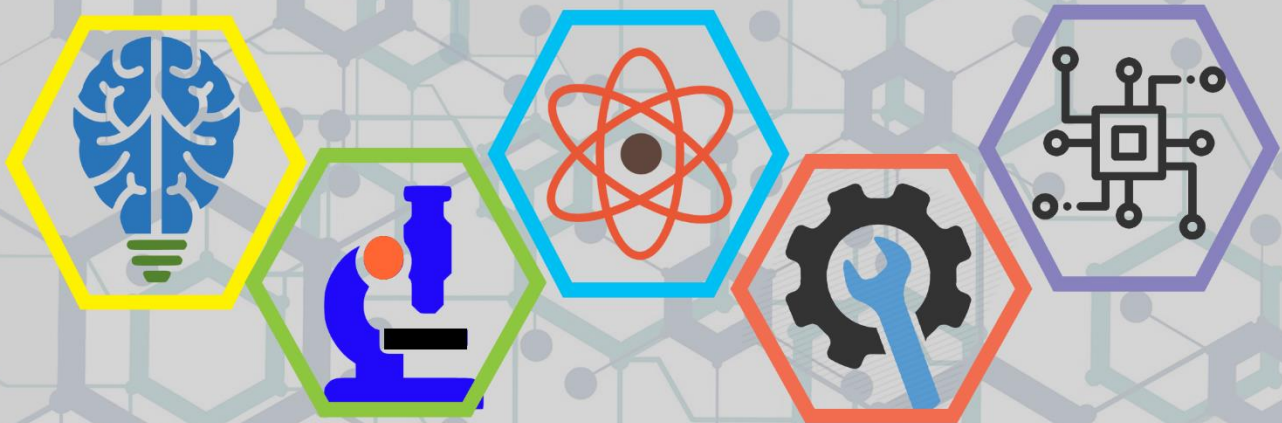


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BLOK ZİNCİR TEMELLİ GÜVENLİ ELEKTRONİK OYLAMA MODELİ

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ÖZET: Günümüzde bir konunun araştırılması, toplumun görüşünün alınması ya da tutumunun tespit edilebilmesi için araştırma anketleri, yüz yüze danışma, telefon görüşmeleri, web anketleri gibi çeşitli yöntemler kullanılmaktadır. Bu yöntemlerden en hızlı ve düşük maliyetli olan yöntem web anketleridir. Günümüzde küresel bazda yaşanan Covid-19 bulaş hastalığının kalabalık alanlarda yarattığı riskler göz önünde bulundurulduğunda web üzerinde çalışan sistemler hayati öneme sahiptir. Web anketi tercih edildiğinde sunucu tabanlı çalışan web uygulamaları kullanılmaktadır. Fakat sunucu tabanlı uygulamalar veri güvenliği ile ilgili bazı endişeler oluşmasına sebep olabilmektedirler. İstemci düğümlerinden sunucuya gönderilen oylama bilgileri, merkezi bir sunucu üzerindeki veri tabanına kaydedilmektedir. Verinin merkezi bir sunucu üzerinde depolanması yönteminin en büyük dezavantajı, oylama sonuçlarının siber saldırılar ya da kurcalanma risklerine savunmasız olmasıdır. Bu durum yapılan oylama sonuçlarının güvenliğini ciddi oranda olumsuz etkilemektedir. Blok zincir teknolojisi son yıllarda veri güvenliği alanında sıkça kullanılmaktadır. Blok zincir teknolojisinde sistemi merkezi bir sunucu yönetmemektedir. Eşler arası ağ oluşturulup hesap defterinin tamamının bütün düğümlerde yer alması prensibi esastır. Bu yapısı ile veri güvenliği açısından avantajlı bir teknolojidir. Ayrıca blok zincir teknolojisi, verilerin tek bir blok olarak şifrelenmesinden dolayı siber saldırılara ve dış müdahalelere karşı da güvenli durumdadır. Bu çalışmada farklı fikir ya da görüşlerin oylanması, oylama sonuçların gösterilmesi için blok zincir temelli güvenli bir elektronik oylama modeli önerilmiştir. Çalışmada C# dilinde blok zincir yapısı oluşturularak düğümlerden kullanılan oy verilerinin bir blok olarak şifrelenmesi ve bloğun zincire eklenmesi sağlanmıştır. Blok zincir tabanlı geliştirilen sistemin güvenli ve güvenilir olmasını, seçimde bulunan insanların güvenini artırmaya yardımcı olmasını bekliyoruz.

Anahtar Kelimeler: Blok Zincir, Veri Güvenliği, Elektronik Oylama Sistemi.

BLOCK CHAIN BASED SAFE ELECTRONIC VOTING MODEL

ABSTRACT: Today, various methods such as research questionnaires, face to face consultation, telephone interviews, web surveys are used to investigate a subject, to get the opinion of the society or to determine its attitude. The fastest and most cost effective method among these methods is web surveys. Given the risks posed by Covid-19 infectious disease on a global basis today in crowded areas, systems operating on the web are vital. When web survey is preferred, server based web applications are used. However, server-based applications may raise some concerns about data security. Voting information sent from the client nodes to the server is recorded in the database on a central server. The biggest disadvantage of the method of storing data on a central server is that the voting results are vulnerable to cyber attacks or tampering risks. This situation adversely affects the security of the voting results. Blockchain technology has been used frequently in the field of data security in recent years. In blockchain technology, the system does not manage a central server. The principle of establishing a peer-to-peer network and placing the entire ledger in all nodes is essential. With this structure, it is an advantageous technology in terms of data security. In addition, blockchain technology is also safe from cyber attacks and tampers due to the encryption of data as a single block. In this study, a secure electronic voting model based on block

chains has been proposed for voting different opinions or opinions and showing voting results. In the study, by creating a block chain structure in C # language, the data used from the nodes are encrypted as a block and the block is added to the chain. We expect the system developed based on block chains to be safe and reliable, helping to increase the trust of the people in the election.

Keywords: Blockchain, Data Security, Electronic Voting System.

1. GİRİŞ

Çalışma hayatında iş görenler yürüttükleri görev ile ilgili farklı problemler ile karşılaşmaktadırlar. Karşılaşılan problemler iş görenin yetki ve tecrübesine bağlı olarak aşılabilen ya da en optimize çözüme ulaşma amacıyla fikir danışma yöntemi ile aşılmaya çalışılmaktadır. İş görenler çözüm bekleyen problem senaryolarına farklı çözüm önerileri getirebilmektedirler. Bu tür durumlarda çözüm için uygulanacak yöntemin seçimi oyçokluğu ya da oybirliği ile belirlenebilir. Bu aşamada yaşanabilecek önemli problemlerden biri, oylama esnasında üyenin kendini baskı altında hissetmeden özgür irade ile gerçek düşüncesini ortaya koyabilmesidir. Bireyler düşündükleri fikrin diğer kişiler tarafından bilinmesini istemeyebilir.

Bu problem senaryosundan yola çıkarak bu problemin yaşanabileceği farklı durumlara da senaryolar genişletilebilir. Örnekleri çoğaltacak olursak, bir holdingin yatırım kararlarının belirlenmesi, bir şirketin çalışanlarına uyguladığı memnuniyet anketleri, bakanlıkların çalışan personeline uyguladığı kurum iklim anketleri, ülke çapında uygulanan yerel seçimler, genel seçimler, referandumlar örnek gösterilebilir. Özellikle referandum, genel ve veya yerel seçimler söz konusu olduğunda mali anlamda yaşanan giderlerin tasarrufu konusunda problemin yaygın etkisi ortaya çıkmaktadır. Problem senaryosunun yaygın etkisine arttıkça, senaryo paydaşlarının görüşlerin öğrenilmesi için harcanan mali tutar artmaktadır.

Kamuoyunun bir konu hakkında düşünce, kanaat ve eğilimlerini öğrenmenin en iyi yolu kamuoyu araştırmalarıdır. Kamuoyu araştırmaları dünyada 19. Yüzyılda ülkemizde ise 1960'lı yıllarda uygulanmaya başlanmıştır. Kamuoyu araştırmaları Türkiye'de 1980'li yıllardan sonra önemini arttırmıştır. İlk araştırmalar 1960'lı yıllarda yapılsa da kapsamlı araştırmalar 1975 yılında başlamış ama yaygınlaşması 1980 sonrasında olmuştur. Kamuoyu araştırmaları sayesinde seçmenlerin siyasî kanaat ve tutumları, gündem konularına yaklaşımı, siyasi lider ve adaylara duydukları ilgi, hangi medya ve medyaları kullandıkları belirlenebilmektedir. Seçmen tercihlerini öğrenmek için siyasiler kamuoyu araştırmalarını sıklıkla kullanmaktadırlar [1].

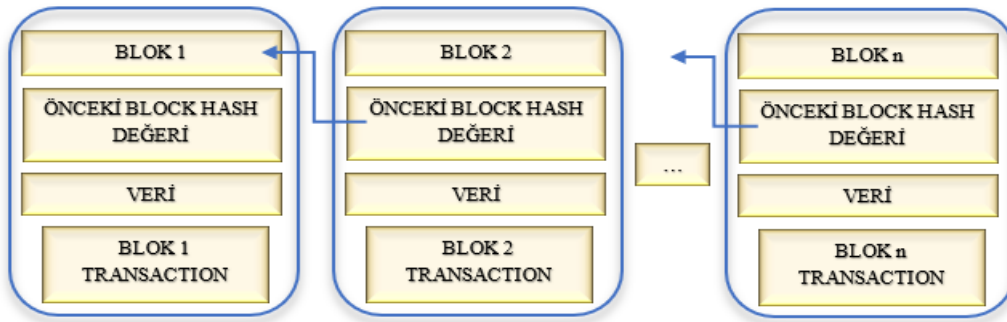
A.H. Eroğlu ve S. Bayraktar kamuoyu araştırmalarının seçmen davranışını yönlendirmek için de kullanılabildiği sonucuna ulaşmışlardır. Yapılan siyasi kamuoyu araştırmalarının seçmene iki farklı yoldan etki ettiğini belirtmişlerdir. İlk etkinin; doğrudan etkilemesidir. Seçmen bazen kitlesel çoğunluğun ağırlıkta olduğu partiye daha meyillidir. Bu durum hem güçlü olan kesim tarafında yer alma hem de nispeten somut beklentilerden kaynaklanabilir. Bazen de seçmen, yakın hissettiği gruba ait oyları parçalamama adına, grubunun favori gösterilen partisini öğrenmek amacıyla da kamuoyu araştırmalarını takip edip etkilenebilir [2]. Fakat toplum zaman zaman anketlerin gerek yanlış davranması gerekse anket sonuçlarının kurcalanarak manipüle edildiği izlenimine kapılarak anketlere karşı güven oluşturamamaktadır. 28 Mart'ta yapılan seçim, 1999 ve özellikle de 2002 genel seçimlerinde büyük sıçrama yapan anketlere olan güveni sarsmış ve onların doğruluklarını şüpheli hale getirmiştir [3].

Kamuoyu araştırmalarında bir veri toplama aracı olarak kullanılan web tabanlı anket metodu, geleneksel anket metodu ile kıyaslandığında, maliyet, zaman ve mesai harcanması açısından

üstündür. Bugün web uygulamalarının hemen hemen hepsi bilgi depolama için veri tabanlarını kullanmaktadır. Web uygulamaları ağırlıklı veri tabanı ile yapısal bir sorgulama dili olan SQL aracılığıyla işlemlerini gerçekleştirir. Saldırgan, veri tabanı hakkında elde ettiği kritik bilgilerle veri tabanında bulunan diğer bilgilere ulaşabilir, bilgileri manipüle edebilir. Sonuç olarak saldırırganın hedeflediği operasyon başarılı olur [4].

1.1.Blok zincir Teknolojisi

Bloklardan oluşan zincir yapısındaki blok zinciri, şifrelenmiş işlem takibini sağlayan bir veri tabanı sistemi olarak tanımlanabilir. Sistem üzerinde gerçekleştirilen her adım bir blok haline getirilip kendinden önceki blok ile ilişkilendirilir. Gerçekleştirilecek olan işlemler sırasında bloklar şifrelenir, değiştirilemez ve kırılmaz hale getirilir [5,6]. Basit anlamda temel blok zincir yapısı Şekil 1’ de gösterilmiştir.



Şekil 1. Blok zincir temel yapısı.

Bilgisayar korsanları birçok farklı yöntemle web sitelerinin tutulduğu sunucu bilgisayarlarına sızabilmekte, veri tabanını ele geçirip kişisel bilgileri elde edebilmekte ya da veri tabanında veriler üzerinde oynamalar yapabilmektedirler []. Blok zinciri, en basit tanımıyla, bir bağlı liste yapısının özelleşmiş halidir. Standart tek bağlı liste yapısında, listenin her elemanı, kendinden sonra gelen elemanı bir işaretçi yordamıyla işaret eder. Bu şekilde listenin başlangıç elemanından kuyruk elemanına kadar bütün elemanlar birbirlerine bağlanmış şekildedirler. Blok zinciri yapısında ise her eleman (blok), sadece sonraki bloğu işaret etmez, aynı zamanda o bloğun öz (hash) değerini de saklar. Diğer bir ifadeyle blok zinciri, özet-işaretçilerle oluşturulmuş özel bir bağlı liste yapısıdır [7].

Blok zincirin, bağlı listeler ile kıyaslandığında öz-işaretçi yapısı açısından elde ettiği en önemli üstünlüğü, liste içerisindeki herhangi bir bloğun değiştirilme durumunda ortaya çıkar. Öz işaretçi yapısı, bu tür bir değişikliğe uğradığında değişiklik yapıldığı rahatlıkla fark edilir. Bunun sebebi yeni eklenen bloğun öz değeri, bu yeni bloğu işaret eden öz işaretçisinin işaret ettiği değerden farklı olacaktır. Bu özellik blok zincirinin güvenli bir yapı olmasını sağlayan en önemli etmendir [8]. Ağda meydana gelen her olay, düğümlerde doğrulanmakta ve kaydedilmektedir. Blok zincirinde ilk başlangıç bloğuna “genesis blok” ismi verilir. Her blok, kendinden önceki bloğun özüt (hash) algoritmasından geçirilmiş içeriğine sahiptir. Böylece sistemdeki bir işlemi değiştirmek isteyen kişi, geriye doğru tüm işlemlerin özüt sonucunu hesaplamak zorundadır. Bu işlem pratik olarak mümkün değildir, çünkü hesaplanan sonuçların tüm madencilerde de aynı olması gerekmektedir [9].

Blok zinciri teknolojisi dağıtık bir defter mimarisi olarak tanımlanabilir. Teorik olarak sistemin defter sayfalarının kullanılması gibi düşünülebilir. Defterin sayfaları defteri kullananlar

tarafından doldurulur. Doldurulan tüm bilgiler defterin önceki sayfalarında silinmeden ve bozulmadan bulunmaya devam eder. Geleneksel defterlerden farklı olarak blok zincirinde her bir sayfa bir sonraki sayfaya şifrelenmiş bir özlme algoritmasıyla bağlanır ve deftere veri akış yönü hep ileri doğrudur [10]. Çalışmanın geri kalan bölümünde sırası ile elektronik oylama sistemleri ile ilgili akademik çalışmalar incelenecek, çalışmada önerilen modelin gerçekleştirilme aşamaları ve algoritmaları açıklanacak ve son olarak önerilen modelin beklenen yaygın etkisinden bahsedilecektir.

2. LİTERATÜR ÇALIŞMASI

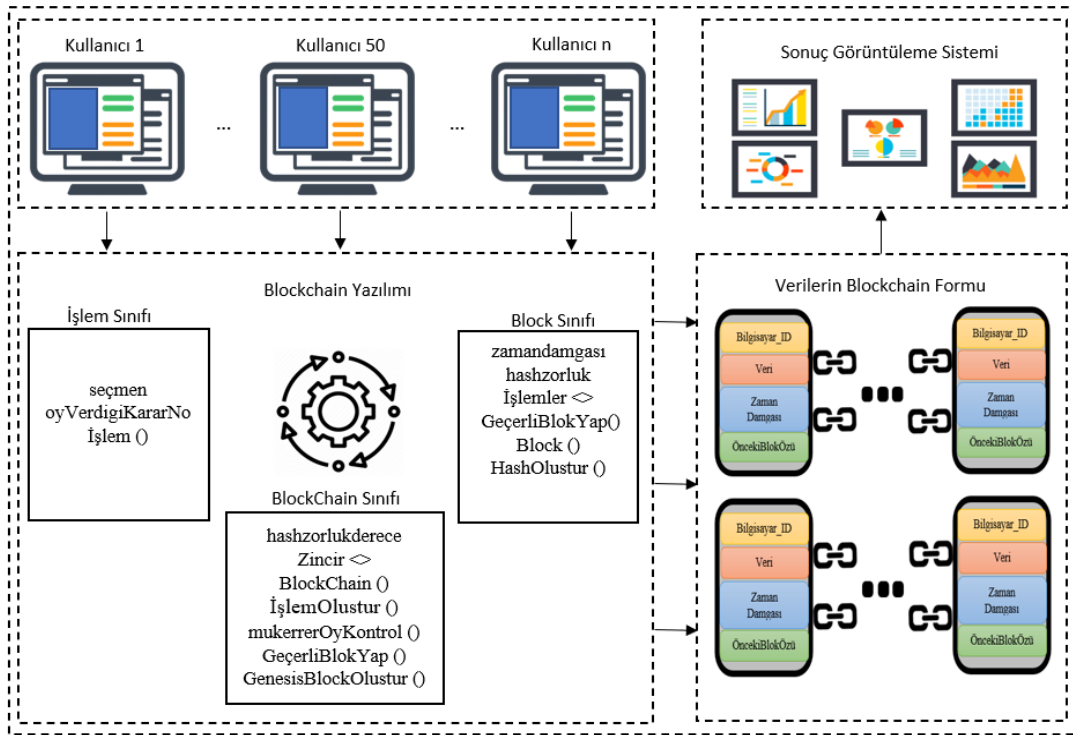
Kohno ve arkadaşları Amerikanın birçok bölgesinde benimsenmiş olan elektronik oylama sisteminin güvenlik açıkları üzerine bir çalışma gerçekleştirmişlerdir. Pazarın önemli bir bölümünde kullanılan bu tür bir makineye kaynak kodunun güvenlik analizini gerçekleştirmişlerdir. Analiz sonucunda, bu oylama sisteminin diğer bağlamlarda geçerli olan en düşük güvenlik standartlarının bile çok altında olduğunu göstermektedir. Yetkisiz ayrıcalık yükseltme, şifrelemenin yanlış kullanımı, ağ tehditlerine karşı zayıflıklar ve kötü yazılım geliştirme süreçleri gibi çeşitli sorunlar tespit edilmiştir. Ayrıca, sisteme düzenlenen ciddi saldırılarda kaynak koduna erişim olmadan bilgilere erişilebildiği gösterilmiştir. Bu tür saldırılar karşısında, içeriden öğrenilen tehditlerle ilgili olağan endişeler tek endişe değildir; yabancılar hasarı yapabilir. Sadece bir anket çalışanı gibi bir içeriden birinin oyları değiştirebileceğini değil, aynı zamanda içerilerin de seçmen mahremiyetini ihlal edebileceğini ve oy kullanan seçmenlerle oyları eşleştirebileceği gösterilmektedir [11]. Bu açıkların tespit edilmesiyle birlikte Kohno ve arkadaşlarının önerdiği model geliştirilerek değiştirilmiş ve güvenlik açıkları kısmen kapatılarak farklı çalışmalar ortaya konmuştur. Clarkson ve arkadaşları Civitas ismini verdikleri, zorlamaya karşı dirençli, evrensel olarak ve seçmen tarafından doğrulanabilen ve uzaktan oylamaya uygun ilk elektronik oylama sistemini oluşturmuşlardır. Sistemlerinin güvenli olduğunu iddia etmelerindeki temel neden kullanıcı doğrulamasını gerçekleştirmeleridir [12]. Çalışmalar güvenlik anlamında başarılı sonuçlar ortaya koydukça maliyet açısından oldukça kazançlı olan bu oylama sistemlerinin kullanımı yaygınlaşmaya başlamıştır. Örneğin Estonya, internet oylamasını ulusal olarak kullanan ilk ülke olmuştur ve bugün oylarının %30'undan fazlası çevrimiçi olarak yayınlanmaktadır [13]. Konuyla ilgili araştırmalar devam ederken, yeni güvenlik konseptlerinden olan blok zincir teknolojilerinden yararlanılmaya başlanmıştır. Aayed yeni bir elektronik oylama sistemi için açık kaynaklı blok zincir tabanlı tasarım önermiştir. Önerdiği modelde SHA-256 hash algoritmasını kullanmıştır [14]. Önerdiği model temel blok zincir prensiplerine sahiptir. Önerdiği modelde dezavantaj olarak kullanıcıdan kaynaklı hataların geri döndürülemez şekilde sistemde yer alması gösterilmiştir. Isirova ve arkadaşları blok zincir teknolojisini kullanarak merkezi olmayan bir elektronik oylama sistemi geliştirmek için iki seviyeli yeni konsept önermiştir. Sunulan blok zincir tabanlı oylama protokolünde, oylama şeffaflığı ve anonimlik de dahil olmak üzere bu tür protokollere yönelik tüm gereksinimleri sağlayan altı adımdan bahsedilmektedir. Çalışmada diğer çalışmalardan farklı olarak merkezi güven noktası yoksunluğundan kaynaklı saldırı hedefinden uzaklığı üzerinde durulmuştur [15].

Akademik alanda elektronik oylama sistemleri üzerine yapılan çalışmalar incelendiğinde tespit edilen ve yeni çalışmalara ilham olan ilk zafiyet güvenlik konusudur. Veri güvenliği konusunda yeni bir konsept olan blok zincir yapısı kullanılarak gerçekleştirilen elektronik oylama sistemleri ile bu çalışmada önerilen model arasında benzerlikler bulunmaktadır. Bunlardan bahsederek kullanılan temel blok zincir esaslarının ve algoritmalarının uygulanması, SHA-256 hash algoritması tercih edilmesi söylenebilir. Mevcut çalışmanın diğer çalışmalarda önerilen

modellerden farkları blok zincire kaydedilen verilerin gösterilme yöntemleri ve aynı cihazdan yalnızca 1 oy kullanabilmeyi sağlayan teknikler olarak söylenebilir.

3. METOD

Bu çalışmada önerilen modelde kullanılan blok zinciri yönetmek için Ethereum, Hyperledger gibi hazır çatılar kullanılmamıştır. C# dili ile uygulamaya özgü blok zincir sınıfları oluşturulup bu yapıyı temel alan güvenli oylama sistemi geliştirilmiştir. Blok zincir sistemini oluşturmak için Block, İşlem ve Blockchain isimli üç ayrı sınıf tanımlanmıştır. Block sınıfı zincirdeki bloklara ilişkin özellik ve metotları içermektedir. İşlem sınıfı zincirde yapılan işlemleri temsil eden nesne yapısını tanımlar. Blockchain sınıfında ise, blok zincirinin yönetimine ilişkin özellik ve metotlar mevcuttur. Bu üç sınıf yapısı aşağıda detaylı biçimde anlatılmaktadır. Geliştirilen yazılımda kullanılan her bir oy bir blok ile temsil edilmektedir. Önerilen modelin mimarisi Şekil 2’de gösterilmektedir.



Şekil 2. Önerilen model mimarisi.

İşlem gerçekleşen her bir oy verme işlemini modelleyen sınıf yapısıdır. İki özellik ve bir kurucu metoda sahiptir. Seçmen, oy kullanılan bilgisayarın ID numarası bu özellikte tutulacaktır. Her bir bilgisayardan sadece 1 oy kullanılabilmesi için mikroişlemci seri numarasından oluşan bir ID numarası kullanılmıştır. oyVerdiğiKararNo, seçmenlerin oy verdiği kararın numara bilgisi bu özellikte tutulacaktır. İşlem sınıfının parametrelili kurucu metodu kendisine gönderilen bilgileri seçmen ve oyVerdiğiKararNo özelliklerine atamaktadır.

Block sınıf yapısındaki özellik ve metodlarını detaylandırarak olursak; zamandamgası, bloğun zincire dahil olduğu tarih/saat bilgisini temsil eder. Hashzorluk özelliği, bir bloğa ait hesaplanan hash değerinin zorluk derecesinin yüksek olması, güvenlik açısından istenen bir durumdur. Block sınıfında bulunan GeçerliBlokYap metodu, hash değerinin ilk iki rakamının 0 olması kuralına uyan hash değerini buluncaya kadar sürekli olarak farklı hash değerleri üreten bir

döngü algoritması içermektedir. Eğer üretilen hash değeri belirtilen zorluk kuralına uymuyorsa başka bir hash değeri üretebilmek için şifrelenecek veri yapısı içinde her adımda değişecek bir veri lazımdır. Bu değişimin sağlanması için bir sayısal değişkenin değeri her denemede 1 artırılmıştır. Örneğin bir bloğa ait üretilen hash değerinin ilk iki rakamı 0 ile başlamıyor kabul edilir ise hashzorluk değişkeni 1 artırılarak tekrar hash değeri hesaplanır ve kurala uyup uymadığına bakılır. Bu şekilde istenen kurala uyan hash değeri hesaplanıncaya kadar hashzorluk değeri 1 artacaktır.

İşlem, blok içerisinde İşlem sınıf yapısındaki elemanlardan oluşan liste yapısıdır. Blok içinde işlem bilgileri bu listede tutulur. Oylama uygulamasında ise kimin hangi karara oy verdiği bilgisi İşlems listesinde tutulacaktır. Hangi seçmenlerin oy kullanıp kullanmadığı, kararların oy miktarları gibi değerlendirmelerin yanı sıra mükerrer oy kullanılmasının önüne geçmek için de İşlems bilgileri kullanılacaktır. ÖncekiBlokÖzü, bir önceki bloğa ait şifrelenmiş özet değerini barındırır. Hash, mevcut bloğa ilişkin şifrelenmiş özet bilgisini barındırır. Bu değer, bir önceki bloğun hash değeri üzerine mevcut blok verisini eklenip tekrar şifrelenmesi sonucu ortaya çıkar.

GeçerliBlokYap metodu, yeni geçerli bloklar oluşturmak için kullanılacak metottur. Metoda gönderilen hashzorlukderece değeri hesaplanacak hash değerinin zorluk derecesini temsil eder. GeçerliBlokYap metodu, hash değerinin ilk birkaç rakamının 0 olması kuralına uyan hash değerini buluncaya kadar sürekli olarak farklı hash değerleri üreten bir döngü algoritması içermektedir. İlk rakamların kaç tanesinin 0 olacağı hashzorlukderece değişkenine gönderilen değerle belirlenir. Eğer üretilen hash değeri belirtilen zorluk kuralına uymuyorsa başka bir hash değeri üretebilmek için tekrar hesaplama yapılır. HashOlustur metodu ile bloktaki zamandamgası, ÖncekiBlokÖzü, İşlemler ve hashzorluk verileri birleştirilerek bir string değer elde edilir. Oluşan string SHA256 (Kriptografik Hash Algoritması) ile şifrelenerek yeni bir hash verisi oluşur. Bu duruma göre bir bloğun hash verisi zaman damgası, bir önceki bloğun hash değeri, işlemler listesi ve hashzorluk değerinin şifrelenmesinden oluşan bir veridir. Ayrıca Block sınıfı kendine gönderilen değerleri sınıf özelliklerine atayan bir kurucu metoda da sahiptir. Hash oluşturma işlemi için uygulanan yöntemin matematiksel modeli Formül 1’de gösterilmiştir.

i: Kayıt indisi,

ZD: Zaman damgası,

YK: Yeni kayıt girişi,

GH: öz çıkarma işlemi,

GAH: Tüm kayıtların özü olmak üzere:

$$YK_i = GH(YK_i + ZD + GAH_{i-1}) \quad (1)$$

BlockChain sınıfı blok zincirinin yönetimine ilişkin özellik ve metotları barındıran sınıftır. Hashzorlukderece zincirdeki blokların sahip olduğu hash değerinin zorluk derecesini temsil eder. Matematiksel modelde yeni kaydın sırasını belirten indis numarası “i” ile gösterilmektedir. “ZD” işlemin gerçekleştirildiği ana ait zaman damgası bilgisini tutan değişkendir. “YK” yeni kayıt oluşturulmasında kullanılan değişkendir. “GH” yeni oluşacak kayıt ile yeni kaydın öncesindeki tüm kayıtların (“GAH”) birleştirilerek yanlarına zaman damgası ilave edildikten sonra öz işlemini gerçekleştiren fonksiyondur.

Block sınıfı yapısında tanımlanmış “Zincir” ismindeki yapı, zincirdeki blokları içeren ve Block sınıfından elemanlar barındıran listedir. İşlemOlustur metodu yeni bir oy verme işlemi oluşturur. İşlem bilgisini İşlem türünde bir parametre yardımıyla dışardan alır ve işlem bilgisini zincir listesine ekler. GeçerliBlokYap metodu yeni bir blok oluşturur. Şu anki zaman bilgisini ve zincirdeki işlemleri içeren zincir listesini kurucu metod yardımıyla bloğa gönderir. Hashzorlukderece özelliğinde tutulan zincirin zorluk derecesine göre bloğa ait hash bilgisini oluşturur. Zincirdeki en son bloğun hash değerini de blok içerisine dâhil eder. Tüm bunların ardından bloğu zincire ekler. Son olarak da zincirdeki işlem listesini boşaltır. IsValidChain metodu blok zincirindeki blokların kendi hash değerlerinin doğruluğuna bakar. Eğer bir sorun yoksa bloğun kendi içinde barındırdığı önceki bloğun hash verisi ile bir önceki bloğun kendi hash verisini karşılaştıran bir algoritma yardımıyla zincirin doğruluğunu test eder. Kurcalanma tehlikesine karşı zincirin doğruluğunu araştırır. GenesisBlockOlustur metodu genesis bloğu ya da başlangıç bloğu olarak adlandırılan bir blok zincirinin ilk bloğunu oluşturmayı sağlar. MukerrerOyKontrol metodu blok zincirdeki bütün oyları kontrol edilerek bir seçmenin daha önce oy kullanıp kullanmamasına göre true ya da false döndürür. Tekrarlı oy kullanılmasının önüne geçmek için bu metod kullanılmıştır.

