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Investigation of the Effect of Vulcanization Time on Belt Strength

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ABSTRACT

In today's technology, the power of mechanization has emerged in places where manpower is insufficient in order to meet the increasing needs at many facilities. With belt conveyor systems, it has become much easier to transport the material from one site to another in the facilities in terms of time, distance, and capacity. Since belt conveyors are a reliable and cost-effective system in material handling, the quality of the belt used should be carefully determined. It is important that the wear and tear that occurs on the belt over time is repaired quickly and effectively in order not to prolong the downtime in the plant. A small damage detected needs to be repaired immediately so that it does not cause bigger problems. In this study, vulcanization time, which is one of the parameters affecting the belt strength in belt splice made by vulcanization method, is discussed. By studying the effect of time on belt strength, it is aimed to extend the life of the belt splicing area. According to the test results, it has been observed that the increase in vulcanization time has a positive effect on the tape strength and the usage of welding machine saves time in terms of faster use of the tape in the facility.

Vulkanize Kaynak Süresinin Bant Mukavemetine Etkisinin Araştırılması

MAKALE BİLGİSİ

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Birleştirme
Konveyör bandı
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ÖZET

Günümüz teknolojisinde birçok tesiste artan ihtiyaçları karşılamak amacıyla insan gücünün yetersiz kaldığı yerlerde makineleşmenin gücü ortaya çıkmıştır. Konveyör sistemleri ile tesislerde malzemenin bir noktadan diğer bir noktaya taşınması zaman, mesafe ve kapasite yönüyle çok daha kolay hale gelmiştir. Bantlı konveyörler, malzeme taşımada güvenilir ve maliyet açısından da avantajlı bir sistem olduğundan kullanılan bandın kalitesinin itina ile seçilmesi gerekmektedir. Zamanla bantta meydana gelen yıpranma ve aşınmaların, tesiste duruş süresini uzatmamak adına çabuk ve etkili bir şekilde tamir edilmesi ve tespit edilen küçük bir hasarın daha büyük sıkıntılara yol açmaması için derhal onarım yapılması önemlidir. Bu çalışmada, vulkanize kaynak yöntemi ile yapılan bant birleştirmelerinde bant dayanımına etki eden parametrelerden biri olan vulkanizasyon süresi ele alınmıştır. Sürenin, mukavemete olan etkisi incelenerek bant ek yerlerinin ömrünü uzatmak amaçlanmıştır. Yapılan çalışmada, bantlı konveyörlerin genel özellikleri, bantlı konveyör çeşitleri, bant yapısı ve özellikleri, vulkanizasyon tanımı, vulkanize kaynak yöntemi ile birleştirme işlem adımları ve farklı sürelerde uygulanan vulkanizasyonun etkisini incelemek amacıyla yapılan deney çalışmalarından bahsedilmiştir. Test sonuçlarına göre vulkanizasyon süresindeki artışın bant mukavemetine olumlu etki yaptığı ve kaynak makinesi kullanımının bandın tesiste daha hızlı kullanılması açısından zamandan tasarruf sağladığı gözlemlenmiştir.

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1. INTRODUCTION (GİRİŞ)

The endless belt conveyor system is one of the most important systems that English engineer Lyster found in 1868 and is still used in material handling today. Conveyors are continuous transfer systems that can operate in a closed loop, allowing the materials to be transported from the air or from the ground, and the continuity of the material transmission is one of the most effective parameters in the business economy [1,2]. Today, belt systems can generally operate up to distances of 20-30 km, and the longest operating system since 1970 is 100 km long [3].

Belt conveyors represent an endless belt between two tensioned pulleys, fixed with rollers. Belt conveyors provide the most suitable and economical solution when material transport is carried out over long distances and at large capacities. These conveyors, which play a role in the transport of all kinds of dry and wet materials, have an important application area, especially in the transport of bulk materials such as ore, grain, sand, and coal. The conveyed material is carried by a belt driven by one or more drums [1]. Conveyor belts are equipment that wraps the entire facility like blood vessels in the human body and delivers the needed material to the desired location at the desired time [4].

