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Tekstil Bilimleri ve Teknolojileri Alanında Araştırmalar ve **DEĞERLENDİRMELER**

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İÇİNDEKİLER

BÖLÜM 1

BCF İPLİK ÜRETİM TEKNOLOJİSİ

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1. Giriş

Küresel sentetik iplik pazarında, BCF (Bulked Continuous Filament – Hacimli Sonsuz Filament) iplikçiliği büyük bir paya sahiptir ve 2030 yılına kadar %5,4'lük bir bileşik büyüme oranında büyüyerek tahmini satış hacminin 20,5 milyar dolara ulaşması beklenmektedir. BCF iplik üretiminde kullanılan başlıca polimerler polipropilen, polyester ve poliamiddir. Sonsuz filamentlerden oluşan BCF ipliklerin en önemli avantajı yüksek mukavemeti ve dayanıklılığıdır, ayrıca tüylenme ve boncuklanmaya karşı dayanıklı olduğundan ürünlere uzun ömürlü bir kullanım imkânı sunarlar. BCF iplikler makine halıcılığı başta olmak üzere, döşemelik tekstil ürünleri ve endüstriyel kumaşlar da dâhil olmak üzere çeşitli uygulamalarda kullanılabilmektedir. Müşteri talepleri ve ürünlerin kullanım alanlarına göre BCF iplik üretim sistemi çeşitli özelliklerde (puntalı, bükümlü, bükümsüz, fikseli, fiksesiz, frizeli gibi) iplik üretimine imkân tanıyan bir teknolojidir [1].

BCF iplik üretim hattında, BCF makinesinin ardından kablolama (katlama) ve büküm makinesi, frize ünitesi (kıvırcıklandırma) ve fikse (heat-set) makinesi yer almaktadır. BCF makinesinden çıkan iplikler, müşteri talebi doğrultusunda istenen fonksiyonelliği kazanabilmek için diğer işlemlerden de geçirilerek nihai formunu alır.

2. BCF İplik Üretim Makinesi

BCF iplikler, yüksek hacim ve dayanıklılık özelliklerinden dolayı makine halıcılığında hav ipliği olarak en çok tercih edilen yarı mamullerdir. BCF iplikleri makine halısı sektöründe ön plana çıkaran en önemli unsurlar, nihai üründe istenen birçok performansı sağlayabilme yeteneğinin yanı sıra, sistemin sağladığı yüksek randıman ve üretim sürecinin temizliğidir. BCF iplik üretim makinesi; dozajlama ve besleme, ekstrüzyon, filtrasyon, pompalama, eğirme, soğutma ve katılaştırma, spin-finish uygulaması, tekstüre, puntalama ve sarım aşamalarından oluşan entegre bir üretim teknolojisine sahiptir. Tekstüre ve puntalama işlemleri, BCF iplikleri konvansiyonel eriyikten çekim filament ipliklerden ayıran en önemli özelliklerdir. Ana üretim basamaklarında bir değişiklik olmamakla birlikte, kullanılacak hammaddeye göre proseste bazı farklılıklar gerekebilir. Örneğin, polipropilen polimeri için standart işlem adımları geçerliyken, poliamid kurutma sonrasında, polyester ise kristalizasyon ve kurutma işlemlerinin ardından makineye beslenerek üretime alınır [2-5].

Şekil 1. BCF iplik üretim makinesi [6]

BCF iplik üretimi, polimer cipslerin ekstrüdere beslenmesi ile başlar. Polipropilen polimeri genellikle eriyikten boyama metoduyla renklendirildiğinden, polimer cips ile masterbatch (pellet formdaki boyarmadde) ekstrüdere birlikte dozajlanarak beslenir. Polimerin bazı özelliklerini iyileştirmek adına kullanılması gereken yardımcı kimyasallar da (örneğin; UV stabilizatör), bu aşamada dozajlanır ve ekstrudere beslenir. Dozajlama volümetrik olarak da yapılabilmektedir, ancak daha kontrollü bir karışım imkânı sağladığından genel olarak gravimetrik yöntem tercih edilmektedir. Masterbatch, istenen renk tonu ve derinliğine bağlı olarak, polimerin ağırlıksal olarak %1-4'ü kadar eklenir, daha yüksek oranlarda masterbatch eklentisi polimer eriyiğinde yabancı madde gibi davranacağından, polimerin fiziksel ve kimyasal özelliklerini değiştirir.

Şekil 2. Polimer cips (dozajlama) [7]

Ekstruderler kapalı kovan içeresinde dönen bir vida sistemi ile çalışır. Vida yivleri arasına dolan polimer cipsler vidanın dönmesiyle birlikte ileri doğru hareket ederken, artan ısı ve basıncın da etkisiyle eriyerek homojen bir polimer eriyiği elde edilir.

Şekil 3. Ekstrüder [7]

Ekstruderden çıkan polimer eriyiği, düzelere pompalanmadan önce çekim başlığına gelerek filtreden geçirilir. Burada amaç, polimer eriyiği içerisindeki olası yabancı maddelerin veya erimemiş partiküllerin uzaklaştırılarak düze deliklerinin tıkanmasını ve filament formunda yer alarak düzgünsüzlüğe neden olmasını önlemektir. Filtreden geçirilen polimer eriyiği ölçüm pompası vasıtasıyla düze başlığına gönderilir. Düze özellikleri, üretilecek filamentlerin çapı, kesit geometrisi ve iplik kesitindeki filament sayısı gibi parametrelere göre belirlenir. BCF iplikler genellikle 144, 180, 200 ve 240 filament sayıları ile üretilebilmekle beraber, güncel makine tasarımlarında 700 filamente kadar üretim imkânı sunulmaktadır. Ayrıca BCF iplikler, 500 dtex ile 6000 dtex (kablolu ipliklerde 12000 dtex değerine çıkılabilir) aralığında iplik numaralarında ve 1,5 dpf ile 40 dpf aralığında filament inceliklerinde üretilebilmektedir. BCF iplik üretiminde farklı geometriler de kullanılabilmekle birlikte, trilobal, yuvarlak ve delta en çok tercih edilen filament kesit şekilleridir. Öte yandan, BCF iplikler tek renk (monocolor) veya üç renk (tricolor) olarak üretilebilirler. Ancak, üç renk iplik üretiminde her renk için ayrı ekstruder ihtiyacı vardır. Farklı ekstrüderlerden gelen farklı renkteki polimer eriyikleri, yan yana konumlanmış düzelere beslenir ve filament üretimi gerçekleşir [5-9].

Polimer eriyiği düzelerden filament formunda çıkan bir sıvı kütlesidir ve soğutularak katılaşmak üzere soğutma kabininden geçirilir. Soğutma kabini birkaç metre uzunluğundadır ve ortam sıcaklığına yakın değerdeki üniform hava akışı ile filamentlerin kontrollü bir şekilde katılaşması sağlanır. Soğutma işlemi, ipliklerin kazanacağı mukavemet ve uzama özelliklerini doğrudan etkileyen bir unsurdur, çünkü eriyik haldeki polimerlerin molekül yapıları değişime oldukça müsaittir.

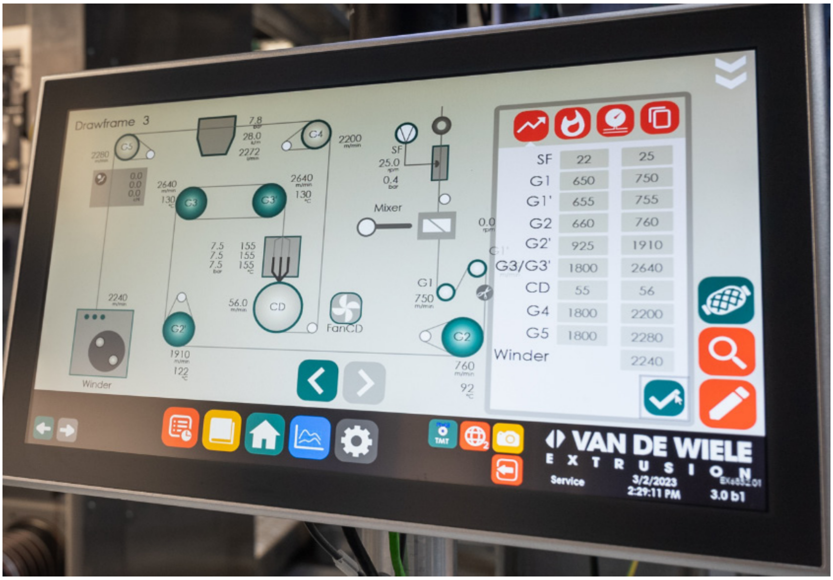
Şekil 4. Düzelerden çıkan filamentler (üç renk iplik üretimi) [6]

Şekil 5. Soğutma kabini [7]

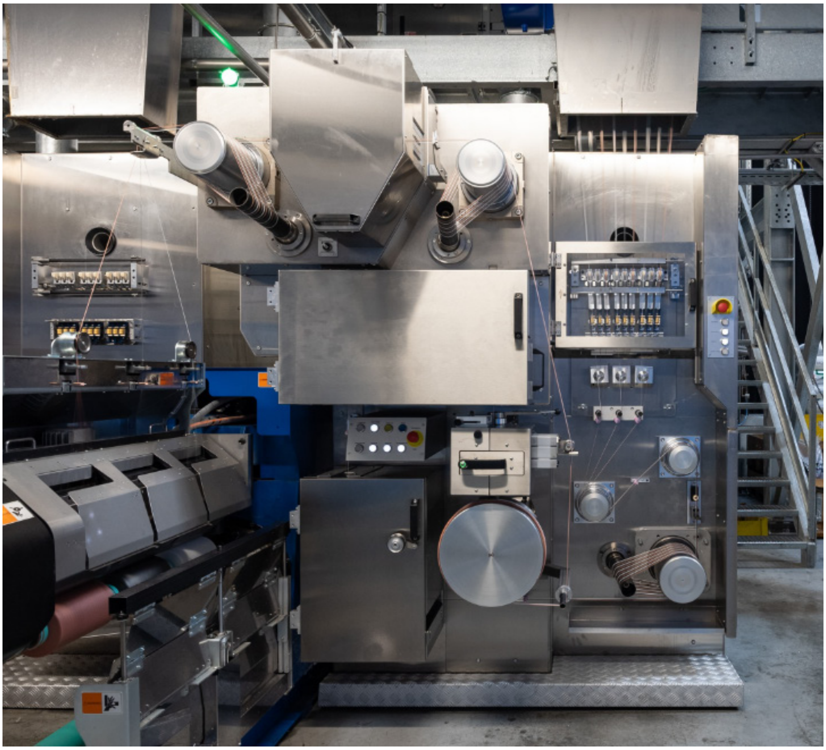
Kurutma bölgesinden katılaşarak ayrılan filamentlere spin-finish yağı uygulanır. Bu uygulamanın temel amacı, filamentler üzerindeki statik elektriklenmeyi önlemek ve filamentlerin sürtünme katsayılarını azaltarak elyaf-elyaf ve elyaf-metal sürtünmelerinden kaynaklanabilecek deformasyonları engellemektir [2,9].

Şekil 6. Spin-finish uygulama bölgesi [7]

Spin-finish uygulamasından sonra filamentler çekim bölgesine doğru hareket ederler. Kullanılan hammaddeye göre, filamentler 2,5-4 çekim oranında çekilerek polimerin moleküler yönelimi iyileştirilir ve böylece uzama değeri azalırken mukavemet artar. BCF makinelerinde çekim işlemi, godet adı verilen silindir çiftlerinde (duo silindirler) gerçekleştirilir ve temel prensibi silindirler arası hız farkına dayanmaktadır. Çekim silindirleri ısıtma sistemine sahiptir ve kullanılan polimerin termal özelliklerine bağlı olarak godet sıcaklıkları farklılık gösterebilir. Sıcak çekim işlemi ile filamentlerin gerilme esnasında deforme olması engellenirken, aynı zamanda filamentler bir sonraki işlem olan tekstüreye de hazırlanmaktadır [2, 8-10].

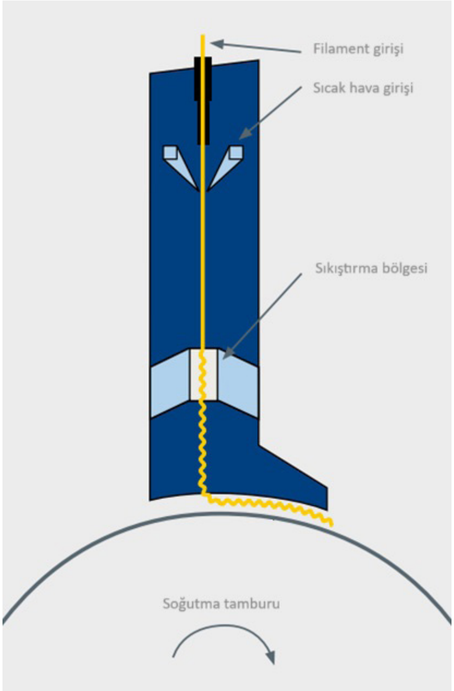


Şekil 8. BCF makinesinin şematik proses diyagramı [7]



Şekil 7. BCF makinesinin alt kısmı: spin-finish, 1.çekim, 2.çekim, tekstüre, soğutma tamburu, puntalama ve sarım bölgeleri [7]

Çekim işleminin ardından BCF ipliklerin en karakteristik özelliği olan hacim ve esnekliğin kazandırılabilmesi adına, filamentlere tekstüre işlemi uygulanır. BCF makinelerinde tekstüre işleminin temel prensibi, genellikle sıkıştırma kutusu veya yığma kutusu olarak tanımlanan tekstüre metoduna dayanmaktadır. Tekstüre ünitesine giren filamentlerin üzerine 150-160 ºC aralığında ve 5-6 bar basınçta sıcak hava gönderilir, ardından jetin alt kısmında filamentler sıkıştırılarak bir tıkaç oluşumu sağlanır. Oluşan bu yığın sebebiyle, filamentlerin lineer yapıları bozulur ve zig-zag yapıda iki boyutlu bir yapı kazanırlar. Bu fiziksel deformasyon neticesinde filamentler ve dolayısıyla BCF iplikler hacim, esneklik ve yumuşaklık gibi en önemli özelliklerini kazanırlar.



