and synthetic fibers such as wool, cotton and jute are used in production. It is expected that the fibers of the yarns to be used in the manufacture of carpets have different performance characteristics than the fibers of the yarns to be used in the production of other textile materials. In particular, properties such as fineness, flexibility, bulkiness and high strength must be good for carpet yarns [1, 4, 5]. Increased competition in the carpet weaving industry necessitates continuous production without

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interruption. For this reason, the long life of the weaving machines and apparatus has become very important to gain production time. The knives used as carpet weaving machines are generally used in carpet width and length cutting (slicing machine) operations, integrated with machines or with independent cutting machines (Figure 2, 3). There are also commonly used portable cutting machines (Figure 6). Cutting tools used in textile cutting machines (Figures 2-4) are made in different forms (circular, straight, etc.) and tool steels (AISI D2, AISI M2 etc.).

Figure 1. Carpet weaving machines [3].

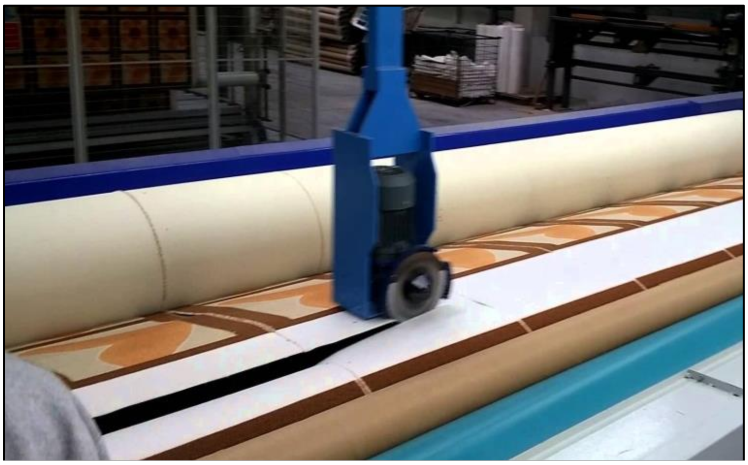


Figure 2. Carpet cutting machines [6, 7].

Figure 3. Carpet cutting machines [6, 7].

Figure 4. Portable carpet cutting machines [6-8].

Increasing the life of tool steel blades (Figure 5), which has been strengthened and cuts carpet fibers made of different materials, is important to reduce the production cost in machine carpets. Today, many dimensions blades are readily available (Figure 5) but can be specially manufactured from tool steels when diameter measurements are enlarged or when special profiled blades are required. Cutting operations on machine carpets are fast, important for the perfection and productivity of the production, which is entirely related to the properties of the cutter blades and the cut carpet material. It is important to prevent cutting blade wear at carpet cutting machines in order to reduce the costs of making quality and uniform cuts. The need for frequent replacement or sharpening of worn blades is essential for proper cutting in carpet cutting machines. Alternative work is being done to increase the cutting blade life and reduce wear. It is known that a new application, cryogenic machining, particularly when applied to tool steel materials, is effective on the amount of wear on the cutting tool during machining and extends the tool life of most cutting tool materials. This process; it is a permanent operation that is performed once, which affects the whole of the part unlike the coatings. Furthermore, no study has been reported in the literature on the effect of cryogenic processing on AISI D2 shear blades performance in carpet cutting machines. Cryogenic process; is a modified cooling process applied to increase wear resistance in high wear exposed tools. In the conventional hardening methods applied to the tool steels, the steel austenitizing process is followed by cooling to room temperature, which is the lowest natural temperature in various cooling media depending on the type of material and martensitic structure is obtained. With conventional cooling up to room temperature, the metastable phase is left in the steel itself, which is called high residual austenite. The most effective way to remove the residual austenite phase, which affects the wear resistance of the tool in the negative, is the application of cryogenic treatment after conventional cooling. The cryogenic process went down to -196 ° C, making the heat treatment more efficient and trouble free. With this process, tool life made from tool steel is increased 4 times; high wear resistance; high toughness, low friction on the surface [9-15].