The weakest points of belt conveyors operating at long distances and high capacities are splice. For the long-lasting use of the belts, high quality and correctly applied splice are important [5]. The costliest component in conveyor belts is the belt itself. Correct operation of the system is important for reliability. During the operation of the conveyor, the belt is exposed to many varying loads. Materials carried along the conveyor line while in the loading and unloading cycle cause wear on belt covers, roller assemblies and cleaning systems. Another factor in the wear of rubber and belt is environmental conditions. All the factors mentioned cause natural wear and tear of the belt. The wear process varies depending on the working conditions and the selection of the belt suitable for these conditions. Belt wear is also affected by compliance with operating conditions. In order to prevent wear, it is necessary to follow the operating conditions of the conveyor (especially loading the belt along the axis of the conveyor, not overloading, ensuring sufficient initial tension). The strength of the splice should be suitable for the working conditions since the wear can occur mostly at the belt splice, which is the weakest point of the belt conveyors. The strength of the splice depends on the splicing method used and the quality of the attached part. Belt bonding or hot-cold bonding with the vulcanization method is the most suitable solution to provide the best strength and durability [6,7]. Today, mechanical splicing (attachment) method, cold splicing method, and hot splicing (vulcanization) methods are used in the splicing process of rubber conveyor belts. If the tensile strength of these belts is 100 %, this value decreases to 35-45 % when fixed with mechanical attachment, to 65-75 % when fixed with cold splicing, and to 75-80 % when bonded with vulcanization. As can be seen, the weakest point of the belt is the junction points [8-10]. Vulcanization and mechanical attachment methods are applied all over the world. Especially in North America, mechanical attachment of the belt is more common, while vulcanization is more common outside of North America.

Soyubol investigated the parameters affecting the static and dynamic properties of elastomer materials and revealed that parts with different properties can be obtained by changing the vulcanization parameters. In the measurements obtained by changing the vulcanization times, it was observed that the change in elongation at break with the increase of the firing time and the elastomer type were an important factor for this change. The rupture and elongation values of EPDM and NR raw material specimens cured at 175 °C for 6 and 8 minutes were investigated [11]. Hardygora et al., in their study on the analysis of splice in conveyor belts, showed that the strength loss can vary between 30 % and 45 % depending on the coefficient, that the strongest splice can be made between belts with the same strength characteristics, and that the tests performed at the Wroclaw University of Technology Belt Transport Laboratory (LTT) showed that by reducing the layers spliced by hot vulcanization, the middle layers can be shorter than the outer splice without losing the strength of the splice [6]. Şahbaz, when examining the test specimens taken from the same points of the conveyor belts after the hot press bonding and cold vulcanized bonding process, determined that the shear stress values were 2070 N in the hot press bonding process and 2920 N in the cold vulcanized bonding process, with the obtained result, it has been shown that the cold vulcanized bonding developed can be applied to the hot press bonding zone [12]. Zhaoxiang et al., in their study, to examine the effects of vulcanization on the rubber gasket, a modeling showing the stress-strain relationship taking into account thermal expansion, cold shrinkage and shrinkage was created. A temporary analysis method was developed for the thermal-mechanical-chemical bonding of the process from rubber gasket vulcanization to mold opening, and dimensional changes of the rubber gasket in the mold and after cooling were predicted. The research results showed that an increase in the vulcanization temperature causes an increase in the dimensional shrinkage of the gasket. As the vulcanization temperature increased from 165 °C to 185 °C, the dimensional shrinkage rate increased non-linearly from 3.2 % to 3.8 %. The vulcanization molding time causes a greater seal shrinkage, which may be associated with the high elastic modulus of the rubber, which limits the release of thermal stress, for example, for the curing temperature of 175 °C, the dimensional shrinkage rate increased by 0.206 % for every 1 % increase in shrinkage caused by the vulcanization reaction [13]. Chen et al., prepared the ZnS (Zinc Sulfide) film by vulcanization at 440 °C for 2, 4, 6 and 8 hours in a sulfur vapor atmosphere. The crystal structure, surface morphology, microscopic defects and optical properties of the specimens were measured retrospectively by XRD, SEM, slow positron beam, Doppler expansion spectroscopy and UV visible spectrophotometer. The results showed that the vulcanization time had a significant effect on the crystallinity and optical properties of the specimens, and the crystallinity of the specimens increased as the vulcanization time increased. However, excessive vulcanization time weakened the crystallinity of the specimen. It was determined that the crystallinity of the specimens was the best and the belt gap value was 3.49 eV (electronvolts) during the vulcanization period of 6 hours. The optimum vulcanization time at 440 °C was found by investigating the vulcanization time, and the properties of the ZnS film prepared by low temperature vulcanization were optimized and potentially used in various optoelectronic devices [14].

In this study, it was aimed to examine in detail the splicing steps of the belt conveyors used in industrial facilities with the vulcanization method in the belts that break as a result of the wear that occurs over time. Unlike the literature, a vulcanized welding machine with different properties was used and the splicing effect of vulcanization time was investigated. In addition, it was objective to determine the most appropriate time to be applied in the facilities by investigating the effect of the vulcanization time on the belt strength.

