

# **Design & Development of Automotive Seat Cover using 3D Woven Structures**

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**DEPARTMENT OF TEXTILE AND FIBRE ENGINEERING**

**INDIAN INSTITUTE OF TECHNOLOGY DELHI**

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by

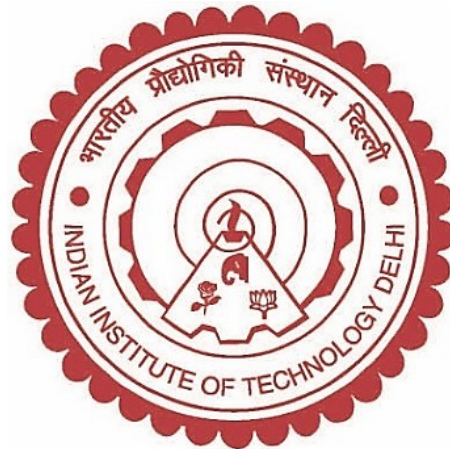
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**Dedicated to My Mother**



# CERTIFICATE

This is to certify that the thesis entitled “**Design & Development of Automotive Seat Cover using 3D Woven Structures**”, being submitted by **Mr. Ashok Kumar Shriwastawa**, Entry No. **2017TTZ8344** to the Indian Institute of Technology Delhi, for award the degree of **Doctor of Philosophy**, is a record of Bonafide research work carried out by him under my guidance and supervision. He has worked fulfilled the requirements for submission of the thesis which has attained the standard required for a Ph.D. degree of this institute. The results contained in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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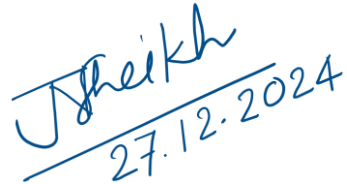


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## Abstract

Car seat covers play an integral role in enhancing vehicle interiors by providing both functional protection and aesthetic value. As passengers' primary point of interaction, these covers must balance durability, comfort, and visual appeal. Historically, seat covers have been manufactured using materials such as leather, synthetic textiles, and polyurethane (PUR) foam, tailored to fit universal or specific car models. However, growing concerns over sustainability, environmental impact, and the need for enhanced comfort have driven research into alternative materials and manufacturing processes. This study delves into developing and applying three-dimensional (3D) woven structures as potential substitutes for traditional two-dimensional (2D) fabrics and PUR foam in automotive seat covers.

The significance of seat comfort has risen with increased time spent in vehicles, emphasizing the importance of materials that can provide high air permeability and effective water vapor transmission. Traditional seat covers, often produced with air-texturized polyester yarns, have relied on compact loop structures for abrasion resistance and durability. However, their limited design innovation and reliance on environmentally harmful manufacturing processes necessitate advancements in textile engineering.

One promising avenue is the use of 3D woven fabrics, which incorporate stuffer, filler, and binder yarns arranged along the X-, Y-, and Z-axes, creating robust and dimensionally stable materials. Unlike 2D fabrics, 3D woven structures provide superior mechanical properties, including enhanced strength, abrasion resistance, and thermal control. This study explores the potential of 3D orthogonal woven fabrics to address the limitations of traditional seat covers while offering

significant benefits such as reduced material usage, integrated structures, and decreased production steps.

Natural fibres such as hemp, flax, jute, and cotton, alongside recycled polyester, are gaining traction as sustainable alternatives in automotive applications. Major automobile manufacturers like Mercedes, BMW, and Volvo have begun integrating these fibres into interior components to align with environmental goals. This trend underscores the feasibility of combining advanced textile technologies with eco-friendly materials to meet evolving industry demands.

Experimental analysis within this research involved the development of seat cover samples using polyester, hemp, and recycled polyester yarns. 2D fabrics, 3D solid woven structures and 3D woven spacers, produced on a customized sample weaving machine. These were compared to conventional 2D fabrics in terms of mechanical and comfort properties, including air permeability, water vapor transmission, abrasion resistance, and thermal performance.

The results revealed that 3D woven fabrics offer significant improvements over traditional seat cover. Orthogonal structures exhibited superior dimensional stability, mechanical strength, and thermal control due to their perpendicular yarn arrangement. Spacer fabrics provided additional advantages such as thermal control and reduced areal density, making them suitable for applications requiring lightweight yet resilient materials. Furthermore, the integration of sustainable fibres demonstrated comparable performance to synthetic counterparts, aligning with global efforts to reduce reliance on non-renewable resources.