3.1. Oy Verme ve Gösterme İşlemi

Seçmen bilgisayarın önerilen model içerisinde yalnızca 1 oy kullanabilme hakkı vardır. Seçmen bilgisayar ID numarası şifreleme işlemine tabi tutularak her bilgisayardan sadece 1 oy kullanılması sağlanmış olunur. Oy verme işlemi esnasında yürütülen algoritma adımları adımlar Tablo 1’de gösterilmiştir.

Tablo 1 Oy verme algoritması

Giriş verileri: Önceki bloğun hash değeri, zaman damgası, işlem verisi, zorluk değişkeni
Çıkış verileri: Yeni hash değeri
<ol style="list-style-type: none"> 1) Başla 2) Uygulama çalıştırıldığında ağ ortamından blok zincir hesap defterini çek. 3) Mikroişlemci seri numarasını temel alarak benzersiz bir ID numarası üret. 4) Üretilen ID numarasını şifrelenmiş veriye dönüştür. 5) Blok zincirdeki işlem kayıtları kontrol et. 6) Seçmen bilgisayarların ID numaraları ile o anki seçmen bilgisayarın ID numarası karşılaştırılır. 7) Bu bilgisayardan daha önce oy kullanılmışsa oy verme işlemi yapma. 8) Eğer bu bilgisayardan ilk defa oy kullanılıyorsa blok zincirde yeni bir işlem kaydı oluştur. 9) Oy kullanılan bilgisayar ID numarası ve hangi seçime oy verildiği bilgisini kaydet. 10) Önceki bloğun hash değeri, zaman damgası, işlem verisi, zorluk değişkeni verileri kullanılarak yeni bir Hash değeri oluştur. 11) Oluşan Hash değerini yeni bloğun Hash değeri olarak ayarla. 12) Oluşturulan bloğu zincire ekle. 13) Son

Şifreleme işlemi ise hangi seçmenin hangi seçeneğe oy verdiğinin bilinmemesi içindir. Daha sonra bu seçmenin daha önce oy kullanıp kullanmadığı tespit edilmektedir. Eğer ilk defa oy kullanıyorsa blok oluşturulup zincire dahil edilir. Önerilen modele uygulama ara yüzü Şekil 3’de gösterilmektedir.



Şekil 3. Önerilen modelin uygulama ara yüzü.

Blok zincirdeki tüm kayıtlardaki seçmen bilgisi ve oy verdiği karar numarası listelenmektedir. Burada önemli olan seçmen kimlik numaralarının şifrelenmesinden dolayı kimin hangi karara oy verdiği anlaşılamamaktadır.

4. SONUÇ

Bu çalışmada, planlanan bir seçim aksiyonunun hızlı, güvenli, şeffaf ve düşük maliyetler ile nasıl gerçekleştirilebileceğine yönelik alternatif bir güvenli elektronik oylama modeli önerilmiştir. Önerilen modelin kullanımı okul, şirket, holding gibi küçük çaplı organizasyonlardan yerel seçimler, genel seçimler, referandumlar gibi büyük çaplı organizasyonlara kadar geniş bir yelpazeye hitap edebilir. Günümüzde küresel bazda yaşanan Covid-19 bulaş hastalığının kalabalık alanlarda yarattığı riskler göz önünde bulundurulduğunda önerilen modelin önemi daha net ortaya çıkmaktadır. Çalışmanın bir sonraki basamağında önerilen modelin web ortamına taşınması ve kimlik doğrulama sistemlerinin mevcut modele entegre edilmesi planlanmaktadır.

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MODELLING OF A FLAT PLATE SOLAR COLLECTOR SYSTEM USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT: In this study, performance analysis of flat plate solar collector has been carried out analytically. A comprehensive mathematical modelling of thermal performance is modelled using Response Surface Methodology and optimal geometrical and thermodynamic parameters are predicted pertaining to optimum performance of the system. In this study a model was developed for evaluating and predicting the efficiency, outlet temperature and performance of a flat plate solar collector considering the hour angle, day and input temperature as input parameters. In the cause of the work it was found that the days and months close to the beginning of the year (January, February, March and April) yielded higher outlet temperature and solar radiation due to dry season, while the months at the middle of the year showed lower outlet temperature and solar radiation due to the rainy season. The months towards the ending of the year also showed higher outlet temperature and solar radiation respectively.

Keywords: Hour Angle, Day Temperature, Efficiency, Design of Experiment, Solar Collector.

1. INTRODUCTION

The role of energy becomes increasingly important to fulfil the needs of modern societies and to sustain fast economic and industrial growth worldwide. In view of the world's depleting fossil fuel reserves and environmental threats, development of renewable energy sources receives importance as an alternative to serve as a form of power source. Solar energy stands out as one of the renewable energy resources that has continuously meet the energy demand in the world, as a result of the availability of sunshine on a daily basis. Though it is location and time dependent, it requires efficient collection and storage systems for economic use.

Solar energy can assist in some areas like water treatment, hot/process water for domestic and industrial use. One of the easiest ways to utilize solar energy for heating applications is to convert it into thermal energy by using solar collectors.

Solar energy collectors are special kinds of heat exchangers that transform solar energy to internal energy of water. The thermal analysis of the collectors is very complicated because all the possible modes of heat transfer and radiation are taken into consideration. The determination of the heat losses coefficient is the main goal of an energetic analysis because this leads to the determination of the useful energy rate from the solar collector.

Several studies which compare experimentally results with results base on Computational Fluid Dynamics (CFDs) have been published in recent times [1]. Many researchers have used exergy analysis in order to improve the efficiency of collectors by decreasing the losses. Hamed and Ban, [2] used MATLAB to optimize a flat plate collector with this method. Parametrical analysis is also useful in the analysis of flat plate solar collector, as it helps in determining optimum parameters which in turn influences the output efficiency. Hottel and Woertz, [3] calculated the overall heat loss coefficient and the collector efficiency under different conditions such as the absence of cover, with single and double glazing under different ambient conditions, tilt angles, wind speeds, emissivity of both glass cover and absorber plate. Paulescu et al, [4] discussed the influence of various parameters on the efficiency of solar collectors and concluded that at low solar insolation in the range of 200-600 W/m² double glazed collectors are superior to single glazed. Stanciu and Stanciu, [5] examined the performance by changing the colors of solar collector. Based on the transmittance-absorptance result of various colored collectors the hypothetical performances of these collectors were calculated using the Hottel-Whillier-Bliss 1-D steady-state model given by [6]. By these experiments they concluded that the color of the collector plays a major role in thermal efficiencies of the collectors.

In this study Response Surface Methodology (RSM) was used as a modelling tool, considering both input and output parameters/responses.

2. MATERIALS AND METHOD

The purpose of the model was to predict the performance of the flat plate solar collector using hour angle, day and inlet temperature as input parameters. The output parameters or responses that were obtained are outlet temperature and efficiency respectively. This modelling enabled the development of a new mathematical model to also validate the experimental work that was later carried out.

The modelling of the system was done using Response Surface Methodology (RSM), boundary conditions and the considerations of the design during the thermodynamic analysis. The design was carried out using factorial design on design expert to check for every limit on each block of the values to ascertain the correlation between the input variables and the output variables. The Box Behnkens design was used for the full factorial design.

Box-Behnken designs are response surface designs, specially made to require only 3 levels, coded as -1, 0, and +1. Box-Behnken designs are available for 3 to 10 factors. They are formed by combining two-level factorial designs with incomplete block designs. This procedure creates designs with desirable statistical properties but, most importantly, with only a fraction of the experiments required for a three-level factorial. Because there are only three levels, the quadratic model is appropriate. Blocking options are also offered for most of these designs.

You may also add categorical factors to this design. This will cause the number of runs generated to be multiplied by the number of combinations of the categorical factor levels.

Table 1 provides the design of experiment that was used for the analysis and modelling. The input factors and the output factors or response are considered during the design of experiment, the input factors are hour angle, day and inlet temperature. The output/response are input temperature and efficiency.

I. Hour Angle (Degrees)

The hour angles affect the design because the position of the sun on a particular day is dependent on the local time of the place. The solar noon was considered to be 0° and every hour was counted as 15° . Hours before noon took a negative sign while hours after noon was positive for example, 9:00A.M in the morning is 3hrs from solar noon thus was read as $15 \times 3 = 45$, since it is before noon, it is therefore recorded as -45° . The design considered times from 9:00A.M to 3:00P.M.

II. Day (number from 1st January)

The days were counted from 1st of January, so it is counted from 1 to 365 days. The day greatly affects the amount of solar radiation on the surface as the distance from the sun varies and the position of the specific location changes as the earth revolves around the sun.

III. Inlet Temperature (Kelvin)

The Inlet temperature of the fluid is a factor that will greatly affect the efficiency of the collector. The inlet temperature of the fluid determines the outlet temperature when all other factors remain constant. The Inlet temperature was varied from 295K to 353K.

Table 1. Design of experiment.

St d	Ru n	Block	Factor 1 A:Hour Angle (deg)	Factor 2 B:Day	Factor 3 C: Inlet Temp.(K)	Response 1 Efficiency	Response 2 Outlet Temp. (K)
3	1	Block 1	-45.00	365.00	324.00	0.72	361.97
8	2	Block 1	45.00	183.00	353.00	-0.27	351.88
15	3	Block 1	0.00	183.00	324.00	0.59	336.56
6	4	Block 1	45.00	183.00	295.00	0.93	314.22
5	5	Block 1	-45.00	183.00	295.00	0.93	314.22
14	6	Block 1	0.00	183.00	324.00	0.59	336.56
17	7	Block 1	0.00	183.00	324.00	0.59	336.56
10	8	Block 1	0.00	365.00	295.00	0.88	342.25
1	9	Block 1	-45.00	1.00	324.00	0.73	362.36
16	10	Block 1	0.00	183.00	324.00	0.59	336.56
7	11	Block 1	-45.00	183.00	353.00	-0.27	351.88
4	12	Block 1	45.00	365.00	324.00	0.72	361.97
13	13	Block 1	0.00	183.00	324.00	0.59	336.56
12	14	Block 1	0.00	365.00	353.00	0.52	375.12
2	15	Block 1	45.00	1.00	324.00	0.73	362.36
11	16	Block 1	0.00	1.00	353.00	0.52	375.08
9	17	Block 1	0.00	1.00	295.00	0.88	342

3. RESULTS AND DISCUSSION

The model was developed using Response Surface Methodology. The study type uses was Response Surface Methodology a technique that can be used to study the effect of two or more constraints in a process, the design considered was the Box-Behnkn which is an independent quadratic design, it does not contain an embedded factorial design and the design model chosen was the quadratic from. The input factors were hour angle, day and inlet temperature as shown in Table 2 and table 3 respectively. The responses where efficiency and outlet temperature respectively.

Study type: Response surface
Design: Box-Behnken
Design model: Quadratic

Table 2. Design model summary 1.

Factor	Name	Units	Type	Low actual	High actual	Low coded	High coded	Mean	Std. dev
A	Hour angle	Degree	Numerical	-45.0	45.0	1.0	1.0	1.0	30.87
B	Day		Numerical	1.0	365.0	-1.0	1.0	183.0	124.85
C	Inlet temp.	K	Numerical	295.0	353.0	-1.0	1.0	324.0	19.894

Table 3. Design model summary 2.

Res pon	Name	Unit s	Obs	Analysis	Min	max	Mean	Std dev	Ratio	Tran s	Model
Y1	Efficiency	%	17	Polynomi al	0.270	0.930	0.586	0.340	-3.44	none	Rquadrat ic
Y2	Outlet temp	K	17	Polynomi al	314.2	375.1	346.9	17.6	1.19	none	Quadrati c

Table 2 and 3 present the design summary that involves the input and the response using a quadratic model and activity using a linear model.

3.1. Graph Columns

The graph columns display the correlation between a response and an input factor. It displays the response on the vertical axis while the input on the horizontal axis. The different factors can be selected to check the following situations:

It is used to view the Block effects. Plot the response versus the input to visually determine whether the input were influential or not. It is used to gather information about the practical importance of factors that are not statistically significant. For instance, you may not want to include a factor in the model because their effect on the response is very low.

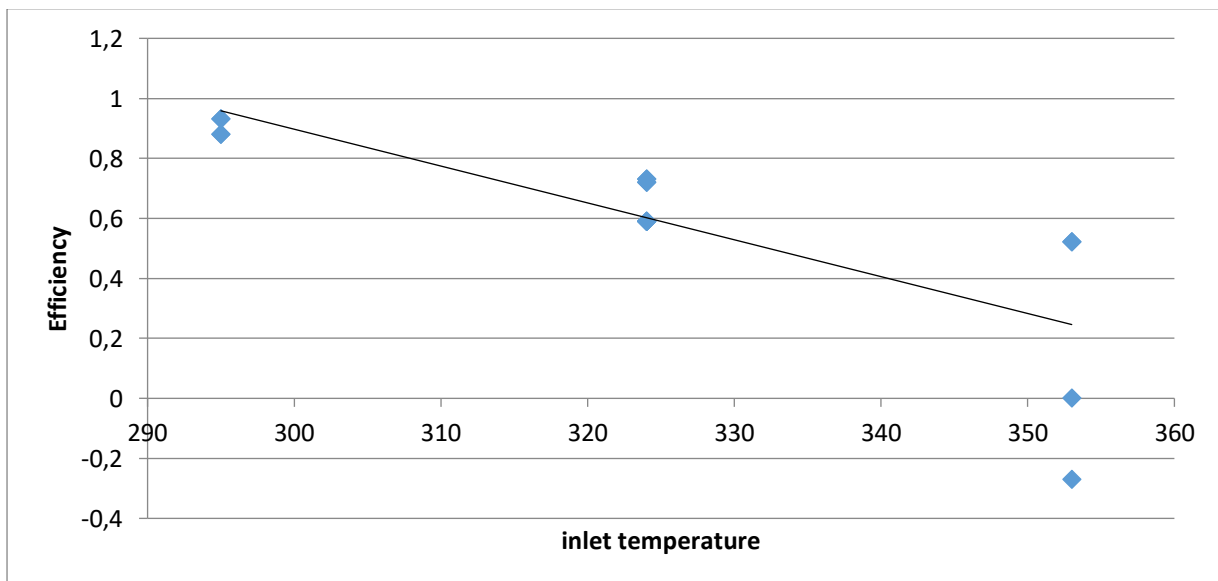


Figure 1. A graph of efficiency against inlet temperature.

Figure 1 shows the correlation between the input parameter and the response parameter. The efficiency is the response parameter and the inlet temperature is the input parameter. An increase in inlet temperature leads to a decrease in efficiency. This shows that the inlet temperature does not have a positive effect on the system. A correlation of -0.788 was achieved after using Response Surface Methodology, this shows there is no correlation between the input parameter and the response parameter.

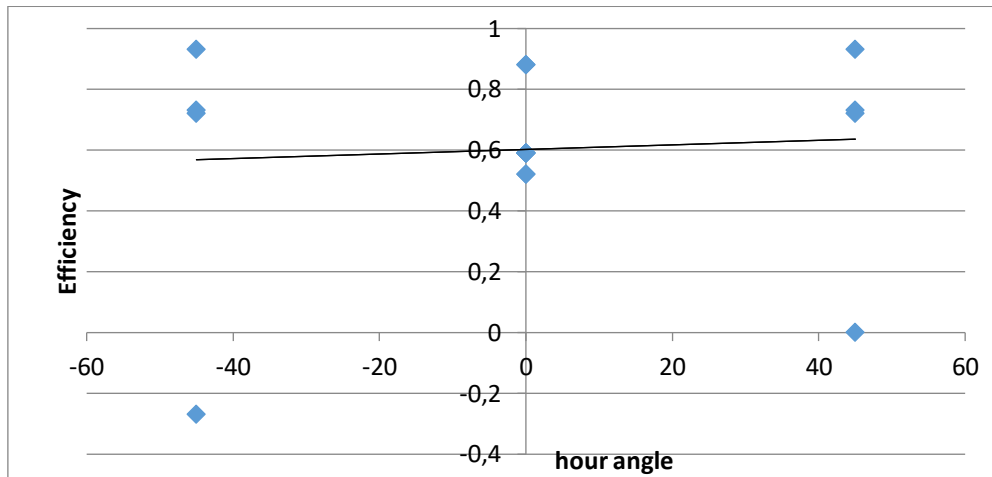


Figure 2. A graph of efficiency against hour angle.

Figure 2 shows the correlation between the input parameter and the response parameter. The efficiency is the response parameter and the hour angle is the input parameter. An increase in the hour angle does not give a significant increase in the efficiency. A correlation of 0.000 was achieved after Response Surface Methodology was employed, this shows that there is no correlation between the input parameter (hour angle) and the response (efficiency). As such there is no significant effect on the response.

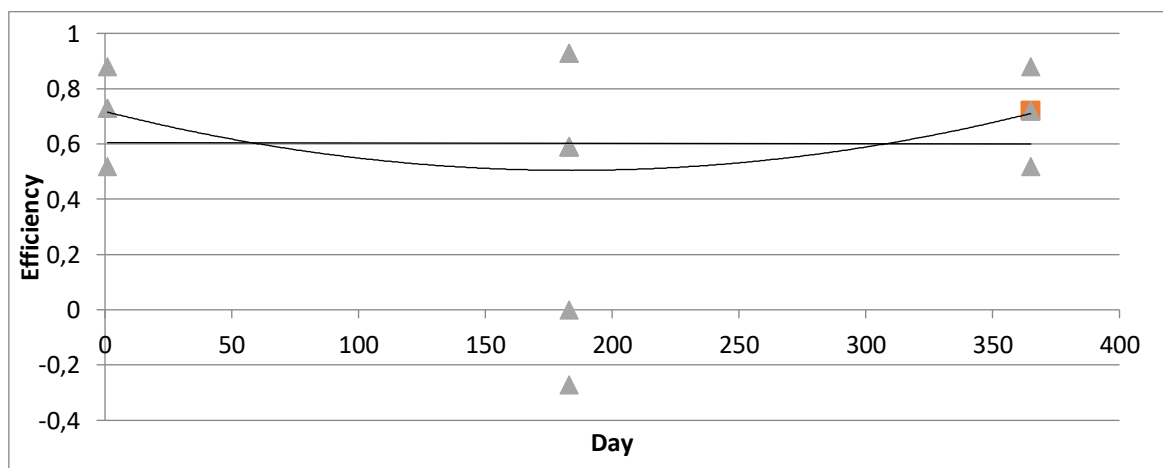


Figure 3. A graph of efficiency against day.

Figure 3 shows the correlation between the input parameter and the response parameter. The efficiency is the response parameter and the day is the input parameter. An increase in the day does not give a significant increase in the efficiency. A correlation of -0.005 was achieved after Response Surface Methodology was used, this indicates that there is no correlation between the input factor and the response parameter.

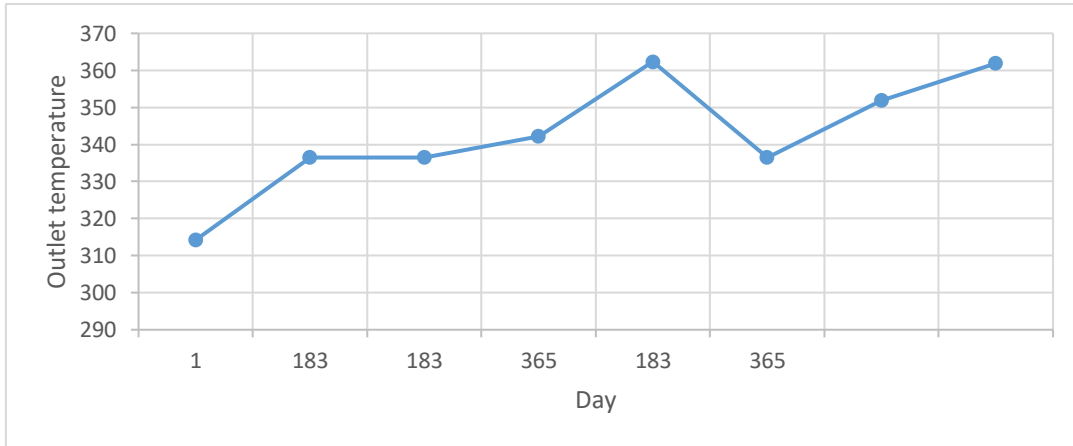


Figure 4. A graph of outlet temperature against day.

Figure 4 shows the correlation between the input parameter and the response parameter. The outlet temperature is the response parameter and the day is the input parameter. An increase in the number of days produced an unsteady performance as related to the outlet temperature. A correlation of -0.002 was achieved, this shows that there is no correlation between the input factor and the response parameter.

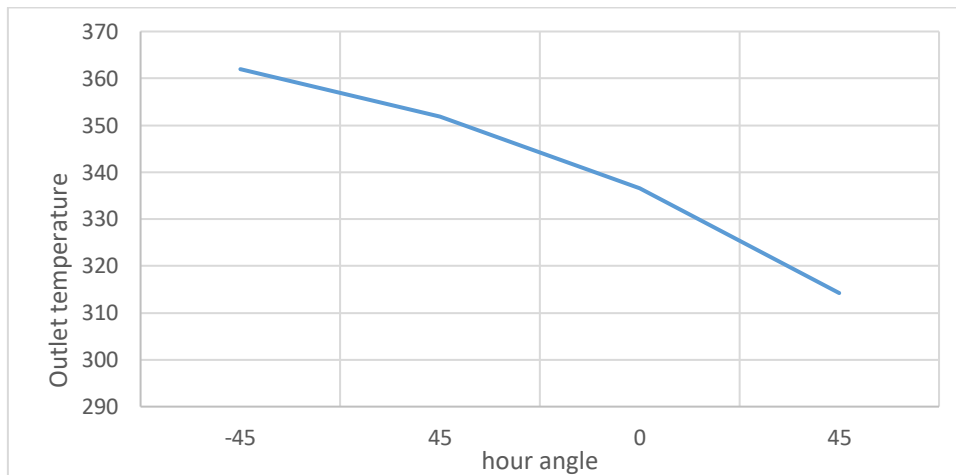


Figure 5. A graph of outlet temperature against hour angle.

Figure 5 shows the correlation between the input parameter and the response parameter. The outlet temperature is the response parameter and the hour angle is the input parameter. As hour angle increased there was a decrease in output temperature, this shows that the hour angle does not have a positive effect on the system. A correlation of 0.000 was achieved using Response Surface methodology, this shows that there is no correlation between the input parameter (hour angle) and the response (outlet temperature). As such there is no significant effect on the response.

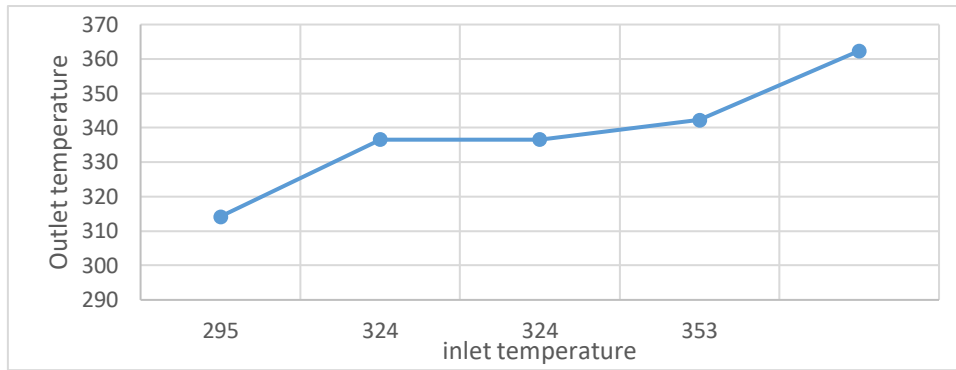


Figure 6. A graph of outlet temperature against inlet temperature.

Figure 6 shows the correlation between the input parameter and the response parameter. The outlet temperature is the response parameter and the inlet temperature is the input parameter. An increase in the inlet temperature lead to an increase in the outlet temperature. A correlation of 0.687 was achieved when Response Surface Methodology was used, this shows that there is a correlation between the input factor and the response parameter.

Response 1 Efficiency

Transform: Power

Lambda: 2.37 Constant: 0.297

Backward Elimination Regression with Alpha to Exit = 0.100

Forced Terms: Intercept

Table 4. ANOVA for Response Surface Reduced Quadratic Model.

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F
Model	3.29	3	1.10	49.10	< 0.0001
<i>B</i> -Day	2.981E-004	1	2.981E-004	0.013	0.9098
<i>C</i> -Inlet Temperature	3.00	1	3.00	134.07	< 0.0001
<i>B</i> ²	0.30	1	0.30	13.20	0.0030
Residual	0.29	13	0.022		
Lack of Fit	0.29	9	0.032		
Pure Error	0.000	4	0.000		
Cor Total	3.58	16			

Table 5. Analysis of variance.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.79	1	0.050	0.68	0.89	
<i>B</i> -Day	-6.194E-003	1	0.053	-0.12	0.11	1.00
<i>C</i> -Inlet Temperature	-0.61	1	0.053	-0.73	-0.50	1.00
<i>B</i> ²	0.26	1	0.073	0.11	0.42	1.00

Considering Table 4 and 5 of the flat plate solar collector, the model F-value implies that the model is significant. Values of “Prob > F” less than 0.0500 indicate that the model terms are significant. In this case *C*- inlet temperature and *B*² are more significant model terms. Values greater 0.1000 indicates that the model terms are less significant. Equations 1 and 2 are relations to predict the efficiency of the flat plate solar collector.

Final Equation in Terms of Coded Factors:

$$(Efficiency + 0.30)^{2.37} = 7.895 - 0.0006194B - 0.61C + 0.26B^2 \tag{1}$$

Final Equation in Terms of Actual Factors:

$$(Efficiency + 0.30)^{2.37} = 7.895 - (2.950 \times 10^{-3})Day - 0.021Inlet\ temp + (7.968 \times 10^6)Day^2 \tag{2}$$

The ANOVA Table confirms the adequacy of the quadratic model (the model Prob > F is less than 0.05), the probability values for each individual term in the model is shown as displayed. When the probability values is greater than 0.10, it is best to consider removing the terms for proper modelling.

Response 2: Outlet Temperature
Transform: Power, Lambda: 2.8, Constant: 0
Backward Elimination Regression with Alpha to Exit = 0.100
Forced Terms: Intercept

Table 6. ANOVA for Response Surface Reduced Quadratic Model.

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	5.725E+013	6	9.541E+012	51247.08	< 0.0001
A-Hour Angle	0.000	1	0.000	0.000	1.0000
B-Day	4.182E+008	1	4.182E+008	2.25	0.1648
C-Inlet Temperature	2.684E+013	1	2.684E+013	1.442E+005	< 0.0001
A ²	5.301E+009	1	5.301E+009	28.47	0.0003
B ²	3.020E+013	1	3.020E+013	1.622E+005	< 0.0001
C ²	3.463E+011	1	3.463E+011	1859.87	< 0.0001
Residual	1.862E+009	10	1.862E+008		
Lack of Fit	1.862E+009	6	3.103E+008		
Pure Error	0.000	4	0.000		
Cor Total	5.725E+013	16			

Table 7: Analysis of variance table.

Factor	Coefficient Estimate	Df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	1.191E+007	1	6102.16	1.189E+007	1.192E+007	
A-Hour Angle	0.000	1	4824.18	-10748.94	10748.94	1.00
B-Day	-7230.16	1	4824.18	-17979.10	3518.77	1.00
C-Inlet Temperature	1.832E+006	1	4824.18	1.821E+006	1.842E+006	1.00
A ²	35480.83	1	6649.67	20664.44	50297.22	1.01
B ²	2.678E+006	1	6649.67	2.663E+006	2.693E+006	1.01
C ²	-2.868E+005	1	6649.67	-3.016E+005	-2.720E+005	1.01

Considering Table 6 and 7 of the flat plate solar collector, the model F-value implies that the model is significant. Values of “Prob > F” less than 0.0500 indicate that the model terms are significant. In this case C- inlet temperature, A², B² and C² are more significant model terms. Values greater 0.1000 indicates that the model terms are less significant. Equations 3 and 4 are relations to predict the outlet temperature of the flat plate solar collector.

Final Equation in Terms of Coded Factors:

$$(outlet\ temp)^{2.8} = +1.19 \times 10^7 - 7230.16B + 1.83 \times 10^6C + 35480.83A^2 + 2.68 \times 10^6B^2 - 2.87 \times 10^5C^2 \tag{3}$$

Final Equation in Terms of Actual Factors:

$$(outlet\ temp)^{2.8} = -4.16 \times 10^7 - 29629.65\ Day + 2.84 \times 10^5\ Inlet\ Temp + 17.52\ Hour\ Angle^2 + 80.84(Day)^2 - 340.99 (Inlet\ temp)^2 \tag{4}$$

The ANOVA Table confirms the adequacy of the quadratic model (the model Prob > F is less than 0.05), the probability values for each individual term in the model is shown as displayed. When the probability values is greater than 0.10, it is best to consider removing the terms for proper modelling.

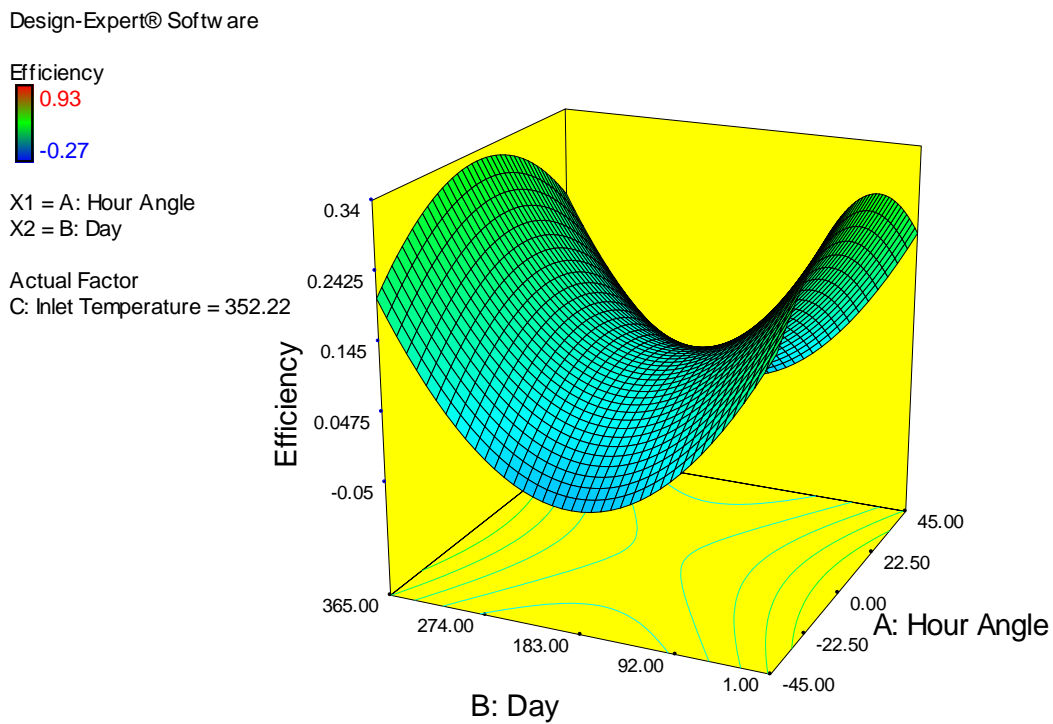


Figure 7. A 3D graph of efficiency against day and hour angle.