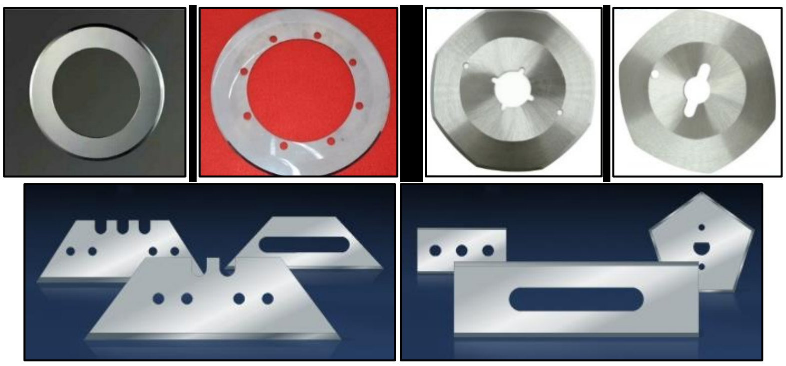


Figure 5. Carpet Cutting Knives with Different Shapes [6-8].

In this study, circular carpet cutting blades made of D2 tool steel were supplied as ready-to-market products, taking into account the improvements in tool performance of the cryogenic process described above. The blades and D2 samples were cryogenically treated at -145 ° C for 36 hours. In SU LEE RC-280 carpet cutting machine, we tried to determine the effects of cryogenic process and the effects on the wear performance and life span by performing cutting operations on uncut blades and machine carpets of acrylic, cotton and wool materials with a pile height of 10 to 13 mm.

2. Material and method

Carpet cutting operations The circular carpet cutting blades of dimensions 90x16x1 mm made of D2 tool steel were supplied as ready-made products from the market. The chemical composition of the cutting knife material is given in Table 1.

Table 1. Chemical content of AISI D2 material.

Material (%)	C	Mn	Si	Cr	S	P	Ni	Mo	V	W
AISI D2	1,59	0,50	0,36	12,43	0,006	0,025	0,24	0,87	1,00	0,039

In this work, the manufacturer has applied the same process to the D2 tool steel blades as in the general heat treatment process in industrial applications. In summary, the heat treatment process applied to the D2 tool steel is pre-stressed at 450 ° C for 15 minutes before pre-austenitizing, then preheated at 650 ° C for 30 minutes. Immediately after preheating, the process was cured by intermediate stage heating at 850 ° C for 30 minutes followed by 15 austenitizing at 1050 ° C followed by cooling with 4 bar nitrogen. Cryogenic processing was performed in the liquid nitrogen oven immediately after the hardening of the blades by the same process (Figure 6). After heat treatment, the samples were cooled at 5 ºC / min, cryogenic at -145 °C for 36 hours, then heated to 5 ºC / min, and then tempered at 520 °C for 3 hours after cryogenic treatment. When the liquid nitrogen in the pressurized environment enters the furnace, it is converted to the gas phase and a homogeneous gas distribution is obtained in the furnace by means of the fan. Thus, the possibility of cracking is prevented by means of the liquid nitrogen in the sample of the blades and samples. As mentioned above, the cooling and heating processes have been carried out gradually so that the blades are not exposed to thermal shocks. The blades and samples are coded according to the operations as follows (Table 2). The schematic of the furnace and the system to which the cryogenic process is applied is shown in Fig. 8.

Table 2. Carpet blades material codes.

