UNFOLDING MORPHOLOGIES:

The Dynamics of Folding for Adaptive Spatial Design

by

Sepehr Fathi

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

This thesis investigates folding as a transformative design strategy for creating responsive architectural elements. While folding techniques are often used in architectural design, their potential for adaptive responsiveness is, in most cases, untapped due to a limited understanding of their underlying behavior. Focusing on small-scale prototypes, particularly architectural textiles and wearable designs, this research examines the Miura-Ori folding pattern as a fundamental system for generating dynamic, reconfigurable forms. Using component studies and physical prototypes, a bi-stable wearable is created to demonstrate folding's ability to produce flexible configurations that respond to environmental and user input. This wearable illustrates folding's capacity to contribute both functional adaptability and aesthetic versatility. Through this work, folding is positioned as a powerful tool for adaptive, user-oriented design, fostering innovation in responsive architectural spaces.

KEYWORDS

Folding, Origami, Adaptive Architecture, Pattern, Miora Ori, Responsive Architecture, Flexibility, Spatial Transformation, Architectural Textiles, Transformable Structure, Wearable Architecture.

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DEDICATION

To those who have embraced my folds with love and supported me
as I unfolded into myself.

TABLE OF CONTENTS

Author's Declaration *ii*
Abstract *iv*
Aknowledgements *vi*
Dedication *ix*
List of figures *xiii*

INTRO *1*

Introduction *3*
Research overview *6*

PART I | Theoretical Foundations *9*

I.I Folding in Architecture *10*
I.II Folding for Responsiveness *18*

PART II | Folding Frameworks *23*

II.I Method *24*
II.II Material *28*
II.III Medium *34*
II.IV Making *42*

PART III | Design Experimentation *60*

III.I Component Study *62*
III.II Growth Patterns *90*

PART IV | Design Implementation *104*

IV.I Design Proposal *106*
IV.II Parts *110*
IV.III Whole *148*

PART V | Conclusions *170*

V.I Conclusions *171*

LIST OF FIGURES

INTRO

2 *Fig 0.1 Two young women folding paper cranes.*

Source: Isoda, Kory sai. Children Folding a Paper Crane. Japan, 1772 [or 1773]. Photograph. Library of Congress. Accessed March 7, 2025. https://www.loc.gov/item/2008660852/.

PART I | Theoretical Foundations

11 *Fig 1.1 Sketch of Greg Lynn's study models for Embryological House.*

Source: Illustrated by the author

14 *Fig 1.2 Chuck Huberman's sphere expanding.*

Source: Fenix_21. Hoberman Sphere. January 6, 2008. Flickr. Accessed March 8, 2025. https://www.flickr.com/photos/fenix_21/2262277576/in/photostream/.

16 *Fig 1.3 Conceptual model for Chapel In Valleaceron.*

Source: S.M.A.O. "Chapel in Valleacerón." ArchDaily, April 30, 2009. Accessed March 11, 2025. https://www.archdaily.com/20945/chapel-in-villeaceron-smao.

21 *Fig 1.4 Rigid foldable origami materialized by Tomohiro Tachi*

Source: Tachi, Tomohiro. "Rigid-Foldable Thick Origami." Accessed March 11, 2025. https://www.researchgate.net/figure/Volume-substituted-by-two-constant-thickness-panels_fig6_265154174.

PART II | Folding Frameworks

25 *Fig 2.1 Miura Ori Pattern and its auxetic behavior.*

Source: Photograph by the author

29 *Fig 2.2 Fabriano paper roll, 120gr.*

Source: Photograph by the author

31 *Fig 2.3 100% Polyester Organza, lightweight and transparent.*

Source: Photograph by the author

32 *Fig 2.4 Transparency of 100% Polyester Organza –single layer.*

Source: Photograph by the author

33 *Fig 2.5 Transparency of 100% Polyester Organza –single layer.*

Source: Photograph by the author

35 *Fig 2.6 Body's movement and formal complexity.*

Source: Illustration by the author

37 *Fig 2.7 Coffee table skirt by Hussein Chalayan*

Source: Wikimedia Commons contributors. File: Coffee Table Skirt Hussein Chalayan. Photograph. Wikimedia Commons. Accessed March 8, 2025. https://commons.wikimedia.org/w/index.php?title=File:Coffee_table_skirt_Hussein_Chalayan.jpg&oldid=863059678.

39 *Fig 2.8 Pleated polyester ensemble by Issey Miyake*

Source: Wikimedia Commons contributors. File: Black Pleated Polyester Ensemble by Issey Miyake, 2004. Photograph. Wikimedia Commons. Accessed March 8, 2025.

43 *Fig 2.9 Engraving the pattern on paper using speedy 300 Laser cutting machine.*

Source: Photograph by the author

45 *Fig 2.10 Placing the Organza between two layers of engraved paper.*

Source: Photograph by the author

46 *Fig 2.11 Sewing the layers to fix the fabric between the paper mold.*

Source: Photograph by the author

47 *Fig 2.12 Sewing the layers to fix the fabric between the paper mold.*

Source: Photograph by the author

49 *Fig 2.13 The unfolded and folded mold.*

Source: Photograph by the author

50 *Fig 2.14 Folded mold with two layers of organza in between.*

Source: Photograph by the author

51 *Fig 2.15 Folded mold with two layers of organza in between.*

Source: Photograph by the author

52 *Fig 2.16 Folded molds tied for maximum compression on the fabric in between.*

Source: Photograph by the author

54 *Fig 2.17 Introducing heat to the tied molds.*
Source: Photograph by the author

56 *Fig 2.18 Pleated organza.*
Source: Photographed by the author

PART III | Design Experimentation

62 *Fig 3.1 Symbols representing different features and functions.*
Source: Illustration by the author

64 *Fig 3.2 Sequential displacement of mountain node in -Y axis and their 4x4 tessellation.*
Source: Illustration by the author

65 *Fig 3.3 Changing surface behavior through displacement of mountain node in -Y axis.*
Source: Photograph by the author

66 *Fig 3.4 Sequential displacement of valley node in +Y axis and their 4x4 tessellation.*
Source: Illustration by the author

67 *Fig 3.5 Changing surface behavior through displacement of valley node in +Y axis.*
Source: Photograph by the author

68 *Fig 3.6 Folded surface bending through the displacement of valley node in +Y axis.*
Source: Photograph by the author

70 *Fig 3.7 Sequential centerline offset and their 4x4 tessellation.*
Source: Illustrated by the author

71 *Fig 3.8 Change in surface behavior through progressive offset of centerline in X axis.*
Source: Photograph by the author

72 *Fig 3.9 Compaction of space pockets through v-pleats between them in a tessellation.*
Source: Photograph by the author

73 *Fig 3.10 Formal flexibility of the modified pattern.*

Source: Photograph by the author

74 Fig 3.11 Sequential displacement of mountain and valley node in -Y axis and their 4x4 tessellation.

Source: Illustrated by the author

75 Fig 3.12 Change in surface behavior through progressive mountain and valley node displacement in -Y axis.

Source: Photograph by the author

76 Fig 3.13 Sequential displacement of valley node in +Y axis and their 4x4 tessellation.

Source: Illustrated by the author

77 Fig 3.14 Change in surface behavior through progressive mountain and valley node displacement in +Y axis.

Source: Photograph by the author

78 Fig 3.15 Introduction of new v-pleat and sequential displacement of mountain/valley node in +Y axis, along their 4x4 tessellation.

Source: Illustrated by the author.