This study highlights the transformative potential of 3D weaving techniques in automotive seat cover design. By enabling the creation of integrated structures with tailored mechanical and comfort properties, 3D weaving reduces the need for post-weaving processes such as lamination.

Additionally, it addresses critical challenges associated with traditional seat covers, including poor recyclability, thermal discomfort, and environmental impact from PUR foam production. The findings advocate for a shift toward sustainable and innovative textile solutions, paving the way for next-generation vehicle interiors that prioritize performance, comfort, and ecological responsibility.

This research provides a comprehensive framework for the adoption of 3D woven structures in automotive seat cover application. It underscores the importance of interdisciplinary collaboration in material science, textile engineering, and automotive design to achieve superior outcomes. By leveraging advancements in 3D weaving and sustainable fibre utilization, the automotive industry can redefine seat cover manufacturing, aligning with consumer expectations and regulatory mandates for sustainability and performance.



## सार

कार सीट कवर कार्यात्मक और सौंदर्य दोनों मूल्य प्रदान करके वाहन के अंदरूनी हिस्सों को बढ़ाने में एक अभिन्न भूमिका निभाते हैं। यात्रियों को आकर्षित करने के लिए, प्राथमिकता के साथ इन सीट कवरों के टिकाऊपन, आरामदायकता और दृश्य अपील के मध्य संतुलन उत्पन्न करना चाहिए। ऐतिहासिक रूप से सीट कवर चमड़े, सिंथेटिक वस्त्र और पॉलीयुरेथेन (PUR) फोम जैसी सामग्रियों का उपयोग करके निर्मित किए जाते , जिन्हें सार्वभौमिक या विशिष्ट कार मॉडल में फिट करने के लिए तैयार किया गया है। हालाँकि, स्थिरता, पर्यावरणीय प्रभाव और बेहतर आराम की आवश्यकता पर बढ़ती चिंताओं ने वैकल्पिक सामग्रियों और विनिर्माण प्रक्रियाओं में अनुसंधान को प्रेरित किया है। यह अध्ययन ऑटोमोटिव सीट कवर में पारंपरिक दो-आयामी (2D) कपड़ों और फोम के संभावित विकल्प के रूप में त्रि-आयामी (3D) बुने हुए संरचनाओं के विकास और अनुप्रयोग पर गहराई से विचार करता है।

वाहनों में बैठने के समय में वृद्धि के साथ सीट आराम का महत्व बढ़ गया है, जो उन व्यवस्थाओं के महत्व पर जोर देता है जो उच्च वायु पारगम्यता और प्रभावी जल वाष्प संचरण प्रदान कर सकते हैं। अक्सर एयर-टेक्सचराइज्ड पॉलिएस्टर यार्न के साथ पारंपरिक सीट कवर उत्पादित किया जाता है, क्योंकि इनकी घर्षण प्रतिरोध क्षमता और टिकाऊपन के लिए कॉम्पैक्ट लूप संरचनाओं पर निर्भर करते हैं। हालांकि, उनके सीमित डिजाइन नवाचार और पर्यावरण के लिए हानिकारक विनिर्माण प्रक्रियाओं पर निर्भरता के कारण कपड़ा इंजीनियरिंग में प्रगति की आवश्यकता है।

एक आशाजनक तरीका 3D बुने हुए कपड़ों का उपयोग है, जिसमें X-, Y- और Z-अक्षों के साथ व्यवस्थित स्ट्रफ़र, फ़िलर और बाइंडर यार्न शामिल हैं, जो मजबूत और त्रि-आयामी रूप से स्थिर कपड़ा बनाते हैं। 2D कपड़ों के विपरीत, 3D बुने हुए ढांचे बेहतर यांत्रिक गुण प्रदान करते हैं, जिसमें बढ़ी हुई ताकत, घर्षण

प्रतिरोध और तापीय चालकता शामिल है। यह अध्ययन पारंपरिक सीट कवर की सीमाओं को संबोधित करने के लिए 3D ऑर्थोगोनल बुने हुए कपड़ों की क्षमता का पता लगाता है, जबकि कम सामग्री के उपयोग, एकीकृत संरचनाओं और कम उत्पादन चरणों जैसे महत्वपूर्ण लाभ प्रदान करता है।