Codes	Process
HT	Heat treatment + 3 hours at 520 °C
CT	Heat treatment and 36 hours -145 °C cryogenic process + 3 hours Tempering at 520 °C

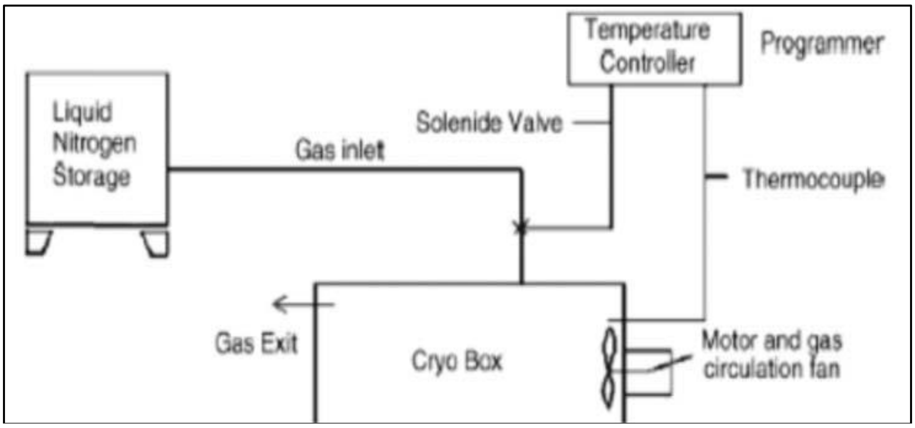


Figure 6. Cryogenic processing system diagram [15].

Macro and micro hardness, tensile strength analyzes were performed to determine the change in mechanical properties resulting from the cryogenic process. Rockwell hardness tester was used for macrohardness measurement. The samples were prepared according to the test standards and the Rockwell hardness (HRC) scale was used for the evaluation of the D2 tool steel material using the Hoytom 1003 test machine. The microhardness grade of the samples was determined by DUROLINE-M microhardness tester. Previously made samples for tensile strength analysis were made according to test standards. X-ray diffraction (SEM), EDX, XRD analysis of the amount of retained austenite were carried out with FEI brand Quanta FEG 250 scanning electron microscope to determine the changes in microstructure caused by the cryogenic process.


Figure 7. Carpet cutting operations using cutting machine

The blades SU LEE RC-280 Model Carpet Cutting machine made of acrylic, cotton and wool materials with a pile height of 10 to 13 mm was cut manually at a cutting speed of 900 rpm. Cutting operations were performed with each knife at a size of about 2x100 cm and a carpet cutting operation was carried out for a total length of 5000 m (Figure 7). Weight loss of each blade; At the end of 1000, 2000, 3000, 4000 and 5000 m cuts were also measured using the AD413ZTA Dino-Lite Pro 2 model and the Dino-Lite Digital Microscope Pro mark (OM) measuring instrument. For weight loss, $1x10^{-3}$ g precision precision scale (ELE L 200S Sartorius Laboratory) was used.

3. Findings and discussion

3.1. Examination of hardness and tensile strength values

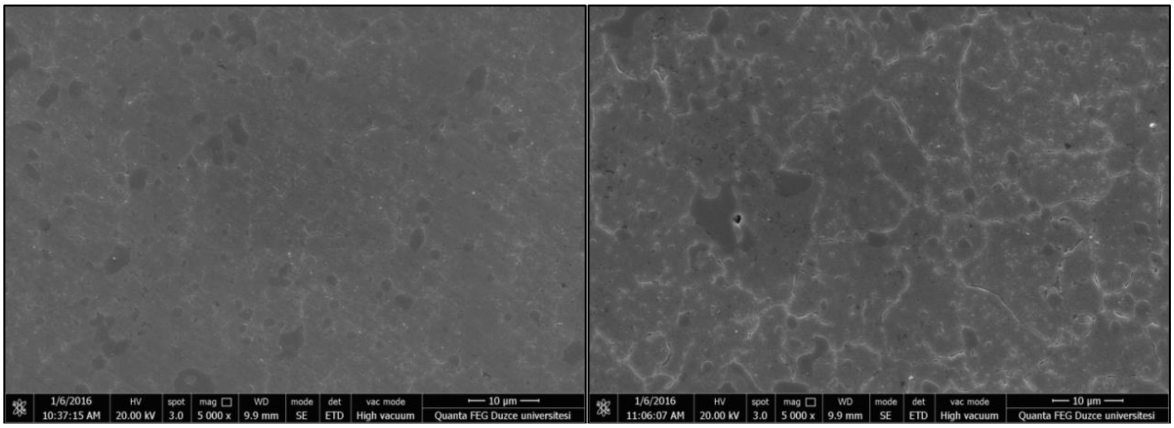
Hardness after cryogenic treatment applied to pre-cut blades ranged from 64-65 HRc. After tempering was measured at around 60-62 HRc, which is the hardness of use. Compared to those with conventional heat treatment (HT), there was an increase of about 1 HRc in those with cryogenic processing (CT). A similar increase was observed in micro hardness values. Those with CT increased about 65 HRc. This increase is consistent with the literature. Tensile test results also changed as hardness. The CT tensile strengths of the D2 steels were about 18 MPa higher than those of the HT steels. Only hardness and tensile stress data have been found to increase the wear resistance of the cryogenic treated material but have shown that it will provide definitive characteristic data in the assessment of wear [16].