2. EXPERIMENTAL STUDIES (DENEYSEL ÇALIŞMALAR)

In our study, the effect of the welding time on the belt strength during the assembly of the conveyor belts used in the Kardemir A.Ş Sinter Directorate facility with the vulcanized welding method is examined. EP800-1000-5-6/3 mm A-type wear-resistant belt is used as the conveyor belt. This belt with a capacity of 1000 t/h is used during the transmission of material transfer between facilities at the facility and carries sinter, coke powder, lime powder and ore materials. The TS EN ISO 283 standard is used in the vulcanized welding method for the conveyor belt we use. This standard describes the test method to determine the elongation at break of textile fabric conveyor belts. It is desired that the tensile test device is capable of elongation at a constant rate of (100 ± 10) mm/min uninterrupted. In addition, as can be seen in Figure 1, it is recommended to use transverse serrated jaws in the device [15].

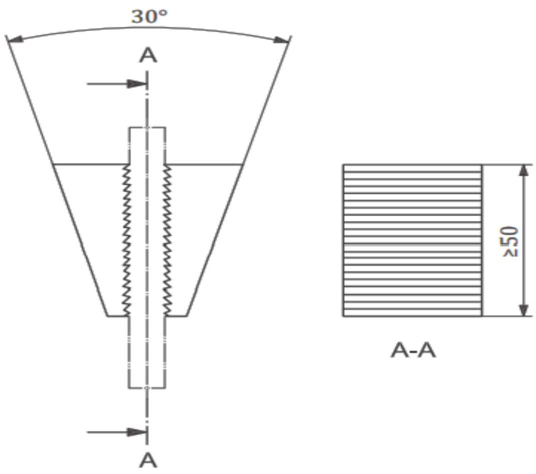

Figure 1. The serrated jaws of the tensile tester device [10] (Çekme test cihazının tırtıklı çeneleri).

2.1. Specimen Preparation (Numune Hazırlama)

In order to prepare the vulcanization specimens (Figure 2), first of all, belt cutting was performed. After the belt was cut, the opening process was applied and the cleaning process was carried out on the opened floors. Adhesive vulcanized belt solution was applied to the cleaned surfaces. After this process, intermediate rubber is positioned between the stages. This promotes better adhesion of the rubber belt to each other. Then, the sleepers were divided into two parts and the lower part of the belt was placed on the upper part of the lower sleeper, and the other part of the belt was placed on the upper sleeper. In the last stage, two belts were pressed by applying force at the determined pressure and temperature value, during the planned time.

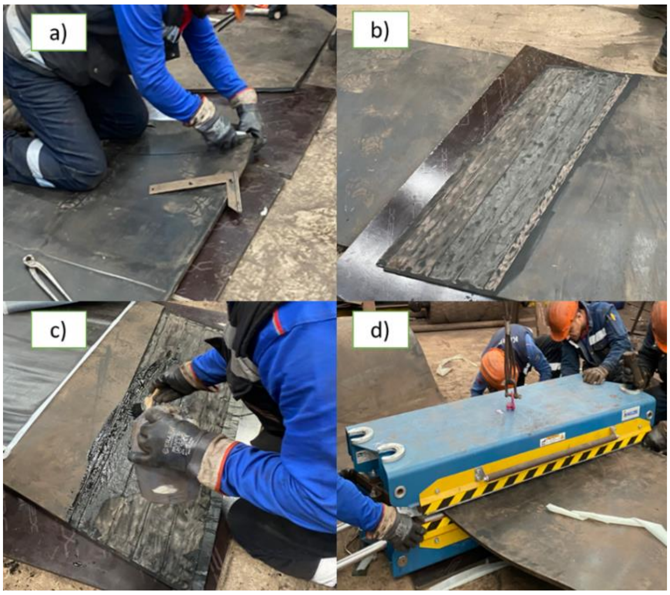

Figure 2. Preparation of vulcanization specimen processes, a) Cutting b) Opening c) Solution coating d) Pressing.

The vulcanization process was carried out on the belt specimens, which will be subjected to tensile testing, at the times given in Table 1. A total of 12 specimens were prepared, 3 specimens each for 15, 30, 45 minutes, and 3 specimens for the untreated belt, with the vulcanization temperature fixed at 145 °C. According to ISO 37, the specimens were cut according to the bow tie apparatus [16]. The cutting process was carried out using the B Type template in the TS EN ISO 283 standard. Specimens were cut from the inside of the belt lengthwise, 50 mm from the edges. All specimens were subjected to tensile testing until rupture occurred. Type B bow tie specimen apparatus is shown in Figure 3.