भांग, सन, जूट और कपास जैसे प्राकृतिक रेशे, पुनर्नवीनीकरण पॉलिएस्टर के साथ, ऑटोमोटिव अनुप्रयोगों में टिकाऊ विकल्प के रूप में प्रयोग किये जाते रहे हैं। मर्सिडीज, बीएमडब्ल्यू और वोल्वो जैसे प्रमुख ऑटोमोबाइल निर्माताओं ने पर्यावरणीय लक्ष्यों के साथ संरेखित करने के लिए इन रेशों को आंतरिक घटकों में एकीकृत करना शुरू कर दिया है। यह प्रवृत्ति विकसित उद्योग की मांगों को पूरा करने के लिए उन्नत वस्त्र प्रौद्योगिकियों को पर्यावरण के अनुकूल सामग्रियों के साथ जोड़ने की व्यवहार्यता को रेखांकित करती है।

इस शोध के भीतर प्रायोगिक विश्लेषण में पॉलिएस्टर, भांग और पुनर्नवीनीकरण पॉलिएस्टर यार्न का उपयोग करके सीट कवर के नमूनों का विकास शामिल है। 2D कपड़ो, 3D बुने हुए संरचना और 3D बुने हुए स्पेसर एक नमूना बुनाई मशीन पर उत्पादित किए गए हैं। 3D कपड़ो की तुलना टिकाऊपन और आरामदायक गुणों के संदर्भ में पारंपरिक 2D कपड़ों से की गई, जिसमें वायु पारगम्यता, जल वाष्प संचरण, घर्षण प्रतिरोध और थर्मल गुण शामिल हैं।

परिणामों से पता चला कि 3D बुने हुए कपड़े पारंपरिक कपड़ो की तुलना में महत्वपूर्ण भूमिका प्रदान करते हैं। ऑर्थोगोनल संरचनाओं ने अपने लंबवत यार्न व्यवस्था के कारण बेहतर आयामी स्थिरता, शक्ति और तापीय नियंत्रण का प्रदर्शन किया। स्पेसर कपड़ों ने थर्मल नियंत्रण और कम क्षेत्रीय घनत्व जैसे अतिरिक्त लाभ प्रदान किए, जिससे वे हल्के लेकिन लचीले पदार्थों की आवश्यकता वाले अनुप्रयोगों के लिए उपयुक्त हो गए। इसके अलावा, संधारणीय फाइबर के एकीकरण ने सिंथेटिक समकक्षों के लिए तुलनीयप्रदर्शन का प्रदर्शन किया, जो गैर-नवीकरणीय संसाधनों पर निर्भरता को कम करने के वैश्विक प्रयासों के साथ संरेखित है।

यह अध्ययन ऑटोमोटिव सीट कवर डिजाइन में 3D बुनाई तकनीकों की परिवर्तनकारी क्षमता पर प्रकाश डालता है। अनुरूपित टिकाऊपन और आराम गुणों के साथ एकीकृत संरचनाओं के निर्माण को सक्षम करके 3D बुनाई वाले कपड़े, लेमिनेशन जैसी बाद की प्रक्रियाओं की आवश्यकता को कम करती है। इसके अतिरिक्त, यह पारंपरिक सीट कवर से जुड़ी महत्वपूर्ण चुनौतियों को संबोधित करता है, जिसमें खराब पुनर्चक्रण, थर्मल असुविधा और PUR फोम उत्पादन से पर्यावरणीय प्रभाव शामिल हैं। इस अनुसन्धान के निष्कर्ष टिकाऊ और अभिनव कपड़ा समाधानों की ओर बदलाव की वकालत करते हैं, जो अगली पीढ़ी के वाहन इंटीरियर के लिए मार्ग प्रशस्त करते हैं जो प्रदर्शन, आराम और पारिस्थितिक जिम्मेदारी को प्राथमिकता देते हैं।

यह शोध ऑटोमोटिव अनुप्रयोगों में 3D बुने हुए संरचनाओं को अपनाने के लिए एक व्यापक रूपरेखा प्रदान करता है। यह बेहतर परिणाम प्राप्त करने के लिए मटेरियल विज्ञान, कपड़ा इंजीनियरिंग और ऑटोमोटिव डिजाइन में अंतःविषय सहयोग के महत्व को रेखांकित करता है। 3D बुनाई और टिकाऊ फाइबर के उपयोग का लाभ उठाकर, ऑटोमोटिव उद्योग सीट कवर निर्माण को फिर से परिभाषित कर सकता है, जो स्थिरता और प्रदर्शन के लिए उपभोक्ता अपेक्षाओं और नियामक जनादेशों के साथ संरेखित होता है।

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