The 3D graph of efficiency against day and hour angle shows that at an inlet temperature of 352.22°C, it can be observed that the maximum efficiency is at a value of 52 percent in January with a temperature of 353K. This is because at this temperature the system may lose temperature to the plate. Little consideration will show temperature difference between the plate and fluid temperature is proportional to efficiency and thus at higher temperatures the efficiency undergoes a steady drop. Low inlet temperature may increase efficiency by 36 percent for days at the beginning and tail end of the year and a drop in maximum efficiency.

It gets to its bottom point at 183 day of the year. These results are obtainable at an hour angle of 0 degrees. However as the hour angles passes noon, the efficiency increases for all days from 1-365 at all inlet temperatures. The range of efficiency tends to increase as hour angle moves towards noon for a single day and difference in inlet temperature. The efficiency rises to almost

93 percent at 3pm in January when the inlet temperature is at room temperature but drop to zero at 353K. The hour angle seems to have little effect on the efficiency of the system.

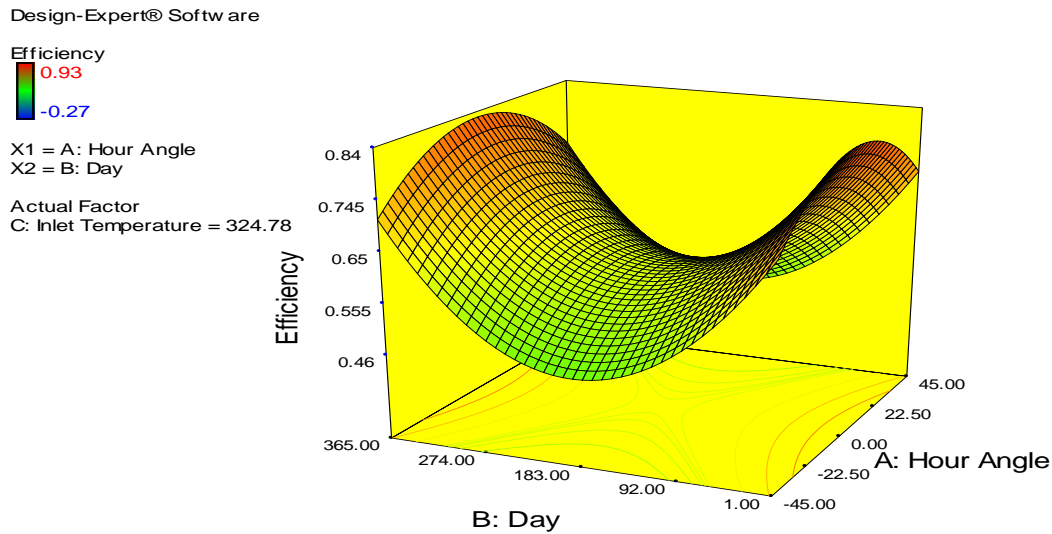


Figure 8. A 3D graph of efficiency against day and hour angle.

The 3D graph of efficiency against day and hour angle shows that at an inlet temperature of $324.78^{\circ}C$, a reduction in the number of days lead to a decrease in efficiency towards the mid-point of 183 days. As observed from the mid-point to the end, there was an increase in the efficiency and the hour angle. This implies that January, February and March which has a mid-month with lower days has more efficiency and it drops while approaching the middle of the year which is the raining season and it rises towards the end of the year (September, October, November and December). The colour indication at the edge of the 3D graph shows that using inlet temperature of $324.78^{\circ}C$ allows only the months close to the edge, which is January and December get an efficiency that is close to 0.93.

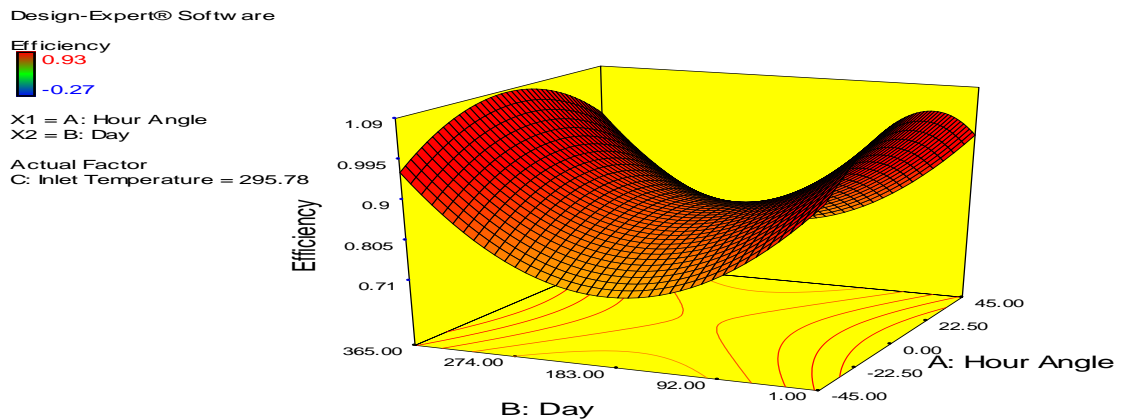


Figure 9. A 3D graph of efficiency against day and hour angle.

The 3D graph of efficiency against day and hour angle shows that at an inlet temperature of $295.78^{\circ}C$, a decrease in the number of days causes a decrease in efficiency towards the mid-point considering it at 183 days as shown in figure 9. As observed from the mid-point to the tail end there is an increase in efficiency, as the hour angle increases there is also an increase in the efficiency. This implies that January, February and March which has a mid-month with lower

days has more efficiency and it drops while approaching the middle of the year which is the raining season and it rises towards the end of the year (September, October, November and December). Looking at the colour of the 3D graph which appears red in almost all its part as indicated on the efficiency factor key (turning red is attaining close to 0.93 efficiency and blue is moving away from the efficiency). An outlet temperature of $295.78^{\circ}C$ shows that almost all part of the year can attain 0.93 efficiency but it is darker at the edge, indicating January, February, March, fairly April, September, October, November and December can achieved maximum efficiency of 0.93.

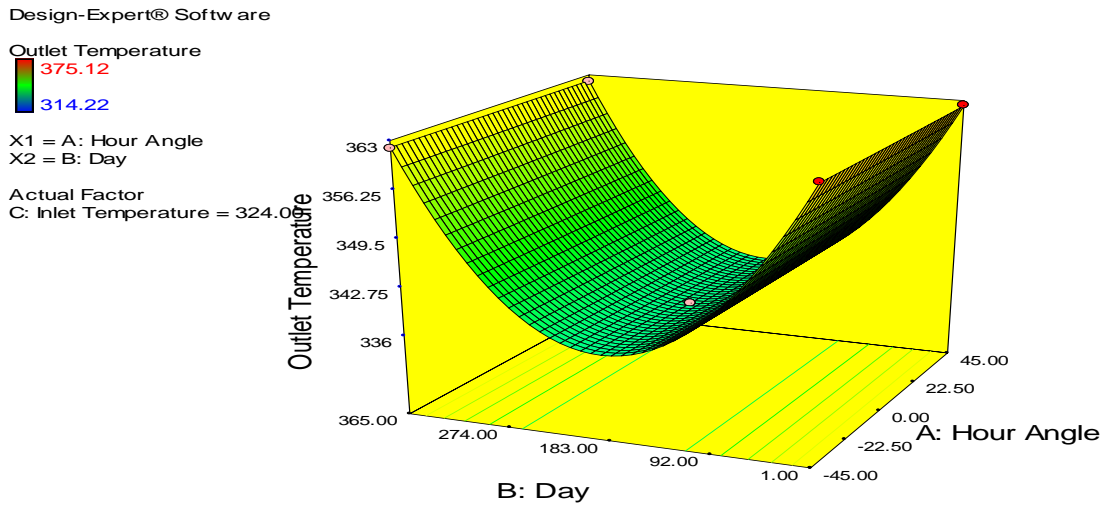


Figure 10. A 3D graph of outlet temperature against day and hour angle.

The 3D graph of efficiency against day and hour angle shows that at an inlet temperature of $324.00^{\circ}C$, a reduction in the number of days causes a decrease in outlet temperature towards the mid-point of about 183 days. From the mid-point to the tail end, there is an increase in outlet temperature. As the hour angle increase there is also an increase in the outlet temperature. This implies that January, February and March which has a mid-month with lower days has more outlet temperature and it drops while approaching the middle of the year which is the raining season and it rises towards the end of the year (September, October, November and December). Using an inlet temperature of $295.78^{\circ}C$ it shows on the 3D graph as indicated by the colour patterns that the outlet temperature of $375.12^{\circ}C$ cannot be achieved.

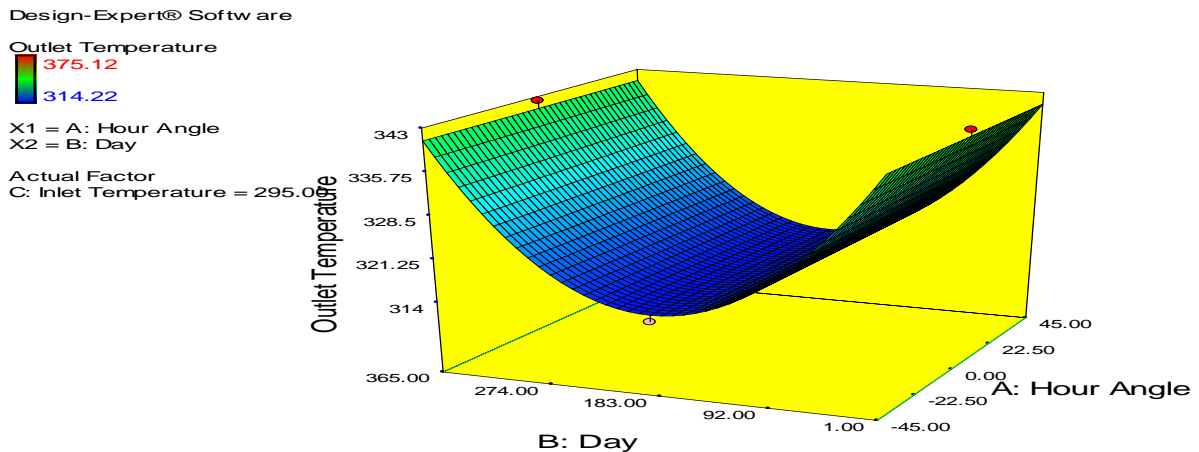


Figure 11. A 3D graph of outlet temperature against day and hour angle.

The 3D graph of efficiency against day and hour angle shows that at an inlet temperature of 295.00°C , a reduction in the number of days causes a decrease in the outlet temperature as it tends towards the mid-point of the graph but after the mid-point and moving towards the tail end, the outlet temperature increases. An increase in the hour angle leads to an increase in the outlet temperature. This implies that January, February and March which has a mid-month with lower days has more outlet temperature and it drops while approaching the middle of the year which is the raining season and it rises towards the end of the year (September, October, November and December). Using an inlet temperature of 295.00°C it shows on the 3D graph using the colour pattern that the outlet temperature of 375.12°C cannot be achieved.

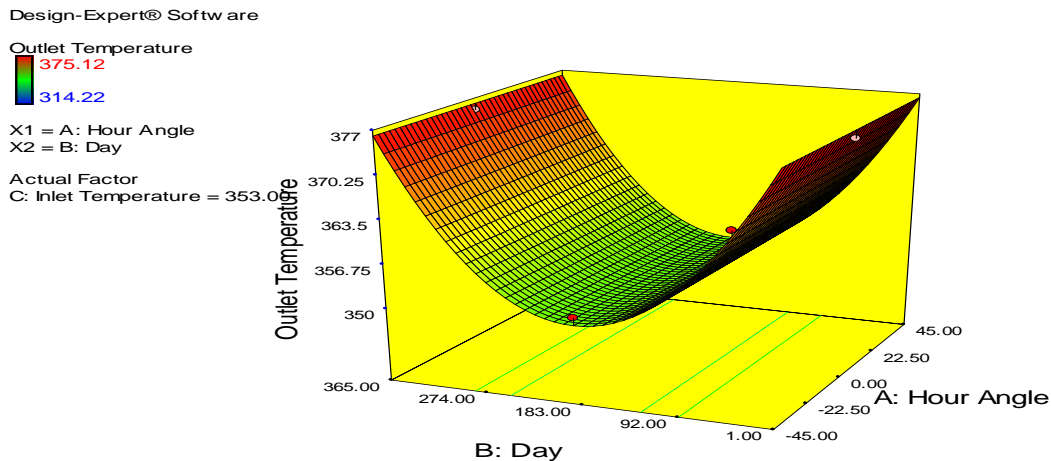


Figure 12. A 3D graph of outlet temperature against day and hour angle.

The 3D graph of efficiency against day and hour angle shows that at an inlet temperature of 353.00°C , a reduction in the number of days causes a decrease in outlet temperature till it gets to the mid-point of 183 days and from the mid-point the curve tends to move upwards, causing an increase in outlet temperature. An increase in hour angle also leads to an increase in outlet temperature. This implies that January, February and March which has a mid-month with lower days has more outlet temperature and it drops while approaching the middle of the year which is the raining season and it rises towards the end of the year (September, October, November and December). Using an inlet temperature of 353.00°C it shows on the 3D graph from the colour pattern that the outlet temperature of 375.12°C can be achieved by the months closer to the edges of the curve.

4. CONCLUSION

In this study a model was developed to effectively predict the output temperature and efficiency of the solar thermal system. The response parameters and the considered input parameters were output temperature, efficiency and hour angle, day, input temperature respectively. It was found that the temperatures and solar radiation were higher at the beginning and ending of the year, the months at the middle of the year experience a reduction in temperature and solar radiation due to the rainy season.

January, February, March, fairly April and September, October, November, and December experience a higher temperature and solar radiation respectively.

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OPTIMISATION OF INJECTION MOULDED POLYPROPYLENE SAWDUST COMPOSITE USING RESPONSE SURFACE METHODOLOGY AND ARTIFICIAL NEURAL NETWORKS

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ABSTRACT: This study focuses on the optimisation of the injection moulded Polypropylene –Sawdust composite. The Polypropylene material and sawdust were mixed together to form a homogenous mixture with various percentage composition by volume as recommended by the design of experiments using the central composite design (CCD). The two screw plunger injection moulding machine was used to produce Polypropylene-Sawdust composite at various temperature. The produced composite was evaluated for its mechanical properties which included tensile strength, proof stress, percentage elongation and flexural strength. The response surface methodology (RSM) and artificial neural networks (ANN) were used to determine the effect of the interaction of temperature, material type and percentage by volume of material on the mechanical properties of the produced Polypropylene -sawdust composite. The models were validated using coefficient of determination (R^2), the coefficient of determination (R^2) obtained ranged from 0.9435 (94.357%) to 0.9988 (99.88%) which indicates that a substantial good fit was achieved by the developed models. A desirability of 0.952 was obtained which shows the adequacy of the model terms the optimization results for Polypropylene -Sawdust composite shows that the tensile strength, proof stress, flexural strength and flexural modulus were maximized with a values of 31.90 MPa, 41.94 MPa, 88.22 MPa and 2.72 GPa respectively which was obtained at barrel temperature of 224.65 °C. Percentage elongation and average deflection were minimized with a values of 74.12% and 6.46 cm respectively. The artificial neural networks gave the optimal of the two examined models.

Keywords: Central composite design, Composite, Modeling, Polypropylene, Sawdust.

1. INTRODUCTION

Injection moulding is a very complex process and its process variable like barrel temperature, injection pressure, the material flow rate, mould temperature and flow pattern usually influence the properties of polymeric materials [1]. Injection moulding is a cost-effective way to produce complex, three dimensional shapes at high volumes. In the plastic industry, injection moulding makes up about 32% weight of all plastic processing methods, this is second only to extrusion which is 36% weight. Composite are man-made materials which are currently being used in wide application in the manufacture of industrial as well as consumer products [2]. The deformable state achieved by plastic-sawdust composites at elevated temperature before chemically setting, allow them to be shaped to any intricate form. According to this principle of combined action; new properties, better property combinations, or a higher level of properties are fashioned by the judicious combination of two or more distinct materials. A typical composite material is a system of materials comprising two or more materials (mixed and bonded) on a macroscopic scale.

Investigation was carried out to model the fundamental bonding characteristics and performance of wood composite [3]. In this investigation, a mathematical model and a computer simulation model were developed to predict the variation of inter-element (strand) contact during mat consolidation. The mathematical predictions and the computer simulations agree well with each other. Their results showed that the relationship between the inter-element contact and the mat density was highly nonlinear and was significantly affected by the wood density and the element thickness.

Moreover, empirical models were developed making use of previously obtained experimental data to estimate the properties of produced composite material from agro waste. The developed empirical models were used to predict the properties of composite material (hardness, yield strength, ultimate tensile strength, modulus of elasticity, modulus of rupture, internal bond strength, density, thickness of swelling and water absorption) taking the inputs as percentage of sawdust composition and percentage of palm shell composition respectively [4].

The effect of reinforcement combination on the mechanical strength of glass reinforced plastic was examined using compression moulding. A Proof stress of 29.52N/mm^2 at a barrel temperature of 232°C was obtained [5]. The effects of temperature relative humidity and feedstock temperature on injection moulded part dimension and short term mechanical properties observed from tensile testing was investigated and results indicated that environmental conditions influenced the moulded part quality to varying degrees and that the environmental conditions should be controlled for applications with tight tolerances [6].

Injection modelled polypropylene sawdust composite produced and some mechanical properties like, tensile strength, proof stress, percentage elongation, average deflection, flexural modulus and flexural strength were determined [7].

This study therefore seek to optimize the produced polypropylene-sawdust composite in order to determine the optimal composition of the input parameters.

2. MATERIALS AND METHODS

The following materials were used for this work: Polypropylene (PP) in powdered form, Sawdust (from Mahogany tree obtained from saw mill in Benin City, Edo State Nigeria, two stage-screw plunger Injection machine (Fox and offord), 120 tons two stage-screw plunger, a toggle clamp attached to the injection end of injection moulding, MONSANTO TENSOMETER, Type 'W' Serial No. 8991 and a mould made from Silicon.

2.1. Method of Data Collection

In this study, primary data were collected from the mechanical properties test results obtained from the developed Polypropylene-Sawdust composite.

2.2. Experimental Designs

In this study, a two-variable central composite design (CCD) was used to plan the experiments, develop statistical models for predicting the chosen responses and to optimise the responses and factors. The design points are made up of $2n$ factorial points as well as star points. The star points are particularly necessary for estimating the curvature of the response surface especially

for nonlinear models. The CCD is the only response surface design that can be used for planning experiments with two factors [8].

2.3. Models Development

Design Expert[®] software version 7.0.0, (Stat-ease, Inc. Minneapolis, USA) was used to design the experiment and to analyze the experimental data obtained. The factors considered were temperature and the level of polymer (PP) in the matrix. The range and levels of these factors are shown in Table 2 and was calculated using Equation (1). In generating the experimental design matrix, the Design Expert[®] software utilizes the concept of randomisation and the essence of this is to minimise the effect of unexplained variability in the chosen responses [9]. In this case, the responses chosen for consideration were tensile strength, proof stress, percentage elongation, average deflection, flexural strength and flexural modulus.

$$x_i = \frac{X_i - X_o}{\Delta X_i} \quad (1)$$

In Equation 1, x_i and X_i are the coded and actual values of the factors respectively while X_o is the actual value of the factors at the centre point, and ΔX_i is the step change in the value of the actual values of the factors.

In selecting the appropriate model for predicting the responses, different model types in the Design Expert software library were considered. The first type of model usually investigated is a linear model shown in Equation (2). It is usually proposed to predict the response of the dependent variables and to predict their optimum values when the relationship between the factors and the responses is thought to be linear.

$$Y = b_o + \sum_{i=1}^N b_i X_i + \sum_{i=1}^N e_i \quad (2)$$

Where Y_i is the dependent variable or predicted response, X_i is the independent variables, b_o is offset term, b_i is the regression coefficient and e_i is the error term.

Equation (3) is a two-factor interaction regression model which was also proposed to predict the response of the dependent variables and to predict their optimum values.

$$Y = b_o + \sum_{i=1}^N b_i X_i + \sum_{i,j=1}^N b_{ij} X_i X_j + \sum_{i=1}^N e_i \quad (3)$$

X_j is the independent variables or factors while b_{ij} is the coefficient of the interaction terms. For situations where the relationship between the factors and the responses is thought to be nonlinear, a second order model as shown in Equation 4 can be used to predict the response.

$$Y = b_o + \sum_{i=1}^N b_i X_i + \sum_{i,j=1}^N b_{ij} X_i X_j + \sum_{i=1}^N b_{ii} X_i^2 + \sum_{i=1}^N e_i \quad (4)$$

The second order model is the most widely used model for response surface methodology [9].

Table 1. R² and RMSE Values of MNFF and MFFF using Different Training Algorithms for Flexural Strength (PP- sawdust composite).

Network architecture	Training algorithm	R squared	RMSE	Network architecture	Training algorithm	R squared	RMSE
*MNFF	*IBP	0.9987	0.2359	MFFF	IBP	0.9971	0.3567
	BBP	0.9976	0.3245		BBP	0.9975	0.3263
	QP	0.9749	1.0416		QP	0.9705	1.1288
	GA	0.9968	0.3708		GA	0.9969	0.3636
	LM	0.3603	5.2583		LM	0.9221	1.8351

*best learning algorithm and network

3. RESULTS AND DISCUSSION

The range and levels of these factors are shown in Table 2 and they were calculated using Equation.1 [10]. In this case, the responses chosen for consideration were tensile strength, proof stress, percentage elongation, average deflection, flexural strength and flexural modulus.

Table 2. Coded and Actual Levels of the Factors for PP-Sawdust Composite.

Factors	Unit	Symbols	Coded and Actual Levels				
			-1.414	-1	0	1	1.414
Temperature	°C	X ₁	210.00	224.64	260.00	295.36	310.00
PVC level	%	X ₂	60.00	61.46	65.00	68.54	70.00

3.1. Determination of Appropriate Model

Table 3 shows the summary of model fit results for PP-Sawdust composite

Table 3. Summary of Model Fit Results (PP-Sawdust Composite).

Tensile strength						
Source	Standard deviation	R ²	Adjusted R ²	Predicted R ²	PRESS	Remark
Linear	4.06	0.0289	0.0165	0.0161	323.34	
2FI	4.28	0.0289	0.0249	0.0152	429.50	
Quadratic	1.86	0.8579	0.7564	0.0470	170.83	Suggested
Cubic	0.66	0.9872	0.9692	0.2456	128.28	Aliased
Proof stress						
Source	Standard deviation	R ²	Adjusted R ²	Predicted R ²	PRESS	Remark
Linear	4.04	0.0339	0.01593	0.008	318.57	
2FI	4.25	0.0339	0.0288	0.0152	426.14	
Quadratic	1.83	0.8614	0.7625	0.0268	164.08	Suggested
Cubic	0.78	0.9821	0.9571	0.7404	169.85	Aliased

Table 4. Lack of Fit Test Results (PP-Sawdust composite).

Tensile strength						
Source	Sum of square	Degree of freedom	Mean square	F-value	p-value	Remark
Linear	164.95	6	27.49	610.93	< 0.0001	
2FI	164.95	5	32.99	733.10	< 0.0001	
Quadratic	23.98	3	7.99	177.65	0.081	Suggested
Cubic	2.00	1	2.00	44.44	0.0026	Aliased
Pure Error	0.18	4	0.045			
Proof stress						
Source	Sum of square	degree of freedom	Mean square	F-value	p-value	Remark
Linear	162.52	6	27.09	294.43	< 0.0001	
2FI	162.52	5	32.50	353.31	< 0.0001	
Quadratic	22.99	3	7.66	83.31	0.0510	Suggested
Cubic	2.64	1	2.64	28.75	0.0058	Aliased
Pure Error	0.37	4	0.092			

Source: Aliyegbenoma et al 2020

Tables 3 and 4 shows the Summary of model fit results and Lack of fit test results for PP-Sawdust composite respectively. As seen from the results, the quadratic model was suggested as the most appropriate model to predict the responses. This decision was reached based on the statistical parameters backing up the quadratic model. Among a number of alternatives, the model chosen should be the one with the desirable statistical parameters such as high R^2 value, low standard deviation, and low PRESS. The quadratic model was found to have the highest R^2 values for all the responses for tensile strength and proof stress as shown in Table 3 for PP-Sawdust composite. The quadratic model was also found to have the lowest standard deviation and PRESS as shown in Table 4 for PP-Sawdust composite. Thus, the quadratic model was adopted for predicting the responses under investigation in this study.

Table 5 shows the RSM predicted result and the experimental for tensile strength and proof stress for PP-Sawdust composite, while table 6 shows the ANN predicted and experimental results for tensile strength and proof stress for PP-Sawdust composite.

Table 5. Experimental and RSM Predicted Results for Tensile Strength and Proof Stress (PP-Sawdust Composite).

Run	Factors				Response			
	Coded values		Actual values		Tensile strength (MPa)		Proof stress	
	X_1	X_2	X_1	X_2	Experiment	Predicted	Experiment	Predicted
1	0	0	260.00	50.00	33.70	33.50	43.60	43.48
2	1	-1	295.36	42.93	28.60	29.23	39.60	40.17
3	1	1	295.36	57.07	29.40	28.87	39.10	38.64
4	1.414	0	310.00	50.00	33.80	33.77	43.80	43.80
5	0	-1.414	260.00	40.00	25.50	24.60	36.60	35.68
6	0	1.414	260.00	60.00	23.30	24.03	33.70	34.23

7	-1	-1	224.64	42.93	28.50	29.20	38.60	39.46
8	-1.414	0	210.00	50.00	33.80	33.66	43.90	43.50
9	-1	1	224.64	57.07	29.20	28.75	39.10	38.93
10	0	0	260.00	50.00	33.70	33.50	43.30	43.48
11	0	0	260.00	50.00	33.50	33.50	43.10	43.48
12	0	0	260.00	50.00	33.20	33.50	43.50	43.48
13	0	0	260.00	50.00	33.40	33.50	43.90	43.48

Table 6. Experimental and ANN Predicted Results for Tensile Strength and Proof Stress (PP-Sawdust Composite).

Run	Factors				Response			
	Coded values		Actual values		Tensile strength (MPa)		Proof stress	
	X ₁	X ₂	X ₁	X ₂	Experiment	Predicted	Experiment	Predicted
1	0	0	260.00	50.00	33.70	33.50	43.60	43.48
2	1	-1	295.36	42.93	28.60	28.60	39.60	39.60
3	1	1	295.36	57.07	29.40	29.40	39.10	39.10
4	1.414	0	310.00	50.00	33.80	33.80	43.80	43.80
5	0	-1.414	260.00	40.00	25.50	25.50	36.60	36.60
6	0	1.414	260.00	60.00	23.30	23.30	33.70	33.70
7	-1	-1	224.64	42.93	28.50	28.50	38.60	38.60
8	-1.414	0	210.00	50.00	33.80	33.80	43.90	43.90
9	-1	1	224.64	57.07	29.20	29.20	39.10	39.10
10	0	0	260.00	50.00	33.70	33.50	43.30	43.48
11	0	0	260.00	50.00	33.50	33.50	43.10	43.48
12	0	0	260.00	50.00	33.20	33.50	43.50	43.48
13	0	0	260.00	50.00	33.40	33.50	43.90	43.48

3.2. Comparison of RSM and ANN Predictive Performance

In order to determine the optimal parameters and the accuracy of RSM and ANN in predicting tensile strength, proof stress, percentage elongation, average deflection, flexural strength and flexural modulus, the comparison is directly related to their predictive capability. The model with the better predictive capability will be able to predict the responses with a higher accuracy. The predictive capability of RSM and ANN was assessed using R^2 value, adjusted R^2 value, root mean square error (RMSE) and absolute average deviation (AAD) as shown in Table 7 for PP-Sawdust composite. A good and accurate model prediction is usually characterized by high values of the R^2 value and adjusted R^2 value as well as very low RMSE and AAD. A comparison of the predictive capability of RSM and ANN as observed from the R^2 value, adjusted R^2 value, root mean square error and absolute average deviation shows that ANN performed better than RSM. This is because ANN had a very high R^2 and adjusted R^2 values with a very low RMSE and AAD values compared with RSM as shown in Table 7.

Table 7. Comparison of RSM and ANN Predictive Performance (PP-Sawdust Composite).