79 Fig 3.16 Change in surface behavior by introducing a new pleat and node displacement.

Source: Photograph by the author

80 Fig 3.17 Periodic change in convex and concave bending.

Source: Photograph by the author

82 Fig 3.18 Introduction of new pleat in between every mountain and valley.

Source: Illustration by the author

83 Fig 3.19 Folded tessellation transforming the surface into cylindrical geometry.

Source: Photograph by the author

84 Fig 3.20 Sequential introduction of new pleats and their 4x4 tessellation.

Source: Illustration by the author

85 Fig 3.21 Folded tessellations progressively transforming the surface into cylindrical geometry.

Source: Photograph by the author

86 Fig 3.22 Sequential displacement of valley node in -X axis and their 4x4 tessellations.

Source: Illustration by the author

87 *Fig 3.23 Flat foldability of the tessellation through the displacement of valley node in -X axis.*

Source: Photograph by the author

88 *Fig 3.24 Surface folding flat.*

Source: Photograph by the author

89 *Fig 3.25 Details of flat foldable tessellation.*

Source: Photograph by the author

91 *Fig 3.26 Instances of grid systems.*

Source: Illustrated by the author

92 *Fig 3.27 The base component is structured by an underlying grid system with progressively increasing unit sizes, generating a gradient effect.*

Source: Illustrated by the author.

93 *Fig 3.28 Folded tessellation with gradient effect.*

Source: Photograph by the author

94 *Fig 3.29 Paul Jackson's 'Reflection' technique mirrors components to maintain alignment, ensuring continuity and enhancing pattern complexity.*

Source: Illustrated by the author

95 *Fig 3.30 Folded model of mirrored gradient effect.*

Source: Photograph by the author

96 *Fig 3.31 Disorientation of symmetry lines. First variation.*

Source: Illustrated by the author

97 *Fig 3.32 Folded model of tessellation with disoriented lines of symmetry. First variation.*

Source: Photograph by the author

98 *Fig 3.33 Disorientation of symmetry lines. second variation.*

Source: Illustrated by the author

99 *Fig 3.34 Folded model of tessellation with disoriented lines of symmetry. Second variation.*

Source: Photograph by the author

100 *Fig 3.35 Radial Growth, First variation.*
Source: Illustrated by the author

101 *Fig 3.36 Folded prototype of Radial Growth, First variation.*
Source: Photograph by the author

102 *Fig 3.37 Radial Growth, second variation.*
Source: Illustration by the author.

103 *Fig 3.38 Folded prototype of Radial growth, second variation.*
Source: Photograph by the author

PART IV | Design Implementation

107 *Fig 4.1 A continuous surface wraps around the body and defines space.*
Source: Illustrated by the author

109 *Fig 4.2 Formal complexities of the torso in motion*
Source: Illustrated by the author

113 *Fig 4.3 Sketch illustrating the direction of accordion folds in a flexible sleeve.*
Source: Illustrated by the author

114 *Fig. 4.4 Flexibility of the cylindrical folded surface.*
Source: Photograph by the author

116 *Fig 4.5 Small displacement of the mountain node applied to the entire tessellation to shape the sleeve.*
Source: Illustrated by the author

117 *Fig 4.6 Section of the Sleeve, illustrating how the surface loops back onto itself.*
Source: Photograph by the author

118 *Fig 4.7 Repetitive tessellation of the component with large displacement in its mountain node.*
Source: Illustrated by the author

119 *Fig 4.8 Section of the Sleeve, illustrating how the surface loops back onto itself.*
Source: Photograph by the author

120 *Fig 4.9 Repetitive tessellation of the component with medium displacement in its mountain node.*
Source: Illustrated by the author

121 *Fig 4.10 Section of the Sleeve, illustrating how the surface loops back onto itself.*
Source: Photograph by the author

122 *Fig 4.11 Flexible behavior of the sleeve structure achieved through folding.*
Source: Photograph by the author

123 *Fig 4.12 Flexible behavior of the sleeve structure achieved through folding.*
Source: Photograph by the author

124 *Fig 4.13 Compactability of the sleeve structure achieved through folding.*
Source: Photograph by the author

125 *Fig 4.14 Compactability of the sleeve structure achieved through folding.*
Source: Photograph by the author

126 *Fig 4.15 Flexibility of the sleeve in relation to arm movement.*
Source: Photograph by the author

129 *Fig 4.16 Sketch illustrating the direction of accordion folds in a flexible Hood.*
Source: Illustration by the author

130 *Fig 4.17 Small scale prototype of the hood*
Source: Photograph by the author

132 *Fig 4.18 Compactability of the hood prototype.*
Source: Photograph by the author

133 *Fig 4.19 Compactability of the hood prototype.*
Source: Photograph by the author

134 *Fig 4.20 Grid division of the surface for component organization.*
Source: Illustration by the author

134 *Fig 4.21 Coding the grid with numerical values and colors assigned to different component variations.*

Source: Illustration by the author

135 *Fig 4.22 Distributing different components across the surface based on the color-mapped grid.*

Source: Illustration by the author

137 *Fig 4.23 Sketch of the accordion folds for bodice.*

Source: Illustrated by the author

138 *Fig 4.24 Sketch illustrating the bodice section from neck to shoulder.*

Source: Illustrated by the author

139 *Fig 4.25 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.*

Source: Illustration by the author

139 *Fig 4.26 Grid division of the surface for component organization.*

Source: Illustration by the author

139 *Fig 4.27 Coding the grid with numerical values and colors assigned to different component variations.*

Source: Illustration by the author

139 *Fig 4.28 Distributing different components across the surface based on the color-mapped grid.*

Source: Illustration by the author

140 *Fig 4.29 Sketch illustrating the bodice section from shoulder to shoulder.*

Source: Illustrated by the author

141 *Fig 4.30 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.*

Source: Illustrated by the author

141 *Fig 4.31 Grid division of the surface for component organization.*

Source: Illustrated by the author

141 *Fig 4.32 Coding the grid with numerical values and colors assigned to different component variations.*

Source: Illustrated by the author

141 *Fig 4.33 Distributing different components across the surface based on the color-mapped grid.*

Source: Illustrated by the author

142 *Fig 4.34 Sketch illustrating the bodice section from shoulder to waist in the front.*

Source: Illustrated by the author

143 *Fig 4.35 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.*

Source: Illustrated by the author

143 *Fig 4.36 Grid division of the surface for component organization.*

Source: Illustrated by the author

143 *Fig 4.37 Coding the grid with numerical values and colors assigned to different component variations.*

Source: Illustrated by the author

143 *Fig 4.38 Distributing different components across the surface based on the color-mapped grid.*

Source: Illustrated by the author

144 *Fig 4.39 Sketch illustrating the bodice on the waist in the back.*

Source: Illustrated by the author

145 *Fig 4.40 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.*

Source: Illustrated by the author

145 *Fig 4.41 Grid division of the surface for component organization.*

Source: Illustrated by the author

145 *Fig 4.42 Coding the grid with numerical values and colors assigned to different component variations.*

Source: Illustrated by the author

145 *Fig 4.43 Distributing different components across the surface based on the color-mapped grid.*

Source: Illustrated by the author

146 *Fig 4.44 Sketch illustrating the bodice section on the waist in the front.*

Source: Illustrated by the author

147 *Fig 4.45 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.*

Source: Illustrated by the author

147 *Fig 4.46 Grid division of the surface for component organization.*

Source: Illustrated by the author

147 *Fig 4.47 Coding the grid with numerical values and colors assigned to different component variations.*

Source: Illustrated by the author

147 *Fig 4.48 Distributing different components across the surface based on the color-mapped grid.*

Source: Illustrated by the author

149 *Fig 4.49 The bodice wrapping around the torso, adapting to its formal complexity.*

Source: Photograph by the author

150 *Fig 4.50 Diagram illustrating the complete plan assembly.*

Source: Illustrated by the author

152 *Fig 4.51 Diagram illustrating the overlapping connection between the bodice and hood.*

Source: Illustrated by the author

155 *Fig 4.52 Diagram illustrating the overlapping connection between the bodice and sleeve.*

Source: Illustrated by the author

156 *Fig 4.53 Wearable surface.*

Source: Photograph by the author

158 *Fig 4.54 Flexibility of the hood.*

Source: Photograph by the author

159 *Fig 4.55 Compactability of the sleeve.*

Source: Photograph by the author

160 *Fig 4.56 Wearable surface.*

Source: Photograph by the author

162 *Fig 4.57 Sleeve and hood compacted.*

Source: Photograph by the author

164 *Fig 4.58 Pleated organza prototype.*

Source: Photograph by the author

166 *Fig 4.59 Pleated organza prototype.*

Source: Photograph by the author

168 *Fig 4.60 Pleated organza prototype.*

Source: Photograph by the author

INTRO



Fig 0.1 Two young women folding paper cranes.