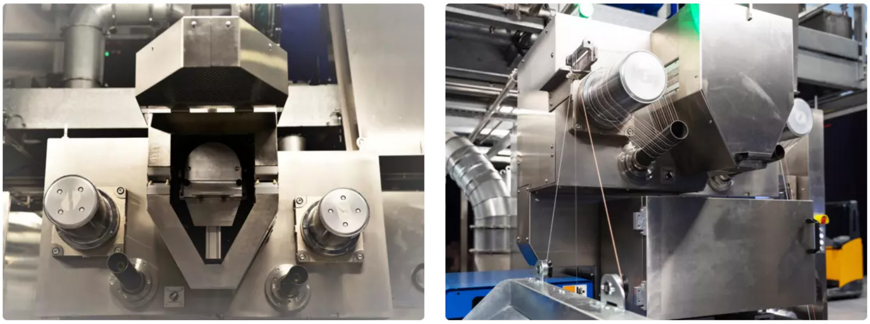
Şekil 9. Tekstüre işlemi şematik gösterimi (yığma kutusu/sıkıştırma metodu) [6]

Filamentlerin kazandıkları tekstüre efektinin fikselenebilmesi için, tekstüre ünitesinin hemen alt kısmında bir soğutma tamburu yer almaktadır. Sıcak haldeki kıvrımlı filamentler, çapı makine tasarımına göre 40-80 cm aralığında değişen bir soğutma tamburu üzerinden geçirilerek ortam havası ile soğutulur ve tekstüre efekti filamentlere fikselenir. Ardından tekstüreli filamentler puntalama işlemine geçer [2,5,7,8].

Şekil 10. Tekstüre ünitesi ve soğutma tamburu [7]

BCF makinesinde, büküm yerine puntalama ile iplik formuna getirilir. Gerekli olması halinde ise büküm, harici bir büküm makinesinde BCF ipliklere ayrı bir işlem olarak uygulanabilir. Puntalama işlemi, bir hava jeti içerisinden geçirilen filamentlere 6-8 bar basınçta soğuk havanın kesikli ve dikey bir şekilde püskürtülmesiyle, filamentlerin belirli noktalardan birbirlerine dolaşarak punta noktaları oluşturması ve ipliğe gerekli kohezyonun sağlanması esasına dayanır. İpliklerin punta sayısı müşteri talebi doğrultusunda değişmekle birlikte genelde 30-40 tur/m olacak şekilde uygulanır.

Şekil 11. İplikte punta noktası [6]



Şekil 12. Puntalama bölgesi [7]

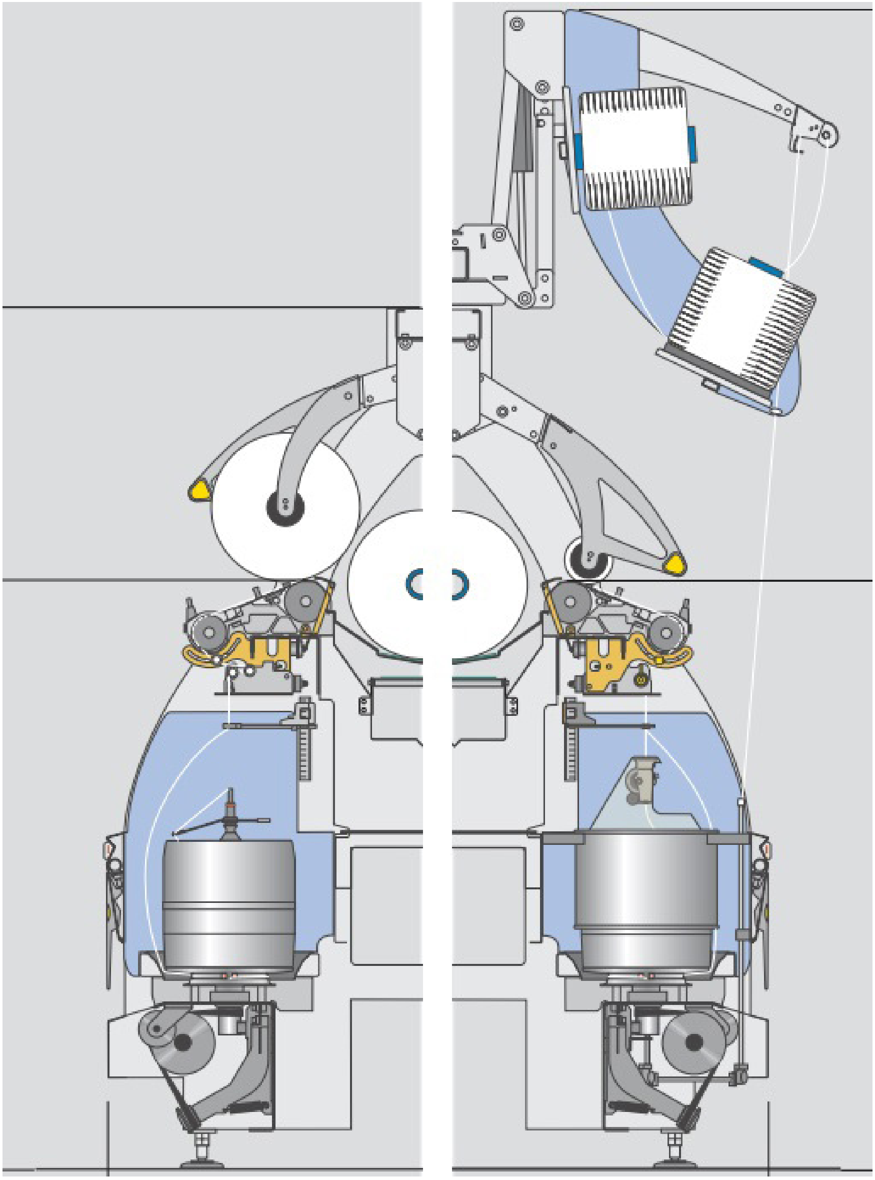
Puntalama işlemi ile birlikte üretim prosesi tamamlanan BCF iplikler, sarım hızı 3700 m/dk'ya ulaşan yüksek hızlı sarıcılar tarafından bobinlerine aktarılır. Makine tasarıma göre iki veya üç adet bobin yan yana sarılabilmektedir [2,7,8].

Şekil 13. Bobin sarım bölgesi [7]

3. Kablolama (Katlama) ve Büküm Makineleri

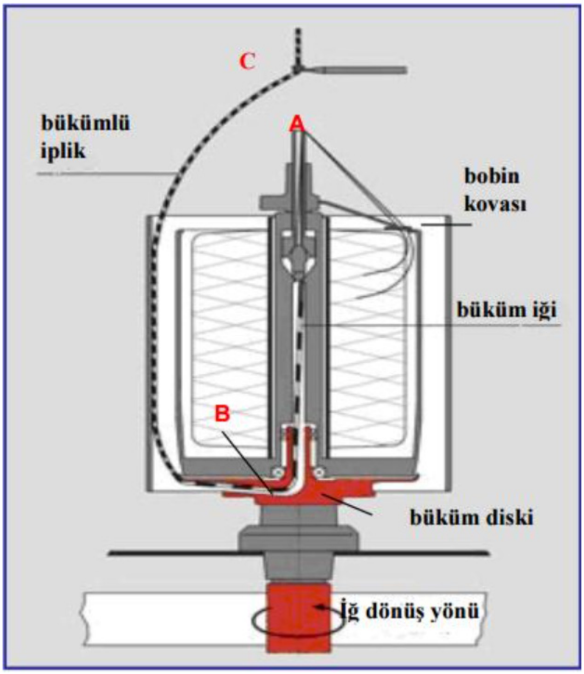
BCF makinesinden çıkan puntalı BCF iplikler, talep doğrultusunda kablolama ve büküm işlemlerinden geçirilebilir. BCF iplikçiliğinde, bükümsüz tek kat ipliklerden çift katlı iplik üretimi için doğrudan kablolama ifadesi kullanılır. Doğrudan kablolama işleminde iki iplik birbiriyle bükülür, ancak iplikler kendi yapılarında bükülmezler. Sistemin çalışma prensibi; iğe yerleştirilen besleme ipliği bobininden herhangi bir bükülme olmadan eksenel olarak sağılan iplikle, ikinci bobinden bir mil içerisinde sağılan ipliğin balon oluşturarak bir noktada birleşmesi ve birlikte bükülmesi esasına dayanır.

Şekil 14. Kablolama işleminin temel prensibi [2]



Şekil 15. Büküm makinesi (sol) ve kablolama makinesi (sağ) şematik gösterimi [11]

Kablolama işlemi yapılmadan da tek kat puntalı BCF ipliğe büküm verilebilir. BCF ipliklerin büküm işlemi genellikle two-for-one olarak adlandırılan makinelerde gerçekleştirilmektedir. Two-for-one makinesinin temel prensibi, iğin her devrinde ipliğe iki büküm verilmesi esasına dayanır. Şekil 16'da gösterildiği üzere, tek kat iplik bobininden sağılan iplik, üstten içi boş büküm iğine girer (A noktası) ve dönen iğin içinden geçerken ipliğe birinci büküm verilir (A ve B noktaları arası). Ardından, iğin içindeki iplik alt kısımda büküm diskinden (B noktası) çıkarak kova içerisinde yukarı doğru sevk edilirken ikinci büküm verilir (B ve C noktaları arası). Bükümlü iplik, daha sonra makinenin üst kısmında bobine sarılır.



Şekil 16. Two-for-one prensibine göre büküm oluşumunun şematik gösterimi [12]

Büküm verilmiş BCF iplikler daha kompakt bir yapıya sahip olduklarından, hav ipliklerinin dokuma esnasında dağılmaması ve halıların hav yapılarının daha stabil olması gibi avantajları söz konusudur. Ayrıca, hav ipliklerinin nokta efekti daha yüksek olacağından, halı yüzeyinde desenin daha belirgin görülmesi sağlanır. Tek kat BCF iplikler için 40-700 tur/m, çift kat (kablolu) BCF iplikler içinse 20/350 tur/m büküm değerlerinde çalışılabilmektedir [2,3,11].

4. Frize Ünitesi

BCF iplik üretim hattında frize ünitesi opsiyonel olarak yer alır ve fikse (heat-set) makinesinin hemen ön tarafında konumlandırılır. Frize işlemi, bükümlü BCF ipliklerin (tek iplik veya katlı iplik olabilir) bir sıkıştırma kutusunda, önce belirli bir sıcaklık ve basınç altında sıkıştırılması, ardından buhar verilerek ipliklerin kıvırcıklandırılması prensibine dayanır. Frizeli iplikler, oldukça yüksek bir bukle ve dalga efektine sahip olduklarından, frize ünitesinden çıktıktan hemen sonra fikse işlemine tabi tutulurlar.

Şekil 17. Frize ünitesinden çıkan iplikler

Frizeli iplikler bukleli yapılarından dolayı yüksek hacim ve yumuşaklığa sahiplerdir, ayrıca halılarda yüksek örtme faktörü gösterirler [2,4,13].

Şekil 18. Bükümlü iplik (sol) ve frizeli iplik (sağ) [13]

4. Fikse (Heat-Set) Makinesi

Fikse (heat-set) makinesi, BCF iplik üretim hattının son aşamasıdır. Kablolama/büküm ve frize işlemlerinden geçen BCF ipliklerin fiziksel yapılarını sabitleme amacıyla yapılan ısıl işleme fikseleme denir. Temel prensibi, konveyör bantlara yerleştirilerek bir tünel sistemi içerisinden geçirilen ipliklere ısı uygulanmasıdır. Fikseleme işlemi makine tasarımına bağlı olarak kuru sıcak hava ortamında gerçekleşebildiği gibi, alternatif metot olan sıcaklık ve basınç altında doymuş buhar atmosferinde yapılan termofiksaj yönteminin daha çok tercih edildiği söylenebilir. Fikse makinesinde ipliğe uygulanan termal işlemin etkinliğini belirleyen bir takım parametreler vardır. Bu parametrelerden en önemlisi ipliği oluşturan polimerin yumuşama ve erime sıcaklığı gibi termal davranışlarıdır. Bu durum göz önüne alınarak belirlenmesi gereken en önemli unsur tünel sıcaklığıdır. Ayrıca tünel basıncı, tünelde bekleme süresi ve konveyör bant hızı gibi faktörler de termofiksajın etkinliğini belirleyen diğer önemli hususlardır [2,4,5,13,14].

Tablo 1. Hammadde türüne göre fikse işlem parametreleri [13]

Polimer	Tünel Sıcaklığı °C	Bekleme Süresi (s)
Poliamid 6	120-126	30-60
Poliamid 66	130-135	30-60
Polipropilen	125-135	30-60
Polyester	140-145	35-90

Fikseleme işlemi sonrası ipliğin dayanıklılığı ve boyutsal kararlılığı artar. Ayrıca, ısı ve buharın etkisiyle, ipliğin önceki işlemlerde üzerine yüklenen gerilimler ortadan kaldırılacağından, iplik yumuşaklığı ve hacimliliği artarken, halıda nokta efektinin ve hav ipliklerinin rezilyans performanslarının da iyileştiği söylenebilir [13,14].

Şekil 19. Fikse makinesi

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14. https://superba.com/en/machines/dhs3

BÖLÜM 2

WİLTON HALI ÜRETİM TEKNOLOJİSİ

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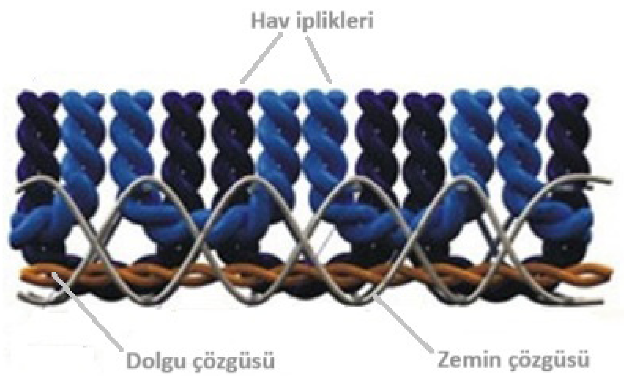
1. Giriş

Halı, zemin döşemesi olarak kullanılan bir tekstil yüzeyidir. Üretim metoduna göre yapısal farklılıklar göstermekle beraber, makine dokuması halılar genellikle atkı, çözgü ve hav ipliğinden oluşan üç boyutlu konstrüksiyona sahiplerdir. Hav ilmeleri, el halılarında düğüm biçimde oluşturulurken, makine halılarında genellikle atkı iplikleri arasına "U" veya "V" biçiminde yerleştirilir. Makine halıcılığı sektöründe Wilton dokuma en yaygın kullanılan üretim tekniğidir. Bu teknikle üretilen makine halıları; zemin çözgüsü (gevşek çözgü), dolgu çözgüsü (berk çözgü), hav çözgüsü ve atkı ipliğinden oluşmaktadır [1,2].



Şekil 1. Wilton halı yapısı

2. Wilton Dokuma Halılarda Kullanılan İplikler

2.1. Zemin Çözgüsü (Gevşek Çözgü)

Halının zemin dokumasını oluşturan zincir çözgülerdir. Halı yapısı içerisindeki gerginlikleri, dolgu çözgüsüne göre daha düşük olduğundan işletmelerde gevşek çözgü olarak adlandırılırlar. Zemin çözgüsünde pamuk, polyester veya polipropilen iplikleri tek başına veya karışım olarak kullanılabilirler [1-3].