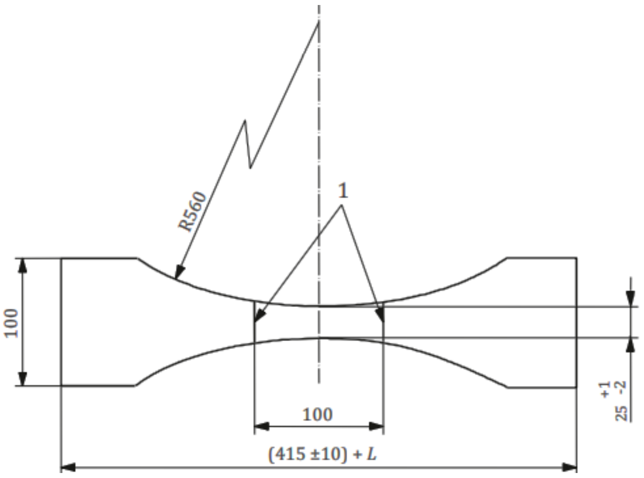

Figure 3. Type B bow tie apparatus [10].

Table 1. Vulcanization time and number of prepared specimens (Vulkanizasyon süresi ve hazırlanan numune sayısı).

Specimen Name	Number of Specimens	Vulcanization Time	Vulcanization Temperature
Untreated Belt Specimens			
N-1,2,3	3 specimens	Original Unspliced Belt	Original Unspliced Belt
Specimens Prepared by Water Cooled Welding Machine			
S-15-1,2,3	3 specimens	15 Minutes	145 °C
S-30-1,2,3	3 specimens	30 Minutes	145 °C
S-30-1,2,3	3 specimens	45 Minutes	145 °C

Specimen pictures prepared by cutting according to Type B bow tie apparatus at different vulcanized welding times are as follows (Figure 4, Figure 5, Figure 6, Figure 7).

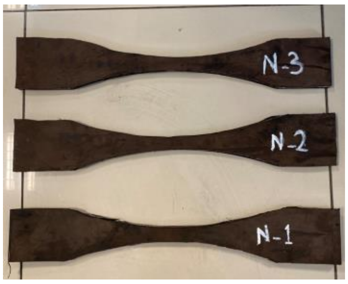

Figure 4. Untreated belt specimens (İşlenmemiş bant numuneleri).

Figure 5. Specimens prepared according to the vulcanization time of 15 minutes (15 dakikalık vulkanizasyon süresine göre hazırlanan numuneler).

Figure 6. Specimens prepared according to the vulcanization time of 30 minutes (30 dakikalık vulkanizasyon süresine göre hazırlanan numuneler).

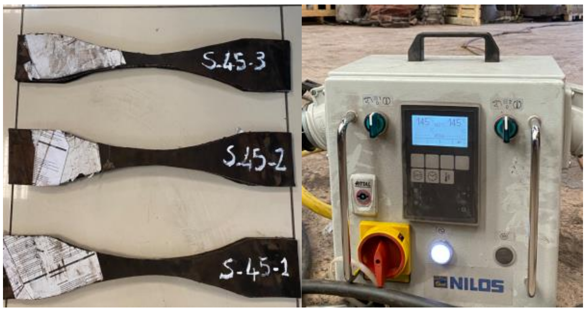

Figure 7. Specimens prepared according to the vulcanization time of 45 minutes (45 dakikalık vulkanizasyon süresine göre hazırlanan numuneler).

2.2. Tensile Test (Çekme Testi)

In the tensile test, jaw positions for Type B template were adjusted according to the size of 415±10 mm. Width for each specimenis 1000 mm, number of cloth coatings is 5, top coating thickness is 6 mm, bottom coating thickness is 3 mm, total thickness is 16 mm. The test specimen was fixed by placing it between the jaws. The dimensions required to start the tensile test (diameter of the specimen, thickness and width) are defined. After the finished test, all the detected test results were obtained in the test software program. Likewise, these processes were repeated for all other specimens and separate data were obtained for each specimens. The sample specimens picture of the experiments performed is shown in Figure 8.