INTRODUCTION

A fold—the mere creation of a crease—can reveal a multitude of interpretations and meanings. (D'Acunto 2018, 18). Folding manifests across different scales, dimensions, and contexts, with its definition varying across cultures, disciplines, and applications. Traces of folding have appeared in many cultures throughout history. In ancient Japan, the origins of origami, folding was considered sacred and reserved for ceremonial rituals (Fig 0.1) (Lebée 2015, 55). However, mathematical explorations and widespread applications of origami emerged much more recently (Lebée 2015, 55), particularly in engineering and architectural design. In this thesis, folding refers to the transformation process of a two-dimensional surface into a three-dimensional form through the introduction of creases and geometric operations, a process applicable in various design scenarios on many scales.

The application of folding in architecture can be classified into three main categories: folded-plate structures, folded transformable mechanisms, and folded developable surfaces (D'Acunto & Castellón 2015, 1). These categories are distinguished by their geometric properties, structural behavior, and functional purposes. Folded developable surfaces are characterized by their ability to transform from a two-dimensional sheet into a three-dimensional configuration (Dureisseix 2012, 1). They can also serve as the basis for deployable structures (D'Acunto 2018, 20). Folded deployable mechanisms are dynamic structures capable of shifting between compact and expanded states, such as retractable roofs and foldable tensegrities. These mechanisms often utilize rigid bars connected by movable joints to achieve controlled motion (D'Acunto 2018, 20). On the other hand, folded-plate structures consist of rigid, interconnected plates that efficiently distribute loads. Unlike the other two categories, folded plate structures do not exhibit oscillative or compressive qualities. Instead, they function as load-bearing elements in architectural design.

However, folded surfaces do not always fit neatly into a distinct category, as they can simultaneously exhibit multiple properties. A folded developable surface, transformed from a flat sheet, can exhibit deployability—shifting between compact and expanded states while preserving both rigidity and structural stiffness. Such a duality in structural behavior, offered by folding, enables structures to serve changing functional demands in a system. Beyond its structural advantages, folding enables continuity within an architectural body, interweaving various elements, spaces, and functions into a single system (Lynn 1993, 24). This continuity is evident in folding patterns inspired by origami, such as Miura-Ori—often the foundation of folded developable surfaces—which is classified as patterns of unlimited growth. These patterns can be infinitely repeated across a surface, embedding multiple spatial and functional requirements into a flat sheet. Once folded, the sheet transforms into a three-dimensional system of interconnected parts, where local modifications within the pattern allow changing surface behavior to accommodate different functions throughout the system.

Yet, despite its potential and vast implications in architecture and design, most of its appearance in architectural design remains static, as a strategy for load distribution. Even in cases such as retractable roofs or kinetic façade panels where its flexibility is utilized, it is typically restricted to discrete elements appended to an otherwise static structure rather than being an inherent part of a continuous design logic (Wierzbicki 2014, 83). The challenge, therefore, lies in moving beyond these static and fragmented applications toward a truly integrated, continuous design logic where folding functions dynamically across static and transformable conditions. This thesis addresses this gap by investigating folding's capacity to operate beyond individual components, integrating various structural, formal, and functional components into a continuous system, responsive internally as it meets its intended design requirements and externally as it adapts to changing contexts and users.

Through the review of a number of literary works, this thesis establishes its position within the ongoing discourse on folding in architecture. It examines historical and contemporary folding applications to define its contributions and potential as a design strategy. Building upon an analysis of existing methodological approaches, it proposes a structured design process to guide designers in integrating folding principles into responsive and adaptive spatial systems. With their ability to transition from a flat state to folded, deployable forms and their potential for infinite growth, folded developable surfaces form the central focus of this thesis. Using a research-by-design approach, the study investigates the Miura-Ori pattern, which is particularly suited for this context due to its deployability, rigidity, and capacity for infinite growth, to inform the design of multi-stable developable surfaces capable of shifting between flexibility and stability. This investigation culminates in a folding manual, providing designers with the tools to control the behavior of different parts of a folded surface and apply it as a design strategy across various scenarios, contexts, and scales. The study develops a wearable prototype as a proof of concept, demonstrating how folding can generate a continuous, multi-behavioral surface that integrates structural, functional, and aesthetic considerations within a single system.

RESEARCH OVERVIEW

This thesis is structured into five interrelated parts, each addressing the research's critical aspects, from theoretical inquiry to practical application. The structure ensures a logical progression of ideas, beginning with the exploration of theoretical frameworks and culminating in the development and implementation of folding in a responsive artifact.

Part I: Theoretical Foundations

The theoretical framework establishes the foundation of the research by critically examining the concept of folding in architecture through historical and contemporary lenses. The first part explores key theoretical perspectives, including the philosophical contributions of Gilles Deleuze, who conceptualized the fold as a mechanism of continuity and transformation; Peter Eisenman, who distinguishes between conceptual folding and actual transformation within architectural design; and Greg Lynn, who advances digital and dynamic folding through the lens of emerging computational technologies. The second part of the theoretical framework reviews folding applications within the context of adaptive architecture. It presents folding not only as a conceptual or load-bearing strategy but as a dynamic geometric system with implications in responsive architecture to generate transformable spaces that adapt to environmental conditions and user interactions. A concluding discussion evaluates the gaps between the folding theory and historical and contemporary implementations of folding in architectural design.

Part II: Folding Frameworks

The research methodology outlines the strategic approach undertaken to explore folding as a design tool, focusing on the interplay of method, material, medium, and manipulation. Inspired by Paul Jackson's Origami for Designers, the method outlines the structure of the geometry study on folding patterns. The material exploration evaluates various sheet materials' properties and performance to determine their suitability for research prototypes and final artifacts. The medium introduces the body as a site and dresses as an intimate space, addressing concerns similar to those

of buildings to shelter the body and define space. The human body serves as an ideal site for this study due to its curvature complexity, and accessible scale for iterative testing. The concept of dress as an intimate architectural space is explored through historical precedents like the Skins and Bones exhibition and case studies of architectural explorations inspired by dressmaking. The manipulation section introduces the fabrication process of pleated textiles, using paper molds and heat to make the pleats permanent.

Part III: Design Exploration

The Design Exploration investigates folding patterns through a structured process of component study and growth study, following a bottom-up design approach. The chapter begins with closely examining pattern units(components), where key parameters such as angles, lengths, and orientations are sequentially modified to understand their changing formal behavior. This analysis informs the development of a growth study, which employs a grid-based framework to investigate diverse pattern aggregation and organization modes through iterative testing and optimization. The findings from these studies re compiled into a pattern manual that provides designers with a systematic approach to utilizing folding techniques for creating dynamic, responsive tessellations that can be tailored to different design scales and applications.

Part IV: Design Implementation

The Design Implementation chapter translates theoretical and experimental insights into a cohesive architectural proposal by applying folding principles to develop two dresses. The Design Proposal section presents these wearable prototypes—one designed for responsiveness and adaptability and the other for compactability and space-making—demonstrating how folding can improve spatial efficiency and user interaction. The Design Development section documents these prototypes' iterative formation and optimization, examining their structural, formal, and functional aspects by integrating folding strategies.

Part V: Conclusion

The conclusion synthesizes the key findings of the research, summarizing its contributions to the field of responsive architecture. It reflects on the broader implications of folding as a design strategy and highlights its potential to address contemporary architectural challenges related to adaptability, sustainability, and user interaction. Additionally, the conclusion identifies opportunities for future research, advocating for further exploration into material innovations, advanced parametric design techniques, and new fabrication processes to enhance the practical application of folding in architecture.