2.2. Dolgu Çözgüsü (Berk Çözgü)

Dolgu çözgüleri, halıya boyutsal stabilite ve ağırlık kazandırma amacıyla kullanılırlar ve halı zemin yapısı içerisinde hiçbir iplik grubuyla kesişim yapmadıkların dolayı halının alt ve üst yüzeylerinde görünmezler. Halı yapısında, zemin çözgülere göre daha yüksek gerginlikte olduklarından, berk çözgü olarak da tanımlanırlar. Dolgu çözgüsü olarak pamuk, polyester veya polipropilen iplikleri tek başına veya karışım olarak kullanılmaktadır [1-3].

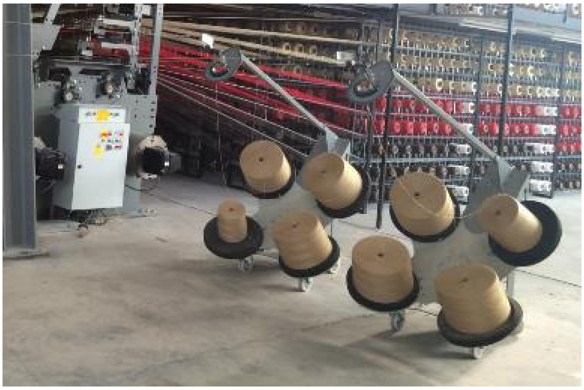
Şekil 2. Zemin, dolgu ve hav çözgüleri

2.3. Hav Çözgüsü

Hav iplikleri halı yapısının en önemli bileşenidir ve dokumaya çözgü yönünde dâhil olurlar. Hav çözgülerinin gerginliği diğer çözgülerden daha düşüktür. Hav ipliği materyali olarak yün elyafı üstün özellikleri sebebiyle her daim popüler olmuştur, ancak yüksek maliyeti ve sınırlı üretiminden dolayı, makine halıcılığında daha çok akrilik, polipropilen, polyester ve poliamid gibi sentetik polimerler daha ön plana çıkmaktadır. Ayrıca, hav iplikleri BCF, High-Bulk, DTY gibi farklı iplik üretim teknikleri ile üretilmektedir [1-4].

2.4. Atkı İpliği

Atkı iplikleri, örgü yapısına göre zemin çözgüsüyle kesişim yaparak halının zemin dokumasını oluşturan ve hav çözgülerinin yerleşimini sağlayan iplik grubudur. Genellikle sert ve dolgun yapısı nedeniyle jüt ipliği tercih edilmekle beraber, pamuk ve polipropilen iplikler de kullanılmaktadır [1-5].



Şekil 3. Jüt atkı iplikleri

3. Wilton Halı Dokuma Makinesi

Wilton tipi halı dokuma makineleri, zemin çözgüleri için armür mekanizmasından, hav çözgüleri içinse jakar mekanizmasından tahrik edildiğinden dolayı, ileri dokuma sistemi olarak tanımlanır. Makinenin temel hareketleri, konvansiyonel dokuma makinelerinde olduğu gibi çözgü salma, ağızlık açma, atkı atma, tefeleme ve halı sarma işlemlerinden oluşur.

Şekil 4. Wilton tipi halı dokuma makinesi

Cağlık, dokuma makinesine hav ipliklerini besleyen bobinlerin dizildiği bir raf sistemidir. Bobin dizilimi, dokunacak halının renklerine göre yapılır. Cağlıktaki renk diziliminin değişimi üretim kaybına neden olacağından ve uzun işçilik süresi gerektirdiğinden, zorunlu olmadıkça yapılmaz. Bu sebepten planlama departmanı üretim planlaması yaparken cağlıktaki mevcut renk dizilimini göz önünde bulundurur. İplik bobinleri cağlık üzerindeki bobin iğlerine renk sırasına göre dizilirler. Cağlık kapasitesi, tarak numarası, makine eni ve renk sayısı dikkate alınarak aşağıdaki eşitlik doğrultusunda belirlenir.

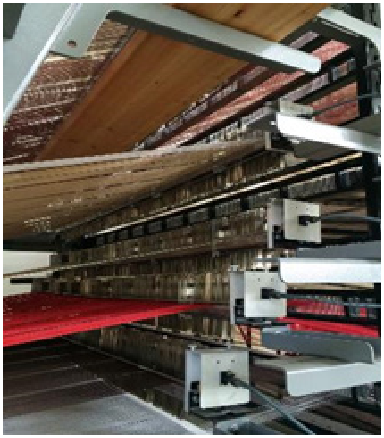
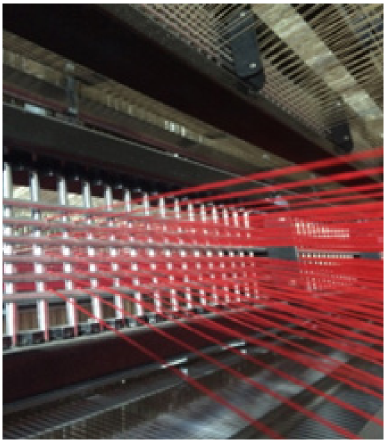
Cağlık kapasitesi = Tarak numarası × Makine eni (dm) × Renk sayısı [3,5,6].

Şekil 5. Cağlık

Cağlıktaki bobinlerden sağılan hav çözgülerine gerekli iplik gerginliğinin sağlanabilmesi için bobinlere ağırlıklar takılır ve iplik numarası ile bobin çapına göre değişiklik gösterir (Şekil 6). Ağırlıklar olmadığında hav çözgüleri halının yapısına gevşek bir şekilde dâhil olacağından, halıda dalgalanma söz konusu olabilir. Hav çözgülerinin gerekenden fazla bir gerginliğe sahip olması durumunda ise iplik kopuşları ve düşük hav yüksekliği (çökme hatası) görülebilir [3].

Şekil 6. Ağırlıklar

Cağlıktaki bobinlerin düzgün bir şekilde sağılabilmesi için hav iplikleri hav süzgecinden geçerler. Süzgecin her gözünden bir hav ipliği geçer. Bu süzgeçler sayesinde hav iplikleri birbirine dolaşmadan dokuma bölümüne taşınırlar.

Şekil 7. Cağlıktaki hav süzgeçleri

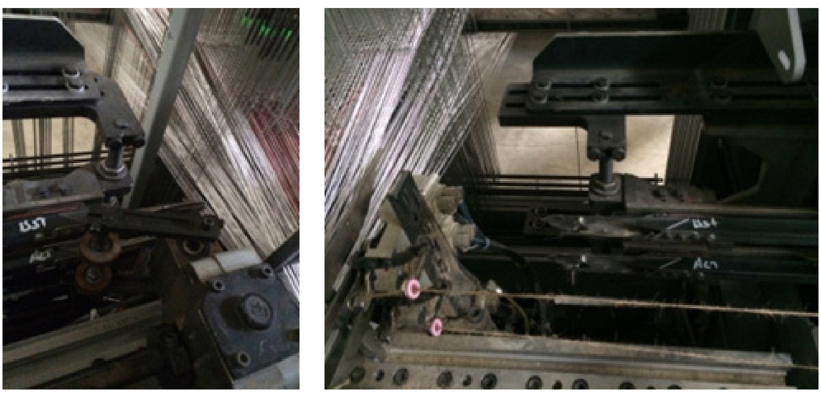
Zemin ve dolgu çözgüleri makineye farklı leventlerden beslenirler ve hareketleri armür mekanizması tarafından kontrol edilerek çerçeveler vasıtasıyla gerçekleştirilir. Dolgu çözgülerinin gerginliklerinin, zemin çözgülerinden daha fazla olması gerekir ve bu sebepten dolgu çözgü levendi tezgâhın dokuma bölümüne daha yakın konumlandırılır. Leventlerden alınan çözgüler, ipliklerin karışmasını ve kaymasını engellemek amacıyla önce çapraz çubuklardan, sonra iplik kopuş kontrolünü sağlayan lamellerden geçirilip dokuma bölgesine sevk edilirler. Cağlıktan beslenen hav çözgülerinin ise tahrik mekanizması jakar sistemidir ve her bir hav çözgüsü bir harniş ipi tarafından kontrol edilir. Jakar sistemi tezgâhın üst kısmına konumlandırılır ve gerektiğinde ikinci jakar mekanizması yerleştirilerek desen kapasitesi arttırılır [1-3].


Şekil 8. Armür ve jakar mekanizmaları

Yüz yüze halı dokuma makinelerinde alt ve üst halı arasındaki mesafenin ayarlanarak hav yüksekliğinin belirlenebilmesi için dokunacak halının hav yüksekliğine göre farklı enlerde lansetler kullanılır. Lansetler, tezgâha her tarak dişine bir tane olacak şekilde yerleştirilir ve dolayısıyla makine enine ve tarak numarasına göre kullanılacak lanset sayısı belirlenir [1-3].

Şekil 9. Wilton yüz yüze halı sisteminde kullanılan lansetler

Halı dokuma işleminin gerçekleşebilmesi için açılan ağızlığa atkı atımı rapier vasıtasıyla yapılır. Wilton tipi halı dokuma makineleri tek rapierli, çift rapierli veya üç rapierli olmakla birlikte sektörde yaygın olarak iki ve üç rapierli sistemler kullanılmaktadır. Dokunacak halının kalitesine ve tarzına bağlı olarak her birinin kendine özgü avantajı vardır [1,2,5,6].



Şekil 10. Çift rapierli atkı atma mekanizması

Şekil 11. Üç rapierli atkı atma mekanizması

Atkı atma ve tefeleme işlemleri sonrasında dokuma prosesi tamamlanan halılar, taşıma arabasına yüklenerek konfeksiyon bölümüne gönderilir.

4. Wilton Halı Dokuma Teknikleri

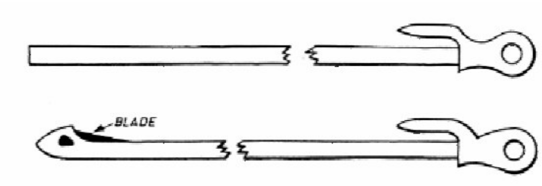
Wilton tipi halılar, üretim yöntemlerine göre tel çubuklu ve yüz yüze olarak ikiye ayrılmaktadırlar.

4.1. Tel Çubuklu Wilton Sistemi

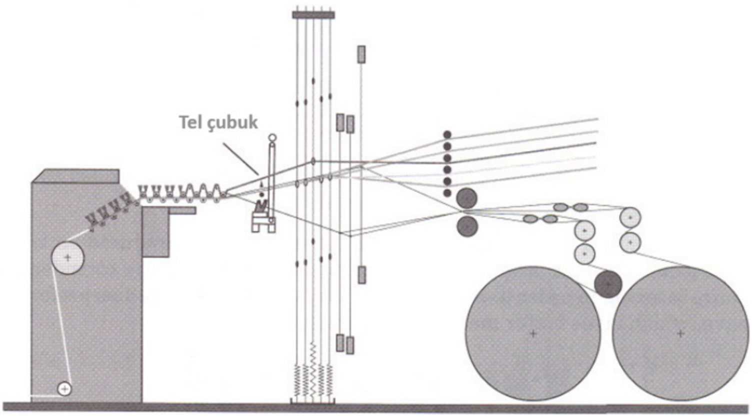
Tel çubuklu Wilton sisteminde dokuma işlemi, ağızlık içerisine atılan tel çubuklar vasıtasıyla gerçekleştirilir. Açılan ağızlık içerisine yerleştirilen tel çubuklar üzerinde bağlantı kuran hav çözgüleri, tellerin ağızlık içerisinden geri çekilmesi ile hav ilmelerini oluşturur. Tel çubukların kesiti ilme sıklığını ve yüksekliğini belirleyen önemli bir faktördür [5,6].

Şekil 12. Tel çubuklu Wilton sistemi

Tel çubuklu Wilton sisteminde, ağızlığa yerleştirilen tel çubukların düz veya bıçaklı olmasına bağlı olarak, bukle havlı veya velür (kesik) havlı halılar üretilebilmektedir.



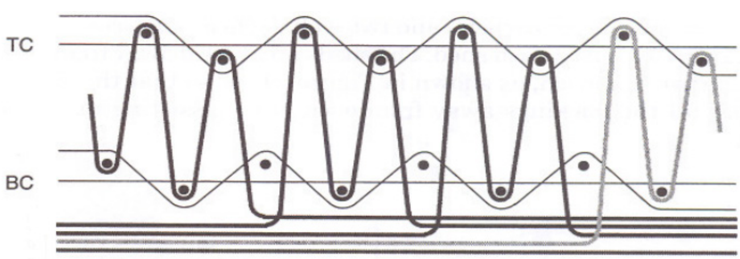
Şekil 13. Düz ve bıçaklı tel tipleri



Şekil 14. Tel çubuklu Wilton sistemi

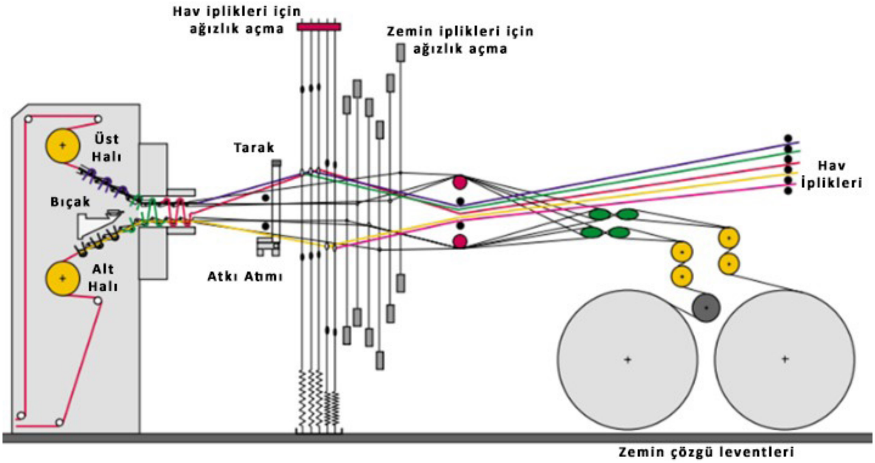
4.2. Yüz Yüze (Face to Face) Wilton Sistemi

Bu sistemde, iki ayrı zemin dokuma arasında hav iplikleri bağlantı kurar ve eş zamanlı olarak iki halı dokunur. Dokuma sonrası oluşan çift kat arasındaki havlar ortadan kesilerek alt halı ve üst halı olarak tanımlanan iki ayrı halı elde edilir. Halılar ayrı olmasına rağmen aynı desene sahiplerdir. Yüz yüze dokuma tekniği, tel çubuklu sisteme göre daha yüksek verimliliğe sahiptir. Şekil 15'te temel yüz yüze halı yapısının şematik gösterimi verilmiştir [1].