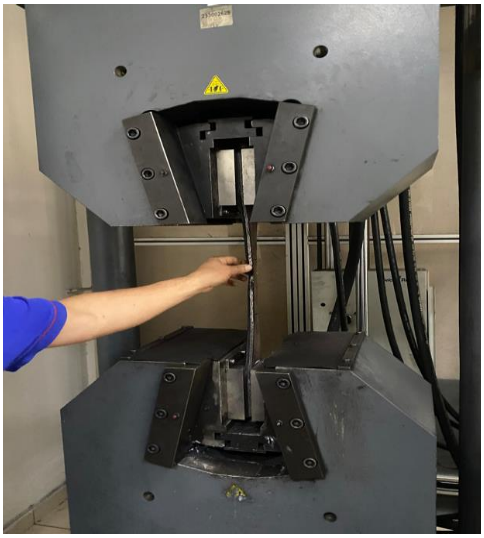

Figure 8. Tensile test applied to a vulcanized welded specimen (Vulkanize kaynaklı numunesine uygulanan çekme testi).

3. EXPERIMENTAL RESULTS AND DISCUSSION (DENEYSEL SONUÇLAR VE TARTIŞMA)

The maximum force generated during the tensile test is divided by the width of the test specimens. The arithmetic average of these values, which were found for a total of 12 belt specimens, of which 3 original unspliced belt specimens and 3 each prepared according to the vulcanization time of 15, 30, 45 minutes with a water-cooled vulcanized welding machine, were taken. Accordingly, the breaking strength of the belt is expressed as Eq.1, with F_{max} breaking strength being the narrowest width of the belt D_0.

$$\sigma_T = \frac{F}{A_0} \left(\frac{N}{mm^2}\right) \tag{1}$$

The tensile strength test results of untreated belt specimens are shown in Table 2, the rupture-elongation diagram in Figure 9, and the rupture photograph of specimen N-1 as an example in Figure 10.

Table 2. Tensile strength values of untreated specimens (İşlem görmemiş numunelerinin çekme dayanımı değerleri).

Specimen No.	Thickness (mm)	Width (mm)	Area A_0 (mm^2)	Pulling Force F_{max} (N)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)
N-1	16	27.8	444.80	20098	45.18	46.57 ± 2.38
N-2	16	25.8	412.80	18665	45.22	
N-3	16	25.8	412.80	20361	49.32	

Figure 9. Break-elongation curve diagram of original unspliced belt specimens (Orijinal eklenmemiş kayış numunelerinin kopma-uzama eğrisi diyagramı).

Figure 10. Breaking of specimen N-1 after tensile test.

According to these results, the average breaking strength of the untreated belt specimen is 46.57 N/mm^2. Evaluations of the specimens that were combined with a water-cooled welding machine, applied with a vulcanization time of 15 minutes are shown in Table 3, Figure 11, Figure 12.

Table 3. Tensile strength values of specimens numbered S-15 (S-15 numaralı numunelerin çekme dayanımı değerleri).

Specimen No.	Thickness (mm)	Width (mm)	Area A_0 (mm^2)	Pulling Force F_{max} (N)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)	% Power Value in Terms
S15-1	16	25	400.00	8464	25.00	22.48 ± 2.42	% 48.27
S15-2	16	23,6	377.60	7613	20.16		
S15-3	16	25	400.00	8910	22.28		

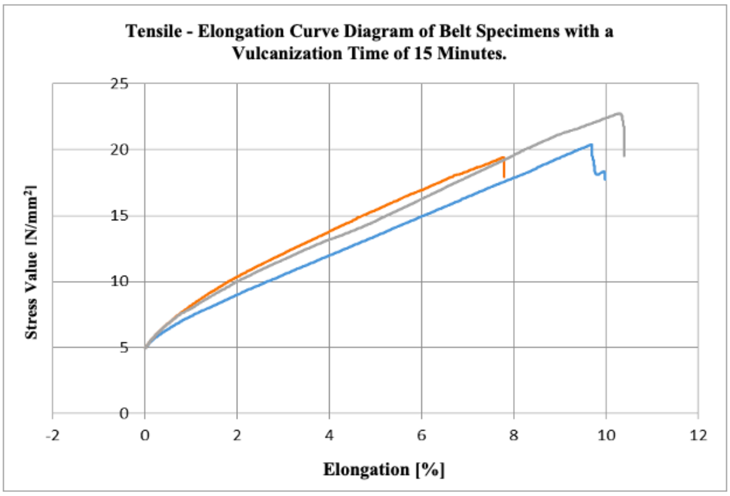

Figure 11. Tensile-elongation curve diagram of belt specimens with a vulcanization time of 15 minutes.

Figure 12. Breaking of specimen S-15-3 after tensile test (S-15-3 numunesinin çekme testinden sonra kırılması).