PART I | THEORETICAL FOUNDATIONS

I.I

FOLDING IN ARCHITECTURE

"The problem is not how to finish a fold, but how to continue it, to have it go through the ceiling, how to bring it to infinity." (Deleuze, 1993, p. 34).

Folding, as a transformative geometric operation, redefines spatial relationships by introducing continuous fluidity, adaptability, and complexity. As Greg Lynn explains in his essay *Architectural Curvilinearity: The Folded, the Pliant, and the Supple, in Folding in Architecture*:

"Pliancy allows architecture to become involved in complexity through flexibility."
(Lynn, 2004, p.24)

Folding challenges conventional notions of fixed boundaries and static hierarchical structures, offering a dynamic system in which forms expand and contract, constantly generating new configurations. It avoids fractures (Carpo, 2004, p. 14), instead integrating various elements and emphasizing continuity and flexibility, while responding to external forces that redefine it constantly (Lynn, 2004, p. 24). The 1990s marked the widespread application of folding in architecture, with Peter Eisenman being one of the first architects to explore it as a process for promoting continuity and transformation, inspired by his interpretation of *Le Pli: Leibniz et le Baroque* by Gilles Deleuze. Mario Carpo highlights this phase:

"Eisenman's reading of Deleuze's fold, in this early stage, retained and emphasized this notion of forms that can change, morph, and move: a new category of objects defined not by what they are, but by the way they change and by the laws that describe their continuous variations" (Carpo ,2004, p. 14)

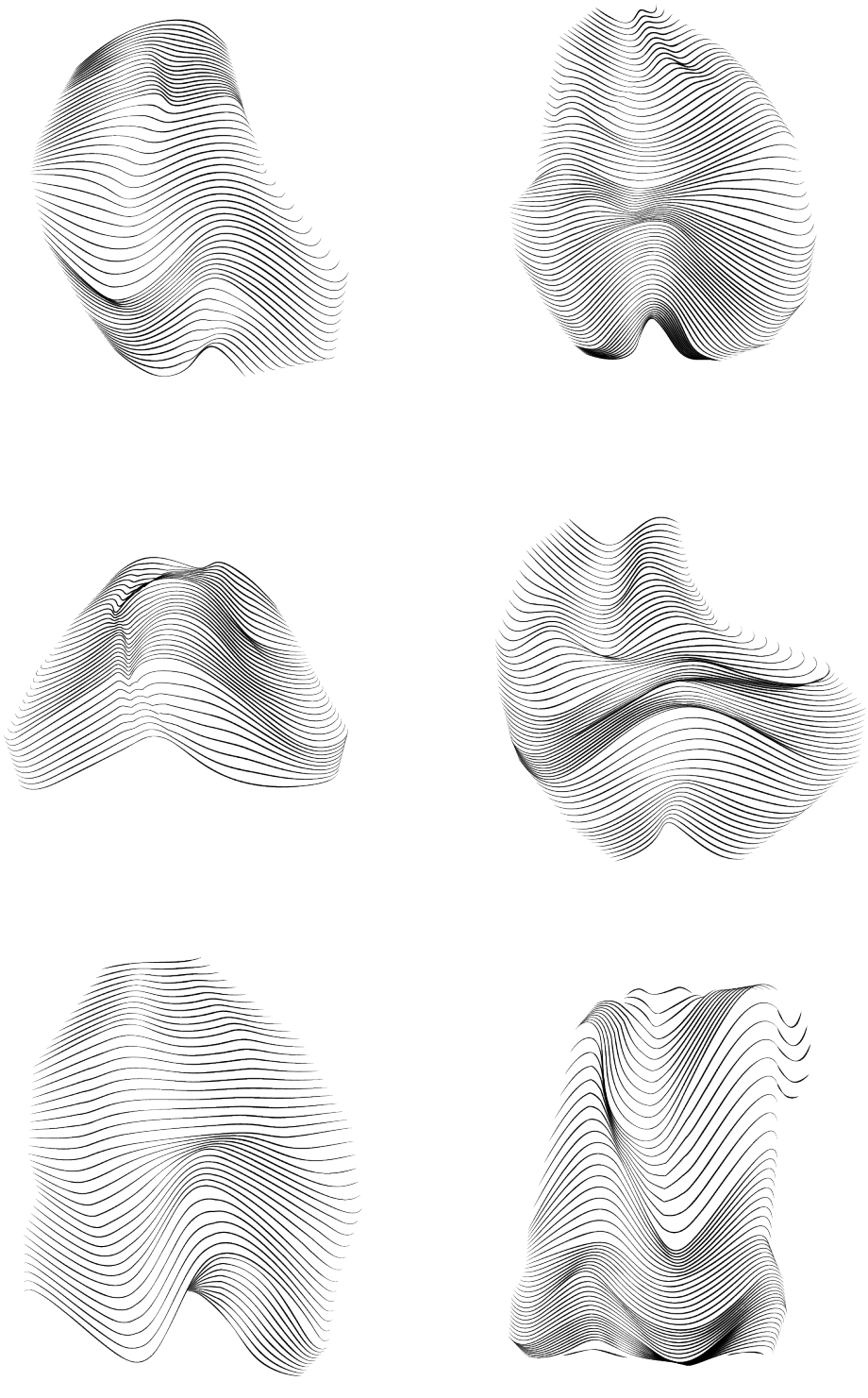


Fig 1.1 Sketch of Greg Lynn's study models for Embryological House.

For Eisenman, the fold was less about literal folding and more about creating architecture that reflects endless transformation and motion. This aligns with Deleuze's vision of the fold as a process for change—a concept Eisenman expanded into his design strategy. For instance, in his Rebstockpark masterplan, Eisenman used folding to disrupt traditional Cartesian grids, introducing new forms of spatial continuity that reflect Deleuze's "object-event." In this framework, architecture becomes an event—a moment of transformation—rather than a fixed and finite form. However, in Rebstockpark project, the function of the fold remains at a metaphorical level, symbolizing movement and transformation, while the architecture itself stays static (Carpo, 2004, p. 17). Its form stands as still frame, a fragment of a larger metamorphosis, hinting at the invisible stages of continuous transformation. (Carpo, 2004, p.17)

Eisenman's exploration of folding inspired a wave of design experimentation, coinciding with the introduction of CAD design software to architectural practice, referred to as Digital Turn (Carpo, 2013, p. 8). However, as Greg Lynn notes, the architects featured in Folding in Architecture had already formed ambitions for new models of formal and spatial complexity (Lynn 1993, 9). CAD tools enabled the visualization and simulation of dynamic transformations that were previously unattainable. For instance, Lynn's digitally animated models introduced forms that could respond dynamically to context and site conditions (Fig 1.1). However, as with Eisenman's metaphorical folds, these digital models ultimately resulted in static architectural forms, capturing transformation only during the design phase within digital environments.

This thesis explores the potential of folding beyond metaphorical representations to create physically dynamic architectures capable of responding to changing conditions in real-time. This approach to folding aligns closer to Hobermans interpretation of transformation. In his essay Transformation in Architecture and Design, he states:
"I believe that transformation is a major new frontier of design. For me, this word refers to an object or structure that transforms itself by itself – one that has an innate property of controlled change. A transforming object may be foldable, retractable or shape shifting. Such capabilities lead to functional benefits: portability, instantaneous opening, and intelligent responsiveness within the built environment." (Hoberman, 2006, p.70)

His expandable spheres exemplify his definition of a transforming object, emphasizing behavioral characteristics such as continuity, reversibility, and three-dimensionality (Fig 1.2 and 1.3) (Hoberman, 2006, p. 70)). His design theory highlights the potential to design specific behaviors into objects, such as controlled folding in response to external forces. The design principles of his transformable objects involve being composed of multiple interconnected parts that function as a unified whole, exhibiting a dual nature and operating in accordance with the underlying geometric structure. (Hoberman 2006, 71). Yet, the transformations in these spheres are limited to changes in size or scale without achieving new spatial characteristics or forms (Lynn, 2004, p. 30). Their behavior is not flexible but monotonous (Foged et al., 2010, p. 1).