3.2. Evaluation of SEM, EDS and XRD analyzes

The purpose of the microstructure examination is to explain the increased hardness values and the improved tool life. On the other hand, the performances of piercing and cutting tools are known to depend on the properties of carbides in the microstructure [15-19]. In the XRD analyzes, the CT specimen showed a retained austenite fraction of 5%. This meant that 50% by volume of the retained austenite observed in HT specimen was practically transformed into martensite by CT. Compositions of carbides determined from the SEM-EDS and XRD analyzes of the D2 tool steel are: Cr7C3 and Fe7C3 carbides are mostly also defined as FeC, NiC and CrC carbides. Residual austenite values of the cryogenic process; it is obviously lower than conventional heat treatment. Literature studies have shown that the cryogenic process provides martensite transformation of the retained austenite, not only providing new carbide formation but also homogeneous carbide distribution (Figure 8), positively affecting wear resistance in this microstructure change [13-20].

3.3. Assessment of weight losses of blades

Generally, during all cutting operations, the tool life at the cutting time required to achieve the cutting time between two successive grinding times or a certain criterion (cutting smoothness, burr, etc.) is called as the cutting tool life. The life of cutting tools is closely related to wear losses. In carpet cutting experiments; After each of the 1000 m cutting lengths, the relationship between the cutting length and the weight loss relation between the blades was evaluated. As can be seen in Figure 9, the HT code blade has begun to weigh losses in the first 2000 m cutting operation and shows a rapid reduction in cutting operations of 3000, 4000, 5000, 7500 and 10000 m. The CT-coded blade showed less weight loss than the HT-code cutting blade at the same cutting lengths. At the end of the cutting length of 10.000 m, the HT code cutting blade showed approximately 75% more weight reduction than the CT code blade. The cryogenic process has been shown to positively affect the wear performance of the D2 tool steel shear blade.



a) HT b) CT

Figure 8. D2 cutting blade material microstructure change (SEM 5000x).