It was observed that the belt specimens, which were applied with a vulcanization time of 15 minutes, lost 51.72 % of their strength compared to the untreated belt.

Evaluations of the specimens with a vulcanization time of 30 minutes given in Table 4, Figure 13 and Figure 14.

Table 4. Tensile strength values of specimens numbered S-30 (S-30 numaralı numunelerin çekme dayanımı değerleri).

Specimen No.	Thickness (mm)	Width (mm)	Area A_0 (mm^2)	Pulling Force F_{max} (N)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)	% Power Value in Terms
S30-1	16	25	400.00	9349	23.37	22.09 ± 1.75	% 47.74
S30-2	16	26.2	419.20	9562	22.81		
S30-3	16	26	416.00	8362	20.10		

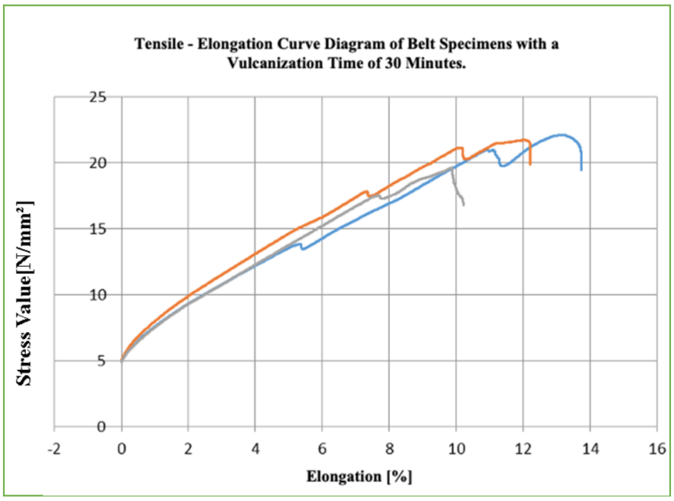

Figure 13. Tensile-elongation curve diagram of belt specimens with a vulcanization time of 30 minutes.

Figure 14. Breaking of specimen number S-30-3 after tensile test(S-30-3 numunesinin çekme testinden sonra kırılması).

It was observed that the belt specimens, which were applied 30 minutes of vulcanization time, lost 52.56 % of their strength compared to the untreated belt.

Evaluations of the specimens with a vulcanization time of 45 minutes are given in Table 5, Figure 15 and Figure 16.

Table 5. Tensile strength values of specimens numbered S-45.

Specimen No.	**Thickness (mm)**	**Width (mm)**	**Area A_0 (mm^2)**	**Pulling Force F_{max} (N)**	**Tensile Strength (N/mm^2)**	**Average Tensile Strength (N/mm^2)**	**% Power Value in Terms**
S45-1	16	25	400.00	10438	26.10	24.95 ± 0.99	% 53.57
S45-2	16	27	432.00	10552	24.43		
S45-3	16	20	320.00	7787	24.33		

Figure 15. Breaking of specimen number S-45-2 after tensile test (S-45-2 numaralı numunenin çekme testinden sonra kırılması).

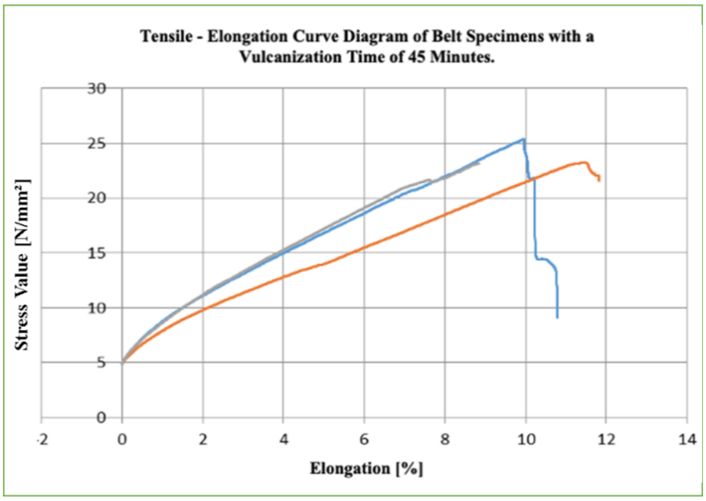

Figure 16. Tensile-elongation curve diagram of belt specimens with a vulcanization time of 45 minutes.

It was observed that the belt specimens, which were applied with a vulcanization time of 45 minutes, lost 46.42 % of their strength compared to the original unspliced belt.