Parameter s	RSM						ANN					
	Tensile strength	Pro. Stress	% elongation	Aver. deflection	Flexural strength	Flexural modulus	Tensile strength	Pro. stress	% elongation	Aver. deflection	Flexural strength	Flexural modulus
R^2	0.9810	0.9781	0.9791	0.8834	0.9887	0.8965	0.9988	0.9973	0.9957	0.9709	0.9987	0.9435
Adj. R^2	0.9675	0.9625	0.9641	0.8000	0.9807	0.8226	0.9979	0.9954	0.9926	0.9501	0.9978	0.9031

RMSE	0.3817	0.3847	0.6077	0.2655	0.5404	0.0699	0.0949	0.1356	0.2775	0.1328	0.1828	0.0519
AAD	0.0088	0.0064	0.0055	0.0265	0.0044	0.0189	0.0012	0.0013	0.0016	0.0081	0.0010	0.0083

3.3. Polarity Plot for RSM and ANN

Figures 1 (a) and (b) show the ANN parity plot of the responses for PP sawdust composites. It is a plot of the predicted response values versus the experimental response values. The purpose is to detect a value, or group of values, that are not easily predicted by the model. Comparison of the experimental values of the response and those predicted by the ANN model showed that there was an acceptable level of fit between the experimental and model predicted results. This is evident from the fact that the data points all clustered around the 45° diagonal line showing that there was minimal deviation between experimental and predicted values thus indicating optimal fit of the model. Comparing these results with those presented in Figures 1(c) and (d) for the RSM prediction, it can be seen that the data points in Figures 1 (a) and (b) clustered around the 45° diagonal line closer than that for the RSM results. This is an indication that the ANN model has better predictive capability compared to the RSM model. Therefore the optimal composition model is shown in Equation 5.

$$\text{PP sawdust composite} = 45.56X_2 + 54.44X_3 \text{ at temp of } 224.64 \text{ } ^\circ\text{C} \quad (5)$$

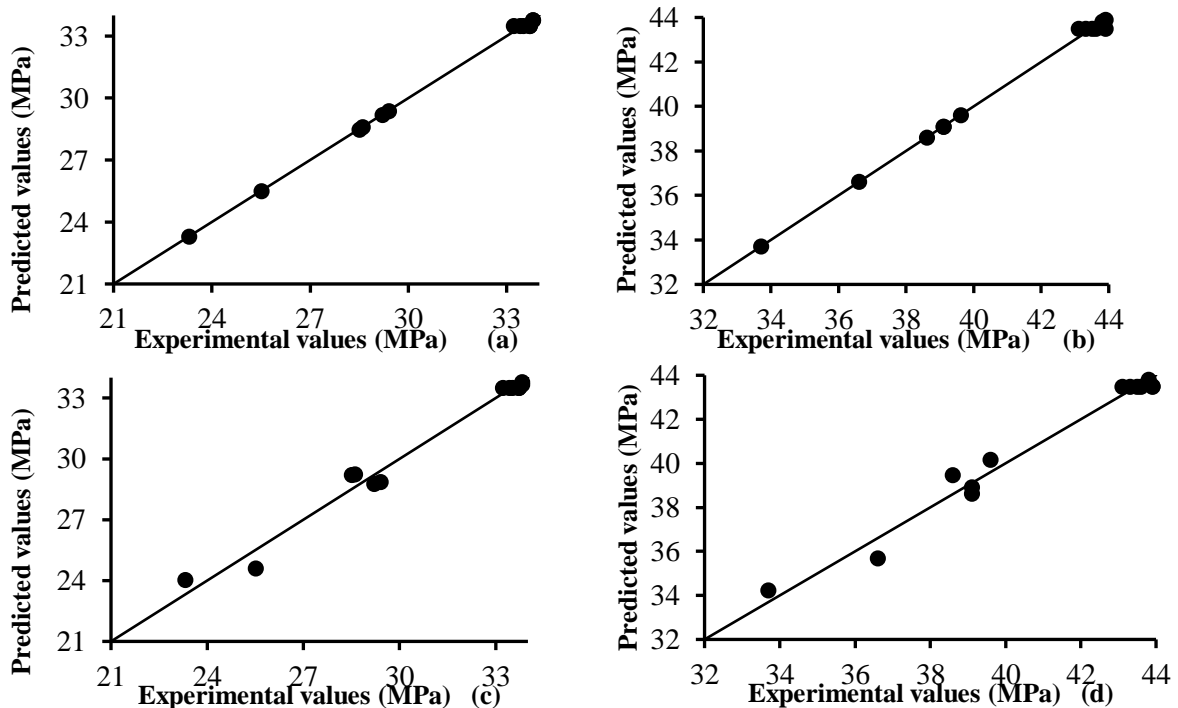


Figure 1. (a) Tensile strength (b) proof stress for ANN parity plot and (c) tensile strength (d) proof stress for RSM parity plot for PP-Sawdust composite.

3.4. Optimal Composition for PP-Sawdust Composite

Table 8 shows the variables and their optimal values for PP-sawdust composite.

Table 8. Optimization result for PP-sawdust composite

Variable	Value
Temperature	224.64 °C
Polymer level	45.56%
Maximum tensile strength	31.90 Mpa
Maximum proof stress	41.94 Mpa
Minimum percentage	74.12%
Minimum average	6.46 cm
Maximum flexural strength	88.22 Mpa
Maximum flexural	2.72 Gpa
Desirability	0.952

3.5. Response Surface and Contour Plot

Figure 2 shows the response surface and contour plot showing the effect of temperature and polymer level on (a) tensile strength (b) proof stress for the PP-sawdust composite. Intermediate levels of PP-sawdust were necessary to achieve optimum values of tensile strength as shown in Figure 2 (a). On the other hand, the effect of temperature on tensile strength was not very significant. For proof stress, Figure 2 (b) shows a similar trend to that shown in Figure 2(a). In the same way, intermediate levels of PP-sawdust were necessary to achieve optimum values of proof stress while temperature did not significantly influence the value of proof stress.

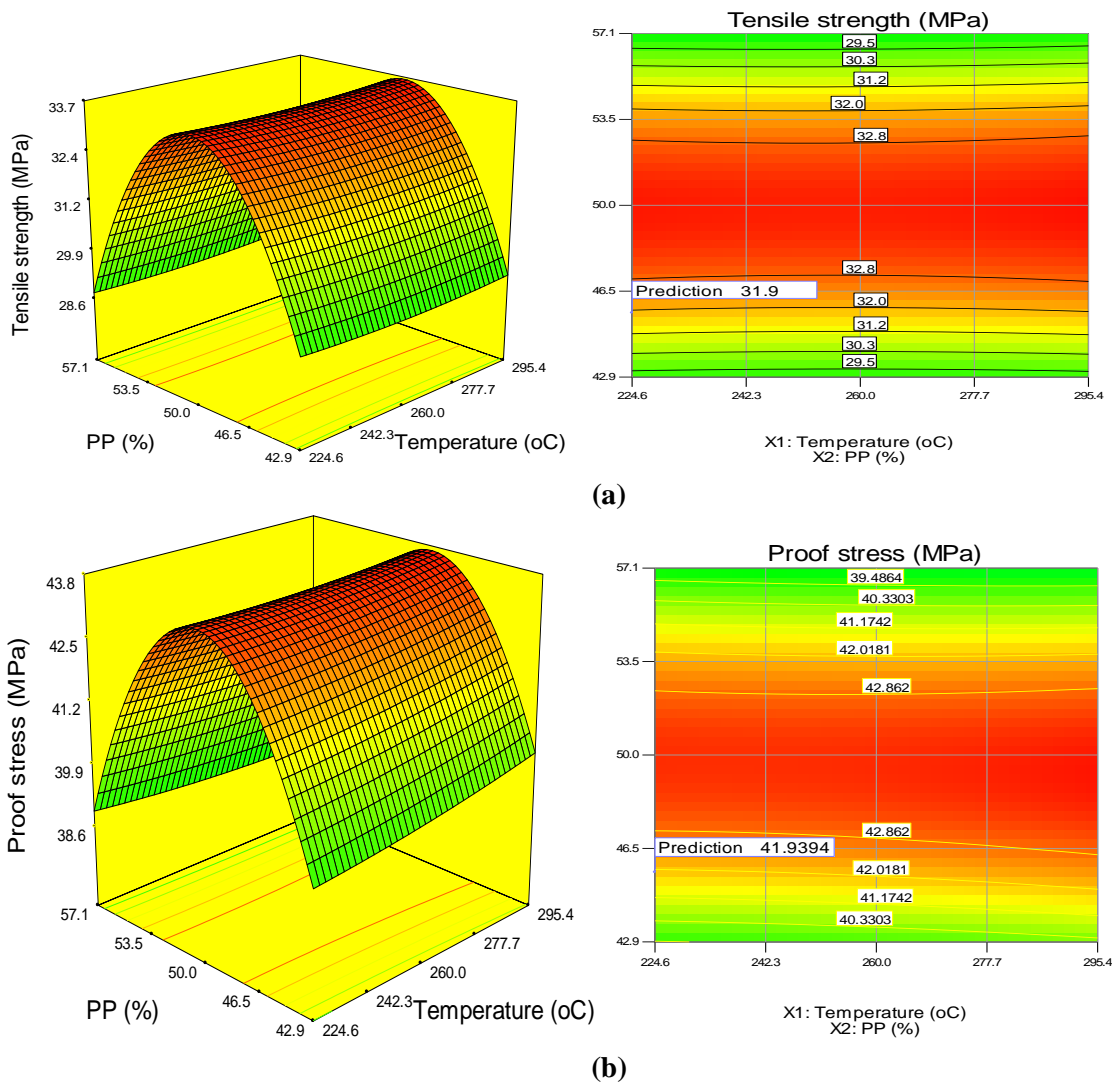


Figure 2. Response surface and contour plot showing effect of temperature and polymer level on (a) tensile strength (b) proof stress for PP-Sawdust composite.

4. CONCLUSION

Models were developed for predicting the optimal mechanical properties (tensile strength, proof stress, percentage elongation and flexural strength) for the produced Polypropylene-sawdust composites with a desirability of 0.952. In validating the model coefficient of determination (R^2) was used which gave a range of values between 0.9135 and 0.9988 which is an indication of achieving substantial good fit by the developed model. Also from the result of the R^2 , adjusted R^2 , RMSE and ADD.

The optimization results for Polypropylene-sawdust composite shows that the tensile strength, proof stress, flexural strength and flexural modulus were maximized with values of 31.90 MPa, 41.94 MPa, 88.22 MPa and 2.72 GPa respectively obtained at barrel temperature of 224.65 °C and polymer level of 45.56% while percentage elongation and average deflection were minimized with values of 74.12% and 6.46 cm respectively.

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REGRESSION BASED RISK ANALYSIS IN LIFE INSURANCE INDUSTRY

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ABSTRACT: Risk analysis is a crucial part for classifying applicants in life insurance business. Since the traditional underwriting strategies are time-consuming, recent works have focused on machine learning based methods to make the steps of underwriting more effective and strengthening the supervisory. The aim of this study is to evaluate the linear and non-linear regression-based models to determine the degree of risk. Therefore, four linear and non-linear regression algorithms are trained and evaluated on a life insurance dataset. The parameters of algorithms are optimized using Grid Search approach. The experimental results show that the non-linear regression models achieve more accurate predictions than linear regression models and the LGBM algorithm has the best performance among the all regression models with the highest R2, lowest MAE and RMSE values.

Keywords: Life insurance, Predictive analytics, Insurance analytics, Regression-based risk analysis.

1. INTRODUCTION

Insurance is one of the important business domains affected by digital transformation and technology [1]. Many data are produced in the insurance sector, such as requests from different channels, and sales from different platforms. When we consider the data types collected, it is possible to categorize types of insurances as follows i) Elementary insurances: They include standard data (model, color, engine etc.), past damage and repair information of cars for specific types such as motor insurance and traffic ii) Life insurances and private pension insurances: These types of insurances include detailed information from the demographic information of the person to the financial situation [2].

For a life insurance company, the traditional underwriting strategies are time-consuming and expensive. Therefore, finding ways to make the underwriting process faster and more cost efficient is crucial. Machine learning methods have proven effective in streamlining the method of underwriting and strengthening decision-making [3].

As stated in [4] underwriting process requires gathering detailed insurance claim records, which may be lengthy. The candidates are typically submitted to different medical examinations and the insurance provider must be supplied with all appropriate documentation. A research by [5] indicates that low capacity underwriting is a prominent operating concern among insurance firms surveyed in Bangladesh. Another risk to life insurance providers is not being prepared to

confront unfavorable competition. In this study it is aimed to apply predictive models to identify the degree of risks based on a dataset [6] containing 1,338 applications and to propose the most appropriate regression model for the risk management to optimize the underwriting process. The rest of the paper is organized as follows: Section 2 gives information about the materials and methods used. Section 3 presents evaluation results of the proposed study. Section 4 discusses and concludes the paper.

2. MATERIALS AND METHODS

2.1. Linear and Non-Linear Regression Methods

Regression which is one of the main areas of interest in statistical science, estimates the value of the dependent variable (y) based on the value of at least one independent variable (X) and explains the effects of changes in the independent variable on the dependent variable. In general regression models are examined in two groups as linear and non-linear.

Linear regression models use linear equations. A line is defined by a simple equation, measuring y from X , slope and intercept. The aim of linear regression is to find slope and intercept values which define the line that is closest to the samples data [7].

$$y(X) = \theta_0 + \theta_1 \cdot X_1 + \theta_2 \cdot X_2 + \dots + \varepsilon \quad (1)$$

Non-linear regression is more general than linear regression and can match the data with any model. It finds parameter values that generate the curve closest to the samples data [8]. Equation 1 and 2 show linear and non-linear regression formulas respectively. X_1 , X_2 and X_3 specifies independent variables, θ_0 is intercept, θ_1 , θ_2 and θ_3 are slope coefficients. ε is the random error term.

$$y = h_{\theta}(x) = \theta_0 + \theta_1 \cdot X_1 + \theta_2 \cdot X_2^2 + \theta_3 \cdot X_3^3 \dots + \varepsilon \quad (2)$$

2.2. Evaluated Regression Algorithms

PLS (Partial least squares) Regression is a statistical approach like the principal components' regression. The linear regression model is calculated by projecting the target variables and the observed variables into a new space [9].

RidgeRegression is also known as Tikhonov regularization, usually increases the performance of parameter identification problems giving precise approximate solutions in exchange for an acceptable level of bias [10].

LassoRegression is a method of linear regression that conducts both feature selection and regularization to improve the accuracy of estimation and generalizability of the mathematical model it generates [11].

LGBM (Light Gradient Boosting Method) is a gradient boosting approach based on tree learning algorithms. It supports parallelism and is designed to be capable of handling large-scale data [12].

RandomForest is an ensemble (collaborative) method that can execute both regression and classification tasks using multiple decision trees, and a method called Bootstrap Aggregation, widely known as bagging [13].

CART (Classification and Regression Trees) tree is a binary decision tree which is formed constantly by dividing a node into two child nodes, starting from the root node containing the entire training data set [14].

SVR (Support Vector Regression) is similar to the SVM (Support Vector Machine) classifier and characterized using kernels, sparse solution, and VC (Vapnik-Chervonenkis) control of the margin and the number of support vectors [15].

2.3. Dataset

In the study, “Insurance Premium Prediction” dataset containing 1,338 applications (observations) and 7 attributes (variables) is used [6]. This dataset contains 4 numerical attributes including age (in years), number of children, body mass index and medical costs. It also holds 3 nominal attributes: gender (male, female), smoking status (yes, no) and the region (southeast, southwest, northeast, northwest). The attribute named “expenses” is the dependent target variable and includes medical cost. The independent variables are the remaining 6 attributes. Table 1 shows the top 5 samples from the dataset.

Table 1. Top 5 samples of the dataset.

	age	sex	bmi	children	smoker	region	expenses
0	19	female	27.9	0	yes	southwest	16884.92
1	18	male	33.8	1	no	southeast	1725.55
2	28	male	33.0	3	no	southeast	4449.46
3	33	male	22.7	0	no	northwest	21984.47
4	32	male	28.9	0	no	northwest	3866.86

2.4. Pre-processing and Exploratory Data Analysis (EDA)

Pre-processing of data, also known as the data cleansing stage, includes eliminating noisy data, transforming variables, handling missing values, scaling the range of data, and label-encoding for categorical variables. Since the main purpose of the dataset is to predict medical expenses, the “expenses” variable is transformed to a “risk score” (1-100) using data transformation method named min-max scaler as the first step. Then, the exploratory data analysis (EDA) is applied to analyze the data based on various features such as age, body mass index, number of children, cigarette addiction and location against the current risk score.

EDA consists of univariate and multivariate analyzes. Thanks to EDA, the researchers are provided to understand the different distributions displayed by the features. Moreover, in the bivariate analysis, independent variables which are capable of impacting the target (dependent) variable can be analyzed. It can be seen intuitively which variables affect the target variable more strongly.

Although dozens of EDA analysis have been done in the study, the results of three EDA analyzes are presented and explained. Figure 1 that is a univariate analysis shows the distribution of the risk scores using a distribution plot having twenty bins. A significant part of the samples are in the range in which the risk score variable (target variable) takes a value

between 0-30. Besides there is also a remarkable distribution of samples in the 50-80 value range.

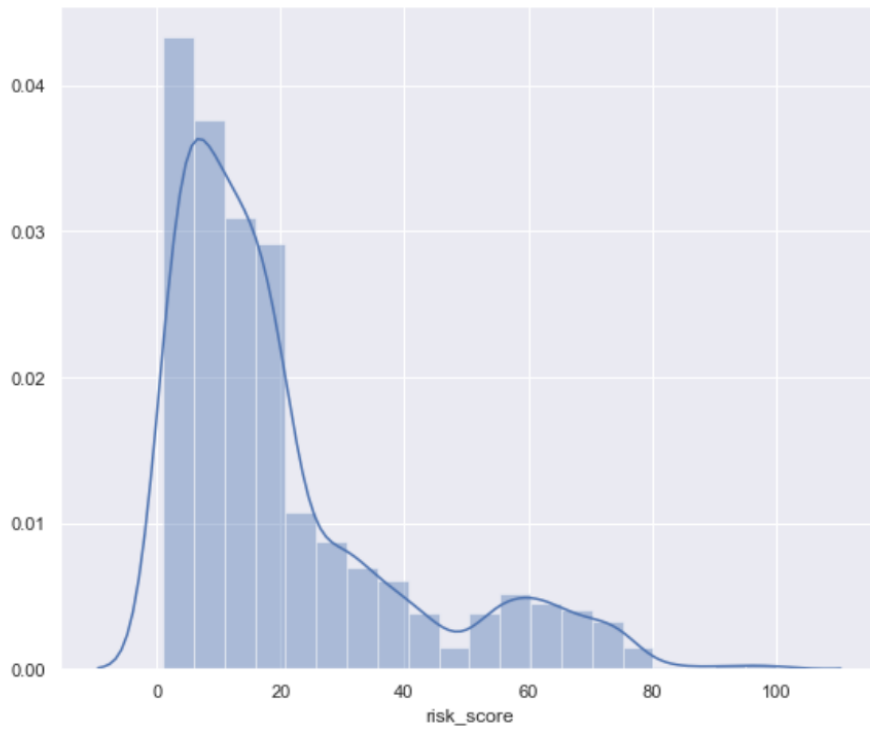


Figure 1. The distribution of risk scores.

Figure 2 presents the distribution of risk scores of smokers using a category plotter. It is observed that smokers have higher risk scores than non-smokers.

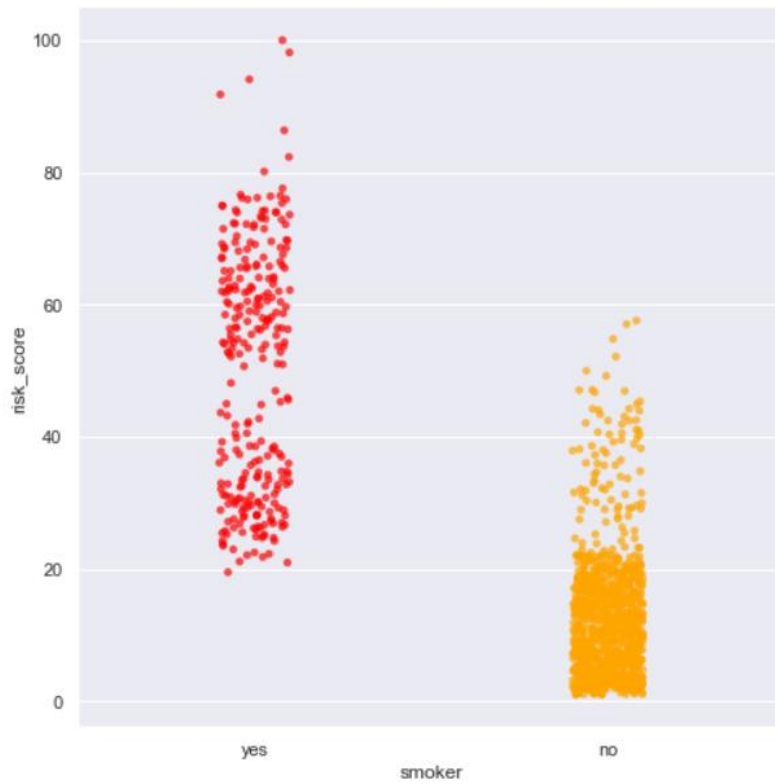


Figure 2. The distribution of smokers with their risk scores.

Figure 3 illustrates the relation between age and risk score considering smoking status. The risk scores of smokers are higher than the risk scores of non-smokers. Regardless of the smoking status, the risk scores of the people increased in accordance with their age, but it is still seen that the smokers' risk scores are higher than the non-smokers.

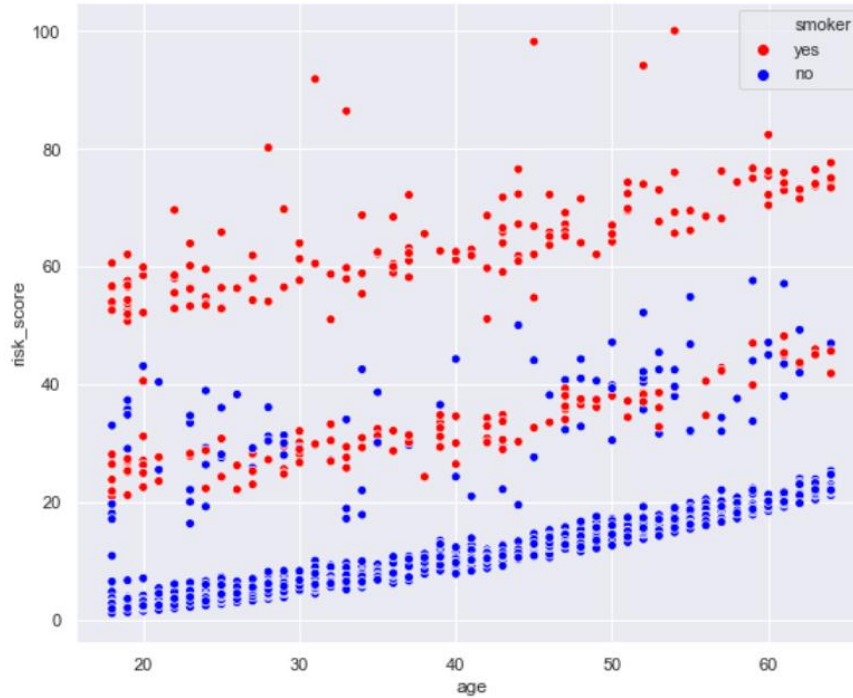


Figure 3. The relation between age and risk score considering smoking status.

3. EVALUATION METRICS

All trained regression models are evaluated utilizing on two common metrics named Root Mean Square Error (RMSE), and coefficient of determination (R^2) [16]. RMSE is a widely used measure of the difference between predicted and the real values of the model from the system that is trained. The RMSE values of a regression model is formulated as the square root of the mean squared error. R^2 indicates percentage variation of prediction values. The value of the R^2 is between 0 and 1. The formulas of metrics are defined as follows.

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (Y_{model,i} - Y_{obs,i})^2}{n}} \quad (3)$$

$$R^2 = 1 - \frac{\sum_{i=1}^n (Y_{obs,i} - Y_{model,i})^2}{\sum_{i=1}^n (Y_{obs,i} - \bar{Y}_{obs})^2} \quad (4)$$

where Y_{obs} are real values, and Y_{model} are the predicted values of model at position i .

4. EXPERIMENTAL RESULTS

In this work, four linear (LinearRegression, PLSRegression, RidgeRegression, LassoRegression) and four non-linear (LGBM, RandomForest, CART, SVR) regression algorithms are trained and obtained models are evaluated using Grid Search parameter optimizations (hyperparameter optimization) [17] which lets the selection of the best

parameters for an optimization problem from a list of parameters which is provided. The experimental results shown in Table 2 and Table 3 indicate that non-linear regression models perform more accurate predictions than linear regression models. CV_R^2 indicates the R^2 value obtained after performing cross validation.

Table 2. The evaluation performances of linear regression models.

	Model	R^2	CV_R^2	RMSE	MAE
1	LinearRegression	0.787472	0.732067	8.0	5.0
2	PLSRegression	0.766873	0.732054	9.0	6.0
3	RidgeRegression	0.767271	0.732054	9.0	7.0
4	LassoRegression	0.767237	0.732107	9.0	7.0

Findings yield as follows; Linear Regression algorithm has the highest performance with the lowest mean absolute error (MAE) value of 5.0 and lowest root-mean-squared error (RMSE) value of 8.0 between the linear regression models. On the other hand, LGBM shows the best performance between non-linear models with the highest R^2 , lowest MAE and RMSE values of 0.942658, 3.0 and 6.0, respectively, as compared to the other non-linear models.

Table 3. The evaluation performances of non-linear regression models.

	Model	R^2	CV_R^2	RMSE	MAE
1	LGBM	0.942658	0.912114	6.0	3.0
2	RandomForest	0.951977	0.907872	6.0	3.0
3	CART	0.903022	0.885989	7.0	4.0
4	SVR	0.893027	0.827012	7.0	4.0

After hyperparameter optimization, obtained optimum parameters' values of the best performing algorithm LGBM is shown in Table 4.

Table 4. The optimum parameters' values of LGBM regression model.

Parameter Name	Value
colsample_bytree	0.9
learning_rate	0.5
max_depth	2
n_estimators	20

5. CONCLUSIONS

With the recent advances of technology, data analytics has become an important trend. In the area of life insurance, predictive analytics using learning algorithms have made a significant difference in how business is conducted comparing to traditional approaches. In this research, four linear algorithms named LinearRegression, PLSRegression, RidgeRegression, LassoRegression and four non-linear regression algorithms named LGBM, RandomForest, CART, SVR are implemented, trained and tested on a publicly available insurance dataset. Hyperparameter optimization is performed to find the best parameters of the algorithms. The experimental results show that non-linear models have better accuracy than linear ones. Finally, it can be concluded that tree-based non-linear regression models (LGBM, RandomForest) are promising to forecast the risk score of applicants and can be used in real-life scenarios.

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DESIGN AND MANUFACTURING OF 3D PRINTED PROSTHETIC HAND USING MUSCLE SIGNALS

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ABSTRACT: The person who has challenges not meeting needs due to the loss of his / her physical, mental and sensorial abilities to a certain extent on account of birth or any reason is defined as 'disabled' if any care or rehabilitation is required. These people have difficulty adapting to social life. Prostheses have been developed to ensure this compatibility. Today, by measuring directly from the patient, the production in place of the organ lost by the patient is carried out suitably. In this study, It was carried out to control muscle signals with EMG sensor prosthetic hand manufactured by a 3D printer. The movement of the fingers was performed by processing the signals received from the EMG sensor with a microcontroller and transmitting them to the servo motors in the form of meaningful values. Findings obtained were evaluated by comparison.

Keywords: Prosthetic, 3D printer, Microcontroller, EMG sensor.

1. INTRODUCTION

Today, with prostheses produced using light materials (plastic, composite, aluminum), a patient-oriented approach enables people who have lost organs to reach their old standards of life. The microchips and robotic systems used in the prosthesis minimize the adaptation and learning process provided by the mechanical movements of the prosthesis[1].The changes in living things occur as a result of the contraction of the muscles. Muscle fibres are transmitted through motor nerves. They can also respond to a warning such as electric current. The contraction of the muscle can take two forms: fixed neck swelling of the neck or both swelling and shortening of the neck. It is an EMG signal that we use for human-machine communication, with the contracted muscles being an electrical physiological signal representing the movements of the relevant motor unit. EMG signal amplitude varies between 0-10 mV or 0-1.5mV. The signal is in the 50-500Hz frequency range [2].

The devices used for rapid prototyping producing layer by layer according to the design to the finest detail are called 3D printers. Since the desired product is encountered in a short time, it is a great invention in technology. It can manufacture from hundreds of kinds of materials (plastic, metal, polymer, ceramic, etc.) [3-5]. 3D printing methods are FDM (Fused Deposition Modeling), SLS (Selective Laser Sintering), SLA (Stereolithography), PJ (Polyjet), LOM (Layered Object Manufacturing), Binder Jet (Binder Jet Technique). The most preferred type of 3D printing is FDM type 3D printing. FDM type printers are the

technology that makes production by placing PLA and ABS thermoplastics as the raw material, on top of each other, in preferred layers.

In the literature, Cinal et al. [6], a virtual prosthesis was designed using single and dual-channel YEMG data. The virtual prosthesis is controlled in real-time by YEMG. With this processed data, the opening of the Virtual Prosthesis maintains its closing position. Kaya et al. [7] kinematic and dynamic analyzes of a hand prosthesis mechanism were performed. With the designed model, it used simulation outputs and motion analysis program to determine its dynamic behaviours accurately and successfully. Besides, it has been examined to provide supervision according to EMG signs. As a result of the experiments, it was revealed that three different hand movements were successful. İşler et al. [8] studied the EMG sensor, which senses the signals in the forearm muscles, with four classifiers for hand control, which can perform four separate movements, tightening, loosening, contraction and release. Here, in the machine learning algorithms, the k-nearest neighbour algorithm has been classified with MLP, RBF, and SWM. As a result of the tests and measurements, the classifier that showed the best performance was SWM.


İşler et al. [9] was drawn a hand prosthesis with Solidworks and printed on a 3D printer. In the design of the Electric-Electronic system, analog signals received from the SEMG were converted into digital signals, and precise movements were performed on the hand prosthesis together with the servo motor. Voltage values are compared and recorded personally. With the study, an inexpensive, lightweight, and easy-to-use application has been carried out for people with disabilities to reach. Taşar [10] was manufactured the prototype of the five-finger and fifteen-jointed prosthetic hand with a 3D printer, and this prosthetic hand was simulated with SimMechanics. The data and signals we received in real-time were compared with those obtained from the simulation, and a 70% success rate was achieved. Kate et al. [11] examined the ease of use, the benefits of living prostheses produced with 3D printing, and the advantages and disadvantages compared to traditional prosthetics. Cabibihan et al. [12] were scanned computed tomography images of the cut and non-cut arm of the sample person. The support structure and mold of the prosthetic arm are prepared with 3D printing with silicone material. This produced prosthetic arm was compared with the non-incision arm that was previously scanned in computed tomography. As a result of the comparison, a high accuracy rate was achieved. In this study, It was carried out to control muscle signals with EMG sensor prosthetic hand manufactured by a 3D printer. The movement of the fingers was performed by processing the signals received from the EMG sensor with a microcontroller and transmitting them to the servo motors in the form of meaningful values. Findings obtained were evaluated by comparison. Aksoy et al. [13] were created by pressing a five-finger robotic arm with a 3D printer. Six servo motors are mounted on the robot arm to move the fingers and wrists on the created robot arm. With the developed Python software, the microcontroller was communicated in series, and the sign language movements were detected by the robot arm.