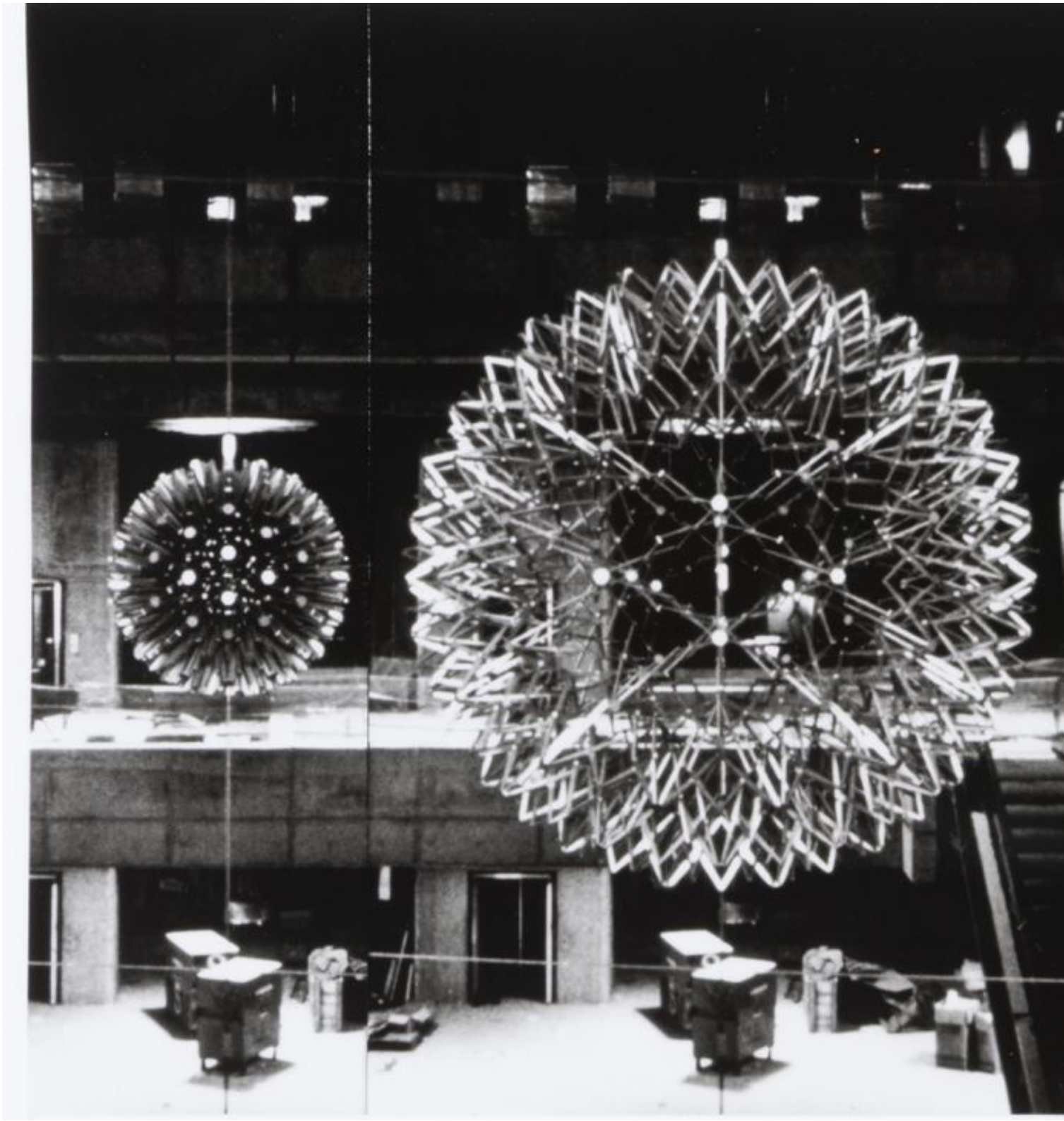


Fig 1.2 Chuck Hoberman's sphere expanding.



Among the contemporary explorations of folding are the investigations of architects Sancho and Madridejos, which employ folding to generate diverse and continuous spatial conditions (D'Acunto, 2018, p. 47). Their work establishes a systematic approach to spatial creation, where architectural space unfolds from a controlled transformation of two-dimensional planes into three-dimensional structures (Fig.1.2) (D'Acunto, 2018, p. 48). However, their folded forms are frozen in concrete, similar to Greg Lynn's CAD models, where transformation occurs during the design phase.

The theoretical frameworks of Deleuze, Eisenman, and Lynn provide critical foundations for understanding folding in architecture. However, their explorations of folding have often remained static and symbolic, capturing transformation either conceptually or digitally. Hoberman's approach to transformation aligns with the premise of this thesis in its emphasis on controlled folding and designed behavior. However, this research extends the concept of controlled folding by exploring its behavior as a means of transformation and formal adaptation, generating responsive spatial configurations. Rather than uniform expansion and contraction, this thesis proposes a system for developing surfaces that fold and behave in response to site conditions, external forces, and user interaction by embedding specific behavioral logic into tessellated folding patterns. Through this lens, folding becomes not only a design process but also an active architectural strategy—one capable of reshaping spatial experience through movement, response, and adaptation.

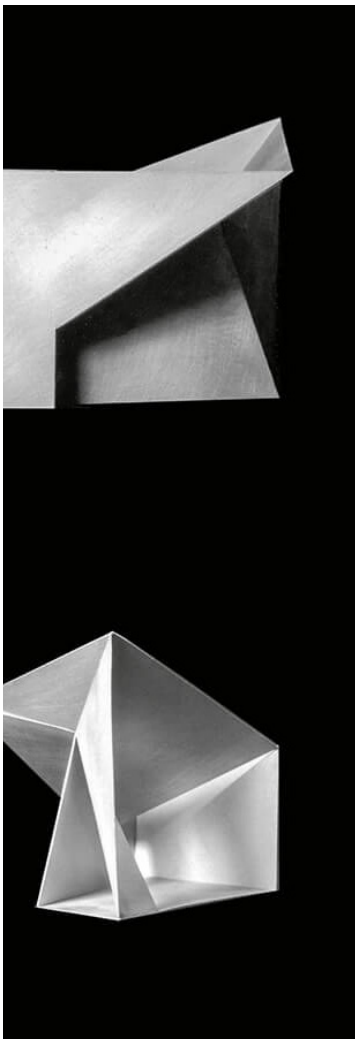
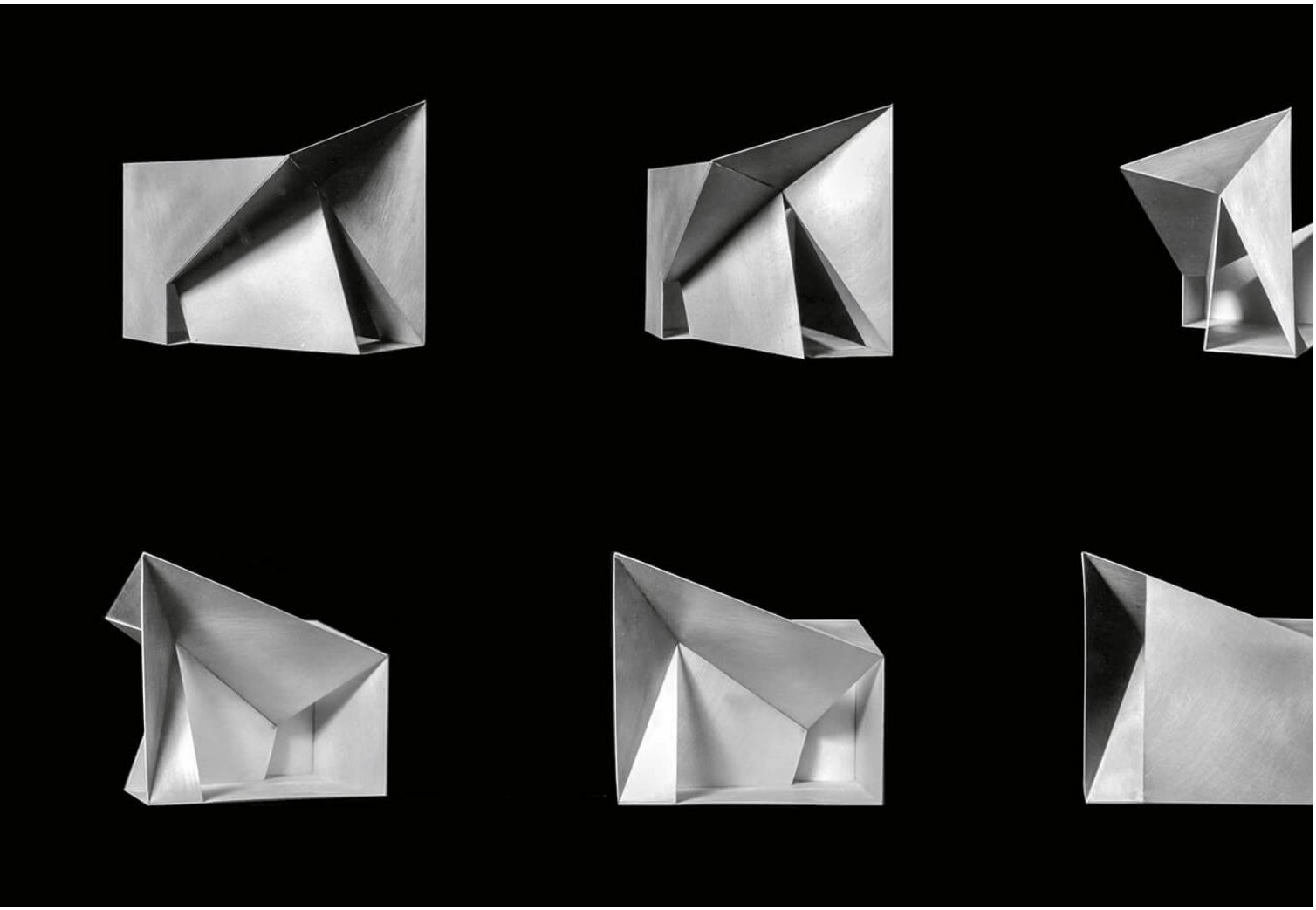