Şekil 15. Yüz yüze halı dokuma yapısı

Yüz yüze halı dokuma sistemi ile dokunan halıların hav yüksekliği, iki zemin dokuma arasındaki mesafenin yarısı kadardır. Alt ve üst halılar arasındaki hav çözgülerinin kesimi makine eni boyunca hareket eden bir bıçakla gerçekleştirilir.

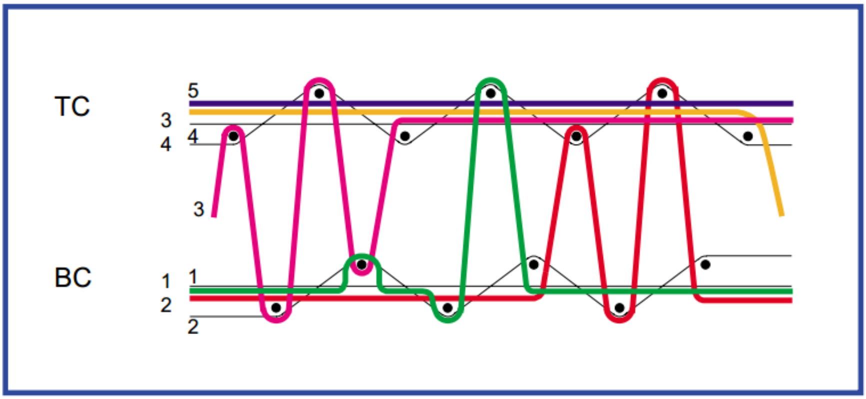


Şekil 16. Yüz yüze wilton halı dokuma

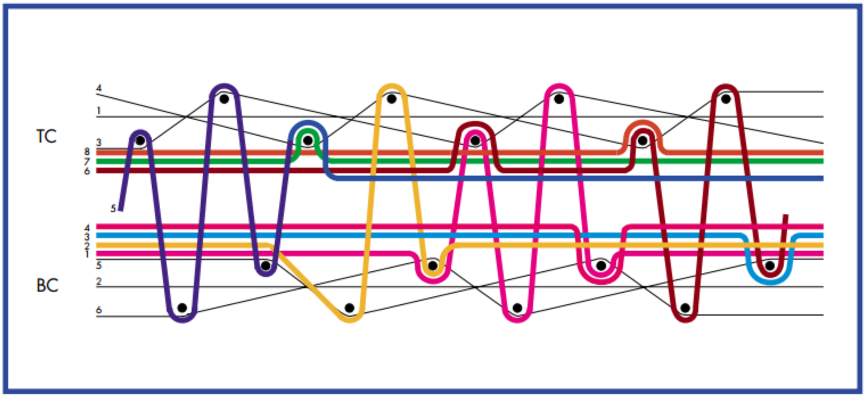
Yüz yüze halı dokuma sisteminde hav bağlantı yapıları, tek rapierli, çift rapierli ve üç rapierli sistemler vasıtasıyla, her hav ipliği için tek atkı (1/1 V), çift atkı (1/2 V) veya üç atkı (1/3 V) atımlı (shot) olacak şekilde yapılabilir. Örneğin; tek rapierli sistemle dokunan 1/1 V bağlantı yapısında her atkıya bir hav bağlantısı gerçekleşir ve bu yapıda üretim hızı fazla, ilmek yoğunluğu ise yüksektir. Ancak hav çözgüleri sürekli bağlantı yaptığından hav ipliği sarfiyatı fazladır. Çift rapierli atkı atımı tek rapierli sisteme göre daha yüksek verimliliğe sahipken, üç rapierli atkı sistem ise en yüksek atkı atım oranına sahiptir [1,2].

4.2.1. Tek Rapierli Atkı Atım Sistemi (Tek Shot)

Tek rapierli sistemlerde dokunan 1/1 V örgü yapısı, makinenin her bir devrinde bir atkı atımı, atkı ipliğinin sırasıyla alt ve üst halıya yerleştirilmesi ile gerçekleştirilir. Açılan her ağızlığa atılan her bir atkı ipliği ile bir hav ipliği bağlantı yaparak hav ilmesini oluşturur ve tefeleme hareketi sonrası bir hav sırası oluşur. Dolayısıyla, makinenin her devrinde bir hav sırası oluştuğundan, hav sıklığı yüksek yoğun halılar üretilebilir [1,2,7].



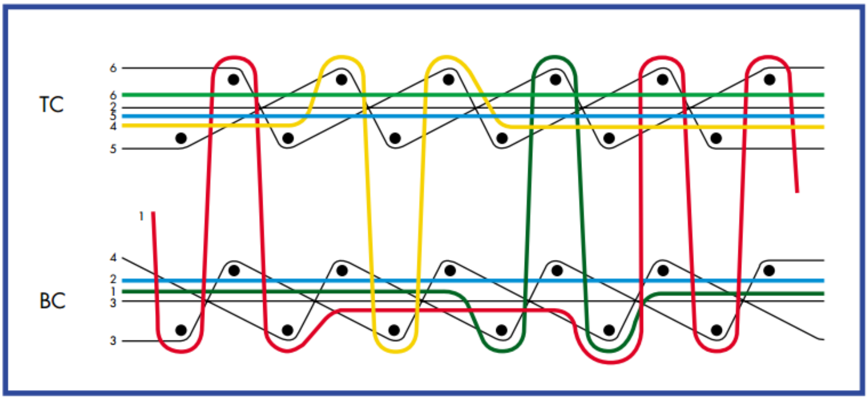
Şekil 17. 1/1 V bağlantılı halı kesiti



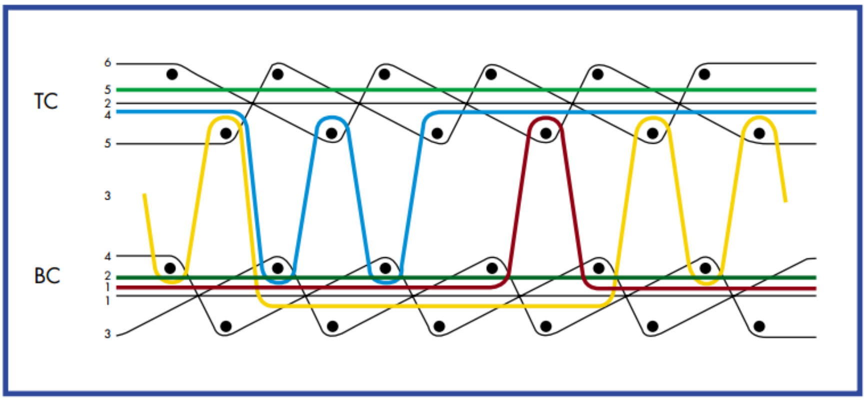
Şekil 18. 1/1 V bağlantılı halı kesiti

4.2.2. Çift Rapierli Atkı Atım Sistemi (Çift Shot)

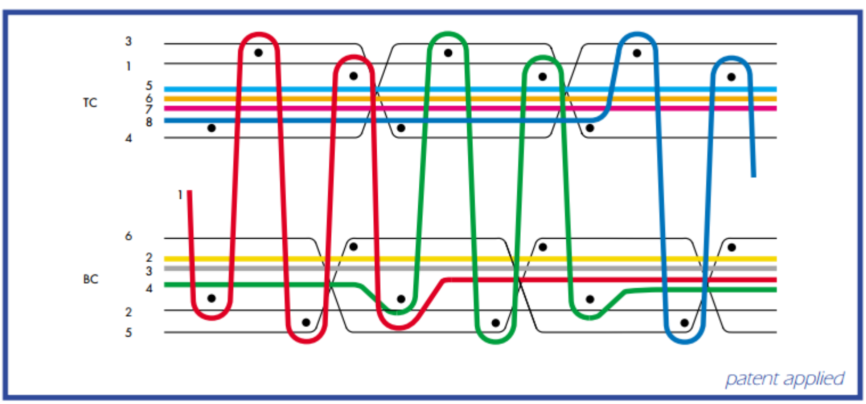
Çift rapierli sistemlerde, aynı anda bir alt halı için bir de üst halı için ağızlık açılır ve rapierler tarafından her bir ağızlığa eş zamanlı birer atkı atımı gerçekleştirilir. Böylece, her iki atkı atımında bir hav sırası oluşur ve dokunan yapı 1/2 V bağlantı yapısı şeklinde tanımlanır. Ancak, daha yüksek sıklıkta halılar üretebilmek adına, çift rapierli sistemlerde boş atkı atımı yapılarak (sırasıyla bir alt halı ve bir üst halıya atkı atımı yapılmaması), 1/1 V bağlantı yapısı ile dokuma yapılabilir. Çift rapierli atkı atım sistemlerinde dokunabilen örgü yapıları Şekil 19-21'de gösterilmektedir [1,2,7].



Şekil 19. 1/2 V bağlantılı halı kesiti



Şekil 20. 1/2 V bağlantılı sırtta görülmeyen halı kesiti



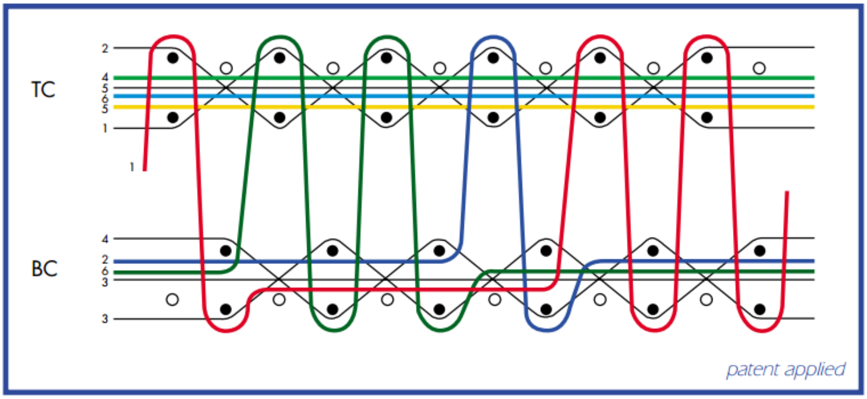
Şekil 21. 1+1/2 V bağlantılı halı kesiti

4.2.3. Üç Rapierli Atkı Atım Sistemi (Üç Shot)

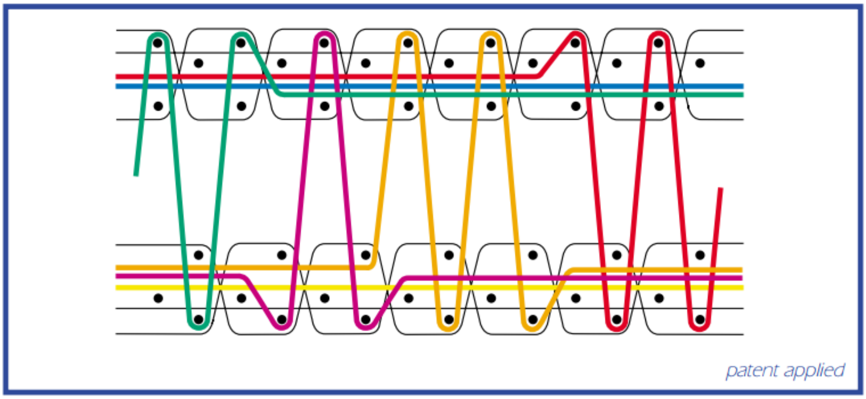
Üç rapierli atkı atım sistemleri, tek ve çift rapierli sistemlere göre daha geniş çeşitlilikte örgü yapıları (1/2 V, 1/3 V, 2/3 V, 2/2 V, 1+2/3 V, 1+1/2 V) oluşturma ve üretimi artırma imkânına sahiptir. Bu sistemlerde, makinenin her devrinde üç atkı atımı yapılabilmektedir. İki halı aynı anda dokunurken, biri alt halı, biri üst halıya ait olan iki ağızlık oluşturulur. Alt ve üst rapierler karşılık gelen halıların ağızlıklarına atkı atımı gerçekleştirirken, orta rapier sırasıyla bir alt halıya, bir üst halıya olacak şekilde atkı atımı yapar (2/3 V bağlantı yapısı). Böylelikle, her bir halı için iki devirde üç atkı atımı sağlanır. Bu durum, üç rapierli sistemlerde üretimin çift rapierli sistemlere kıyasla %50 daha fazla olmasını sağlar.

Üç rapierli sistemlerde, rapierlerin atkı atım düzenleri değiştirilerek (dönüşümlü atkı atımı, eş zamanlı atkı atımı veya rapier kapama) çeşitli yapılar dokunabilir.

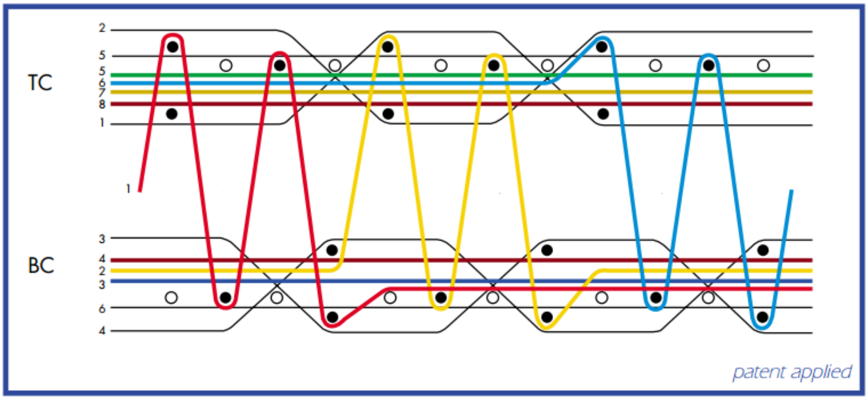
- Tek rapierli bağlantı yapıları: Orta rapier kullanılmazken, alt ve üst rapierler sırasıyla atkı atımı gerçekleştirir (1/1 V).
- Çift rapierli bağlantı yapıları: Orta rapier sürekli atkı atımı yaparken, alt ve üst raiperler sırasıyla kapatılarak atkı atımı gerçekleştirir (2/2 V).
- Üç rapierli bağlantı yapıları: Alt ve üst rapierler sürekli atkı atımı yaparken, orta rapier sırasıyla alt ve üst halıya atkı atımı gerçekleştirir (2/3 V) [1,2,7].