2. MATERIAL AND METHODS

In the study, 3D printer, servo motors, rope line, EMG sensor, the microcontroller used as materials. In the method, design, manufacturing, assembly, and software of the prosthetic hand consists of stages.

2.1. Material

In the material section, the elements for the prosthetic hand designed .stl formats were manufactured by a 3D printer of TwoTreesBluer, such as shown in Figure 1. Processing parameters are printing speed 50mm/sec, nozzle diameter 0.4mm, layer thickness 0.2mm. PLA filament was preferred as the printing material.



Model	TwoTreesBluer
Nozzle diameter	0.4mm
Building table	235 * 235 * 280mm
Accuracy of printing	± 0.1-0.2mm
Layer thickness	0.1-0.4mm
Machine speed	10 ~ 300 mm / s
Printing speed	20-200mm / sn
Materials	PLA, ABS, PETG, wood filament
Dimensional of Machine	L410 * W400 * H520mm
Operating environment	Temperature: 5-40 ° C, humidity:%20-

Figure 1. Overview of the 3D printer

The electrical-electronic circuit system schema is given for the control of the prosthetic hand, as shown in Figure 2. Here, MG995 Servo motors are used to move the fingers of the prosthetic hand according to the signals from the microcontrollers. In the study, the rope line used replaces muscle fibers in the prosthetic hand. The thread line used is made of synthetic thermoplastic known as polyethylene. EMG sensors are a detect that helps in human-machine connection. It converts small electrical signals in muscle nerves to analog signals and allows them to be used in control processes to be performed in driver circuits. In the study, the EMG sensor was used to detect the user's movements in prosthetic hand-making and to control the hand in the prosthetic hand study. EMG sensors output are in the form of analog voltage output. Thus, it can be used with 5V and 3.3V systems. Arduino microcontroller with AtmelAtmega 328P was used as the microcontroller.

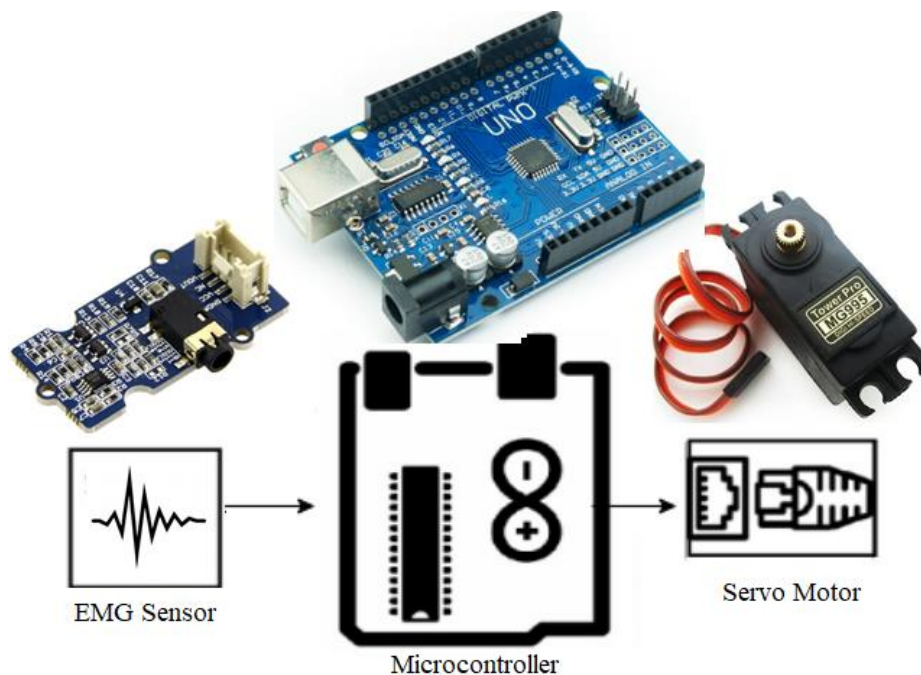
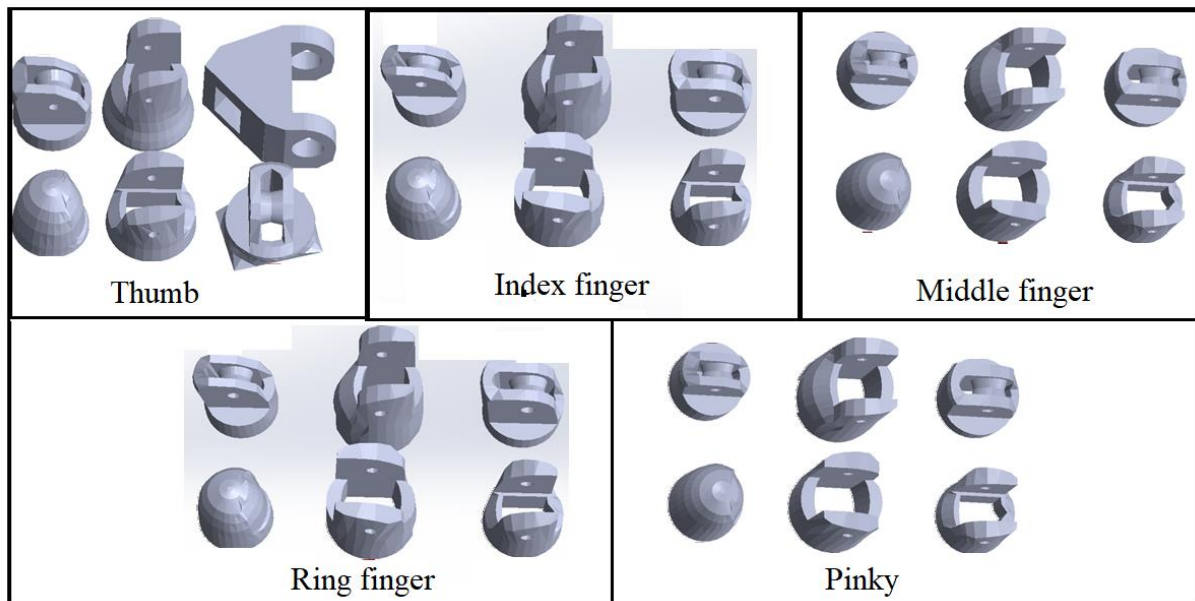


Figure 2. Electric-electronic system diagram

2.2. Method

2.2.1. Design of the prosthetic hand

The drawings of the fingers of the prosthetic hand .stl files with the SolidWorks program are given in Figure 3. The most important aspect of the design of the fingers was the connections of the fingers. Relationships form an essential part of freedom of movement.

**Figure 3.** Overview of the fingers of the prosthetic hand [14]

Palm parts and connecting pins, wrist part arm part, and motor connection parts are given in Figure 4. The design of the prosthesis hand part is carefully drawn as it is the place where the rope lines that will replace the servo motor and muscle fibers are collected.

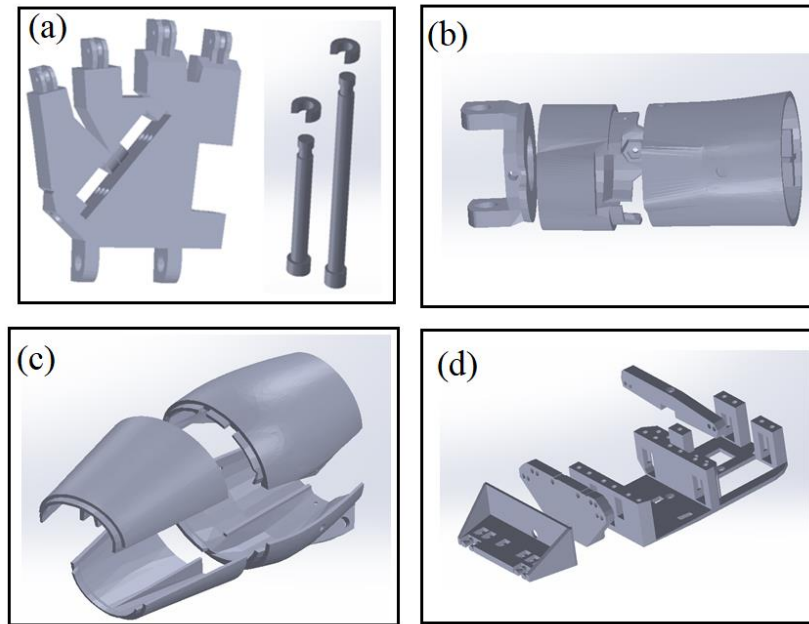


Figure 4. Overview of the other parts of the prosthetic hand [14]

2.2.2. Assembly and manufacturing of the prosthetic hand

The manufacturing mechanical parts of the prosthetic hand were printed with a 3D printer. Due to processing parameters, parts were manufactured with a 3D printer. The roughness and the points to be cleaned on the assembled components are sandpaper, etc. made ready for installation with operations. Its image is as shown in Figure 5 during manufacturing.

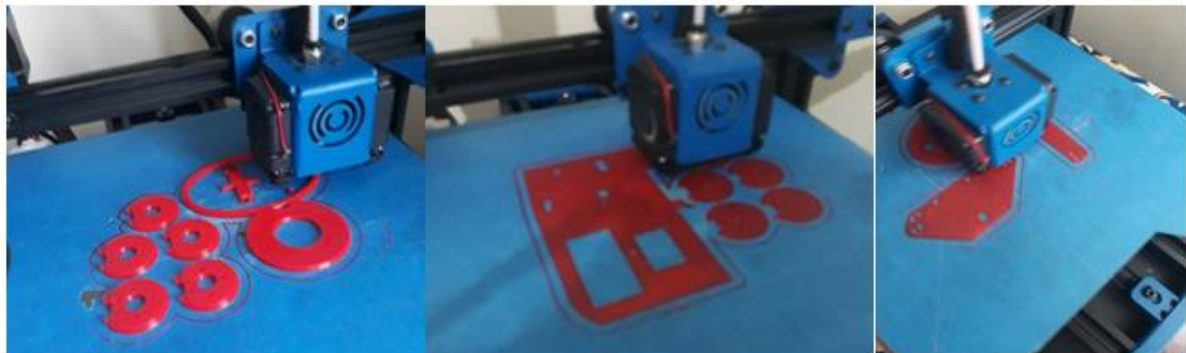


Figure 5. Overview of the manufacturing of the prosthetic hand

The palm section connections were carried out shafts printed by the 3D printer. Pre-assembled fingers were mounted on the prepared the palm with nails used as shafts. The links of harpoon threads have two ropes for opening and closing movements on each finger. The image of ropes palms and fingers, arm, and motor bearing mounted were shown as in Figure 6.

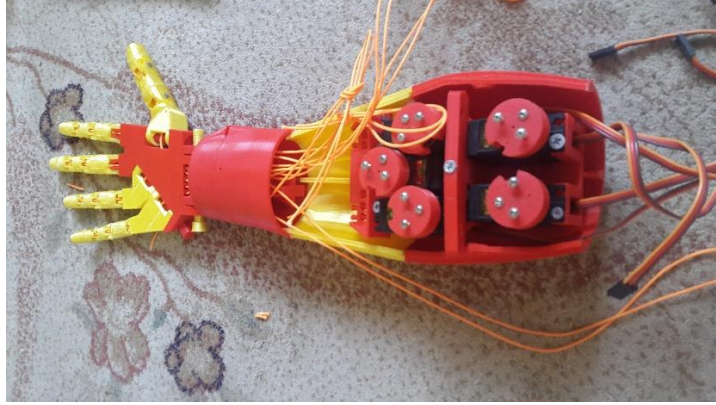
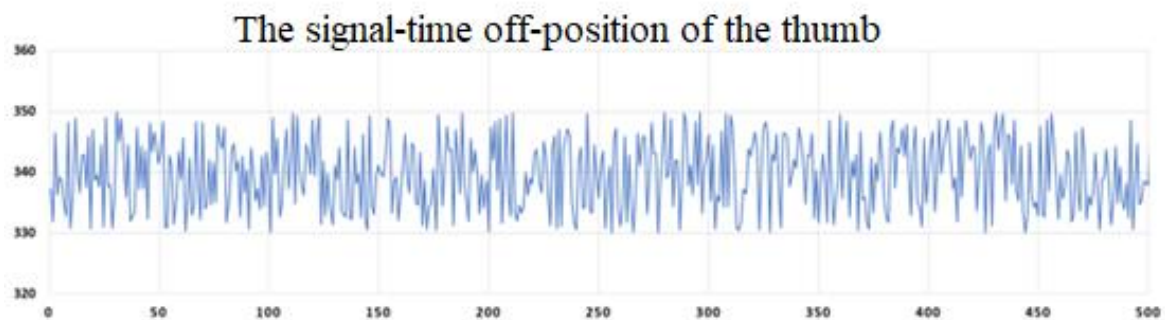


Figure 6. Overview of the assembly of the prosthetic hand and the other components

3. RESULTS AND DISCUSSION

To detect movements and regulate the operation of the prosthetic hand, signals from the arm muscles were obtained with the EMG sensor, and the control of the prosthetic arm was performed. The signals from the muscle signals were obtained with the Emg sensor. The movement of the fingers was achieved by processing the received signals with the microcontroller and transmitting them to the servo motors in the form of meaningful values. The muscle groups for which the signals will be taken for the received signal are accepted at the points where great test results and best results are determined. Different studies have shown that the electrodes of circuit boards and EMG sensors will have different values on different people. As shown in Figure 7, the signal time values determined for each finger are shown. These values indicate that the signals of EMG sensors in the most on and off position of each finger are recorded as a graph of time. In the thumb off-position signal time graph, the signal values vary between 330-350 Hz depending on the time. This value was obtained between 310-330 Hz on the index finger, 280-300 Hz on the middle finger, 380-400 Hz on the ring finger, and 250-280 Hz on the little finger. According to the values obtained, the off-position of the prosthetic hand with the movement of the ring finger muscle signals is felt more effectively. However, the signal was received in the case of fewer off-position in the little finger than the other fingers.



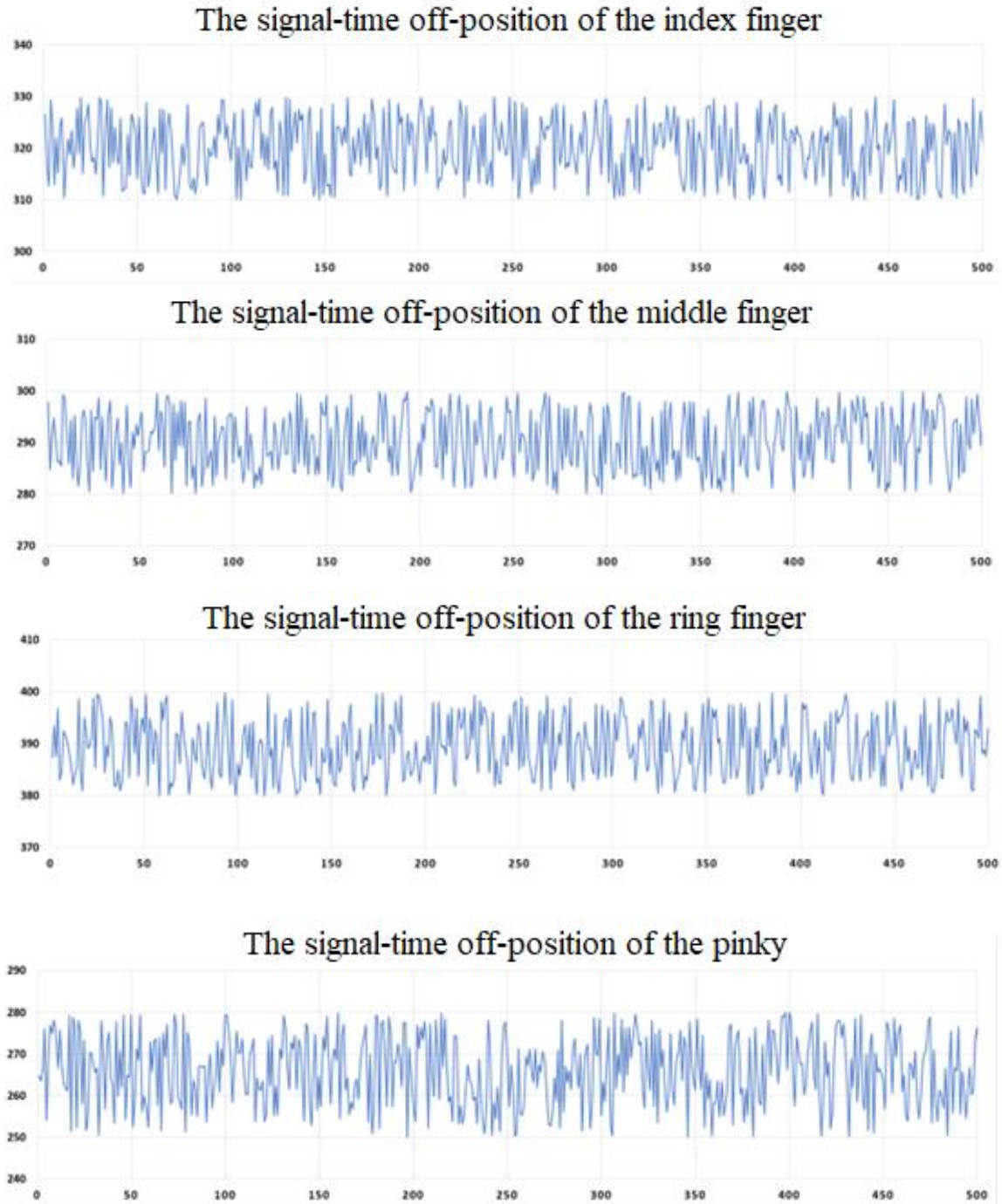
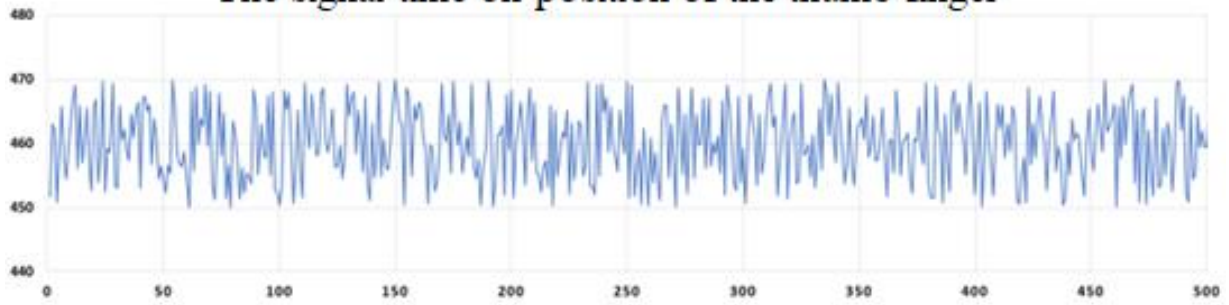


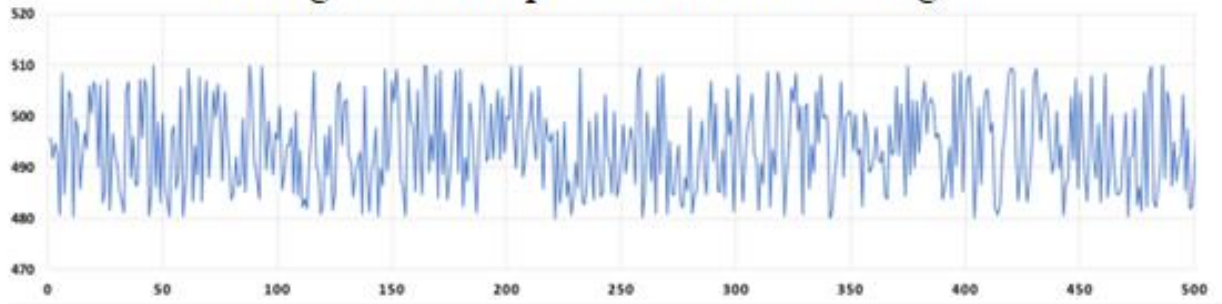
Figure 7. The signal -time off-position of the prosthetic hand

It is shown in Figure 8 that the signals of EMG sensors in the on-position state of the prosthetic hand are recorded as a graph depending on time. In the thumbs-up signal time graph, the signal values range from 450 to 470 Hz, depending on the time. Signal values between 480-510 Hz on the index finger, 520-550 Hz on the middle finger, 590-620 Hz on the ring finger, 565-580 Hz on the little finger were obtained. Depending on the values obtained, the opening of the ring finger muscle signals in the prosthetic hand is felt more effectively. However, the signal was received in case of less opportunity on the thumb than other fingers.

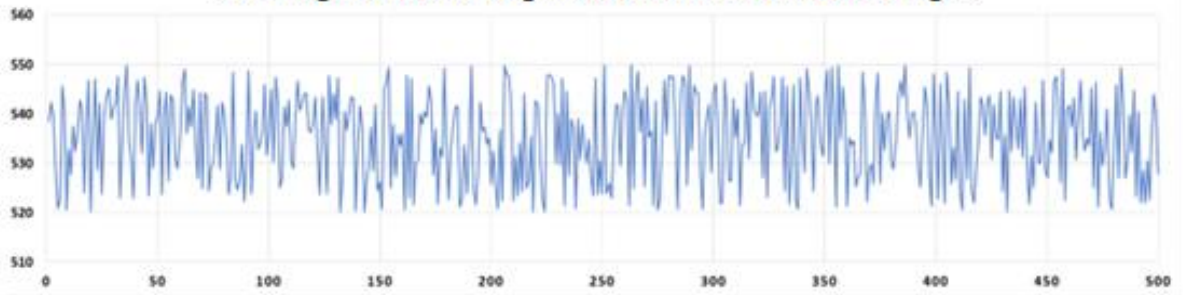
The signal-time on-position of the thumb finger



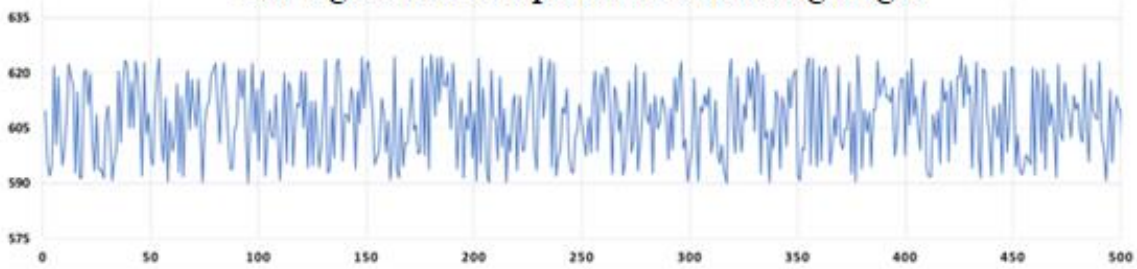
The signal-time on-position of the index finger



The signal-time on-position of the middle finger



The signal-time on-position of the ring finger



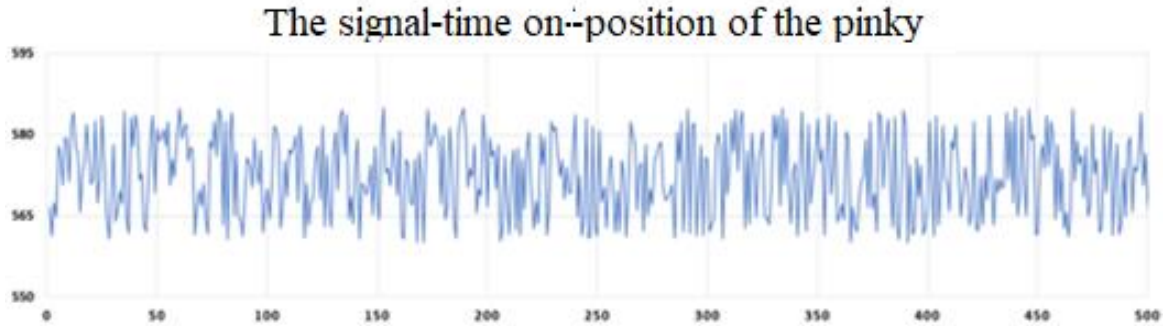


Figure 8. The signal-time on-position of the prosthetic hand

4. CONCLUSIONS

In this study, It was carried out to control muscle signals with EMG sensor prosthetic hand manufactured by a 3D printer. The motion of the servo motors is carried out by converting the analog signals received from the forearm muscle with electrodes to digital signals with a microcontroller. Finger movements were realized with the change of the servo motor. The conclusions are obtained below.

- It has been shown that the physiological signals obtained as a result of muscle and nerve activities in the human arm can be converted into electrical signals, and these signals can be processed and used in electronic circuits. Thus, with the developing technology, people with disabilities will be able to have a more comfortable life.
- In the study, an EMG sensor value was determined completely independent of the value of any EMG sensor.
- The on and off-position of the prosthetic hand with the movement of the ring finger muscle signals is felt more effectively as 380-400 Hz (off-position) and 565-580 Hz (on-position).
- The signal was received in case of less opportunity on the pinky than other fingers in off-position.
- The signal was received in case of less opportunity on the thumb than other fingers in on-position.
- The signal-time graphics obtained from the fingers of the prosthesis vary from customized. It is recommended to experiment with more than one person to obtain an average value.

5. ACKNOWLEDGEMENTS

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ELMA BİTKİSİNDEKİ HASTALIKLARIN YAPAY ZEKÂ YÖNTEMLERİ İLE TESPİTİ VE YAPAY ZEKÂ YÖNTEMLERİNİN PERFORMANSLARININ KARŞILAŞTIRILMASI

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ÖZET: Yapay zekânın hayatımıza girmesiyle tarım alanında yapılan yapay zekâ uygulamaları oldukça popüler hale gelmiştir. Tarım alanında karşılaşılan bitki hastalıkları üzerinde durulması gereken önemli bir konu olup bu problemin çözümü için yapay zekâdan yardım alınmaktadır. Çalışmada, elma bitkisindeki uyuz, siyah çürük ve pas hastalığına sahip yaprakların yapay zekâ ile tespiti için evrimsel sinir ağları (CNN) mimarileri kullanılmıştır. Çalışmada kullanılan CNN içerisinde yer alan AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve SqueezeNet1_0 mimarilerinin karışıklık matrisine göre performansları değerlendirilerek en iyi doğruluk, duyarlılık, özgüllük ve F-skor değerleri bulunmuştur. Sonuç olarak test veri seti için yapay zekâ ile elma bitkisindeki hastalık tespitinde en iyi modelin duyarlılık, özgüllük, doğruluk ve F-skor için sırasıyla %97,64, %99,54, %99,52, %98,62 değerleri ile ResNet-34 olduğu belirlenmiştir.

Anahtar Kelimeler: Yapay zekâ, Tarım, Evrimsel sinir ağları

IDENTIFICATION OF DISEASES IN APPLE PLANTS WITH ARTIFICIAL INTELLIGENCE METHODS AND COMPARISON OF THE PERFORMANCE OF ARTIFICIAL INTELLIGENCE METHODS

ABSTRACT: With the introduction of artificial intelligence into our lives, artificial intelligence applications in agriculture have become very popular. Plant diseases encountered in the field of agriculture are an important issue that should be emphasized and artificial intelligence is used for the solution of this problem. Convolutional Neural Network (CNN) architectures were used for the detection of leaves with scabies, black rot and rust diseases in apple plants with artificial intelligence. The best accuracy, sensitivity, specificity and F-score values were found by evaluating the performances of AlexNet, DenseNet-121, ResNet-34, VGG16-BN and SqueezeNet1_0 models in the CNN architecture by using confusion matrix. As a result, in the detection of diseases in apple plants with artificial intelligence, the best sensitivity, specificity, accuracy and F-score on the test dataset were obtained with the ResNet-34 model, 97.64%, 99.54%, 99.52%, 98.62%, respectively.

Keywords: Artificial intelligence, Agriculture, Convolutional Neural Network (CNN)

1. GİRİŞ

Ziraat veya diğer bir anlamı ile tarım, bitkisel ve hayvansal ürünlerin üretilmesi, üretilen ürünlerin kalitesinin yükseltilmesi ve uygun şartlarda korunup işlenmesiyle ilgilenen bir bilim dalıdır [1]. Tarım sektörünün en temel amacı, insanlığın yaşamını sürdürebilmesi için gerekli olan ihtiyaçları karşılamaktır [2]. Tarım biliminin ana üretim dalları bitkisel ve hayvansal üretimlerdir [3]. Üretim aşamasında, artan nüfus akabinde artan taleplerin karşılanması ve iklim değişikliği sebebiyle gıda güvenliğinin sağlanması oldukça önemlidir [4, 5].

Tarımsal üretimde karşılaşılan bitki hastalıkları üzerinde durulması gereken önemli bir konudur. Bitki hastalıklarına fungal, bakteriyel ve viral hastalıklar neden olmaktadır [6]. Bitki hastalıkları, tarım sektöründe kayıplar yaşanmasına sebebiyet vermektedir. Bu doğrultuda ise bitki hastalıklarının tespiti, problemin çözümü için ilk ve en önemli aşamadır [7]. Hastalığın doğru ve zamanında tespit edilebilmesi, verim ve kalitenin düşmemesi için bitki korumaya yönelik uygulamalar artmıştır [7, 8]. Bitki hastalıklarında karşılaşılan problemlerin çözümü için kullanılan tekniklerin gelişmesiyle yapay zekâ yöntemi kullanılmaya başlanmıştır [9].

Yapay zekâ, insan zekâsını taklit ederek insan gibi davranış gösteren, mantık yürütebilen, kazandığı tecrübeler doğrultusunda kendini geliştirebilen ve eyleme dönüştüren yazılımsal ve donanımsal sistemler bütünüdür [10, 11]. Sosyal ve ekonomik faaliyetlerini önemli derecede etkileyen yapay zekâ, farklı alanlarda karmaşık olan verileri çeşitli yöntemler ile analiz ederek daha anlaşılabilir olması için yorumlamaktadır [12, 13].