Fig 1.3 Conceptual model for



Chapel In Valleaceron.

I.II

FOLDING FOR RESPONSIVENESS

Architecture exists within a constantly evolving context, yet much of its physical presence remains static. The necessity for change and transformation within architectural design has never been more relevant as the demands of users and environments become increasingly dynamic (Asefi, 2012, p. 1005). Instances of sliding roofs and movable walls have demonstrated the potential of architectural elements to adapt to changing needs and conditions within spaces with multiple modes of use. However, these adjustments are not essentially shape changes due to their constrained and inflexible nature of transformation, which lacks the versatility and adaptability required for a space to be genuinely responsive (Foged et al., 2010).

This approach toward architecture is rooted in the understanding that our environment and needs are constantly changing, and traditional static architecture fails to respond to these dynamic scenarios and environments (Asefi, 2012, p. 1005). While there is a wide range of keywords associated with practices that involve such environmental or user-centric adaptations and responses within architectural spaces, it is "responsive architecture" that specifically refers to "a class of architecture or building that demonstrates an ability to alter its form."(d'Estrée Sterk, 2006, p.254)The term "Responsive architecture" was first introduced by Nicholas Negroponte in his book "Soft Architecture Machines" where he explored the idea of an architecture that could adapt and respond to the needs and behaviors of its occupants or environmental conditions. (d'Estrée Sterk, 2006, p.254) His ideas challenged the traditional static notion of architecture and proposed dynamic and flexible systems that could offer efficiency, adaptability, and intelligence to architectural spaces by introducing computing power into built environment. However, this flexibility requires a structure that could adapt and physically alter its form (Kronenburg, 2007).

For a structure to achieve truly responsive physical transformations, it must be lightweight, capable of asymmetrical movement, and designed with a controlled level of rigidity. (d'Estrée Sterk, 2006, p.254). Here, folding emerges as a strategy, shifting from a conceptual approach to an integrated design method that enables transformation and adaptation within the context of responsive architecture. Unlike the static manifestations of folding, responsive folding introduces a system that evolves in real-time, influenced by environmental forces, user interaction, and material behavior.

In the search for transformation in architecture inspired by folding, Tomohiro Tachi's experimentations on origami have demonstrated folding's potential to generate deployable mechanisms and kinetic architectural elements. Rooted in computational origami and digital fabrication, he investigates the design and simulation of rigid foldable surfaces (Tachi, 2011) and their implementation in the design and construction of transformable architectural elements (Tachi, 2010, p.203).

One such application is the adaptable wall by Tomohiro Tachi, which exemplifies how rigid origami principles can be translated into dynamic architectural components (Tachi, 2010, p.203). This project highlights the potential of material-efficient, foldable enclosures that can alter their form in response to spatial and environmental needs. Other recent research projects on architectural applications of origami include the Bloom Project and Resonant Chamber by RVTR, both of which utilize folding patterns to introduce transformability, enabling architectural elements to alter the acoustic performance of space (Furuto 2012)(Yeadon Space Agency 2016) . These projects embody the concept of the fold as an operational mechanism, where movement and transformation become integral to architectural performance.

While these experimental transformable architectural elements—Tachi's Folding Wall (Fig 1.5), Bloom Project by yeadon space agency, and Resonant Chamber by RTVR—demonstrate the potential of folding in architecture, they exist as isolated spatial components rather than as integrated systems. Despite their dynamic capabilities, they remain anchored to static environments, operating as kinetic features within otherwise immobile structures.

The fundamental nature of the fold is continuity, yet its architectural implementations result in fragmented applications rather than cohesive, continuous structures. The challenge is moving beyond isolated folding elements toward a system where folding tessellations blend different performances—contextual adaptability, structural efficiency, and dynamic transformability—into a unified architectural body. To address this challenge, this research develops a geometry manual to advance the implementation of folding in the context of responsive architecture—moving beyond isolated responsive elements toward a continuous, performance-driven architectural system.

While digital simulation tools like Tachi's Origamizer enable the exploration of complex folding tessellations, interactive optimization within these simulators remains challenging. Although they offer some editing capabilities, their constrained platform limits designers' ability to explore and refine folding behavior beyond algorithmic outputs, restricting creative flexibility. Additionally, highlighting the limitations of the surface topology to that of a disk, Tachi suggests future investigations to extend the method to non-disk surfaces, which enables a broader range of applications of origami in architecture (Tachi, 2010, p.214). This thesis introduces a structured framework for analyzing folding behavior, connectivity, and structural integration.