In Figure 17 below, the rupture-elongation curves of 9 and 3 original unspliced belt specimens prepared with a water-cooled welding machine are shown.

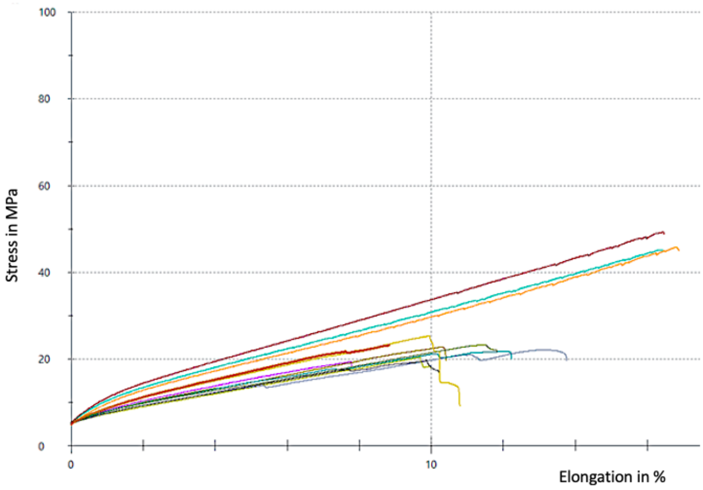

Figure 17. Break-elongation curve diagram of 12 specimens (12 numunenin kopma-uzama eğrisi diyagramı).

The strengths of belt specimens that underwent vulcanization process for 15, 30, and 45 minutes were compared with the untreated specimen. It was observed that there wasn't much difference in strength between the 15-minute and 30-minute specimens, whereas an improvement of approximately 11% in strength was seen when the process was extended to 45 minutes. It was concluded that an optimal increase in vulcanization time leads to an increase in strength [17, 18]. The tensile strengths of 12 specimens were compared in Figure 18.

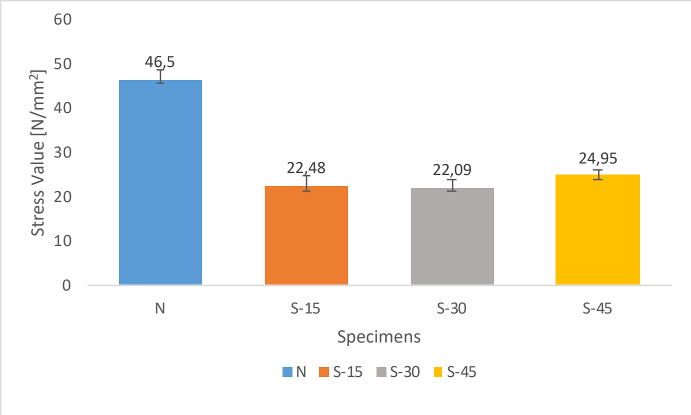

Figure 18. Comparison of tensile strength of specimens (Numunelerin çekme mukavemetinin karşılaştırılması)

4. CONCLUSIONS AND RECOMANDATIONS (SONUÇLAR VE ÖNERİLER)

In this study, EP800-1000-5-6/3-A type wear-resistant belt were used, and splicing was made with a water-cooled vulcanized welding machine at a constant temperature of 145 °C for 15, 30, 45 minutes.

In addition, 3 untreated belt specimens were also prepared. The tensile strengths of the prepared specimens were examined and as a result of the experiments;

- According to the tensile test results of the normal untreated belt, the breaking strength of the belt was calculated as 46.57 N/mm^2 ± 2.38 N/mm^2. This value is lower than 50 N/mm^2, which is the minimum breaking strength according to the TS EN ISO 14890 standard. It is thought that the factors such as the fact that the used belt has been waiting in stocks for around 1-2 years and whether the company from which the belt is supplied has sent in accordance with the desired conditions is considered to be a factor.
- Using a water-cooled welding machine, when the curing temperature is constant at 145 °C, the average breaking strength of 3 specimens with a vulcanization time of 15 minutes was 22.48 N/mm^2 ± 2.42 N/mm^2, the strength value compared to the untreated belt is 48.27 %, the average breaking strength of 3 specimens with a vulcanization time of 30 minutes was 22.09 N/mm^2 ± 1.75 N/mm^2, the strength value compared to the untreated belt is 47.74 %, the average breaking strength of 3 specimens with a vulcanization time of 45 minutes was 24.95 N/mm^2 ± 0.99 N/mm^2, the strength value compared to the untreated belt was found to be 53.57 %. According to this comparison, it was observed that the belt strength increased as the vulcanization time increased. The strength value of the belt specimen, which had a vulcanization time of 45 minutes, exceeded 50 %.
- One of the most important issues in vulcanized belt welding is that there is no dust and moisture on the surface of the belt, that is, the belt is dry. In addition, factors such as unintentional knife blows or leaks on the surface of the belt and the poor quality of the material from which the belt is made play an important role in opening the splice of the belt.