Şekil 22. 2/2 V bağlantılı halı kesiti

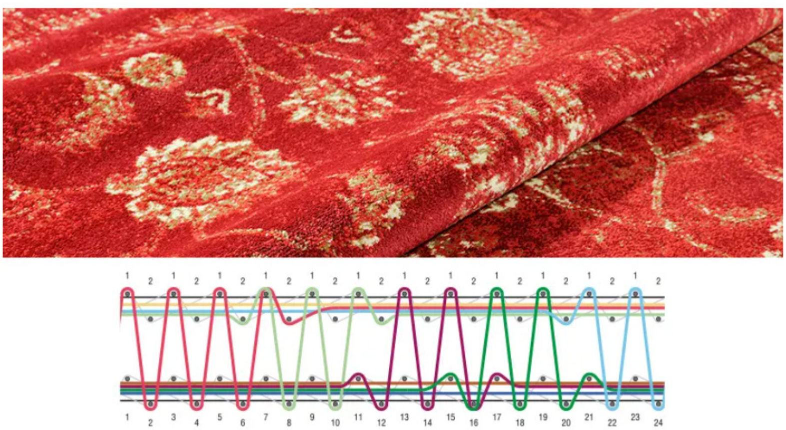


Şekil 23. 2/3 V bağlantılı halı kesiti

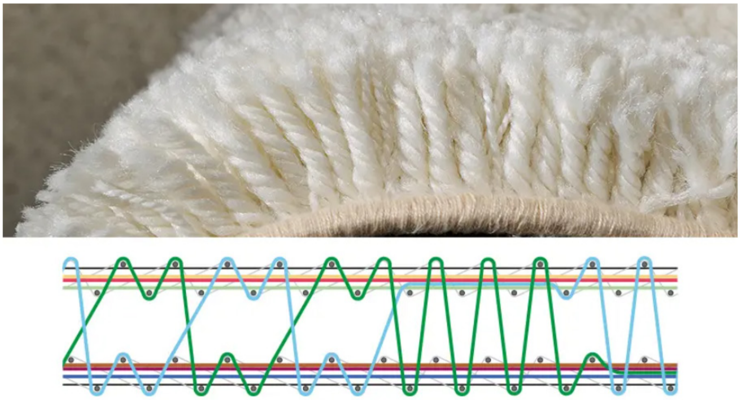


Şekil 24. 1+2/3 V bağlantılı halı kesiti

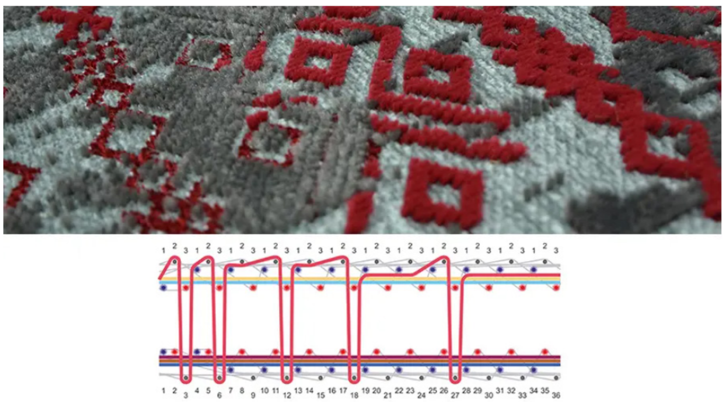
5. Wilton Halı Dokumacılığında Kullanılan Örgü Yapıları



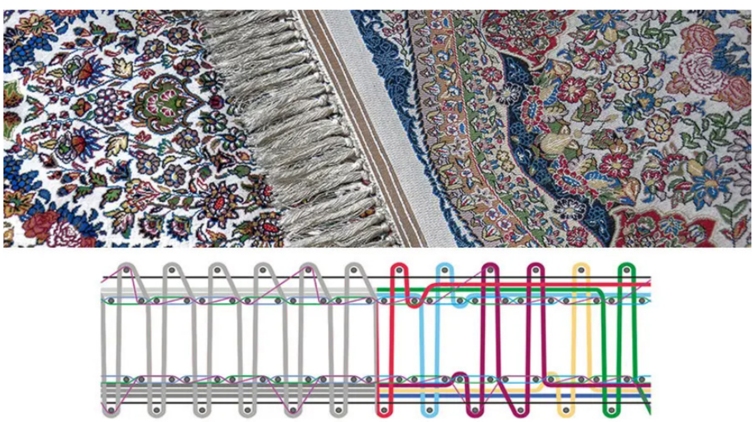
Şekil 25. Standart halı dokuma örneği
(Standart / Staubli) [8]



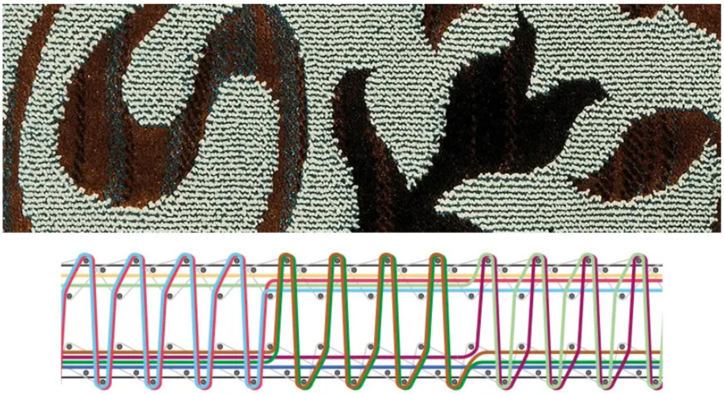
Şekil 26. Shaggy halı dokuma örneği
(Shaggy / Staubli) [8]



Şekil 27. Farklı yüzey efektlerine (havlı&havsız) sahip halı dokuma örneği
(Magic weft effect duo / Staubli) [8]



Şekil 28. Yüksek tarak sıklığındaki gelenek halı dokuma örneği
(Traditional carpet effect / Staubli) [8]



Şekil 29. Çift havlı halı dokuma örneği
(Mega / Staubli) [8]

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BÖLÜM 3

CUT RESISTIVE PROTECTIVE GLOVES WITH IM-PROVED COMFORT PROPERTIES

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Introduction

Protective textiles are the technical textile materials manufactured and employed for people who work in hazardous environment, such as laboratories, hospital, battlefield, rescue, or industrial applications. Protective clothing is a subset of personal protective equipment (PPE) which is defined as "all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects the person against one or more risks to that person's health or safety, and any addition or accessory designed to meet that objective" (The Personal Protective Equipment at Work Regulations; 1992).

Protective functional textiles focus on sophisticated protection needs rather than simply protecting our body from the surrounding and provides protection against cuts, impacts, abrasion, stabs, explosions, flame, foul weathering, extremely high or low temperatures, high voltage, harmful dust and particles, and nuclear, biological, chemical, and hazardous materials. (Rasheed, 2020; Paul, 2019).

Protective clothing can be categorized according to the part of the body it protects. First category comprises the clothing which covers the whole body or the torso, such as bunker suits, lab coats, coveralls, gowns, lifejackets, bulletproof vests, safety harnesses, and aprons. Pants, chaps, gaiters, booties, and boots are used for the protection of the legs and feet while gloves and arm guards offer protection to the arms and hands. Hoods and balaclavas, on the other hand, serve for the head. Other types of PPE aside from protective clothing include respirators, goggles, face shields, helmets, and ear muffs (Dolez, Marsha & McQueen, 2022).

According to the estimates of the International Labour Organization (ILO), nearly three million workers die every year due to work-related accidents and diseases. This figure corresponds to an increase of more than 5% from 2015 to 2023. Most of these fatalities stem from work-related diseases and about 11% of the deaths are caused by the work accidents. (Occupational safety and health, 2023). Due to the fact that hands are used for every task at work, they are more prone to be exposed to several hazards. Depending on the workplace, the hazards might be severe cuts or scratches, abrasions, punctures, chemical burns or absorption, exposure to extreme temperature, etc. (Ertekin & Ertekin, 2020). According to hand injury statistics reported by U.S. Bureau of Labor Statistics, there are 110,000 lost time cases due to hand injuries annually, 70% of workers who experienced a hand injury were not wearing gloves and another 30% of victims had gloves on, but they were damaged or inadequate for the work task. (Hand Safety and Injury Prevention Safety Talk, 2023).

Governmental policies, regulations and standards, which encourage corporations and individuals to take accountable measures for preventing hazardous events and accidents at worksites, increase the demand for protective clothing. The purpose of occupational health and safety studies is to try to prevent the occurrence of such situations by encouraging the use of protective equipment in the workplace.

Gloves offer the most protective solution for reducing accidents at the workplace by forming a physical barrier between the hazard and the skin. It is important to select the glove type appropriately considering the type of activity, objects utilized and environmental conditions. Together with protection, proper fit to hands and sleeve, flexibility and comfort are the issues that should be considered when selecting safety gloves.

Classification of Protective Gloves

The three main categories that the protective gloves can be classified into are generally considered as household, medical and industrial gloves (Phalen & Maibach, 2022).

- Household (or domestic) gloves are usually reusable, quite often with a flock coating comprising fibers to minimize discomfort due to hand sweating.
- Medical gloves are used during medical procedures and examinations for protecting the user from the spread of infection or illness and are disposable. They might be examination, surgical and procedure gloves.
- Industrial gloves are classified as Protective Personal Equipment and provide certain levels of protection against chemical, mechanical, biohazards, thermal, electrical, or radiation risks. They are mostly reusable and heavier than medical and household gloves. Most of the reusable gloves are laminated with an inner fabric liner that provide easy donning and certain level of comfort. This could also improve the cut-resistance performance of the gloves.

On the other hand, gloves are usually classified as types I or II and rarely as type III.

Type I gloves have simple design for minimal risk applications where Type II gloves are for intermediate risks with intermediate design (neither simple nor complex design). Type III gloves, on the other hand, have complex design for irreversible/mortal risks.

A comprehensive list of EN Standards exists for protective and medical gloves of different types and uses. According to the standards, protective gloves are tested against mechanical, hazardous chemicals & micro-organisms risks, air/water penetration, against thermal hazards, heat and/or fire, resistance to ionizing radiation, against vibrations, risk of electric shock, etc. (Phalen & Maibach, 2022; https://www.icmsafety.com/en/protection-guides/p-u/safety-gloves-guide/gloves-en-standards)

When selecting protective gloves in order to ensure they will offer appropriate protection, nature of the work being done, the working environment and any risks that may be created by wearing gloves, such as the risk of getting them trapped in machinery, should be considered. Accordingly, there are different types of gloves which provides;

- Mechanical Protection
- Chemical Protection
- Protection from Harmful Micro-Organisms
- Hot Thermal Protection
- Cold Thermal Protection
- Protection from Hand-Arm Vibration
- Electrical Protection
- Ionizing Radiation and Radioactive Contamination Protection
- Protection for Welding
- Multiple Hazards Protection (Yılmaz, 2022; Özen, 2016; Phalen & Maibach 2022).

Table 1 shows the pictograms and related standards for protective gloves as defined in TS EN ISO 21420 (2020) Protective gloves - General requirements and test methods standard.

Mechanical protection gloves provide protection against mechanical injuries and the resistance of the gloves are tested against wear, tear, puncture, cutting, and punching in accordance with the BS EN 388:2016+A1:2018- Protective gloves against mechanical risks standard. Protection against mechanical hazards is symbolized by a pictogram with a hammer symbols followed by four numbers (performance levels) then two letters. The higher the number, the higher the level of protection. Mechanical protection gloves are made of a combination of polyamide and polyurethane or made of a combination of kevlar and latex, etc.

Table 1. Pictograms and related standards for protective gloves

Pictogram	Meaning & Standard	Pictogram	Meaning & Standard
	Protection against mechanical hazards ISO 7000-2490		Protection against chemicals ISO 7000-2414
	Protection against micro-organism hazards ISO 7000-2491		Protection against heat and flame ISO 7000-2417
	Protection against cold ISO 7000-2412		Protection against the thermal effect of the electric arc IEC 60417-6353
	Protection against ionizing radiation ISO 7000-2809		Protection against static electricity ISO 7000-2415

Chemical and micro-organism protection gloves protect users from exposure to hazardous chemicals and micro-organisms. There is no single type of glove that provides protection against all chemicals and the type of glove material used depends on the chemical and the level of protection required. Protection against chemical hazards is measured by the time it takes for the chemical to leak into the glove. Gloves for hot thermal conditions are used against thermal hazards that occur at temperatures of 100°C or over. Requirements for such gloves provide protection against heat or flames. Gloves for cold thermal conditions, on the other hand, provide protection against convective and contact cold down to -50°C. Resistance to convective cold, resistance to contact cold and impermeability to water are important parameters for cold protection gloves. Anti-vibration gloves reduce vibrations transmitted to the hands and arms. Gloves for the electricians are made of latex of different thicknesses depending on the operating voltage for which they are applied. Gloves that reduce harmful radiation to hands contain a certain amount of lead and, gloves exposed to ionizing radiation can be tailored according to their behavior towards ozone depletion. Protective gloves for manual welding, cutting and related metal machining operations are identified as type A or type B where Type A gloves comply with higher protection requirements for heavy welding processes and Type B gloves offer more freedom of movement.

Manufacturing of Protective Gloves

According to the TS EN ISO 21420 (2020) Protective gloves - General requirements and test methods standard "The protective glove shall be designed and manufactured so that in the foreseeable conditions of use, the wearer can perform the activity as normally as possible with an appropriate protection. For reusable multilayer gloves, the gloves shall be able to be doffed without separation of the layers".

The properties and performance of protective glove's inner and outer surfaces are important for their intended purpose. The inner surface of a glove is expected to provide easy donning and comfort during usage. Thin and soft gloves, such as medical ones, can easily deform while donning. For easing donning and doffing of such gloves are provided by either applying a polymer coating onto the inner surface or by modifying the surface via chlorination.

Reusable (nondisposable) gloves are less prone to deformation since they are thicker and fit to the hand; therefore donning is normally less challenging.

In addition, most nondisposable gloves are laminated with an inner fabric liner made of cotton or synthetic fiber that provides better donnability and comfort. The outer surface of the protective gloves might be smooth or rough. The outer surface of the glove can be modified to decrease the natural tackiness of rubber materials and offer an adequate grip level to the users.

Off-line chlorination is widely used for this purpose as it offers a permanent modification. For some polymers which cannot be chlorinated, surface modification can be achieved through the specific formulation of the rubber (hardness, the addition of fillers) or by treatments such as applying or spraying a thin layer of a hard polymer at the glove surface.

One of the common glove manufacturing processes is application of a dipping process (latex dipping or solution dipping). Hand shaped molds or formers of various sizes from porcelain, metal, or plastic are are dipped into a mixture comprising either a solution or a suspension of the polymeric material. A thin liquid layer is deposited on the mold upon removal from the mixture.