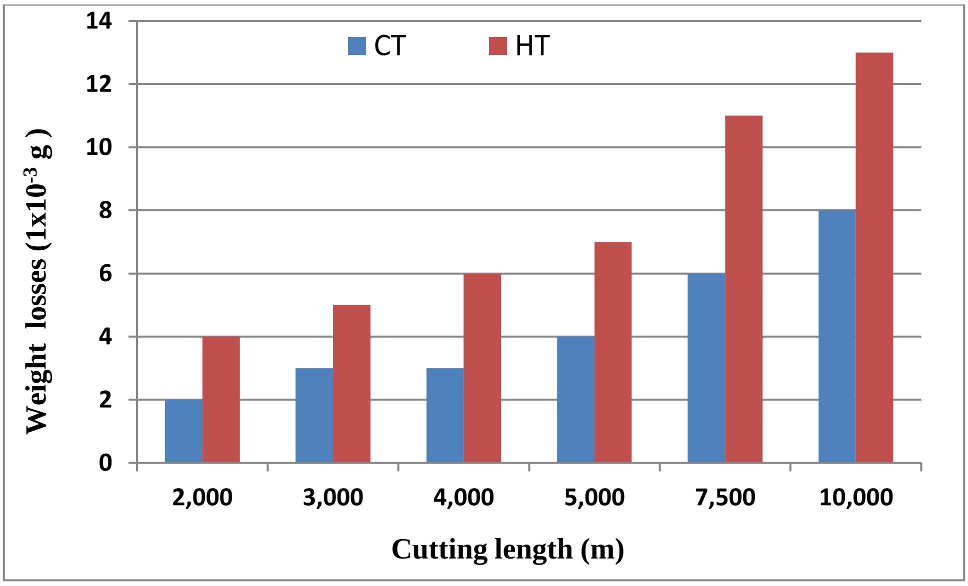
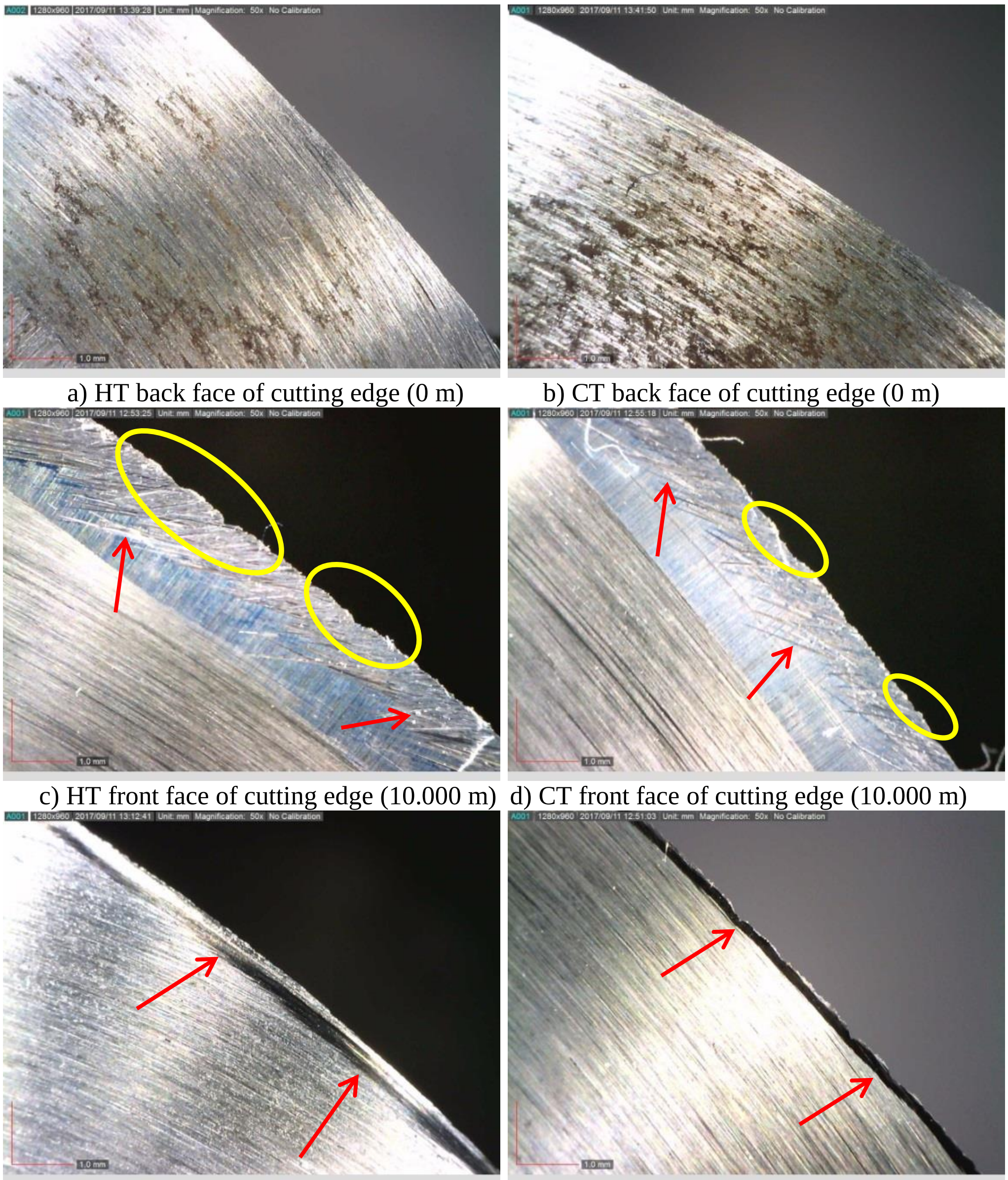