Yapay zekâ kavramı ilk kez 1956 yılında Dartmouth konferansında geçmesine karşın bu alandaki çalışmalar oldukça eskiye dayanmaktadır [14]. 1921 yılında Karel Capek tarafından yapay zekâyâ sahip robotlar ve insanlığın ortak toplumsal sorunlarını ele alınan RUR adlı bilim kurgu tiyatro oyununda robot kelimesi literatüre tanıtılmıştır [15]. 1941 yılında elektronik bilgisayarın doğuşunun ardından makinelerin zekâ ile donatılma konusu ele alınmıştır [16].

1950 yılında Alan Turing, “Makineler düşünebilir mi?” sorusunu cevapladığı ve makinelerin düşünebilme olasılığı hakkında dönüm noktası olarak kabul edilen makalesinde literatüre Turing testi olarak geçen bir öneride bulunmuştur [17]. Turing testinde birkaç insandan oluşan deney grubu bilgisayar ile etkileşime girmekte ve belli bir süre yazışma sonrasında sorgulayıcıya hangisinin insan hangisinin makine zekâsı olduğu sorulmaktadır. Bu test sonucunda bilgisayar kendini sorgulayıcıya insan olduğuna ikna ettiği takdirde düşünme yeteneğine sahip olduğu kabul edilmektedir [18, 19].

Yapay zekânın belli bir dönem popülerliğini kaybetmesinin ardından 1997 yılında IBM Deep Blue yazılımı ilk kez satranç alanında büyük şampiyon olan Gary Kasparov’u yenmiş ve bu sayede tekrar popüler bir konu haline gelmiştir [20]. Yapay zekâ, 1950’lerden günümüze kadar önemli başarılar elde ederek gelmiş ve günümüzde insan beyninden ilham alan algoritmalar ile makinelerin kendi kendine öğrenme uygulamaları oldukça önemli hale gelmiştir [21].

Yapay zekâ, eğitim [22], tıp [23], otomotiv [24], siber güvenlik [25], bankacılık ve finansal hizmetler [26] gibi farklı birçok alanda kullanılmaktadır. Yapay zekânın kullanıldığı önemli alanlardan birisi de bitki hastalıklarının tespitidir. Günümüze kadar yapay zekânın farklı teknikleri kullanılarak bitki hastalıkları alanında çalışmalar yapılmıştır [27]. Bitkide oluşan

herhangi bir hastalık genellikle bitkinin yaprağından tespit edilmektedir. Bu doğrultuda yapılan çalışmalarda, sağlıklı ve hastalıklı yaprak görselleri makinenin eğitimi için kullanılmaktadır [28]. Yapay zekâ ile yaprak hastalıkları tanıma üzerine yapılan akademik çalışmalar incelendiğinde;

Wicaksono ve ark. [29] elma yaprağı hastalığının tespiti üzerine evrimsel sinir ağları (ing. Convolutional Neural Network-CNN) yöntemini kullanmışlardır. Çalışmalarında, PlantVillage veri seti kullanılarak uyuz, siyah çürük, sedir pas hastalığı ve sağlıklı yaprak görüntülerinden oluşan toplam 3151 görüntü verisi kullanmışlardır. Çalışmada evrimsel sinir ağlarının LeNet-5 mimarisi kullanılarak 50,75 ve 100 epoch sayıları için eğitim verilerinde %99,2 ortalama doğruluk, test sonucunda %94,9 oranında ortalama doğruluk elde etmişlerdir.

Cruz ve ark. [30] çalışmalarında, latince ismi “vitis vinifera” bitkisi olan üzümde görülen asma sarılığı (ing. grapevine yellows) hastalığının yapay zekâ ile tespiti üzerinde çalışmışlardır. Bu hastalık sonucu bitki düzensiz olarak olgunlaşarak yaprağında renk değişikliği göstermeye başlamaktadır. Çalışmalarında, asma görüntüleri etiketlenmiş olan açık kaynak PlantVillage veri setini kullanmışlardır. Çalışmalarında sonuç olarak, hastalığı tespit etmek için CNN yöntemi kullanarak en iyi performansın ResNet-101 ile ResNet-50 olduğunu belirtmişlerdir.

Shruthi ve ark. [31] bitki hastalıklarını tespit etmek ve sınıflandırmak amacıyla çalışmalarında destek vektör makineleri (ing. Support Vector Machine-SVM), yapay sinir ağları (YSA), k-en yakın komşu algoritması (k-NN), fuzzy sınıflandırıcı ve CNN’i kullanan çalışmaları incelemişlerdir. Çalışmada kullanılan beş farklı model birbirleriyle karşılaştırılmış ve sonuç olarak CNN yönteminin en yüksek doğruluk oranını verdiğini ifade etmişlerdir. Bu derleme makalesinde %96.3 ortalama doğruluk ile en yüksek doğruluk elde edilen çalışma (Sladoyevic ve ark. 2016) tarafından CNN sınıflandırıcı ile gerçekleştirilen çalışma olduğu görülmüştür.

Fang ve ark. [32] çalışmalarında elma yaprağı hastalığının belirlenmesi için CNN modelinin içerisinde yer alan VGG16 mimarisi kullanmışlardır. Çalışmada kullanılan modelde sınıflandırma doğruluğunu arttırmak için merkez kaybı fonksiyonu ile softmax kayıp fonksiyonu birlikte kullanılmıştır. Veri kümesi olarak antraknoz yaprak yanıklığı, sedir pas, yaprak pas, gri nokta, siyah nokta ve siyah çürük hastalığına sahip olan 5373 hastalıklı yaprak görüntüsü ve 1683 sağlıklı yaprak görüntüsü kullanılmıştır. Çalışmada sonuç olarak önerilen VGG16 modeli ile %95 - %99,70 arasında doğruluk elde edilmiştir.

Baranwal ve ark. [33] tarafından gerçekleştirilen çalışmada, elma yaprağı hastalığı tespiti için CNN içerisinde yer alan GoogLeNet mimarisinden yararlanılmıştır. 22 katmandan oluşan bu mimari, PlantVillage veri kümesinin alt kümesi üzerinde doğrulanmıştır. Veri seti olarak siyah çürük, uyuz ve pas hastalığına sahip 1526 hastalıklı yaprak görüntüleri ve sağlıklı yaprak görüntüleri kullanılmıştır. Çalışmada sonuç olarak önerilen GoogLeNet modelinin ortalama %98,42 doğruluk oranına sahip olduğu görülmüştür.

Alruwaili ve ark. [34] çalışmalarında bitki hastalığının tespiti için CNN içerisinde yer alan AlexNet mimarisini kullanmışlardır. Çalışmada, 14 farklı bitki türü ve 26 farklı hastalığın toplam 54.306 görüntüsü bulunan PlantVillage veri setini kullanmışlardır. Sonuç olarak önerilen AlexNet modeli ile %99,11 doğruluk, %99,49 hassasiyet, %99,29 oranında F1 skoru elde ederek AlexNet mimarisinin farklı bitki hastalıklarını etkin bir şekilde saptadığını ortaya koymuşlardır.

Ferentinos [35] çalışmasında, bitki hastalıklarının teşhisi için derin öğrenme modelleri geliştirmiştir. Çalışmada CNN kullanılarak modelin eğitim ve testi için açık kaynak ve 87.848 görüntüden oluşan veri seti kullanmıştır. Bu görüntüler 25 farklı bitki türünün 58 farklı hastalığını içermektedir. Çalışmada, AlexNet, AlexNetOWTBn, GoogLeNet, Overfeat, VGG modelleri kullanarak en yüksek başarı oranı VGG ile %99,53 olarak elde edilmiştir.

Khitthuk ve ark. [36] renkli görüntülerde bitki hastalık tanısı koymak üzerine yapay zekâ sistemi üzerinde çalışmışlardır. Çalışmalarında, hastalık özellik çıkarma işlemi için istatistik tabanlı gri düzey eş oluşum matrisi (ing. Gray-Level Co-Occurrence Matrix-GLCM) metodu kullanılarak her bir imgeden parametreler elde edilmiştir. Hastalık sınıflandırması için ise denetimsiz sinir ağı olan ARTMAP kullanılmıştır. Veri seti olarak pas, uyuz, tüylü küf hastalığı olan ve hastaliksız toplam 346 üzüm yaprağı görüntüsü kullanılmıştır. Çalışmada sonuç olarak, %90'nın üzerinde doğruluk elde etmişlerdir.

Singh ve Misra [37] çalışmalarında, bakteriyel hastalığı olan gül ve fasulye yaprağı, güneş yanığı hastalığı olan limon yaprağı ve erken yanık hastalığı olan muz yaprağını görüntü segmentasyonu olan genetik algoritma ile tespitini gerçekleştirmişlerdir. Çalışmada, önerilen algoritma ile SVM kullanıldığında genel doğruluk %95,71 oranında elde edilmiştir.

Sladoveviç ve ark. [38] tarafından CNN kullanılarak geliştirilen model sağlıklı yaprağı ve 13 farklı bitki hastalığını tanıyabilmektedir. Çalışmada kullanılan veri setinde 13 farklı hastalık ve sağlıklı görüntülerin olduğu sınıf haricinde daha doğru sınıflandırma yapabilmek amacıyla arka plan görüntülerin olduğu sınıfta bulunmaktadır. Veri setinde bulunan 30880 görüntü eğitim, 2589 görüntü test için kullanılmıştır. CNN' in geliştirilmesi için 8 öğrenme katmanı, 5 evrimsel ve 3 tam bağlı katman içeren Caffe çerçevesi kullanılmıştır. Sonuç olarak model, %91 ile %98 arasında hassasiyet ve %96,3 doğruluk elde etmiştir.

Nachtigall ve ark. [39] çalışmalarında CNN kullanarak elma ağacındaki bozuklukları otomatik olarak tespit etmişlerdir. Çalışmada, maxigala, fuji suprema ve pink lady üç elma ağacı türündeki potasyum eksikliği, magnezyum eksikliği, uyuz hasarı, glomeralla lekesi ve herbisit hasarı olan beş bozukluk üzerine çalışma gerçekleştirmişlerdir. Veri kümesi olarak Brezilya'nın güney kesimindeki meyve bahçelerinden 1970 hastalıklı yaprak görüntüsü, 569 sağlıklı yaprak görüntüsü kullanmışlardır. CNN ile gerçekleştirilen çalışmada %97,3 doğruluk oranında sonuç elde edilmiştir.

Acar [40] çalışmasında, bitkinin kökleri ve yapraklarına gıda alımını durduran bir mantar hastalığı olan pas hastalığının yapay zekâ yöntemiyle tespiti üzerine çalışmıştır. Çalışmasında zambak çiçeği yaprak görüntülerinde pas hastalığı olup olmadığına dair GLCM ve gabor dalgacık dönüşümü (ing. Gabor Wavelet Transform-GWT) tabanlı sınıflandırıcıları öznelik çıkarma metodu olarak kullanılarak bir sistem tasarlanmıştır. Çalışmada veri seti olarak 32 sağlıklı görüntü, 21 hastalıklı görüntü üzerinde k-NN, çok katmanlı algılayıcı ve en küçük kareler SVM kullanmıştır. Sonuç olarak çalışmasında, GLCM tabanlı k-NN ve çok katmanlı YSA ile %88,9 oranında başarı elde ederek bitkideki pas hastalığını doğru tespit etmiştir.

Çalışmanın ilk bölümünde kısaca tarım, bitki hastalıkları, yapay zekâ ve yapay zekânın tarihçesinden, ikinci bölümünde yapay zekâ kullanılarak bitki hastalığı tespiti ile ilgili yapılan çalışmalardan bahsedilmiştir. Çalışmanın üçüncü bölümünde çalışmada kullanılan derin öğrenme modelleri, veri seti ve performans değerlendirme ölçütleri detaylı olarak açıklanmıştır. Çalışmanın dördüncü bölümünde ise elde edilen doğruluk, duyarlılık, özgüllük

ve F-skor deęerleri tablolar halinde verilmiřtir. alıřmanın sonu blmnde ise elma yapraklarında meydana gelen uyuz, siyah rk ve pas hastalıęı iin AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve Squeezenet1_0 yapay zekâ modellerinin performans karřılařtırması yapılmıřtır.

2. MATERİYAL VE METOT

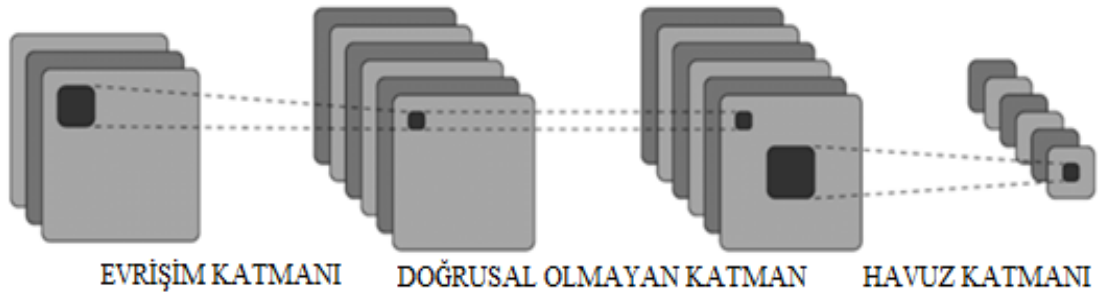
2.1. Materyal

Gerekleřtirilen alıřmada veri bilimciler ve makine ęrenimi uygulayıcı topluluęu olan aık eriřim internet sitesi [41] (<https://www.kaggle.com/>) ‘dan alınan veri seti kullanılmıřtır. Veri seti, elma yapraęına ait toplam 3171 adet grnt ile oluřturulmuřtur. Alınan veri setinde uyuz, siyah rk, pas hastalıęı ve saęlıklı olmak zere drt farklı elma yaprak sınıfı mevcuttur. Veri seti CNN modeli ierisinde yer alan, AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve Squeezenet 1_0 olmak zere beř farklı mimari kullanılarak eęitilmiřtir. Elde edilen sonular duyarlılık, zgllk, doęruluk ve F-skor olmak zere drt farklı performans deęerlendirme ltne gre deęerlendirilmiřtir. alıřmada kullanılan derin ęrenme modelleri, veri seti ve performans deęerlendirme ltleri hakkında detaylı bilgiler ařaęıda verilmiřtir.

2.1.1. Derin ęrenme

Derin ęrenme, son yıllarda makine ęrenimi konusunda heyecan verici bir eęilim olarak karřımıza ıkmaktadır [42]. Derin ęrenme klasik makine ęrenmesinin geniřletilmiř bir halidir. Bu geniřletilme modele daha fazla derinlik eklenerek verileri birkaç hiyerarřik yolla temsiline izin veren fonksiyonların kullanılması olarak tanımlanmaktadır [43]. Derin ęrenme modellerinin yksek hiyerarřik yapısı ve geniř ęrenme kapasitesi sınıflandırma ve tahminlerin tutarlılıkla yapılmasına olanak saęlamaktadır [44]. YSA’nın ok katmanlı ve ok nronlu hali olan derin sinir aęlarının en nemli zellięi probleme uygun olarak otomatik znelik ıkarımı yapılması ve bu zneliklerin aęın ęrenmesiyle oluřmasıdır [45].

CNN mimarisi; derin ęrenmenin eřitli algoritmaları arasında poplerlięi ile ne ıkmaktadır [46]. CNN beynin grsel korteksinden ilham alarak temel olarak grnty sınıflandırmak, benzerlikleri kmelemek ve nesne tanıma yapmak iin kullanılmaktadır [47, 48]. Bu mimari, grnty eřitli katmanlarla iřleyerek evriřim katmanları, doęrusal olmayan katmanlar, havuz katmanları ve tamamen baęlı katmanlardan oluřmaktadır [49]. Őekil 1’de rnek bir CNN mimarisinin temel yapısı gsterilmektedir [47]. Evriřim katmanı en yoęun matematiksel iřlemin gerekleřtięi katman olup grntdeki dřk ve yksek seviyeli zellikleri saptamak iin grntye bazı filtreler uygulamakta, aktivasyon katmanı olarakta adlandırılan doęrusal olmayan katmanda sisteme doęrusal olmayanlıęın tanıtılması gerekleřtirilmekte ve genellikle en iyi sonucu verdięi iin ReLu fonksiyonu kullanılmaktadır. Havuzlama katmanı aę iindeki parametrelerin azaltılması iin zellik haritalarının boyutlarını kltterek sistem zerindeki aęrılık sayısını azaltmaktadır. Tamamen baęlı katmanlar ise giriř ve ıkıř katmanları arasında baę kurarak modelde sınıflandırıcı grevi stlenmektedir [50,51].



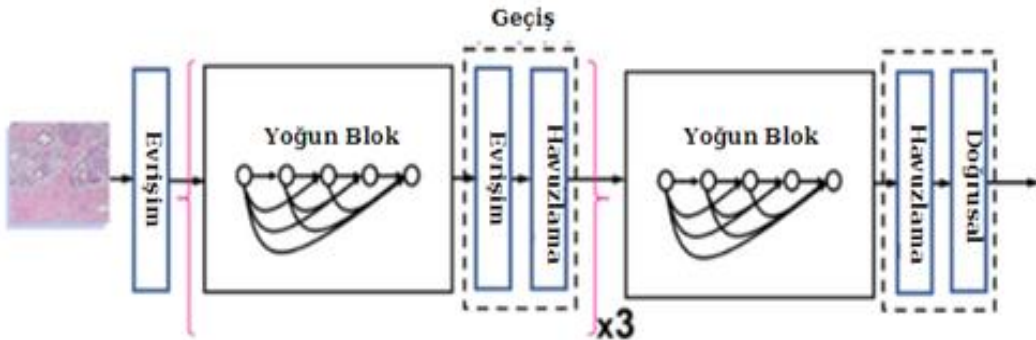
Şekil 1. Evrişimsel sinir ağı katmanları [47].

2.1.1.1. AlexNet

AlexNet mimarisi Krizhevsky ve ark. tarafından tasarlanmıştır [52]. 2012 yılında ImageNet yarışması AlexNet ile kazanılmıştır [53]. AlexNet derin öğrenmeyi hızlandırmak için GPU kullanarak yarışmadaki diğer rakiplerine göre daha iyi performans göstermiş ve bu sayede popüler olmuştur [54]. AlexNet mimarisi genellikle fotoğraf sınıflandırılması için tercih edilmektedir [55]. AlexNet birbirini takip eden sekiz kat derinliğinde evrişim katmanları, havuzlama katmanları ve tamamen bağlı katmanlardan oluşmaktadır [56]. AlexNet mimarisindeki diğer yeni bir yaklaşım ise standart olan tanh yerine ReLu aktivasyonunun ilk kez bu mimaride kullanılmasıdır [57].

2.1.1.2. DenseNet-121

DenseNet-121 (Yoğun bağlantılı evrişim ağı), her katmanı diğer katmanlara ileriye doğru bir şekilde bağlamaktadır. DenseNet mimarisinde her katman önceki tüm katmanların özelliklerini girdi olarak kullanmakta ve katmandaki kendi özellikleri de sonraki katmanlara girdi olarak vermektedir [58]. DenseNet mimarilerinin avantajı özellik yayılımını sağlamak ve özelliğin yeniden kullanılmasına olanak sağlayarak parametre sayısını azaltmasıdır [59]. Şekil 2'de örnek bir DenseNet-121 mimarisi gösterilmektedir [60]. Bu mimari dört yoğun blok, üç geçiş katmanı ve toplam 121 katmandan (117 döngü, 3 geçiş ve 1 sınıflandırma) oluşmaktadır [60].



Şekil 2. DenseNet-121 mimarisi [60].

2.1.1.3. ResNet-34

ResNet (Artık sinir ağı) He ve ark. tarafından 2015 yılında sunulmuş ve ImageNet yarışmasında %3,57 hata oranıyla birinci olmuştur [61]. ResNet-34 34 katmanlı derin artık ağı mimarisidir [62]. ResNet daha derin mimarilerin eğitimini sağlamaktadır. Bu mimaride eğitim

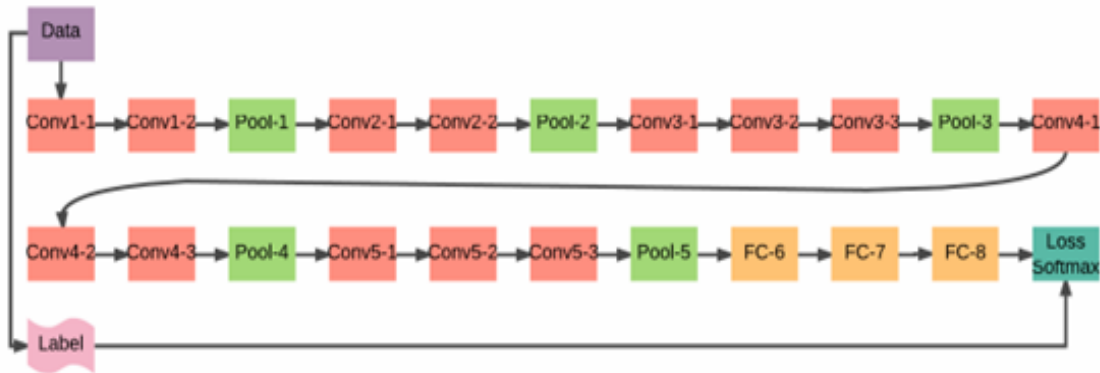
hatasını azaltmak için çok sayıda katman içeren bloklar kullanılmakta ve referanslandırılmamış işlevleri öğrenmek yerine artık değerler sonraki katmanlara eklenmektedir. ResNet mimarisinde katmanlar arasındaki atlama işlemi sayesinde ise kaybolan gradyan problemi de çözülmektedir [63, 64].

2.1.1.4. SqueezeNet

CNN modelinde kullanılan bir diğer popüler mimari ise SqueezeNet mimarisidir [65]. SqueezeNet mimarisi Iandola ve ark. tarafından 2016 yılında sunulmuştur [66]. Bu mimarinin amacı daha az parametreye sahip bir sinir ağı oluşturmak ve mimari 50 kat daha az parametre ile AlexNet düzeyinde doğruluk sağlamaktadır [67]. SqueezeNet mimarisinin avantajı ise daha verimli dağıtılmış katmanlar sayesinde sinir ağındaki iş yükü azalmakta ve bu sayede daha hızlı çalışmaktadır [67, 68].

2.1.1.5. VGG16-BN

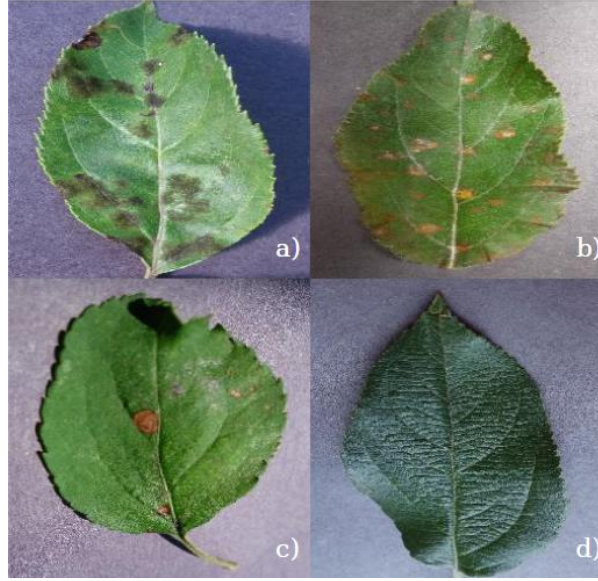
VGG-16 mimarisi Simonyan ve Zisserman tarafından sunulmuştur [69]. VGG16, tamamen bağlı ağı eğiten yaklaşık 138 milyon parametreye sahip büyük ölçekli görüntü tanıma modelidir [70]. VGG16 mimarisi 16 katmandan (13 evrişim, 3 tam bağlı katman) oluşmakta ve nesne sınıflandırma uygulamalarında kullanılmaktadır [71]. Şekil 3'de VGG16 mimarisinin görünümü verilmiştir [72].



Şekil 3. VGG16 mimarisi [72].

2.1.2. Veri seti

Önerilen mimariler bitki hastalığı tespit sisteminde kullanılan PlantVillage veri seti üzerinde eğitilmiştir. Kullanılan veri seti 14 farklı ürün için 54.306 etiketli görüntü içermektedir. Çalışmada, PlantVillage veri setinde bulunan 3171 elma yaprağı görüntüsü kullanılmaktadır. Şekil 4'de elma yapraklarında meydana gelen uyuz, siyah çürük, pas hastalığına sahip örnek görüntüler ve sağlıklı yaprak görüntüsü gösterilmektedir.



Şekil 4. PlantVillage veri setinden örnek elma yaprağı görüntüleri a)uyuz b)pas c)siyah çürük d)sağlıklı.

Çalışmada kullanılan yaprak görüntüleri %65 eğitim, %15 doğrulama ve %20 test veri kümesi için ayrılmaktadır. Tablo 1’de elma yaprağı veri kümesinde bulunan hastalıklı ve sağlıklı yaprak görüntüleri detaylı olarak gösterilmektedir.

Tablo 1. Elma Yapracağı Veri Seti.

Veri	Uyuz hastalığı olan yaprak görüntüsü	Siyah çürük hastalığı olan yaprak görüntüsü	Pas hastalığı olan yaprak görüntüsü	Sağlıklı yaprak görüntüsü	Toplam
Eğitim veri seti	410	404	179	1.070	2.063
Doğrulama	94	93	41	246	474
Test veri seti	126	124	55	329	634

2.1.3. Performans değerlendirme ölçütleri

Modellerin performansını değerlendirmek için sıklıkla karmaşıklık matris (confusion matrix) yöntemi kullanılmaktadır. Tablo 2’de gösterilen karmaşıklık matrisi gerçek sınıf ve sınıflandırıcının tahmin ettiği sınıf olmak üzere iki boyuta sahiptir [73]. Karmaşıklık matrisi sayesinde birçok sınıflandırma performansı tanımlanabilmektedir [74].

Tablo 2. Karmaşıklık Matrisi.

GERÇEK DEĞER	TAHMİN EDİLEN DEĞER		
		POZİTİF	NEGATİF
	POZİTİF	DOĞRU POZİTİF (True positive-TP)	YANLIŞ POZİTİF (False positive-FP)
NEGATİF	YANLIŞ NEGATİF (False negative-FN)	GERÇEK NEGATİF (True negative-TN)	

Duyarlılık (Sensitivity) modelin girdilerden pozitif sınıf etiketini tahmin etmedeki olasılığını göstermektedir. Duyarlılık, Eşitlik 1’de verilen matematiksel ifade kullanılarak hesaplanmaktadır.

$$Duyarluluk = \frac{DP}{DP+YP} \quad (1)$$

Özgüllük (Spesifite) modelin girdilerden negatif sınıf etiketini tahmin etmedeki olasılığını göstermektedir. Özgüllük, Eşitlik 2'de verilen matematiksel ifade kullanılarak hesaplanmaktadır.

$$Özgüllük = \frac{DN}{DN+YN} \quad (2)$$

Doğruluk (Accuracy) modelin genel olarak doğru olup olmadığını belirlemede kullanılmaktadır. Doğruluk, Eşitlik 3'de verilen matematiksel ifade kullanılarak hesaplanmaktadır.

$$Doğruluk = \frac{DP+DN}{DP+DN+YP+YN} \quad (3)$$

F-Skor (F-Score) kesinlik ve duyarlılık performans değerlendirme ölçütlerini birlikte değerlendirme imkânı sağlayan bir değerlendirme ölçütüdür. F skor Eşitlik 4'de verilen matematiksel ifade kullanılarak hesaplanmaktadır [75].

$$F - Skor = \frac{2DP}{2DP+YP+YN} \quad (4)$$

Denklemleri verilen ölçütler ikili sınıflandırma yapılırken kullanılmaktadır. Üç veya daha fazla sınıftan oluşan uygulamalarda performans değerlendirirken her sınıf için hesaplanan ölçümlerin ortalaması alınmaktadır [76]. Doğru ve yanlış sınıflandırmanın oranlarını gösteren matrisler üzerinde ortalama doğruluk, özgüllük, duyarlılık ve F-Skor değeri Eşitlik 5, 6, 7, 8'de verilen matematiksel ifadeler kullanılarak hesaplanmaktadır [76,77].

$$Ortalama Doğruluk = \frac{\sum_{i=1}^l \frac{DP_i+DN_i}{DP_i+YN_i+YP_i+DN_i}}{l} \quad (5)$$

$$Ort. Özgüllük = \frac{\sum_{i=1}^l \frac{DN_i}{DN_i+YN_i}}{l} \quad (6)$$

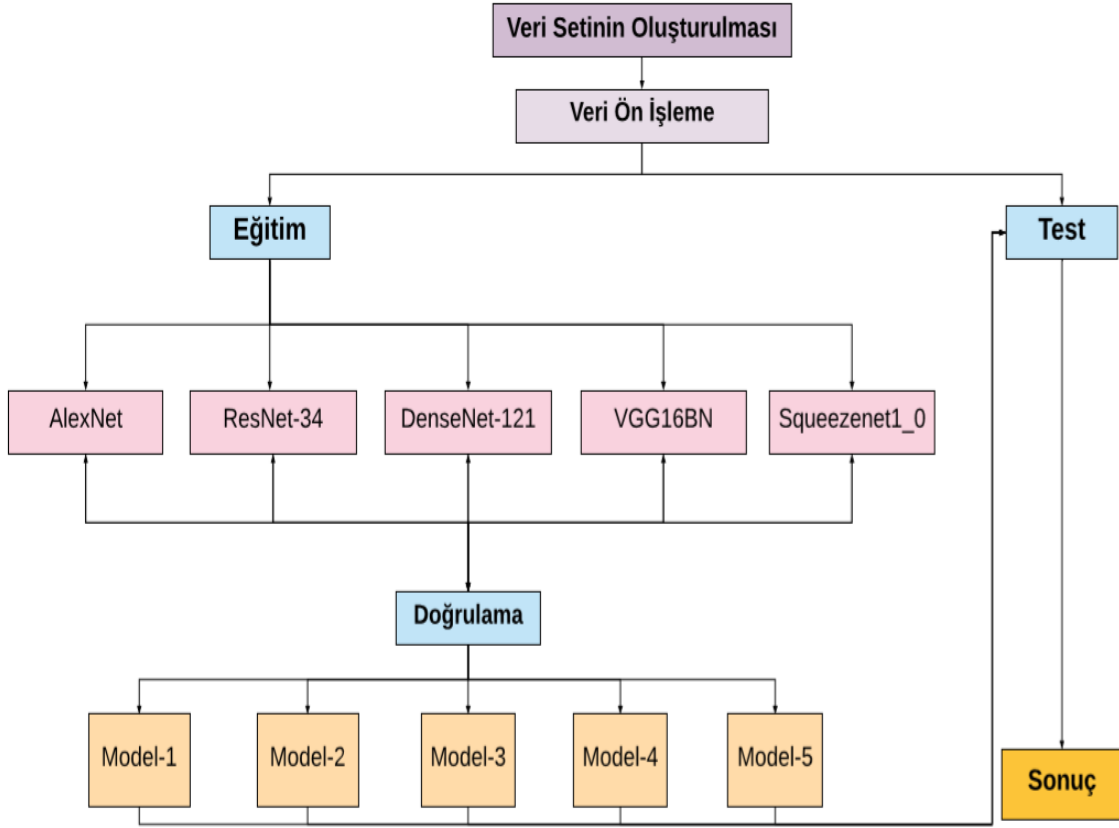
$$Ort. Duyarluluk = \frac{\sum_{i=1}^l \frac{DP_i}{DP_i+YN_i}}{l} \quad (7)$$

$$Ort. F - değeri = \frac{\sum_{i=1}^l \frac{2DP_i}{2DP_i+YP_i+YN_i}}{l} \quad (8)$$

2.2. Metot

Gerçekleştirilen çalışmanın iş akış diyagramı Şekil 5'de verilmiştir. İlk aşamada açık kaynaklı internet sitesi Kaggle'da yer alan PlantVillage veri setinden 3171 adet elma yaprağı görüntüsü alınarak veri seti oluşturulmuştur. Veri seti içerisinde uyuz, siyah çürük, pas hastalığı olan ve sağlıklı yaprak görüntüleri etiketlenmiştir. Dört farklı sınıf bulunan veri setinde eğitim için toplam 2.063 görüntü, doğrulama için 474 görüntü ve test için 634 görüntü kullanılmıştır. İkinci aşama olan veri ön işleme aşamasında ise normalizasyon işlemi gerçekleştirilmiştir. Üçüncü aşamada görüntüler AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve Squeezenet1_0 derin öğrenme modelleri eğitilerek en doğru yöntem tespit edilmiştir. Tüm modeller için elde edilen eğitim oranları optimize edilerek 0.005 olarak belirlenmiştir.