For the production of supported gloves, natural or synthetic latex-coated fabric liners, which can be made of knitted or woven fabrics of cotton, wool, or synthetic blends, are coated or dipped into the glove compound (nitrile, latex, neoprene, polyurethane, PVC, silicone vinyl, or rubber). Supported gloves have excellent resistance to hot and cold temperatures, they absorb sweat, offer superb puncture and abrasion resistance, and are quite durable due to the liner. (Skjerven, 2019; yourglovesource, 2019)

Gloves manufactured by cut and sew method can be made of knitted fabric (cotton, nylon stretch, Kevlar®, and other synthetic blends, fiberglass, and metal yarn), woven fabric (cotton, synthetic blends), woven and/or knitted fabric impregnated with natural latex or synthetic latex, and leather (chromium or vegetable-tanned) and leather/woven fabric combinations. This kind of working gloves has a wide range of applications.

Gloves made by punching and welding are made from two plastic polymer films (single-layered or laminates) punched out and welded simultaneously. They are manufactured in different sizes with a flat shape; therefore, the fitness to the hand and the fingers is not comparable with gloves manufactured by the dipping procedure.

The injection molding process, on the other hand, allows glove production without the use of any solvent or liquid process.

Materials for Protective Gloves

Protective gloves are made from a vast variety of materials. Natural rubber, NBR (Nitrile Butadiene Rubber, a copolymer of acrylonitrile and butadiene), XNBR (Carboxylated Nitrile Butadiene Rubber, an improved nitrile rubber), Polychloroprene (synthetic) rubber sold under the brand name "Neoprene" and is also available in latex form, which is the generic name of colloidal polymeric particles dispersed in water, Polyisoprene Rubber, PCV (Polyvinyl Chloride, a versatile thermoplastic polymer) are the widely used polymers for the production of protective gloves.

For production of industrial gloves where special properties are required, materials such as IRR (Butyl Rubber, a copolymer of isobutene and isoprene), CSM (Chlorosulfonated Polyethylene), EPDM (Ethylene–Propylene Diene Monomer, a synthetic rubber made from ethylene, propylene, and a diene comonomer), FKM (Fluorocarbon elastomers), SBC (Styrenic-Block-Copolymers), Polyvinyl Alcohol, Polyethylene, Polyurethane, Silicone Rubber are essentially used as dry rubber, not as water dispersion (latex).

Materials for Cut Resistant Gloves

Gloves made from cut-resistant materials are used in situations where sharp materials or tools are handled. Cut resistance is defined as the ability of a material to resist damage when challenged with a moving sharp-edged object and can be evaluated by using a cut resistance index (Ertekin & Ertekin, 2020). Cut resistance of the materials are greater when the force needed to cut through is higher. Normal and abrasive forces, which are the two main components of cutting force, differ depending on the type of protective materials.

The cut-resistant gloves from traditional natural fibers have inferior protective performance, showing weak mechanical and weather resistance properties, though they are light weight, have good flexibility and lower price, it is still a commonly.

Cut protection is one of the areas where inorganic fibers, such as glass, basalt, carbon, metal, and boron, have found applications. High levels of cut resistance could be achieved by using steel fibers and this is particularly beneficial in knitted structures for protective gloves. Cut-resistant protective gloves are typically core yarns, having an inner core made from fiberglass, steel, or basalt and a sheath part made of cut-resistant materials such as high-performance polyethylene (HPPE) composite yarn or para-aramid fibers, and a filler made of polyester, spandex, or nylon. The effect of the chemicals on the cut-resistant material employed should be taken into consideration since certain chemicals could easily degrade some cut-resistant materials. In that case, the level of protection from physical damage might reduce bringing the risk of contacting the chemical to skin.

Due to their excellent mechanical strength, good thermal stability and abrasion resistance, high performance fibers have gradually replaced traditional fibers for cut-resistant textile materials. Several kinds of high-performance fibers used in cut-resistant materials mainly include: aramid 1414, (UHMWPE) ultra-high molecular weight polyethylene, HDPE (high density polyethylene), P-benzoxazole polyester, glass fiber, metal fiber, etc. Commercially, cut-resistant gloves are usually manufactured from p-aramid yarns (Kevlar®, Kevlar® Kleen®, Kevlar® Plus®, and Kevlar® Armor from DuPont; Twaron® and Twaron® Premium Line from Teijin) or core-spun yarns, with cores made of stainless steel or cut-resistant textile yarns and with sheaths made of textile yarns, polyethylene yarns (Dyneema® from DSM; Spectra®, Spectra® Guard®, and

Spectra® Guard® CX from Honeywell), glass fibers, and a combination of the above (Kropidłowska et.al, 2021; Zhai et.al, 2021; Dolez et.al, 2022).

Comfort Expectations from Protective Gloves

The longer the time people have to wear gloves, the higher the demand for comfort. There are many different types of protective gloves available as personal protective equipment. Together with their protection potentials against various hazards, protective gloves should be tested for dexterity, breathability (in terms of water vapour transmission and water vapour absorption) and comfort as stated in the relevant standard (TS EN ISO 21420 -2020). The relationship between the dexterity of the wearer and the protection against hazards is inversely proportional. The protection performance of a particular glove might be high but this would be useless if the wearer finds it difficult, or even impossible, to carry out the task when wearing that glove. Despite the fact that there are several studies that deal with the dexterity of protective gloves such as the ones by Orysiak et.al (2022), Bin et.al (20229, Khanlari et.al (2023), studies on moisture related comfort properties of protective gloves are in scarcity.

For evaluating the comfort and mechanical properties of para-aramid containing protective gloves, Ertekin et al. (2020) studied the knitted gloves produced by plating technique. The results indicated that the fabric made with para-aramid yarns performed better in terms of protection with an uncomfortable sensation. A combination of gloves from para-aramid and channelled polyester yarn resulted in a better comfortable experience. With a comparable cut protection performance (Ertekin & Ertekin, 2020). Irfan et.al; (2022) produced needle punched nonwoven felts from a blend of carding waste of para-aramid fibers and virgin fibers to be used in the development of protective gloves. The nonwovens were then quilted with knitted polyester fabric and protective gloves were produced. The study concluded that the heat resistance of the felts was greater at higher GSM but did not change with the change in the blend ratio of the waste aramid and polyester fibers.

If the gloves are uncomfortable, workers might prefer not to use them, which could increase the risk of injury at the work places. Not only proper fit, flexibility, and softer feeling, breathability of the gloves are also important. The work carried out focused on the moisture related comfort properties of inner knitted liners of commercial cut-resistant gloves.

Material and Method

In this study, the selected inner knitted liners of cut-resistant protective industrial type gloves were supplied from Egebant Inc, Türkiye. The general properties of the gloves are given in Table 2 and 3. As may be seen from the tables, the five different types of gloves from HDPE (high density polyethylene) and different combinations of HDPE and elastane/polyester, polyamide and steel filament yarns were manufactured on a flat glove knitting machine of E18 gauge. The ground yarn employed for the gloves was HDPE yarn of 200 denier whereas elastane, polyamide, polyester, and steel yarns were introduced to the structure via plating technique which means the simultaneous formation of one loop from two threads so that one thread will lie on the face of the fabric. The structure of the gloves was plain jersey. The properties of the gloves were tested in accordance with the relevant standards immediately after the samples were conditioned under the standard atmospheric conditions (20 ± 2 ^{0}C and 65 ±2 % relative humidity): areal density (TS EN 12127), thickness (TS 7128 EN ISO 5084), water vapor permeability (ASTM E96-00), air permeability (EN ISO 9237), vertical wicking (DIN 53924), and stiffness (ASTM D4032-8). Additionally, transfer wicking performance of the samples were tested in accordance with the method proposed by Zhoang and et. al (2002). Cut-resistancy of the gloves were determined by the TDM 100 ISO 13997 method, which is designed to better simulate real-world situations such as an accidental cut or slash. The moisture management related properties of the gloves are presented in Table 4, Figure 1 and 2.

Table 2. Industrial Gloves' Fiber Content

Code	HDPE (denier)	Polyamide (denier)	Elastane (denier)	Polyester (denier)	Steel (denier)	Final Yarn Count (denier)	Cut resistancy level
1	200	70	40	-	-	310	B
2		-	-	75	70	345	**B**
3		-	-	75	80	355	**C**
4		70	-	-	120	390	**D**
5		-	70	-	-	270	**C**

Table 3. Industrial Gloves' Properties

Code	Weight (g/m^2)	Rigidity (Kgf)	Stitch Density ($loops/cm^2$)	Thickness (mm)	Air Permeability ($l/m^2/s$)
1	277,836	0,651	89,00	0,95	2202,600
2	370,826	0,554	109,67	0,95	1433,583
3	373,911	0,545	95,67	0,70	1271,073
4	453,711	0,837	67,33	0,85	1070,753
5	419,375	0,578	112,67	0,60	1485,076

Results and Discussion

The comparative study of the samples were conducted in the light of the results given in the relevant tables and figures. It may be seen that the weight and thickness of the gloves are very much dependent on the final yarn count. As the final yarn count increases both properties do increase as well. The yarn count also appears to be influential on stiffness of the samples as the most rigid sample is the one knitted with the highest yarn count (Table 3). Regarding the fact that the samples have made from the combinations of different materials (e.g. HDPE-Polyester-Elastane) (Table 2), the aforementioned dimensional properties such as weight, may have partially determined by the surface frictional properties of these materials, though further study is needed to observe to what extent these properties are effective.

When the air permeability results were studied (Table 3), it may be seen that the fabric weight is the major parameter effecting the samples resistance to air flow as the samples with relatively lower weights such as 1 and 2 give higher air permeability values. This parameter is followed by stitch density and thickness. This is expected as the stitch density decreases, there will be more space between the yarns for air to pass through. The thickness, on the other hand, directly affects the airflow resistance behaviour of textiles since a thicker fabric means longer air passage distance within a structure, which results in an increase in air flow resistivity. Moreover, when knitted fabrics are produced with different stitch densities, the pore sizes between the yarns and the number of pores per unit area are also expected to vary, which in turn will affect the air permeability performance of the samples.

So far as the rigidity is concerned, it appears that structural properties as well as fiber content have an impact on stiffness of the samples such that heavier and/or thicker samples such as 1 and 4 are more rigid than the others. Also, an increase in the amount of steel yarn in the samples (i.e. 2, 3, and 4) increases the ridigity of the corresponding samples (Table 3).

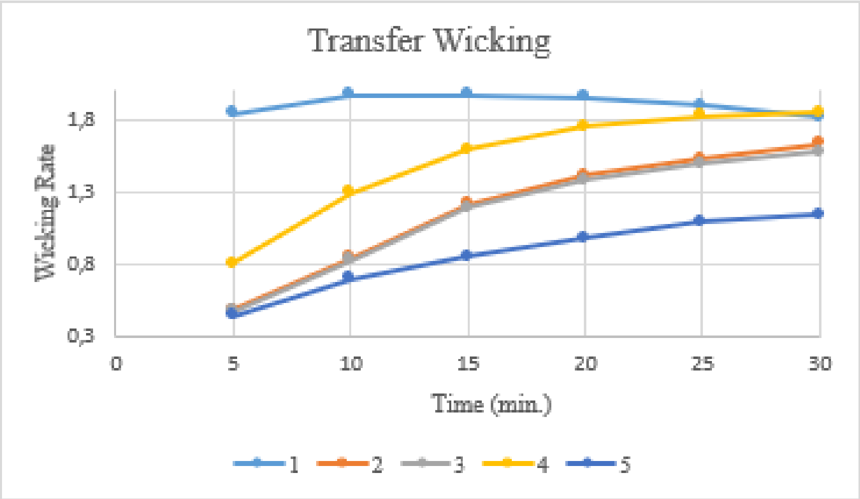

Figure 1. Transfer Wicking Performance of the Samples

The results revealed that the 1 samples had the highest transverse wicking values whilst the 4 one had the lowest. Also, in the first five minutes of the test, the transverse wicking of the samples showed a steep increase which then became more gradual as may be seen from Figure 1. The results revealed that the liquid transfer properties of the samples showed variation in accordance with fiber type such that the samples having steel yarn perform similarly whereas introducing polyamide and/or polyester into the structure (i.e. 4 versus 1) slows down the liquid transport. This is surprising as the surface free energy of synthetic fibers is lower and thus their wettability is also lower. Accordingly, fabrics having hydrophobic fibers such as polyamide/polyester are poor in moisture absorption but have better chance to transport moisture because of few bonding sites for water (Cerne & Simoncic, 2004; Persin et.al, 2004). In this regard, it may be concluded that in addition to fiber content, the fabric parameters such as stitch density and thickness are influential on liquid transfer by affecting pore geometry and pore distribution within a structure (Table 3, Figure 1).

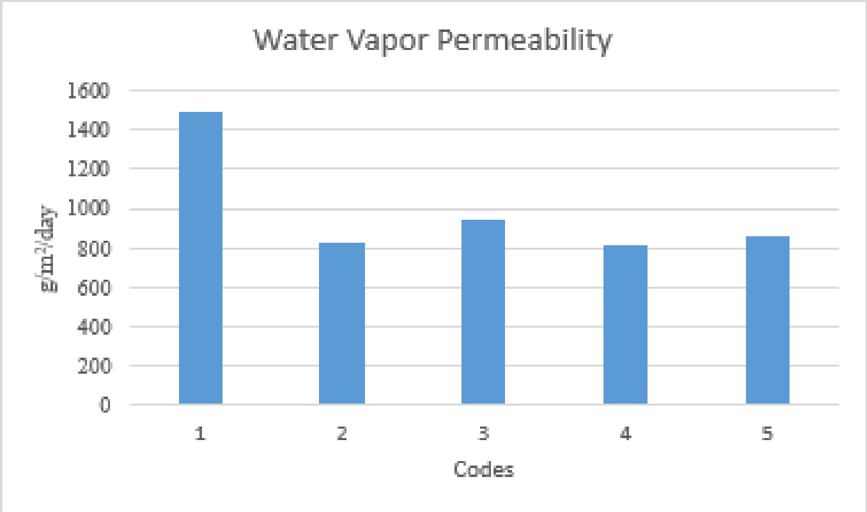

Figure 2. Water Vapor Permeability of the Samples

Water vapor permeability are among the most important factors determining clothing comfort, especially in the case of product worn next to the skin. As may be seen from Figure 2, 1 sample performed significantly better than the others. This is followed by 3 and 4 samples. It appears that introducing synthetic and/or steel yarn components to the structure makes the fabric heavier and the presence of hydrophobic non-cellulosic components (e.g. steel, polyamide, etc.) disturbs the moisture diffusion and its transfer through the fabric resulting in higher water vapor resistance. As a final note, the results suggest that there is a correlation between air permeability and water vapor permeability of the samples as the samples having higher air permeability such as 1 gave lower water vapor resistance (Table 3 and Figure 2). This is in agreement with the literature findings, but further study is needed (Ivanovska et.al, 2022).