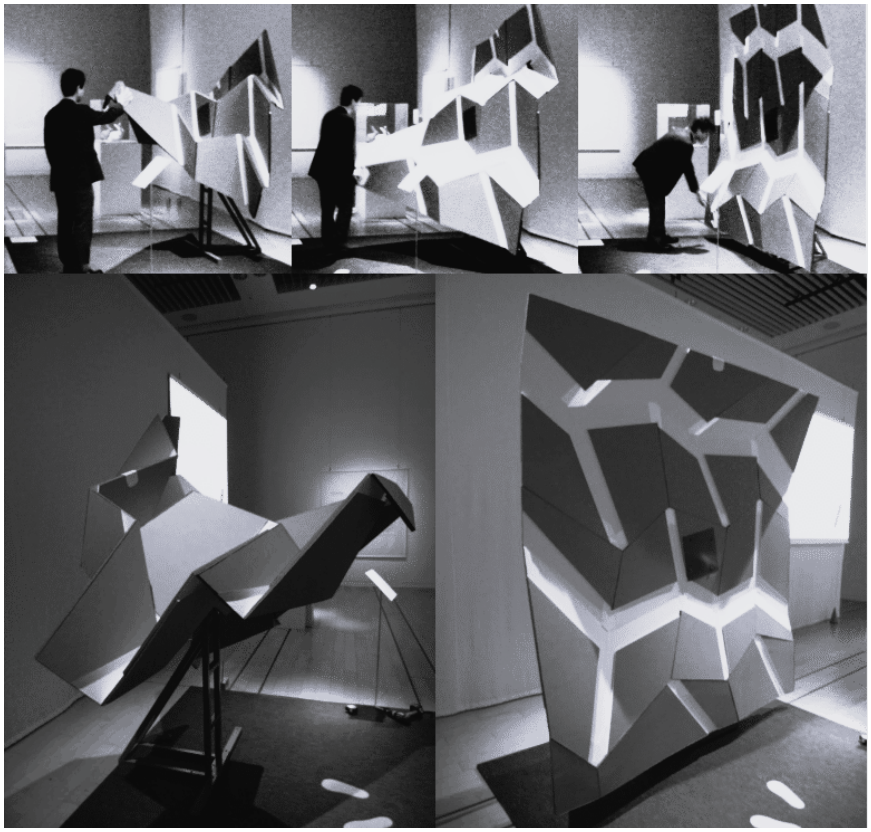


Fig 1.4 Rigid foldable origami materialized by Tomohiro Tachi

Ultimately, this theoretical foundation inspired the design of a wearable structure as architecture at an intimate scale. The artifact developed in this thesis is an engineered textile designed to respond dynamically to the human body as its site. Its complex tessellation resembles a masterplan akin to those developed by Eisenman, yet unlike his approach—where the design is imposed through abstract diagrams such as Thom Rodd's grid—the developed textile is structurally programmed upon the complex grid system derived from the unique topology of its site, the human body. It shares a conceptual similarity with Rebstock Park, as both are conceived as an integral whole composed of various interdependent parts. However, while Eisenman's architecture ultimately remains static, this textile oscillates between what it is and what it can become, allowing different modes of wearability. Its geometry allows it to continuously generate new forms, shaped by its context and user, much like the animated models of Greg Lynn, where the form is fluid, responsive, and ever-evolving, and transformation and adaptability are embedded into the very fabric of the material.

PART II | FOLDING FRAMEWORKS

Part II outlines the research methodology employed in this study, structured into four main sections: Method, Material, Medium, and Making. Each section elaborates on different dimensions of the research undertaken, which are interconnected and create the overall structure of this experimentation.

II.I

METHOD

"Folding as a generative process in architectural design is essentially experimental: agnostic, non-linear, and bottom-up."
(Vyzoviti, 2003, p.8)

This research adopts a bottom-up methodology to investigate the geometrical characteristics of rigid origami patterns, with a particular focus on Miura-Ori. The Miura-Ori pattern is a well-known origami tessellation with unique mechanical and structural properties, making it highly relevant in engineering, architecture, and space applications (Peraza Hernandez & Paulino, 2024). Developed by Japanese astrophysicist Koryo Miura, this folding pattern consists of repeating parallelogram units that allow for a single-degree-of-freedom movement, meaning it can be expanded or contracted by simply pulling or pushing from opposite ends.

One of the key characteristics of the Miura-Ori is its auxetic behavior, which means it exhibits a negative Poisson's ratio—when stretched in one direction, it expands in the perpendicular direction instead of contracting (Fig 2.1) (Turner, Goodwine, and Sen 2016). This makes it highly adaptable for applications where flexibility and compactness are required. Additionally, the pattern is rigid-foldable, meaning it can fold and unfold while maintaining structural integrity without stretching or deforming the material between the creases.

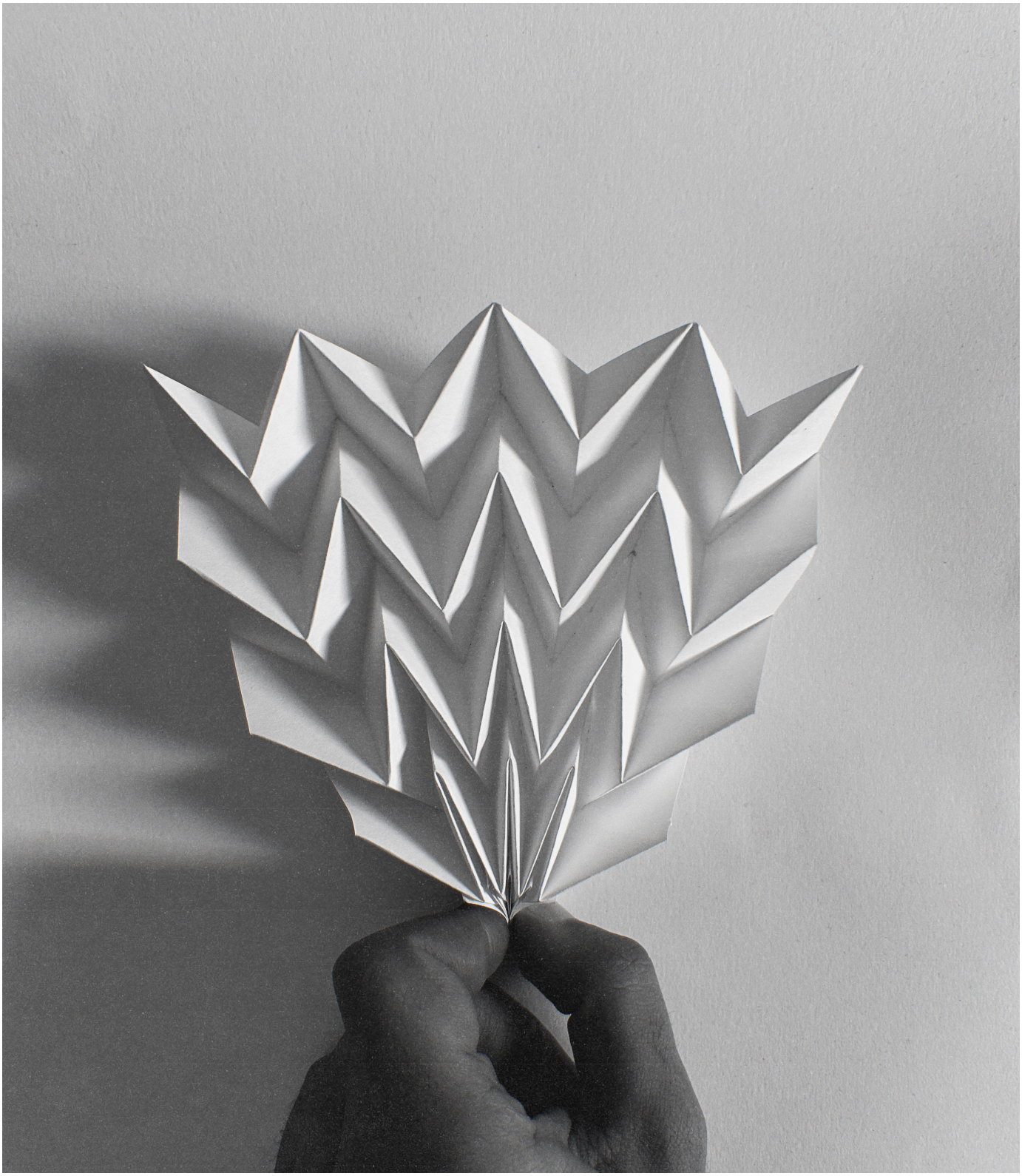


Fig 2.1 Miura-Ori Pattern and its auxetic behavior.

Originally designed for deployable solar panels in space, the Miura-Ori pattern has since been applied in mechanical engineering, biomedical devices, foldable structures, and packaging solutions. Its ability to be folded into a compact shape and then deployed efficiently makes it a valuable tool for designing adaptable and space-saving structures.

The study progresses through two phases: component study and growth study. The component study forms the foundation of the analysis, where individual units of the Miura-Ori pattern are adjusted in their various parameters. This phase explores the effects of modifying the pattern's variables—such as altering crease angles, adjusting vertex distances, and introducing or removing creases—on the overall tessellation. By sequentially varying these parameters, the study reveals how subtle changes at the component level influence the tessellated surface.