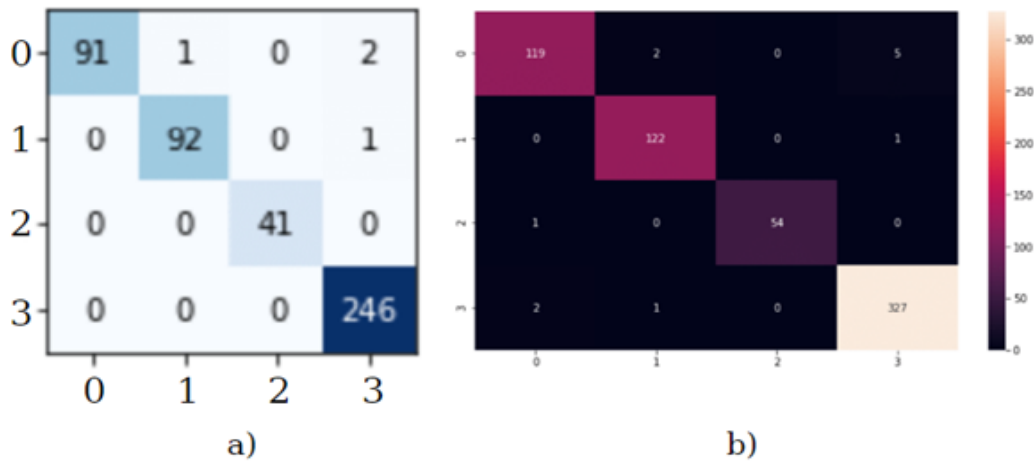
Eğitilen modeller üzerinde hem doğrulama hem test işlemleri uygulanarak modelin doğruluğu test edilmiştir.



Şekil 5. İş akış diyagramı.

3. ARAŞTIRMA BULGULARI

Çalışmada AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve SqueezeNet1_0 olmak üzere beş farklı derin öğrenme yöntemi kullanılarak elma bitkisine ait uyuz, siyah çürük, pas hastalığı olan ve sağlıklı yaprak olmak üzere dört sınıf eğitilmiştir. Eğitilen modeller üzerinde hem doğrulama hem de test işlemleri uygulanarak aşağıdaki sonuçlar elde edilmiştir. İlk olarak AlexNet modelinin doğrulama ve test veri seti için karmaşıklık matrisi Şekil 6'da verilmiştir.



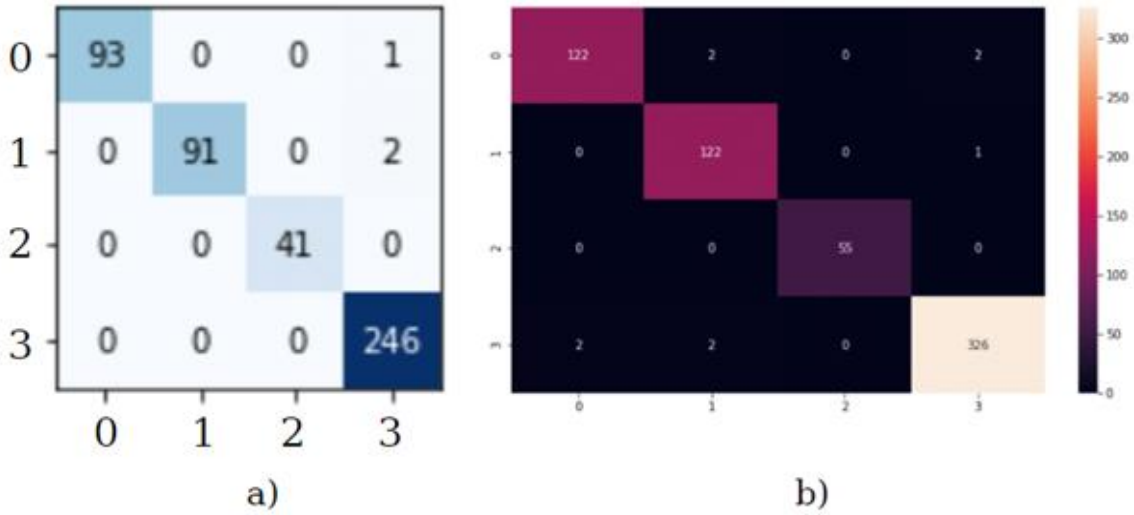
Şekil 6. AlexNet modeli(a) doğrulama veri seti için (b) test veri seti için karmaşıklık matrisi.

Karmaşıklık matrisinde sıfırinci indeks elma yaprağındaki uyuz hastalığını, birinci indeks siyah çürük hastalığını, ikinci indeks pas hastalığını ve üçüncü indeks sağlıklı yaprak görüntülerini göstermektedir. AlexNet modelinin performans değerlendirme ölçütleri Tablo 3’de gösterilmektedir.

Tablo 3. AlexNet Performans Değerlendirme Ölçütleri.

Veri	Duyarlılık	Özgüllük	Doğruluk	F-Skor
Doğrulama veri seti	0,96316	0,99075	0,99156	0,97566
Test veri seti	0,91855	0,97995	0,98099	0,94677

DenseNet-121 modelinin doğrulama ve test veri seti için karmaşıklık matrisi Şekil 7’de verilmiştir.



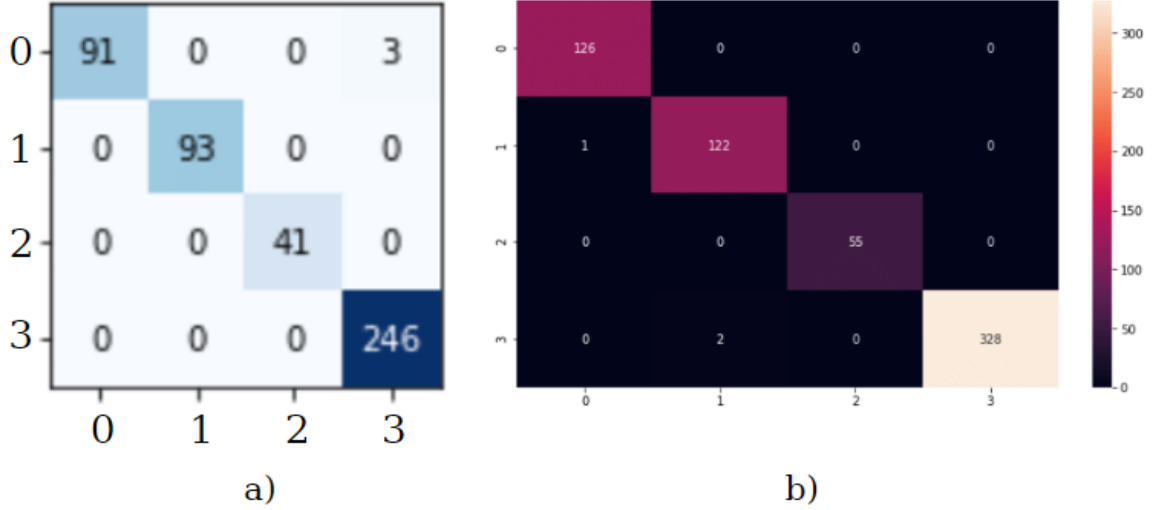
Şekil 7. DenseNet-121 modeli (a) doğrulama veri seti için (b) test veri seti için karmaşıklık matrisi.

DenseNet-121 modelinin performans değerlendirme ölçütleri Tablo 4’de gösterilmektedir.

Tablo 4. DenseNet-121 Performans Değerlendirme Ölçütleri.

Veri	Duyarlılık	Özgüllük	Doğruluk	F-Skor
Doğrulama veri seti	0,97196	0,99300	0,99367	0,98163
Test veri seti	0,93584	0,98562	0,98580	0,95990

ResNet-34 modelinin doğrulama ve test veri seti için karmaşıklık matrisi Şekil 8’de verilmiştir.



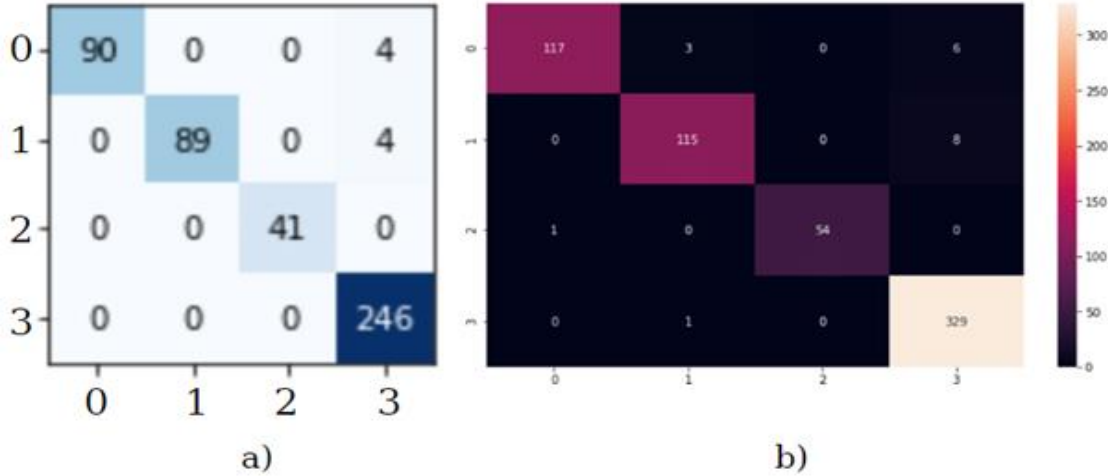
Şekil 8. ResNet-34 modeli (a) doğrulama veri seti için (b) test veri seti için karmaşıklık matrisi.

ResNet-34 modelinin performans değerlendirme ölçütleri Tablo 5’de gösterilmektedir.

Tablo 5. ResNet-34 Performans Değerlendirme Ölçütleri.

Veri	Duyarlılık	Özgüllük	Doğruluk	F-Skor
Doğrulama veri seti	0,97212	0,99300	0,99367	0,98163
Test veri seti	0,97646	0,99542	0,99526	0,98624

VGG16-BN modelinin doğrulama ve test veri seti için karmaşıklık matrisi Şekil 9’da verilmiştir.



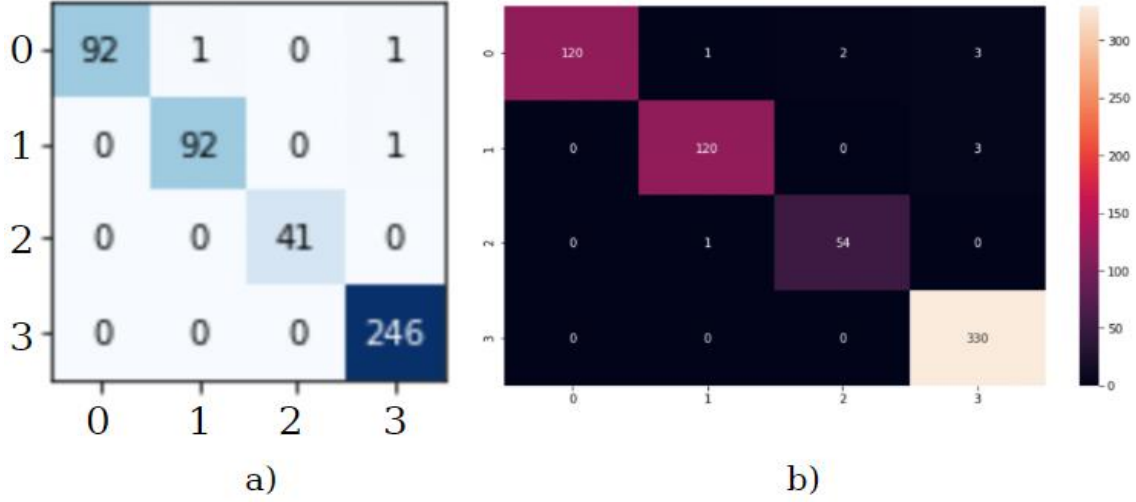
Şekil 9. VGG16-BN modeli (a) doğrulama veri seti için (b) test veri seti için karmaşıklık matrisi.

VGG16-BN modelinin performans değerlendirme ölçütleri Tablo 6’da gösterilmektedir.

Tablo 6. VGG16-BN Performans Değerlendirme Ölçütleri.

Veri	Duyarlılık	Özgüllük	Doğruluk	F-Skor
Doğrulama veri seti	0,92991	0,98135	0,98312	0,95238
Test veri seti	0,88302	0,96712	0,97003	0,91809

SqueezeNet1_0 modelinin doğrulama ve test veri seti için karmaşıklık matrisi Şekil 10'da verilmiştir.



Şekil 10. SqueezeNet1_0 modeli (a) doğrulama veri seti için (b) test veri seti için karmaşıklık matrisi.

SqueezeNet1_0 modelinin performans değerlendirme ölçütleri Tablo 7'de gösterilmektedir.

Tablo 7. SqueezeNet1_0 Performans Değerlendirme Ölçütleri.

Veri	Duyarlılık	Özgüllük	Doğruluk	F-Skor
Doğrulama veri seti	0,97193	0,99300	0,99367	0,98163
Test veri seti	0,93508	0,98249	0,98422	0,95508

Tablo 8'de, AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve SqueezeNet1_0 modelleri için duyarlılık, özgüllük, doğruluk ve F-skor değerleri verilmiştir.

Tablo 8. AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve SqueezeNet1_0 Performans Değerlendirme Ölçütleri.

Model	Duyarlılık		Özgüllük		Doğruluk		F-Score	
	Doğrulama	Test	Doğrulama	Test	Doğrulama	Test	Doğrulama	Test
AlexNet	0,96316	0,91855	0,99075	0,97995	0,99156	0,98099	0,97566	0,94677
DenseNet-121	0,97193	0,93562	0,99300	0,98562	0,99367	0,98580	0,98163	0,95990
ResNet-34	0,97212	0,97646	0,99300	0,99542	0,99367	0,99526	0,98163	0,98624
VGG16-BN	0,92991	0,88302	0,98135	0,96712	0,98312	0,97003	0,95238	0,91809
SqueezeNet1_0	0,97193	0,93508	0,99300	0,98249	0,99367	0,98422	0,98163	0,95508

4. SONUÇ

Çalışmada CNN içerisinde yer alan AlexNet, DenseNet-121, ResNet-34, VGG16-BN ve Squeezenet1_0 mimarileri elma bitkisi hastalıklarının tespiti için kullanılmıştır. Elde edilen sonuçlar dört farklı performans değerlendirme ölçütüne göre değerlendirilerek aşağıdaki sonuçlar elde edilmiştir.

- Modeller performans değerlendirme ölçütü olan karışıklık matrisine göre değerlendirilmiştir. Değerlendirme sonucunda modelin uyuz, siyah çürük, pas hastalığı olan ve sağlıklı yaprakları tespit edebildiği görülmüştür.
- Modeller duyarlılık, özgüllük, doğruluk ve F-skor performans değerlendirme ölçütlerine göre değerlendirilmiştir. Değerlendirme sonucunda doğrulama veri setinde duyarlılık için en iyi sonucun %97.21 ile ResNet-34, özgüllük için %99.3 ile DenseNet-121, ResNet-34 ve Squeezenet1_0, doğruluk için %99.3 ile DenseNet-121, ResNet-121 ve Squeezenet1_0 ve son değerlendirme ölçütü olan F-skor için ise %98.16 ile DenseNet-121, ResNet-121 ve Squeezenet1_0 olduğu ortaya konulmuştur.
- Değerlendirme sonucunda test veri setinde duyarlılık, özgüllük, doğruluk ve F-skor için en iyi sonucun sırasıyla %97.64, %99.54, %99.52, %98.62 değerleri ile ResNet-34 mimarisi olduğu ortaya konulmuştur.

Sonuç olarak yapay zekâ ile elma bitkisindeki hastalık tespitinde en iyi modelin ResNet-34 mimarisi olduğu belirlenmiştir.

Teşekkür

Çalışmada kullanılan PlantVillage veri setininin açık kaynak verilerini internet sitelerinde (Kaggle) kullanıma açan herkese teşekkürü bir borç biliriz.

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SPLIT-SPLIT PLOT ANALYSIS OF THE EFFECTS OF PROCESS PARAMETERS IN THE PRODUCTION OF POLYVINYL CHLORIDE-GRASS COMPOSITE

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ABSTRACT: The interaction of process parameters in the production of polyvinyl chloride-grass composite poses great challenges in the polymeric industries. Most manufacturing processes of injection moulded polyvinyl chloride-grass composite products have been by trial and error due to inadequate knowledge in process parameters and their interactions. This study investigates the effects of process parameters such as percentage by volume of material, material type, barrel temperature and their interactions on the mechanical properties of the produced polyvinyl chloride-grass composite using split-split plot design. The results of the calculated Fisher's ratio (F_{cal}) at significant value of 0.05 for the process parameters and their interactions ranges from -855.35 to 1.00, and were presented on ANOVA table. The results obtained shows that these process parameters contribute significantly to the production of Polyvinyl chloride-grass composite in polymeric industries.

Keywords: Mechanical properties, Polyvinyl Chloride-Grass composite, Process parameters, Split-Split Plot Design.

1. INTRODUCTION

A qualitative analysis of the influence of process parameters such as barrel temperature, percentage by volume of material and material type on the mechanical properties of injection moulded part will be helpful in gaining better insight into PVC-Grass composite processing methods. Moreover, inadequate investigation of the effects of the interaction of process parameters in the production of PVC-grass composites had resulted to most failure in the manufacture of these composite. The utilization of process control and process monitoring are rarely fully implemented for the production of injection moulded products. This may be due to a poor scientific understanding of the moulding process based on the complexities of the process containing multiple variables affecting the final part.

Split plot designs initially developed by Fisher in 1925 were used in agricultural experiments, and are basically the modified form of randomized block designs. These designs are used in situations where complete randomization of runs within block is not possible. These designs are used widely in industrial experiments, experiments where one set of factors may require a large amount of experimental materials (Whole Plot factors), while another set of factors

might be applied to smaller experimental materials (Sub Plot factors) [1]. Olodu and Osarenmwinda [2] examined the effect of process parameters such as temperature in the production of polypropylene-grass composite using split-split plot experimental design, their results shows that temperature contributes significantly to the production of composites in polymeric industries. Aviles and Pinheiro [3] examined the experiments that have complete randomization order of runs which was not feasible or might be too expensive to use when performed. They concluded from their study that the use of split-plot designs and models are feasible, efficient and cheap. Goldsmith and Gaylor [1] carried out extensive investigation on optimal designs for estimating variance components in a completely random nested classification. Loeza-Serrano and Donev [4] constructed D-Optimal design for variance components estimation in a three stage crossed and nested classification. For experiments that include both crossed and nested factor in the same model, no assumption of a complete random model has been made. Ankenman et al; Aviles and Pinheiro [5,3] investigations indicates that experiments involving complete randomization of order of runs which is not feasible or too expensive to use is performed using split plot models. Chungping *et al* [6] carried out a study aimed to model fundamental bonding characteristics and performance of wood composite. In their work, mathematical model and a computer simulation model were developed to predict the variation of inter-element (strand) contact during mat consolidation. The mathematical predictions and the computer simulations agree well with each other. Their results showed that the relationship between the inter-element contact and the mat density was highly nonlinear and was significantly affected by the wood density and the element thickness.

This study therefore focused on the split-split plot analysis of the effects of process parameters in the production of polyvinyl chloride-grass composite.

2. MATERIALS AND METHODS

2.1. Preparation and Processing of Grass

The harvested grass was washed and soaked with dilute Sodium Hydroxide (NaOH) of concentration 0.10mol/dm^3 for 6 hours to ensure effective bonding between the grass and Polyvinyl chloride materials. The grass was ground to granules using crushing machine. The grasses were first air dried in the sun and later transferred to an oven and dried at 105°C . It was continuously monitored until moisture content of about $4 \pm 0.2\%$ was obtained [7]. The ground grass was screened to a particle size of $300\mu\text{m}$ diameters using vibrating sieve machine.

2.2 Mixing, Compounding and Production of Composites

Polyvinyl Chloride (PVC) was mixed with ground grass in the proportion of 20:80, 30:70, 40:60, 50:50, 60:40, 70:30 and 80:20 percentages by volume respectively. The prepared Polyvinyl chloride-grass composite was blended in a cylindrical container until a homogenous mixture was obtained in the composite. The homogenous mixture of the composite was feed into the hopper of injection moulding machine and were produced at various barrel temperature ranging from 210°C to 310°C respectively at an interval of 10°C [8].

2.3. Evaluation of Polyvinyl Chloride-Grass Composite for Mechanical Strength

The produced polyvinyl chloride-grass composite was evaluated for mechanical strength (tensile strength, proof stress, percentage elongation and flexural strength) using Equation 1 to 4 respectively [9].

$$\text{Tensile strength} = \frac{\text{Maximum Load}}{\text{Original Cross - Sectional Area}} \quad (1)$$

The original cross-sectional area of the specimen is 18.9mm².

$$\text{Proof stress} = \frac{\text{Force at yield}}{\text{Cross - Sectional Area}} \quad (2)$$

The Cross-sectional area of specimen =18.9 mm²

$$\text{Hence, proof stress} = \frac{\text{Force at yield}}{18.9} \text{ N/mm}^2$$

$$\text{Percentage (\%) Elongation} = \frac{\text{Extension}}{\text{Gauge Length}} \times 100\% \quad (3)$$

$$EI = \frac{PL^3}{48y} \quad (4)$$

Where y is the deflection in mm, P= Load, L= Length of test specimen

2.4. The Split-Split Plot Designs

The split-split plot design which is an experimental design was used to investigate the interaction between material type, percentage by volume of material and barrel temperature on the mechanical properties of the produced PVC-Grass composite. In simple terms, a split-split plot experiment is a blocked experiment, where the blocks themselves serve as experimental units for a subset of the factors. Analytical and numerical designs using split-split plot design was carryout to investigate the effect of process parameters in the developed PVC-Grass composite.

2.5. The F-test

The F-test was used for comparing the factors of the total deviation (using Equation 5). The statistical significance was tested by comparing the F test statistic.

$$F = \frac{\text{Variance between treatments}}{\text{Variance within treatments}} \quad (5)$$

$$F = \frac{MSTreatments}{MS_{Error}} = \frac{SSTreatments/(I-1)}{SS_{Error}/(nT-1)}$$

2.6. The Interactive Model Developed for PVC-Grass Composite

Equation 6 shows the Interactive model developed and is depicted as:

$$X_{ijkl} = \mu + \gamma_i + \beta_j + \delta_l + y_k + \gamma\beta_{ij} + \gamma y_{ik} + \beta y_{jk} + \gamma\delta_{il} + \beta\delta_{jl} + y\delta_{lk} + \gamma\beta y_{ijk} + \gamma\beta\delta_{ijl} + \gamma y\delta_{ikl} + \beta y\delta_{jkl} + \gamma\beta\delta y_{ijkl} + \varepsilon_{ijkl} \quad (6)$$

Where:

μ = Mean response; γ_i = Block variable (mechanical properties); β_j = Block variable (barrel temperature); δ_l = Treatment Variable (percentage by volume of material); y_k = Treatment Variable (type of material); $\gamma\beta_{ij}$ = Block interaction (mechanical properties and barrel temperature interaction); γy_{ik} = Block and Treatment interaction (mechanical properties and type of material interaction); βy_{jk} = Treatment Interaction (barrel temperature and type of material interaction); $\gamma\delta_{il}$ = Block and Treatment interaction (mechanical properties and percentage by volume of material interaction); $\beta\delta_{jl}$ = Block and Treatment interaction (barrel temperature and percentage by volume of material interaction); $y\delta_{lk}$ = Treatment Interaction (percentage by volume of material and type of material interaction); $\gamma\beta y_{ijk}$ = Block and Treatment interaction (mechanical properties, barrel temperature and type of material interaction); $\gamma\beta\delta_{ijl}$ = Block and Treatment interaction (mechanical properties, barrel temperature and Percentage by volume of material interaction); $\gamma y\delta_{ikl}$ = Block and Treatment interaction (mechanical properties, type of material and Percentage by volume of material interaction); $\beta y\delta_{jkl}$ = Block and Treatment interaction (barrel temperature, type of material and Percentage by volume of material interaction); $\gamma\beta\delta y_{ijkl}$ = Block and Treatment interaction (mechanical properties, barrel temperature, type of material and percentage by volume of material interaction); X_{ijkl} = Response Variable; ε_{ijkl} = Error term.