Table 4 gives the vertical wicking performance of the samples. As may be seen from the table, 1 has the highest wicking height and rate, which is followed by 4. Moreover, replacing the polyester yarn with the polyamide one in the samples having steel yarn (i.e. 2, 3 and 4) resulted in better wicking performance in this group of samples (Table 4).

Table 4. Vertical Wicking Performance of the Gloves

Code	Wicking Liquid Height (cm)	Wicking Weight Change (%)
1	12,87	124,33
2	3,53	33,79
3	5,57	39,88
4	6,30	36,33
5	9,37	44,88

As is well known, wicking rate and liquid transportation in a fabric highly depend on pore sizes and their size distribution within a fabric, which is determined by fiber content as well as by structural properties such as weight and thickness. As the literature suggests there must be an optimum capillary size causing fastest entry of water into the yarn pores. Larger than this very pore size will slow down entry due to low capillary pressure. Hence, both too small and too large pores are detrimental to quick wicking (Chattopadhyay & Chauhan, 2004; Fangueiro et.al, 2010). Regarding the results in Table 3, it may be concluded that 1 and 5 present a satisfactory pore size and distribution for quick wicking.

Conclusions

A protective glove can be defined as a personal protective equipment that protects the hand or any part of the hand from danger. These gloves are designed to prevent the hands of workers from being damaged, but some materials or production methods used in production shorten the comfort values and life of the gloves. From this point of view, the moisture related comfort properties of commercial cut-resistant gloves were investigated. For this purpose, the five different types of gloves from HDPE (high density polyethylene) and different combinations of HDPE and elastane/polyester, polyamide and steel filament yarns were selected. The results showed that although the stiffness value of sample 1 was high, this sample showed the best comfort properties.

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BÖLÜM 4

TEXTILE MATERIALS USED FOR ACOUSTIC CONTROL PURPOSES

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1. INTRODUCTION

Sound is something that is inescapable, serving as a fundamental element of communication for both humans and animals. However, not all sounds are beneficial or pleasant to humans. Therefore, it is crucial to delineate the distinction between pleasant and unpleasant sounds. Noise can be described as "the unwanted loud sound that eliminates the wanted sound and disturbs people and animals in many ways" (Nayak & Padhye, 2016). The distinction between a normal sound and noise, as well as the disturbance level of that noise can vary from person to person. But for most cases, the difference is clear for almost everybody. The sound of music will most likely be a pleasant sound for most people while the sound of a nearby construction or traffic will be uncomfortable.

A comfortable, noise-free environment is crucial for maintaining human health and well-being. Being in an excessively noisy environment creates serious biological, psychological and sociological problems for the society. Individuals exposed to constant noise may face significant health issues, including temporary or permanent hearing loss. (Wang et al., 2021), nerve weakness, heart problems, and high blood pressure over the long term. Sleeping in a noisy environment inevitably leads to poor sleep quality, exacerbating psychological effects such as heightened irritation and anxiety, and chronic insomnia (Kawada, 2011). This situation worsens when combined with inadequate sleeping patterns. Additionally, there are a considerable number of individuals work overnight shifts and need to sleep during the daytime, which inherently exposes them to higher levels of noise. Consequently, this inevitably leads to lower-quality sleep. These physical and mental challenges also give rise to sociological issues such as social incompatibility, loneliness, and aggression. Moreover, noise disturbances don't solely affect humans; animals have also exhibited patterns of disturbance linked to noise, leading to lasting disruptions in the ecosystem (Francis, Kleist, Ortega, & Cruz, 2012).

The steady increase of noise levels, which undoubtedly makes it escalate to hazardous levels with industrial progress, profoundly impacts both the living environments and working conditions. Consequently, noise pollution ranks among the most critical environmental issues today. The measurement and assessment of noise levels, as well as its associated risks, have been conducted through various standards and practices. These standards and practices establish limitations and guidelines to ensure the safety and well-being of individuals exposed to noise. According to the guidelines provided by the World Health Organization (WHO), a good quality nighttime sleep necessitates sound levels lower than 30 dB originating from outside sources. Similarly, in classrooms, sound levels should ideally be lower than 35 dB to facilitate a conducive teaching and learning environment (World Health Organization, 2010).

One of the most efficacious methods to counteract noise is through sound insulation. When a soundwave interacts with a material surface, it can be absorbed, transmitted, reflected, refracted, or diffracted. These interactions are visualized in Figure 1 (Kadam & Nayak, 2016). In sound absorption, incoming soundwaves are completely absorbed and dissipated within the material. This is crucial for noise control. When soundwaves pass through a material without any change in direction or energy loss, it is defined as sound transmission. Reflection occurs when incoming sound waves hit a material surface and are then reflected at the same angle without going through any alteration. Refraction is when sound is being transmitted through the material but changing direction as it exits. Diffraction occurs when soundwaves are reflected by a surface and divided into multiple parts, each traveling in different directions. Depending on the properties of the soundwave and the material, each of these phenomena can occur.

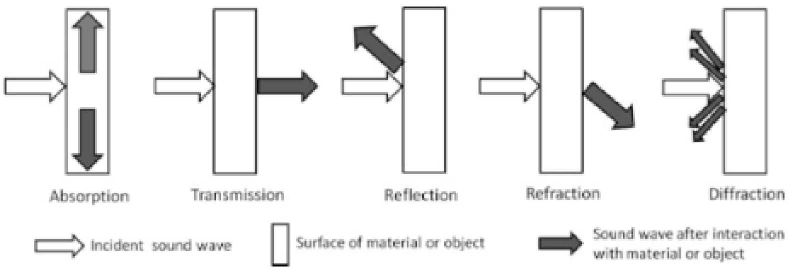

Figure 1. *Soundwave interactions.*

As a result, understanding noise reduction has emerged as a vital area of study across various fields. Today, numerous industries, including automotive and construction, prioritize applications aimed at reducing sound transmission. Noise control methods offer effective means to reduce undesirable sound, and these methods can be categorized into three primary groups: altering the source of the noise, employing barriers to modify the transmission path of sound, and utilizing sound absorbers to diminish sound intensity (Yilmaz, 2016). Among these options, using sound absorbers emerges as the most viable choice. Merely reflecting the sound instead of eliminating it may not be the most effective option, and in numerous applications, altering the sound source itself may not be feasible.

The primary consideration when selecting materials for sound control is to achieve the required sound absorbency levels within the desired frequency range. Furthermore, there are additional requirements based on the application area, such as flame retardancy, light reflectivity, durability, and safety for human health. Different application areas are subject to varying regulations and standards, necessitating careful consideration of these factors during material selection. The acoustic comfort of a room is also influenced by several key parameters. These include the volume and geometry of the indoor space, the characteristics of the sound source, the propagation of sound through the air, and the acoustic properties of the interior surfaces (Mujeebu, 2019). These factors collectively contribute to the overall acoustic experience within a room. Thus, using a material that has easy and affordable modifiability is important so that the material can be applied in different scenarios.

Acoustic control materials are usually in the form of porous structures. When soundwaves enter these porous sound-absorbers, they traverse the internal spaces of these materials. During this process, some of the sound energy converts into heat energy due to friction between the soundwave and the material, as well as the vibration of air molecules within the material. This mechanism helps dissipate acoustic energy during the propagation of sound waves, a significant portion of the sound energy dissipates as it progresses further inside through the pores (Berardi & Iannace, 2015). Porous structures can be found in the form of cellular, granular, or fibrous structures. Cellular structures usually are in the form of high-density building materials such as steel or concrete. But they usually reflect the sound back instead of absorbing it due to their very high density, also they are quite heavy and expensive. Granular structures consist of various forms of polyurethane (PU) foams. They are a popular indoor application, but the downside is that they have very poor flame retardancy and burn very rapidly. In addition, they release a thick and dense smoke as they burn. As such, their applications are quite hard and heavily regulated (Shufen, Zhi, Kaijun, Shuqin, & Chow, 2006).

In terms of fibrous materials, both the studies and many areas of the industry has focused on enhancing the acoustic properties of textile materials. Textiles are recognized to play an important role in acoustic applications; furthermore, textile products are environmentally friendly compared to commercial materials used for acoustic purposes such as mineral wool, fiberglass, polyurethane foam, which have high acoustic performance but have negative effects on ecosystems and human health (Paul, Mishra, & Behera, 2021). Textile materials or textile-based materials are amongst the most popular noise control applications. Given their porous fibril structures, they possess sound-absorbing capabilities. In porous acoustic materials like textiles, sound disperses among the pores, where it transforms into heat energy due to friction between the sound waves and the pore walls (Tao, Ren, Zhang, & Peijs, 2021). Consequently, genuine sound insulation can be attained rather than merely reflecting the sound. They are frequently employed in insulation applications due to their cost-effectiveness, lower weight, and, most importantly, this porous and fibrous structure. The aesthetic appeal of textile materials can be enhanced by incorporating color, texture, and form. Moreover, with the growing research and utilization of technical textiles, everyday textile products can acquire functionality while still retaining their aesthetic properties. The characteristics of textile materials are easily modifiable through the selection of appropriate raw materials, fabric production methods, chemical finishing processes, and adjustments in material relationships. Additionally, various production technologies and raw materials can be combined to achieve desired outcomes. Textile materials are comparatively easy and cost-effective to produce, making them a preferred choice. Furthermore, they are often favored for their environmental friendliness, as textile materials can be recycled more efficiently. Recycled textile materials find applications in various fields, including the production of sound-insulating materials.

Textiles play a significant role in acoustic control to enhance indoor environmental quality. Depending on the application area, textiles can be utilized in fiber and/or yarn form as a component in hybrid material or composites, or in fabric form by themselves for sound absorption purposes. Their fabric form can also be non-woven surfaces, woven fabrics, or knitted fabrics depending on the requirements and limitations of that specific application. In terms of fabric form, everyday home textiles can be utilized indoors for both decorative and functional purposes, can be tailored to increase sound absorption, minimize reverberation time, or prevent reverberation altogether. Various home textiles employed for acoustic purposes include curtains, carpets, upholstery, wall coverings, nonwoven surfaces used as linings, coated fabrics, textile composites, and textile panels (Memon, Abro, Arsalan, & Khoso, 2015).

2. FIBERS AND YARNS

Both neutral and synthetic materials are used for acoustic textiles. Studies show that for fibril structures, the fiber diameter, airflow resistance of the structure, thickness, tortuosity, surface area, material density and the compression are key parameters for its acoustic properties (Hoda S Seddeq, 2009). The suitable material is chosen based on a variety of different factors. One of them is to choose the material depending on the requirements of the application area. It is also quite important to choose a material that has a uniform structure. Materials with non-uniform structures, both on their surface and in their intrinsic properties, pose challenges in terms of control and utilization (Patnaik, 2016).

In this regard, textile materials made from synthetic fibers are often preferred for acoustic applications due to their smooth structure, which is adjustable and robust. Synthetic fibers are easier to work with because they exhibit constant smoothness along the fiber diameter direction. However, today, with the increasing importance of environmental concerns, alternatives created with natural fibers have gained importance over synthetic fibers. Thus, depending on the application area, neutral fibers have also become a popular research and application material for sound insulation. With this increased research efforts and environmental concerns, neutral fibers are emerging as notable alternatives to synthetic materials and are finding applications in various industries.

Natural fibers undoubtedly have certain disadvantages compared to synthetic fibers. They often exhibit non-uniformity and lower strength characteristics. Additionally, their flame retardancy properties are typically inferior to those of synthetic fibers. Many acoustic applications also necessitate secondary requirements such as fire resistance, moisture resistance, or high strength. For instance, employing a natural fiber-based sound absorber in an environment with a high fire risk may not be practical, as most natural fibers tend to begin decomposing at relatively lower temperatures compared to synthetic fibers.

But nevertheless, depending on the application area, neutral textile materials can be mixed with synthetic materials to overcome the intrinsic challenges that they bring. In the automotive sector, for instance, there is an effort to find greener alternatives to replace fiberglass and steel components. Plant-fiber-based composites are currently being investigated or utilized for door panels, dashboard trim panels, seat cushions, and cabin linings. For example, flax fibers are being employed as substitutes for highly toxic asbestos fibers in disk brakes (Adekomaya, 2020; Ashori, 2008). In 2008, Silva et al. investigated the acoustic properties of multi-layered structures intended for use in the construction industry. They utilized coconut fibers compressed into a fiber layer with a thickness of 20mm, which were then combined with foams of varying thicknesses in different combinations. While the sound absorption coefficients ranged between 0.25 and 0.35 for the materials when used separately within the frequency range of 200-3000 Hz, the combined material exhibited a sound absorption coefficient close to 1,0 (Silva, Magalhaes, & Guimieri, 2008). In another example, Zhang et al. (2016) investigated the morphology of a novel electro spun polyvinyl alcohol (PVA) and milk nanofibers. The authors suggest that these nanofibers have potential applications in healthcare, particularly as drug-loaded wound dressings, due to the biodegradable and safe nature of PVA for human health (Zhang, Zhang, Liu, Wang, & Wang, 2016). Researchers from India explored nonwoven sheets made from areca nut leaf sheath fibers (ALS) as a potential material for sound absorption. They achieved a maximum noise reduction coefficient of 0.78 with a 5cm air gap using a sample thickness of 54mm (Raj, Fatima, & Tandon, 2020b).

With increasing environmental awareness and the implementation of new regulations, making environmentally conscious decisions regarding material selection for various applications is more critical than ever. Textile materials are generally comparatively easy to recycle, and recycled textile materials can be effectively utilized in applications such as sound-insulating materials. Using recycled materials will also reduce the costs from the point of a commercial scale. Also, waste materials, such as short wool fibers or shoddy from various fabric manufacturing can be incorporated into different applications to utilize them as absorption materials.

In a study conducted in 2020, the properties of a sound-absorbing material, a composite composed of discarded luffa scraps and environmentally friendly polyester fibers, were investigated. The composite exhibited a three-dimensional network with a rough surface and a substantial number of pores. Increasing the thickness from 20mm to 60mm raised the median sound absorption coefficient from 0.442 to 0.684 and shifted the resonance range to lower frequencies. Additionally, compared to various plant-fiber-based composites, the material displayed a soft surface and good hydroscopic properties (Y. Chen et al., 2020). In a study from 2022, researchers focused on developing knitted fabric-based acoustic materials using cut wastes from various garment industries to reduce industrial textile waste. They collected warp and weft knitted fabrics from different garment factories, which were then shredded and processed using mechanical, aerodynamic, and chemical bonding methods to create an acoustic composite structure. The sound absorption coefficients of the knitted fabric reinforced composite structures were determined using the impedance tube method. Findings revealed that acoustic materials produced from continuous filament yarns like viscose, as well as knitted fabrics made from short fiber yarns such as cotton, wool, and jute, proved effective for weft knitted fabrics. On the other hand, only filament yarns demonstrated effectiveness in warp knitted fabrics. Moreover, it was observed that using a mixture of knitted fabrics resulted in better sound absorption features, with the sound absorption coefficient reaching 0.96 at a frequency of 4000 Hz. As a result of the study, it was concluded that knitted fabric acoustic materials prepared from waste materials hold promise as cost-effective sound-absorbing materials (Temesgen & Sahu, 2022).