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REFERENCES (KAYNAKLAR)

1. T. Er, Bantlı konveyörlerde basınçlı hava risklerini önleme çalışması, Ohs Academy, 2(2): 53-57, 2019.
2. V. Govindan, E. Palaniswamy, M. Sambathkumar, R. Vijayakumar, T. Sakthimuruga, Conveyor belt troubles (bulk material handling), Int. J. Emerg. Eng. Res. Technol., 2: 21–30, 2014.
3. S. Zamarano, Surface ore movement, storage, and recovery systems, SME Mining Eng. Handbook, Darling P. (Ed.), Third Edition, USA, 2011.
4. C. Can, Bir bantlı konveyörün sonlu eleman yöntemiyle dinamik analizi, Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul, Türkiye, 2012.

5. M. Bajda, R. Błażej, L. Jurdziak, Analysis of changes in the length of belt sections and the number of splices in the belt loops on conveyors in an underground mine, Engineering Failure Analysis, 101: 436-446, 2019.
6. M. Hardygóra, M. Bajda, R. Błażej, Laboratory testing of conveyor textile belt joints used in underground mines, Mining Science, 22: 161-169, 2015.
7. L. Xie, Z. Wenqi, Z. Hao, Y. Aibing, Q. Yujun, S. Yougong, Wear process during granular flow transportation in conveyor transfer, Powder Technology, 288: 65-75, 2016.
8. T. Kozłowski, J. Wodecki, R. Zimroz, R. Błażej, M. Hardygóra, A diagnostics of conveyor belt splices. Applied Sciences, 10: 6259, 2020.
9. D. Zaremba, P. Heitzmann, L. Overmeyer, L. Hillerns, T. Hassel, Automatable splicing method for steel cord conveyor belts – evaluation of water jetting as a preparation process, Strojniški vestnik - Journal of Mechanical Engineering, 63(10): 590-596, 2017.
10. L.P. Alviari, M.A. Choiron, I.P. Tama, Optimization of cold splicing parameters in conveyor belt joints on shear strength using taguchi method, Journal of Engineering and Management in Industrial System, 1: 1-10, 2022.
11. B. Soyubel, Elastomerlerin statik ve dinamik özelliklerinin incelenmesi, Yüksek Lisans Tezi, Uludağ Üniversitesi Fen Bilimleri Enstitüsü, Bursa, Türkiye, 2006.
12. D.A. Şahbaz, Soğuk vulkanize yapıştırıcı üretimi ve uygulama koşullarının değerlendirilmesi, Doktara Tezi, Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Enstitüsü, Bilecik, Türkiye, 2017.
13. Z. Zhaoxiang, G. Fei, K. Yuchao, X. Chong, J. Xiaohong, Effect of vulcanization on deformation behavior of rubber seals: Thermal–mechanical–chemical coupling model, numerical studies, and experimental validation, Materials and Design, 224: 111314, 2022.
14. S. Chen, Y. Runsheng, S. Ligang, Z. Rengang, C. Xingzhong, W. Baoyi, Z. Peng, Effect of low temperature vulcanization time on the structure and optical properties of ZnS thin films, Applied Surface Science, 498: 143876, 2019.
15. TS EN ISO 14890, Konveyör bantları - Genel amaçlar için - Kauçuk veya plâstik kaplanmış tekstil karkaslı konveyör bantlarının özellikleri, T.S.E., Ankara, 2013.
16. TS ISO 37, Lastikler ve Termoplastikler – Çekme gerilmesi-uzama özelliklerinin tayini, T.S.E., Ankara, 2017.
17. K.K. Sasidharan, R. Joseph, S. Palaty, K.S. Gopalakrishnan, G. Rajammal, P.V. Pillai, Effect of the vulcanization time and storage on the stability and physical properties of sulfur-prevulcanized natural rubber latex, Journal of Applied Polymer Science, 97: 1804-1811, 2005.
18. M. Wu, L. Yang, Q. Shen, Z. Zheng, C. Xu, Endeavour to balance mechanical properties and self-healing of nature rubber by increasing covalent crosslinks via a controlled vulcanization, European Polymer Journal, 161, 110823, 2021.