Figure 9. Relationship between cutter blade cutting length-weight reduction.

3.4. Examination of cutting edges digital microscope images (OM) of blades

From the optical microscope images at the end of the cutting length of 5000 meters of the blade cutting edge, it is seen that the HT codeed blade is more abraded than the CT code blades. The cutting surface wear images of the blades are shown in Figure 10. When the marked wear zones on the blade cutting surfaces are examined according to the cutting length of 10.000 m; In Figures 10c and d, fatigue wear occurred in the form of plastic deformation at the cutting edge and breakage of the pieces in micro-dimensions, as shown in the front cheek images with the cutting angle in the marked cheek surfaces. As can be seen from the OM pictures in Figures 10c and d, this wear is present in the entire perimeter of the blade and is a form of plastic deformation and fatigue wear which occurs in the form of spalling of parts in micro-dimensions. There were abrasive wears in the form of scratches in different places marked by arrows on the cheek surfaces. 10d and e, the cutting edge was seen as a diffuse wear burning at the pressure and high shear rates around the sidewall surface and arrow marked with arrows near the back cheek end portions, and there was a slight amount of adhesive wear, also referred to as slip or carpet fiber plaster (adhesion) wear . The HT code carpet in Figure 10 is supported with weight losses (Figure 9) where the blade wear is greater than that of the CT coded blade.



a) HT back face of cutting edge (0 m) b) CT back face of cutting edge (0 m)

c) HT front face of cutting edge (10.000 m) d) CT front face of cutting edge (10.000 m)

e) HT back face of cutting edge (10.000 m) f) CT back face of cutting edge (10.000 m)

Figure 10. Cutting edges at the beginning of the blades used for carpet cutting operations and after cutting length of 5000 m (OM 50x)

4. Conclusions

In this study, the following results were obtained according to the carpet cutting processes and the analyzes made with cryogenic treated (CT) and untreated (HT) AISI D2 cold work tool steel circular cutting blades. Cryogenic treatment has a recommended practice and increased tensile strength by approximately 3.2%. It was found that the macro and micro hardness results of the D2 tool steel increased by 1.2% HRC and 2.7% HRC, respectively, in the cryogenic process (CT) structures. The cryogenic process sample showed retained austenite fraction of 5%. This showed that 50% of the retained austenite observed in the untreated sample was converted to martensite by the cryogenic process in practice. CT was found not only to provide new carbide formation but also to provide homogeneous carbide distribution, which positively affected wear resistance in this change in microstructure. The HT code cutting blade showed about 40% more weight reduction than the CT code blade. It has been found that the cryogenic process has a positive effect on the D2 tool steel cutting blade wear performance. Plastic deformation at the cutting surfaces and fragmentation at micro-sizes resulted in fatigue wear in the form of spillage. Adhesive wear, also referred to as abrasive wear, diffusion wear, or plaster wear, has also been observed. From the optical microscope images at the end of the cutting length of 10.000 meters, the cutting edge of the HT-coded blade was more abraded than the CT-coded blades.

In these results, it has been found that the deep-cryogenic process D2 cold work tool steel circular carpet shear blades have a significant contribution to abrasion resistance and tool life. In addition to this, cryogenic treatment can be applied to other steel materials used in cutting textile machines.

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Brief summary the 1st International Demirci Symposium in 2017 was presented. This investigate was expanded. We thank Alper Isıl Islem.

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