Boominathan et al. (2022) investigated the sound absorption properties of nonwoven fabrics obtained by needle punching from natural fibers such as Sansevieria Stuckyi, Banana, Hemp, and their mixtures. All natural fibers were obtained from their respective plant sources. Twelve different needle-punched nonwoven fabrics were produced using mixture forms and single fiber combinations, and the acoustic performances of these fabrics were tested. The study results demonstrated that nonwoven fabrics based on mixed fibers had the maximum sound absorption property. Additionally, nonwoven fabrics with higher hemp fiber content and thickness exhibited maximum sound absorption coefficient values. Finally, the study concluded that the air permeability, porosity, and thermal conductivity of nonwoven fabrics affected their sound absorption properties (Boominathan, Bhuvaneshwari, Sangeetha, Pachiyappan, & Devaki, 2022).

In another study aimed at addressing noise issues in buildings, environmentally friendly acoustic panels were designed using composites produced from 100% textile and packaging waste recycling. Denim fabrics from textile waste and low-density polyethylene bottle caps from packaging waste were used. Denim fabrics shredded into cotton fibers were blended with ground waste polyethylene granules and then subjected to hot pressing to obtain porous textile-reinforced composite structures. The acoustic properties of these structures were tested. According to the acoustic measurement results, the developed composite materials contributed to sound insulation, and high-density structures exhibited a 20dB insulation performance at mid-frequencies (Kucukali-Ozturk, Yalcin-Enis, & Sezgin, 2022).

The sound absorption coefficients of recycled denim and waste jute fibers were examined and compared to commercially used glass wool material. The findings revealed that recycled denim exhibited superior sound absorption characteristics compared to glass wool, while jute showed similar results with increased thickness. Furthermore, both alternatives were found to be at least five times cheaper than glass wool. As such, both samples hold potential to be developed into more environmentally and economically viable alternatives (Raj, Fatima, & Tandon, 2020a). In a separate study conducted in 2012, the acoustic properties of nonwovens made with recycled natural and synthetic fiber blends, as well as lignocellulosic fibers such as rice straw and sawdust, were investigated. The samples demonstrated good sound absorption coefficients at mid to high frequencies. Moreover, the resonant frequency could be shifted to lower frequencies by leaving an air gap behind. Introducing perforations to the samples also led to an increase in the sound absorption coefficient across all frequencies (Hoda Soliman Seddeq, Aly, Marwa A, & Elshakankery, 2013).

In a study investigating the sound absorption potential of wool fibers, short wool fibers collected as waste from sheep were utilized. Yarns containing these short wool fibers were produced and employed as weft yarn in the woven fabric structure. The findings revealed that short fibers tend to become thinner, positively impacting the sound absorption behavior of the fabrics. Conversely, fabrics made of thicker fibers exhibited enhanced thermal insulation performance. These results indicate that woven fabrics manufactured with waste wool fibers possess acoustic and thermal properties comparable to synthetic-based acoustic materials such as glass fiber or mineral wool. The study underscores the potential commercialization of waste wool as an environmentally friendly insulation material, emphasizing its ecological, economical, biodegradable, and readily accessible advantages (Ghermezgoli et al., 2021).

3. FABRICS

Fabric-form curtains or panels are highly effective in sound absorption, as they absorb or diminish reflected noise significantly. Their porous structure allows them to absorb and dissipate soundwaves within them, contrasting with foam or panel structures, which typically reflect sound back into the room. Utilizing curtains for controlling external noise and enhancing room acoustics presents several advantages, including relatively lower cost, lightweight construction, flexibility, and ease of use.

Fabrics used for sound control purposes can take the form of knitted, woven, or nonwoven structures. Depending on the application and requirements, a combination of different structures may be utilized.

Additionally, chemical treatments can be applied to enhance or add acoustic properties through methods such as spraying or coating. In a 2022 study, a film was created on the surface of woven fabric using ultrasonic precision spraying to be used as a noise reduction material. The study investigated the effects of fabric structure, film thickness, filler distribution, filler content, and type on the sound transmission loss of the developed flexible sound insulation material. The results showed that the film coating closed small pores on the fabric surface and increased the reflection of sound energy, leading to the structure exhibiting excellent sound insulation performance. Additionally, the sound energy could be effectively absorbed by this structure. When the film thickness was approximately 50 µm and the filler material was vermiculite, the flexible sound insulation demonstrated the best sound insulation performance, reaching a sound transmission loss value of 9.5 dB, approximately three times that of the substrate. By adjusting the filler distribution, the sound transmission loss value of the structure could be significantly altered. Despite the film-coated woven fabric being as thin as wallpaper, its acoustic performance is equivalent to that of thick curtains (J. Chen et al., 2022).

The transmission of sound waves primarily occurs through air molecules. Therefore, in multi-layer structures, increasing the distance between layers or creating gaps between them can improve sound insulation. This enhancement comes from the combined sound absorption effects of the fiber materials and the resonant absorption of the back cavity caused by the presence of an air gap. A larger air gap at the back of the fiber materials results in a lower resonant frequency, thus improving sound absorption at lower frequencies.

Nonwovens are very commonly used in acoustic applications. Thanks to their complex fiber network geometry and bulkiness, they generally show good sound absorption behavior. Suvari et al. investigated the acoustical properties of hydroentangled nonwovens made using island-in-the-sea type bicomponent fibers, with PA6 as the island polymer and PE as the sea polymer. The fibers varied in the number of islands to assess the impact of different bicomponent cross sections. They found that sound absorption coefficients increased as the number of islands in the cross section increased. This effect can be attributed to the presence of smaller fibers and pores, causing soundwaves to encounter more pore walls and lose energy to friction (Suvari, Ulcay, Maze, & Pourdeyhimi, 2013).

In another study by Suvari et al., they examined the acoustic properties of the same hydroentangled bicomponent nonwovens after removing the sea component of the fiber by chemically dissolving the PE using xylene in a reflux setup. The removal of one component increased the sound absorption coefficient of the samples due to further fibrillation inside the structure. Additionally, this process resulted in a decrease in the weight of the web (Suvari, Ulcay, & Pourdeyhimi, 2018).

In their 2017 study, Çelikel and Babaarslan investigated the impact of using bicomponent fibers, fiber cross-section, and thickness levels in multilayered nonwoven structures on their sound absorbency properties. They utilized PET/coPET bicomponent fibers in one sample group and homocomponent fibers in the other, with trilobal tipped type and sheath/core type bicomponent fibers. Their findings revealed that the use of bicomponent fibers restricted airflow within the samples, leading to improved sound absorbency. Heavier samples demonstrated better acoustic properties overall, with those containing bicomponent fibers showing superior sound absorption across all weights. Through a thermal process, the coPET component of the bicomponent fibers was melted, facilitating bonding between layers of the nonwoven structure. This process resulted in a more intricate porosity within the material, allowing the structure to connect with irregular and hard surfaces. Consequently, the path of sound waves within the sample became more complex, enhancing sound absorption through increased friction and vibration. Comparing fiber cross-section structures, round cross-section bicomponent fibers exhibited better sound absorption compared to both single-component counterparts and samples made from trilobal cross-section fibers. ANOVA analysis revealed that fiber type and basis weight statistically influenced the sound absorbency properties of nonwoven samples at a 95% confidence level. Moreover, the study found that fiber type held more significance compared to basis weight (Çelikel & Babaarslan, 2017).

Nonwovens are also very commonly used as backing materials in different applications and provide various advantages, including better insulation properties. Shoshani (1990) conducted a study on the sound absorption coefficient of tufted carpets, examining variations in pile heights, densities, and backings. The findings demonstrated that incorporating layers of nonwoven materials as backings enhances the sound absorption coefficient of the carpets, with cotton backings yielding superior improvement compared to acrylic backings (Yakir Z. Shoshani, 1990).

Unlike nonwoven surfaces or felts, woven and knitted fabrics generally exhibit lower sound absorption performance due to their reduced thickness (Tang, Zhang, Zhuang, Zhang, & Yan, 2018). However, their widespread use in home and automotive textiles is attributed to their structural design flexibility and dimensionally stable behavior. Woven curtains offer several advantages over other sound-absorbing counterparts. They are more cost-effective and easier to maintain and clean. Moreover, adjusting the acoustic conditions within a space is straightforward by altering the location of the curtains and adjusting their folding. Unlike other indoor sound absorbers, woven acoustic curtains can seamlessly replace traditionally used curtains without requiring significant changes to the room structure or additional acoustic additions (Pieren & Heutschi, 2015). Woven fabrics also offer larger surface coverage depending on the weave design. As such, depending on the application area, woven materials can be employed when it is not practical to use thick and bulky nonwoven structures.

The acoustic performance of fabrics is influenced by several structural factors. As a result of modeling studies on fabric structures and sound insulation coefficients, it has been determined that the sound absorption performance of woven fabrics is directly related to their geometric parameters. Additionally, it has been found that these parameters can be derived in a manner that conforms to specific acoustic requirements (Cai, Li, Gai, Zhang, & Xing, 2020). Different weave designs and layers can contribute to effective sound insulation across various frequencies (Barburski, Blaszczak, & Pawliczak, 2019). Besides its' design and layering, fabric density, fabric structure, properties of the fibers and yarns utilized, thickness, number of layers, and the finishings on the fabric surface. Additionally, factors such as the air gap left behind the fabric, fabric drape and folding, and its placement in the room also impact the acoustic characteristics of the curtains (Haikonen, 2016).

Additionally with the new advancements in technical textiles, everyday household textiles have evolved into bi-functional materials. For instance, blackout curtains can serve not only to provide darkness but also to offer acoustic insulation in bedrooms, enhancing the indoor environment and promoting quality sleep. To assess the acoustic performance of such curtains, the back surfaces of polyester fabrics with different weights of plain and 2/2 Panama structures are coated with resin containing acrylic in various proportions (34.4%, 40%, 60%). To evaluate the sound absorption performance, both the front faces and the resin-coated back sides of the curtain samples are positioned in front of a sound source. This setup enables the assessment of the curtains' ability to absorb both indoor and outdoor sounds. Results from the coated surfaces of the curtains indicate that acrylic resin-coated fabrics demonstrate the best sound absorption performance, suggesting a recommended production parameter for the manufacturing of blackout curtains (Demiryürek & Aydemir, 2017).

In a study aimed at determining the effect of basic weaves on sound absorption performance, fabrics with different weaves such as plain weave, 2/1 twill, 3/1 twill, 2/2 twill, ribs, and satin structures were produced without altering the warp and weft yarn types and their densities. These fabrics were compared based on their sound absorption performance. The findings revealed that plain weave samples exhibited the best sound absorption properties. This result was attributed to plain weave having the highest number of yarn intersections in the fabric structure, incorporating yarns with high crimp (Soltani & Zerrebini, 2012).

Furthermore, the sound absorption properties of plain weave, twill, and honeycomb fabrics with the same warp density were measured. It was determined that the absorption performances of fabrics with different structures changed depending on their pore properties. The porosity ratio, pore shape, and size constitute the pore characteristics of the fabrics, and these characteristics may vary even if the same yarn is used in weaving types with different jump lengths depending on the weave. When evaluating the sound absorption performance of different woven fabrics, it has been suggested to consider how pore properties are affected by construction (Li et al., 2020).

Liu et al. (2021) conducted a study on the acoustic properties of hollow woven fabrics with a honeycomb weave pattern, examining fabrics with different weave repeats. Their findings indicated that above 2000Hz, the honeycomb weave exhibited a better sound absorption coefficient compared to the 2x2 plain-woven fabric. Moreover, the 6x6 and 8x8 honeycomb structures demonstrated superior sound absorbency compared to the 12x12 structure. A smaller weave repeat resulted in a bulkier structure, thereby increasing the sound absorption coefficient of the fabric. Additionally, the researchers tested the fabrics by leaving 3cm and 5cm of air gap behind them. The presence of an air gap shifted the resonant frequency to a lower frequency range, and the sound absorption coefficients exceeded 0.8 between 0-1500 Hz gap for the 6x6 repeat fabric (Liu et al., 2021).

Carpets serve multiple purposes beyond their visual aesthetic in both indoor and automotive settings. They offer thermal insulation, especially during colder months, and contribute to sound absorption due to their dense structure. In transportation applications, such as automotive textiles, carpets are extensively studied and developed to provide not only visual appeal but also additional functionalities like sound insulation, thermal insulation, and antibacterial properties. These characteristics make carpets versatile materials suitable for enhancing the comfort and functionality of various environments. A previous study investigated the impact of various pile properties on sound absorption. Findings revealed that pile height, density, and tufting technique exerted distinct effects on carpet sound absorption across different frequencies. Additionally, in instances where an air gap was present behind the carpet, a notable enhancement in sound absorption performance was observed between 250Hz and 1000Hz, irrespective of the fabric structure. These insights contribute to a deeper understanding of how pile characteristics influence carpet acoustics and underscore the importance of considering air gaps in sound absorption evaluations (Y.Z. Shoshani & Wilding, 1991).

4. CONCLUSION

With the increase in industrial and transportation activities, noise pollution has become one of the greatest environmental issues affecting humanity. Noise control is a critical consideration in Indoor Environmental Quality and an important consideration point in many different settings, from workplaces to educational institutions, theaters, and residential spaces, where effective management of sound contributes significantly to comfort and productivity. Over the years, various types of materials have been developed and implemented for sound absorption or transmission loss applications.

In this context, the investment and investigation into textile materials for acoustic control applications further demonstrates their role and importance. Textiles offer multiple different approaches to sound absorption with materials ranging from natural fibers to synthetics, and different application methods. This enables to do acoustic applications for specific purposes while still accommodating the design aspect and additional functional requirements. Unlike conventional materials like foam and fiberglass, textiles can be designed to be effective sound absorbers for adjusting room acoustics. Textile materials are relatively cost-effective compared to most commercially used porous materials, lightweight, flexible, easy to use, and accommodate variable room acoustics.

Textile materials also offer a versatile array of forms for acoustic applications, ranging from all forms of fabric constructions to fiber-based applications for technical textiles. Fabric formed textiles provide a structured and durable option for acoustic panels, wall coverings, and upholstery applications. Additionally, textiles in fiber form serve as backing materials for acoustic composites and laminates, enhancing their structural integrity while contributing to sound insulation and absorption.

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