2.7. Statistical Computations for PVC-Grass Composite

Equation 7 to 22 was used to calculate for the sum of squares for the process parameters and their interactions which was used to investigate the effects of process parameters using split-split plot designs analysis. The obtained results were presented on Table 2

A) Total Sum of Squares (SS_T)

$$SS_T = \sum_{i=1}^{I=4} \sum_{j=1}^{J=11} \sum_{k=1}^{K=2} \sum_{l=1}^{L=7} X_{ijkl}^2 - \frac{X^2 \dots}{IJLK} \quad (7)$$

Where I=4, J=11, K=2, L=7

B) Sum of squares for materials (SS_A)

$$SS_A = \sum_{k=1}^{K=2} \frac{X^2 \dots K \dots}{IJL} - \frac{X^2 \dots}{IJLK} \quad (8)$$

C) Sum of squares for the percentage by volume of materials (SS_B)

$$SS_B = \sum_{l=1}^{L=7} \frac{X^2 \dots l \dots}{IJK} - \frac{X^2 \dots}{IJLK} \quad (9)$$

D) Sum of squares for mechanical strength (SS_C)

$$SS_C = \sum_{i=1}^{I=4} \frac{X^2 \dots i \dots}{JKL} - \frac{X^2 \dots}{IJLK} \quad (10)$$

E) Sum of squares for temperature (SS_D)

$$SS_D = \sum_{j=1}^{J=11} \frac{X^2_{\cdot j \cdot \cdot}}{IKL} - \frac{X^2_{\cdot \cdot \cdot \cdot}}{IJLK} \tag{11}$$

F) (Material type) X (percentage by volume of material) Interaction (SS_{AB})

$$SS_{AB} = \sum_{k=1}^{K=2} \sum_{l=1}^{L=7} \frac{X^2_{\cdot \cdot k l}}{IJ} - \sum_{k=1}^{K=2} \frac{X^2_{\cdot \cdot k \cdot}}{IJK} - \sum_{l=1}^{L=7} \frac{X^2_{\cdot \cdot \cdot l}}{IJK} + \frac{X^2_{\cdot \cdot \cdot \cdot}}{IJLK} \tag{12}$$

G) (Material type) X (Mechanical Strength) Interaction (SS_{AC})

$$SS_{AC} = \sum_{i=1}^{I=4} \sum_{k=1}^{K=2} \frac{X^2_{i \cdot k \cdot}}{JL} - \sum_{i=1}^{I=4} \frac{X^2_{i \cdot \cdot \cdot}}{JKL} - \sum_{k=1}^{K=2} \frac{X^2_{\cdot \cdot k \cdot}}{IJK} + \frac{X^2_{\cdot \cdot \cdot \cdot}}{IJLK} \tag{13}$$

H) (Material type) X (Temperature) Interaction (SS_{AD})

$$SS_{AD} = \sum_{k=1}^{K=2} \sum_{j=1}^{J=11} \frac{X^2_{j k \cdot}}{IL} - \sum_{k=1}^{K=2} \frac{X^2_{\cdot \cdot k \cdot}}{IJL} - \sum_{j=1}^{J=11} \frac{X^2_{j \cdot \cdot \cdot}}{IKL} + \frac{X^2_{\cdot \cdot \cdot \cdot}}{IJLK} \tag{14}$$

I) (Percentage by Volume of material) X (Mechanical Strength) Interaction (SS_{BC})

$$SS_{BC} = \sum_{i=1}^{I=4} \sum_{l=1}^{L=7} \frac{X^2_{i \cdot \cdot l}}{JK} - \sum_{i=1}^{I=4} \frac{X^2_{i \cdot \cdot \cdot}}{JKL} - \sum_{l=1}^{L=7} \frac{X^2_{\cdot \cdot \cdot l}}{IJK} + \frac{X^2_{\cdot \cdot \cdot \cdot}}{IJLK} \tag{15}$$

J) (Percentage by volume of material) X (Temperature) Interaction (SS_{BD})

$$SS_{BD} = \sum_{j=1}^{J=11} \sum_{l=1}^{L=7} \frac{X^2_{j \cdot \cdot l}}{IK} - \sum_{j=1}^{J=11} \frac{X^2_{j \cdot \cdot \cdot}}{IKL} - \sum_{l=1}^{L=7} \frac{X^2_{\cdot \cdot \cdot l}}{IJK} + \frac{X^2_{\cdot \cdot \cdot \cdot}}{IJLK} \tag{16}$$

K) (Mechanical Strength) X (Temperature) Interaction (SS_{CD})

$$SS_{CD} = \sum_{i=1}^{I=4} \sum_{j=1}^{J=11} \frac{X^2_{i j \cdot \cdot}}{KL} - \sum_{i=1}^{I=4} \frac{X^2_{i \cdot \cdot \cdot}}{JKL} - \sum_{j=1}^{J=11} \frac{X^2_{\cdot j \cdot \cdot}}{IKL} + \frac{X^2_{\cdot \cdot \cdot \cdot}}{IJLK} \tag{17}$$

L) (Material type) X (Percentage by volume of material) X (Mechanical Strength) Interaction (SS_{ABC})

$$SS_{ABC} = \sum_{i=1}^{I=4} \sum_{k=1}^{K=2} \sum_{l=1}^{L=7} \frac{X^2_{i \cdot k l}}{J} - \sum_{i=1}^{I=4} \sum_{k=1}^{K=2} \frac{X^2_{i \cdot k \cdot}}{JL} - \sum_{k=1}^{K=2} \sum_{l=1}^{L=7} \frac{X^2_{\cdot \cdot k l}}{IJ} + \sum_{k=1}^{K=2} \frac{X^2_{\cdot \cdot k \cdot}}{IJK} \tag{18}$$

M) (Material type) X (Percentage by volume of material) X (Temperature) Interaction (SS_{ABD})

$$SS_{ABD} = \sum_{j=1}^{J=11} \sum_{k=1}^{K=2} \sum_{l=1}^{L=7} \frac{X^2_{j k l}}{I} - \sum_{j=1}^{J=11} \sum_{k=1}^{K=2} \frac{X^2_{j k \cdot}}{IL} - \sum_{k=1}^{K=2} \sum_{l=1}^{L=7} \frac{X^2_{\cdot \cdot k l}}{IJ} + \sum_{k=1}^{K=2} \frac{X^2_{\cdot \cdot k \cdot}}{IJK} \tag{19}$$

N) (Material type) X (Mechanical strength) X (Temperature) Interaction (SS_{ACD})

$$SS_{ACD} = \sum_{i=1}^{I=4} \sum_{j=1}^{J=11} \sum_{k=1}^{K=4} \frac{X^2_{i j k.}}{L} - \sum_{i=1}^{I=4} \sum_{j=1}^{J=11} \frac{X^2_{i j..}}{KL} - \sum_{j=1}^{J=11} \sum_{k=1}^{K=7} \frac{X^2_{.j k.}}{IL} + \sum_{j=1}^{J=11} \frac{X^2_{.j..}}{IKL} \quad (20)$$

O) (Percentage by volume of material) X (Mechanical strength) X (Temperature) Interaction (SS_{BCD})

$$SS_{ACD} = \sum_{i=1}^{I=4} \sum_{j=1}^{J=11} \sum_{l=1}^{L=7} \frac{X^2_{i j .l}}{K} - \sum_{i=1}^{I=4} \sum_{j=1}^{J=11} \frac{X^2_{i j..}}{KL} - \sum_{j=1}^{J=11} \sum_{l=1}^{L=7} \frac{X^2_{.j .l}}{IK} + \sum_{j=1}^{J=11} \frac{X^2_{.j..}}{IKL} \quad (21)$$

P) Error Sums of Squares SS_E = SS_T - SS_A - SS_B - SS_C - SS_D - SS_{AB} - SS_{AC} - SS_{AD} - SS_{BC} - SS_{CD} - SS_{ABC} - SS_{ABD} - SS_{ACD}. (22)

2.8. Hypothesis

The null hypothesis with its alternative were formulated for the PVC-Grass composite as follows:

Null Hypothesis(H₀): The percentage by volume of material, material type, barrel temperature and their interactions contributes significantly to the mechanical properties of the composite produced at α-value of 0.05.

Alternate Hypothesis (H₁): The percentage by volume of material, material type, barrel temperature and their interactions does not contributes significantly to the mechanical properties of the composite produced at α-value of 0.05.

3. RESULTS AND DISCUSSION

Table 1 shows the effects of barrel temperature on mechanical properties of PVC-Grass composites while Table 2 shows ANOVA result for the effects of process parameters and their interactions on produced PVC-grass composite. Figure 1-4 shows the split-split plot analytical design of the effects of barrel temperature on tensile strength, proof stress, percentage elongation and flexural strength respectively. Figure 5-8 shows the Split-split plot numerical design of the effects of barrel temperature on tensile strength, proof stress, percentage elongation and flexural strength respectively.

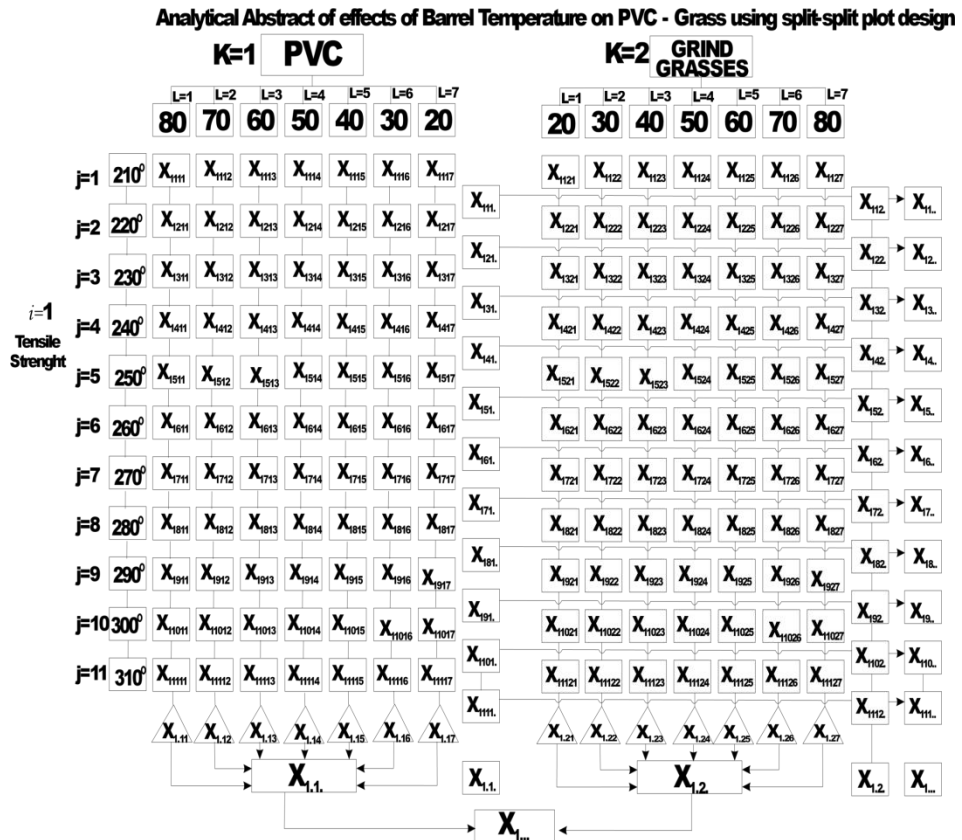


Figure 1. Split-split plot Analytical Design of the Effect of Barrel Temperature on Tensile Strength.



Figure 2. Split-split plot Analytical Design of the Effect of Barrel Temperature on Proof Stress.

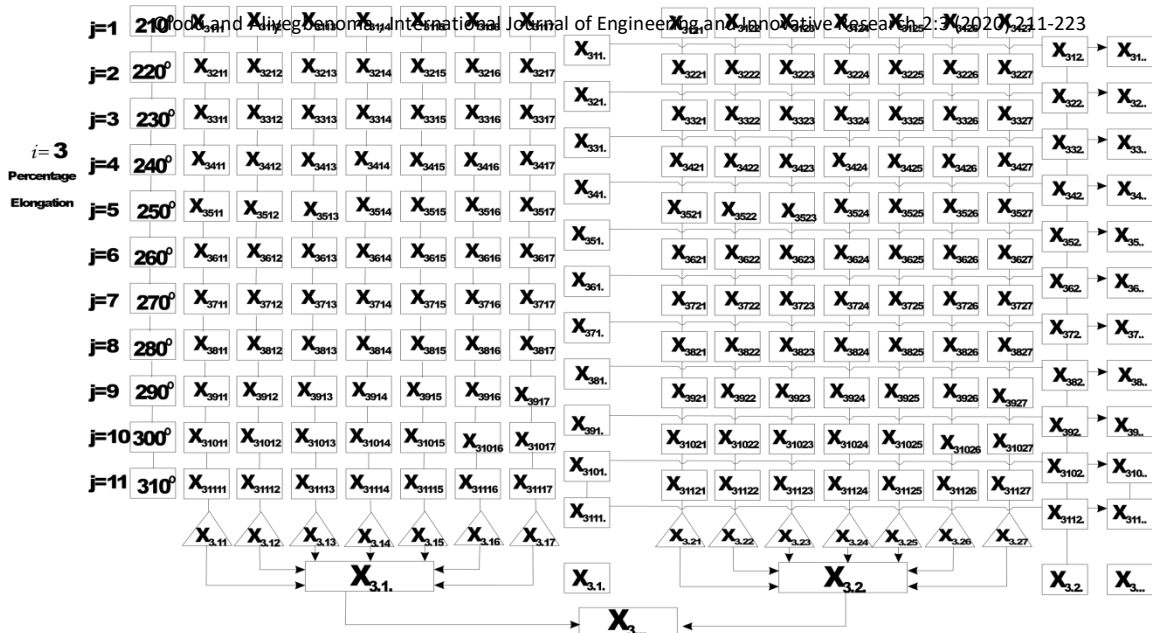
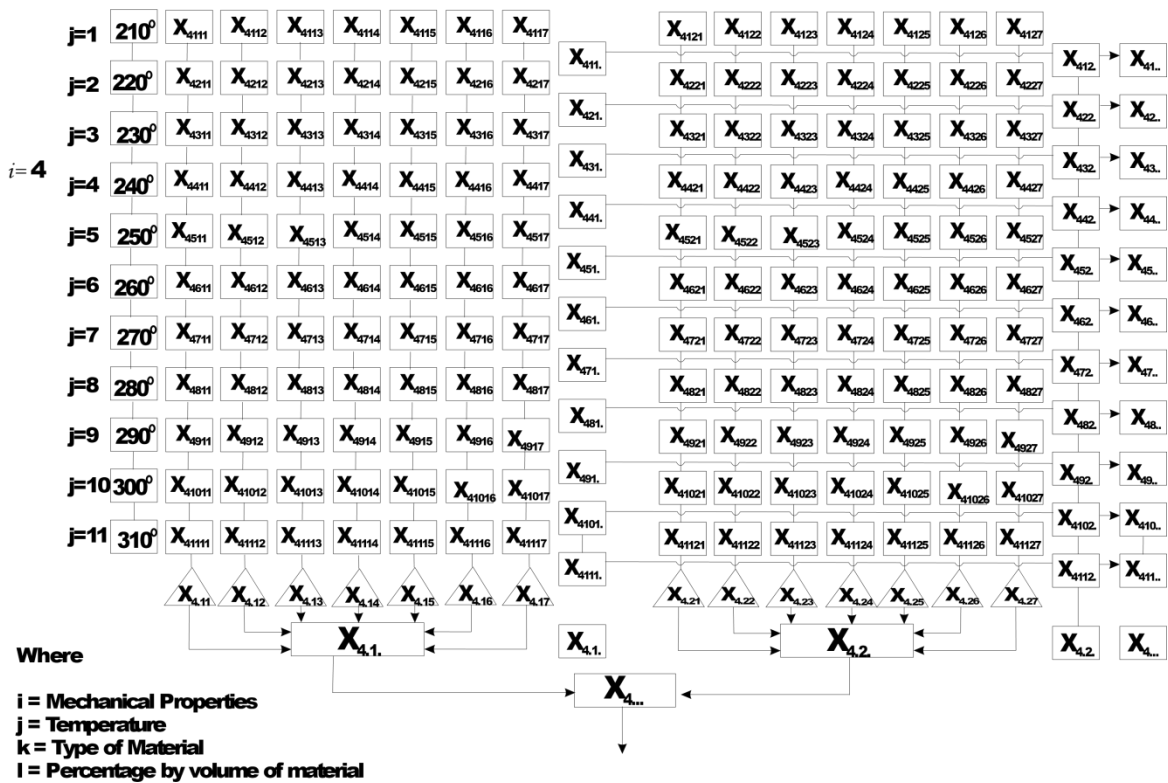


Figure 3: Split-split plot Analytical Design of the Effect of Barrel Temperature on Percentage Elongation.



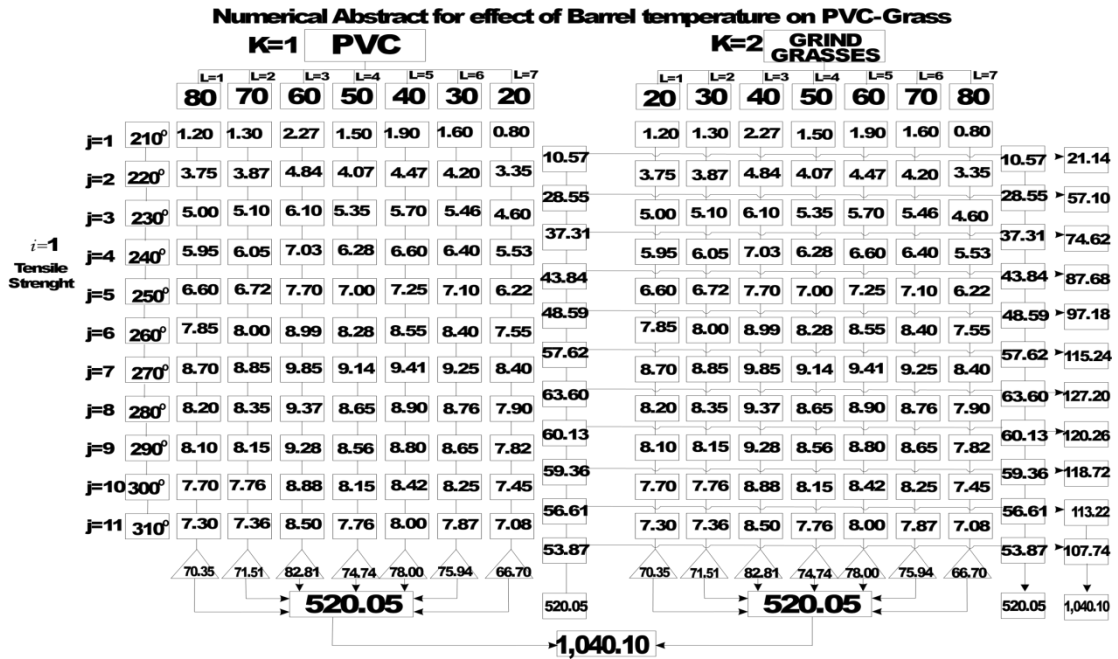


Figure 5: Split-split plot Numerical Design of the Effect of Barrel Temperature on Tensile Strength.



Figure 6: Split-split plot Numerical Design of the Effect of Barrel Temperature on Proof Stress.

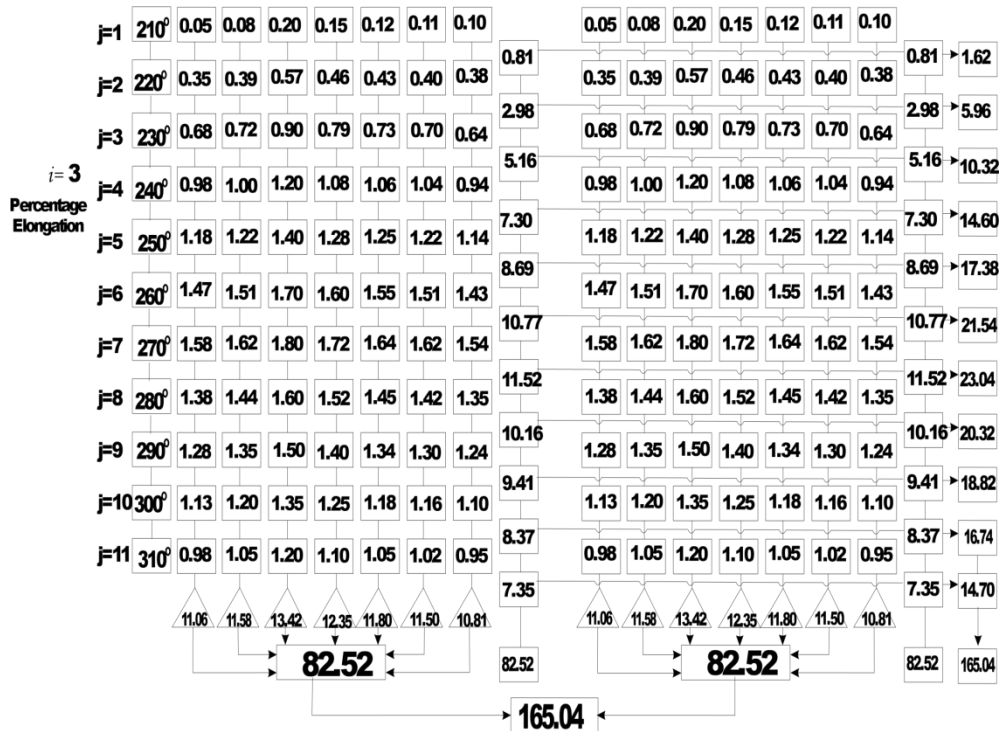


Figure 7. Split-split Plot Numerical Design of the Effect of Barrel Temperature on Percentage Elongation.

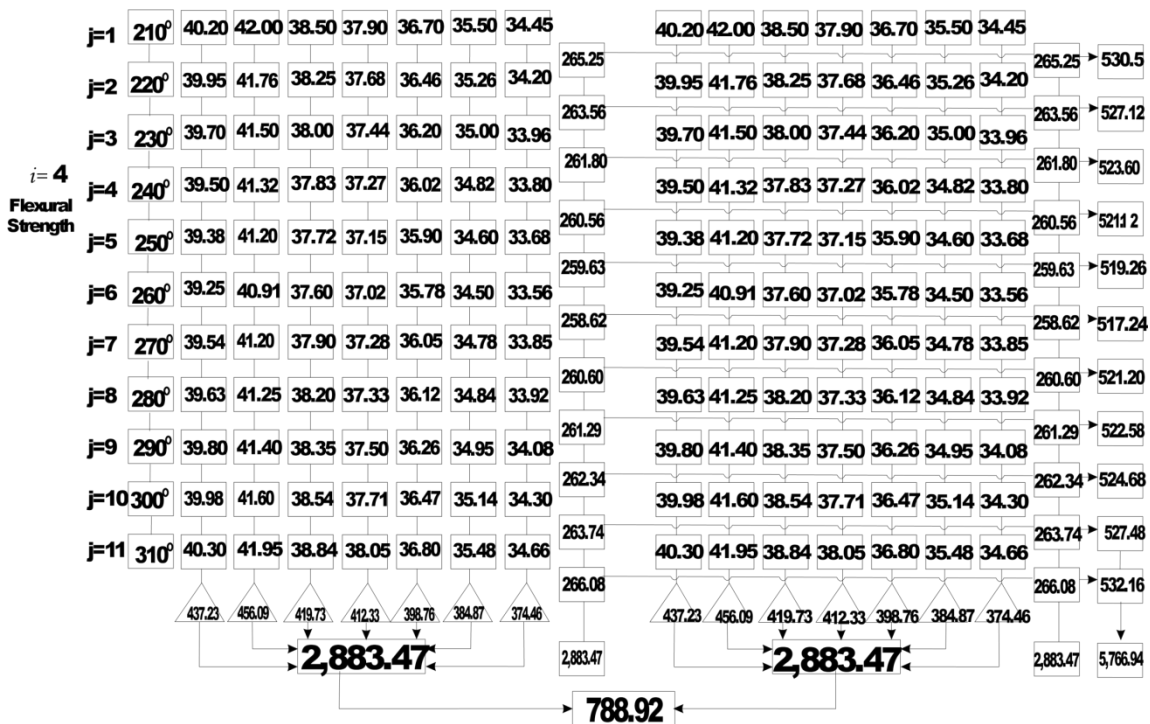


Figure 8. Split-split Plot Numerical Design of the Effect of Barrel Temperature on Flexural Strength.

Table 1. Effects of Barrel Temperature on Mechanical Properties of PVC-Grass Composites.

MECHANICAL PROPERTY	PERCENTAGE BY VOLUME OF PVC (M)	PERCENTAGE BY VOLUME OF GRASS (K)	TEMPERATURE (°C)										
			210	220	230	240	250	260	270	280	290	300	310
TENSILE STRENGTH (N/mm ²)	80	20	1.20	3.75	5.00	5.95	6.60	7.85	8.70	8.20	8.10	7.70	7.30
	70	30	1.30	3.87	5.10	6.05	6.72	8.00	8.85	8.35	8.15	7.76	7.36
	60	40	2.27	4.84	6.10	7.03	7.70	8.99	9.85	9.37	9.28	8.88	8.50
	50	50	1.50	4.07	5.35	6.28	7.00	8.28	9.14	8.65	8.56	8.15	7.76
	40	60	1.90	4.47	5.70	6.60	7.25	8.55	9.41	8.90	8.80	8.42	8.00
	30	70	1.60	4.20	5.46	6.40	7.10	8.40	9.25	8.76	8.65	8.25	7.87
	20	80	0.80	3.35	4.60	5.53	6.22	7.55	8.40	7.90	7.82	7.45	7.08
PROOF STRESS (N/mm ²)	80	20	0.90	1.90	1.85	2.86	3.03	3.12	2.84	2.50	2.20	2.05	1.08
	70	30	1.20	2.20	2.15	3.14	3.32	3.41	3.11	2.82	2.55	2.40	1.41
	60	40	1.82	2.88	3.84	4.83	5.00	5.10	4.82	4.48	4.21	4.07	3.04
	50	50	1.60	2.60	2.53	3.50	3.70	3.81	3.53	3.30	3.05	2.91	1.90
	40	60	1.50	2.51	2.45	3.44	3.64	3.73	3.42	3.30	3.05	2.91	1.90
	30	70	1.40	2.40	2.33	3.31	3.50	3.61	3.32	3.10	2.82	2.67	1.65
	20	80	1.30	2.32	2.25	3.23	3.41	3.52	3.23	3.00	2.75	2.62	1.60
PERCENTAGE ELONGATION (%)	80	20	0.05	0.35	0.68	0.98	1.18	1.47	1.58	1.38	1.28	1.13	0.98
	70	30	0.08	0.39	0.72	1.00	1.22	1.51	1.62	1.44	1.35	1.20	1.05
	60	40	0.20	0.57	0.90	1.20	1.40	1.70	1.80	1.60	1.50	1.35	1.20
	50	50	0.15	0.46	0.79	1.08	1.28	1.60	1.72	1.52	1.40	1.25	1.10
	40	60	0.12	0.43	0.73	1.06	1.25	1.55	1.64	1.45	1.34	1.18	1.05
	30	70	0.11	0.40	0.70	1.04	1.22	1.51	1.62	1.42	1.30	1.16	1.02
	20	80	0.10	0.38	0.64	0.94	1.14	1.43	1.54	1.35	1.24	1.10	0.95
AVERAGE DEFLECTION (mm)	80	20	8.70	8.80	8.65	8.70	8.67	8.60	8.87	8.67	8.88	8.67	8.64
	70	30	9.87	9.64	9.37	9.21	9.11	9.00	9.08	9.15	9.31	9.44	9.66
	60	40	8.11	7.95	7.77	7.66	7.59	7.52	7.57	7.62	7.74	7.83	7.68
	50	50	8.31	8.34	7.95	7.83	7.77	7.68	7.74	7.79	7.90	7.99	8.14
	40	60	8.64	8.47	8.26	8.13	8.09	8.01	8.10	8.14	8.26	8.35	8.21
	30	70	8.89	8.69	8.48	8.37	8.30	8.21	8.29	8.36	8.48	8.58	8.41
	20	80	9.08	8.89	8.65	8.52	8.44	8.34	8.44	8.51	8.65	8.75	8.93
FLEXURAL STRENGTH X10 ³ (N/mm ²)	80	20	18.80	19.32	19.93	20.30	20.50	20.78	20.58	20.30	19.92	19.63	20.10
	70	30	20.70	21.20	21.81	22.20	22.43	22.71	22.51	22.33	21.95	21.64	21.16
	60	40	25.20	25.70	26.30	26.70	26.92	27.20	27.00	26.82	26.40	26.10	26.60
	50	50	24.60	25.10	25.70	26.10	26.31	26.60	26.41	26.23	25.87	25.58	25.10
	40	60	23.65	24.13	24.73	25.15	25.25	25.53	25.24	25.10	24.73	24.47	24.90
	30	70	23.00	23.51	24.11	24.41	24.62	24.91	24.64	24.46	24.10	23.82	24.30
	20	80	22.50	23.00	23.62	24.00	24.22	24.51	24.21	24.02	23.64	23.36	22.90

Table 2. Anova Result Table for Effects of Barrel Temperature on PVC-Grass Composite.

Sources of Variation	Sum of Squares (SS)	Degree of freedom	Mean of Squares (MS)	Fisher's Ratio F _{cal} α=0.05	Fisher's Ratio F _{Table}
SS _A	0.00	K-1=1	0.00	0.00	5.99
SS _B	331.30	L-1=6	55.22	0.00	4.28
SS _C	50,049.04	I-1=3	16683.01	0.00	9.28
SS _D	522.56	J-1=10	52.28	0.00	2.98
SS _{AB}	-0.00001	(K-1)(L-1)=6	-1.67X10 ⁻⁶	0.00	8.94
SS _{AC}	-0.000018	(K-1)(I-1)=3	-1.60X10 ⁻⁶	0.00	3.16
SS _{AD}	0.00	(K-1)(J-1)=10	0.00	0.00	1.99
SS _{BC}	406.65	(L-1)(I-1)=18	22.59	1.00	2.01
SS _{BD}	-7697.86	(L-1)(J-1)=60	128.30	-855.35	0.51
SS _{CD}	392.25	(I-1)(J-1)=30	13.07	0.00	1.37
SS _{ABC}	406.65	(K-1)(L-1)(I-1)=18	22.59	0.43	2.98
SS _{ABD}	-9.03	(K-1)(L-1)(I-1)=60	-0.15	-0.01	0.17
SS _{ACD}	-0.000027	(K-1)(I-1)(J-1)=30	-0.00	0.00	1.93
SS _{BCD}	8070.08	(L-1)(I-1)(J-1)=180	44.83	-135.85	6.57
SS _E	-60.27	(I-1)(J-1)(K-1)(L-1)=180	-0.33		
SS _T	51707.85	IJKL-1=615			

3.1. Interpretation of the Results

Figure 1-4 shows the split-split plot analytical design of the effects of barrel temperature on tensile strength, proof stress, percentage elongation and flexural strength respectively. The values in Table 1 was input into the analytical split-split plot design which resulted to the

Split-split plot numerical design of the effects of barrel temperature on tensile strength, proof stress, percentage elongation and flexural strength respectively (Figure 5-8). Equation 7 to 22 was used to evaluate for the sum of squares for the process parameters and their interactions, the values obtained were presented on Table 2.

The investigation of treatment effect of materials (SS_A), percentage by volume of materials (SS_B), mechanical strength (SS_C) and barrel temperature (SS_D) respectively shows that the calculated Fisher's ratio values were less than the Fisher ratio values obtained from the table at α -value of 0.05 (Table 2). The results compared favourably with the results obtained by Goos, and Vandebroek [10] using D-optimal Split-Plot Designs with given numbers and sizes of whole plots. From the results obtained, it shows that the experimental data do not furnish enough evidence to reject the null hypothesis H_0 treatment at α -value of 0.05. This shows that the treatment effect and the block effect of process parameters contribute significantly to the mechanical property of the produced PVC-Grass composite in industries.

Furthermore, the interaction of the process parameters obtained from treatment effect such as Material type and percentage by volume of material Interaction (SS_{AB}); Material type and Mechanical Strength Interaction (SS_{AC}); Material type and Temperature Interaction (SS_{AD}); Percentage by Volume of material and Mechanical Strength Interaction (SS_{BC}); Percentage by volume of material and Temperature Interaction (SS_{BD}); Mechanical Strength and Temperature Interaction (SS_{CD}); Material type, Percentage by volume of material and Temperature Interaction (SS_{ABD}); Material type, Mechanical strength and Temperature Interaction (SS_{ACD}); Percentage by volume of material, Mechanical strength and Temperature Interaction (SS_{BCD}); Material type, Percentage by volume of material and Mechanical Strength Interaction (SS_{ABC}) respectively shows that the calculated Fisher's ratio value is less than the Fisher ratio obtained from the table at α -value of 0.05 (Table 2). The results compare favourably with the results obtained by Goos and Vandebroek[10]; Loeza and Donev [4]; Edelugo [12] . The experimental data do not furnish enough evidence to reject the null hypothesis H_0 treatment at α -value of 0.05. This shows that the treatment effect and the block effect interaction of these process parameters contribute significantly to the mechanical property of the produced PVC-Grass composite in industries.

4. CONCLUSION

The results obtained from the interactive model developed using the split-split plot design indicates that there were strong interaction between barrel temperature, type of material and percentage by volume of material on mechanical properties (Tensile Strength, Proof Stress, Percentage Elongation and Flexural Strength) for the produced PVC-Grass composites. Hence, these process parameters contributes significantly to the produced injection moulded PVC-Grass composite. Decisions made based on the hypothesis statements shows that there were no enough evidence to reject the null hypothesis at α -value of 0.05 for PVC-Grass composite. The developed interactive model will also be useful to researcher, industrialist and small scale manufacturer to ease the production of plastic-grass composite in polymeric industries.

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