The growth study explores how individual components interact when aggregated into larger assemblies. This phase examines variations in scaling, tiling strategies, and connectivity to assess the emergent behaviors that arise from repeated folding and modular expansion.
The research methodology is grounded in observation, documentation, and analysis of the evolving surface behavior as modifications are introduced to the underlying geometrical rules of the pattern. While the documentation follows a structured format, the experimentation itself remains non-linear. Through iterative prototyping and design optimization cycles—where insights from the component study and growth study are continuously referenced—this learning-by-doing approach fosters a foundational understanding of the folding language. As Sophia Vyzoviti describes:
"Folding produces a language of architecture. It is the strength of the architectonic language that speaks out and determines quality. The first folds must be viewed as sounds that much later become words" (Vyzoviti 2003, p.7)

Scientists, designers, and artists have studied, developed, and documented folding for different applications across various disciplines, including Art, architecture, fashion, product design, and engineering. Early pioneers such as Josef Albers introduced folding into design education at the Bauhaus in the 1920s, using it to explore structural and spatial possibilities (Albers, 1952). His work laid the foundation for later explorations by designers like Paul Jackson, who provided practical methodologies for manipulating sheet materials into three-dimensional forms. Multiple illustrative origami manuals have been developed, such as Origami for Designers by Paul Jackson and The Practical Illustrated Encyclopaedia of Origami by Rick Beech, which documented a geometrical grammar for Origami folding. Another significant contribution to the field comes from Tomohiro Tachi, whose work in computational origami further optimized the form-finding process using algorithms and parametric modeling within CAD environments (Tachi, 2015).

These two methodological strategies are different in their approach to folding experimentation. Paul Jackson and Rick Beech suggest a hands-on approach prioritizing artisanal values of physical experimentation. In contrast, Tomohiro Tachi's work, which utilizes computational methods, emphasizes precision, formal complexity, and optimized performance to achieve refined and efficient folding structures. From an educational perspective, Jackson and Beech's methods offer a more accessible and foundational entry point into folding design, making their approach suitable for a broader audience and easier to implement in design education. While their work primarily focuses on fundamental principles and geometric rules, this thesis extends these studies by analyzing the folding behavior in greater depth to achieve control over it and implement it in the development of folded surfaces with significant potential in Design and Architecture.

II.II

MATERIAL

The choice of material is highly influential in a design process, affecting structural integrity, aesthetic expression, and functional performance of the design. In the context of folding, material properties dictate how surfaces deform, retain pleats, and adapt to dynamic motion, which are essential qualities determining their successful implementation.

Paper, as a material, has long been used for studying folding patterns due to its inherent stiffness, lightweight nature, and ability to hold creases with precision (Fig 2.2). Origami-based architectural and engineering applications often use paper models to explore geometric transformations before translating them into more durable materials. This study uses paper as an accessible prototyping medium, allowing for rapid production of test models.

Multiple paper types were tested to determine the optimal thickness that balances durability and flexibility. Through this process, 120g paper was selected as it proved to be thick enough to withstand laser engraving while remaining thin enough to retain flexibility, making it a suitable sheet material for the prototyping phase.



Fig 2.2 Fabriano
paper roll, 120gr.

For the final wearable application, organza (Fig. 2.3)—a lightweight synthetic textile—was chosen for its exceptional ability to hold creases while maintaining flexibility. Unlike natural fabrics, which tend to relax over time, synthetic organza retains structured folds once exposed to heat (Hong 2014). Its delicate yet resilient nature allows for a garment that is both visually striking and comfortable to wear. Organza is inherently transparent, but its translucency can be manipulated by layering multiple sheets, allowing for a gradual build-up of opacity while still maintaining its ethereal quality (Fig 2.4 & 2.5). This combination of structure, lightness, and aesthetic appeal makes organza an ideal material for achieving a refined, sculptural silhouette.

Fig 2.3 100% Polyester Organza, lightweight and transparent.





Fig 2.4 Transparency of 100% Polyester Organza –single layer.



Fig 2.5 Transparency of 100% Polyester Organza –single layer.

II.III

MEDIUM

"Fashion is architecture, it is a question of proportions" Coco Chanel

Architectural ideas are explored, discussed, and manifested through various media, including sketches, drawings, models, clothing, furniture, and installations. While other disciplines treat these artifacts as final designs, architecture employs them as tools for exploration on a smaller scale (Chen, 2014). The choice of medium significantly influences how effectively an idea is communicated, tested, or experienced. This thesis utilizes wearable design as an architectural representation to investigate folding as a strategy for transformation. Here, the body becomes both the site and the user, while the dress serves as the architecture, defining space through the dynamic relationship between space and user, dress and body.

The intersection of fashion and architecture has long been an area for interdisciplinary research. In recent years, there has been a growing interest in the relationship between fashion and architecture in both research and practice (Allmer, 2013). The Skins + Bones: Parallel Practices in Fashion and Architecture (2006) exhibition explored the intersection of the two disciplines through the works of forty-six international designers and architects. It introduced new connections between fashion and architecture, revealing how both engage with fundamental issues of body, shelter, and identity (Hodge et al., 2006). Beyond these shared concerns, the exhibition also highlighted their parallel design strategies, one of which is folding (Muñoz & Cordero, 2024).

Three designers and their selected works serve as case studies in this thesis, exploring adaptive spatial transformation through the scale of clothing—mirroring the chosen medium of this research. Each designer conceptualizes clothing as an architectural space at a personal scale, examining its transformation and adaptation in response to the dynamic and complex site of the body. Their works illustrate how garments can operate as responsive systems and adapt to movement, define spatial relationships, and facilitate interaction in relation to the body. By analyzing these precedents, this thesis positions wearable design as an experimental architectural medium that blurs distinctions between clothing and built environments.



Fig 2.6 Body's movement and formal complexity.

II.III.I

HUSSEIN CHALAYAN

Hussein Chalayan was among the designers who radically explored these intersections. He incorporated themes of mobility and transformation while investigating the dynamic relationship between body and space to create garments that change in form, silhouette, or function (Rashad, 2023). His designs merged Fashion with Architecture, movement, and space-making, demonstrating how garments can serve as protective structures and transformable spaces (Quinn, 2002).

A prominent example is the "Table Skirt," featured in his Fall/ Winter 2000 "Afterwords" collection (Fig 2.7). This functioning wooden table unfolded into a skirt attached to the model's waist. During his show, models entered the stage, folded and unfolded furniture into garments, and exited, leaving an empty space behind (Hodge et al., 2006). This choreographed sequence symbolized themes of mobility, transformation, transportability, and shelter, which were central to his work while representing how spaces and objects can be reconfigured to serve multiple functions.

Continuing his exploration of transformation, Chalayan's Spring/ Summer 2007 collection "One Hundred and Eleven" featured garments that evolved on the runway, shifting shapes and silhouettes through built-in robotic systems (Pullin, 2010). Dresses in the collection could expand, contract, or morph in response to external triggers, making each garment an interactive and performative piece. This collection did more than introduce the possibility of mechanized transformation in clothing—it served as a metaphor for architectural evolution and spatial adaptability (Antonelli, 2008).

Fig 2.7 Coffee table skirt by Hussein Chalayan.



II.III.II

ISSEY MIYAKE

Issey Miyake was among the most influential fashion designers who explored the intersection of architecture and fashion through folding. Renowned for his innovative approach to pleating and fabric manipulation, he drew upon extensive research on form, materials, and technology to demonstrate how folding can create voluminous, dynamic, and structurally adaptive designs (Muñoz & Cordero, 2024). His work introduced a distinctive silhouette, detached from the wearer, establishing an intermediary space that redefined the relationship between the individual and the garment.

One of Miyake's most recognized contributions to fashion is the Pleats Please collection (1989), which introduced micro-pleating to create garments significantly larger than standard sizes (Buckingham, 2019), which through pleating, could expand, contract, and adapt to the body's natural movement and topographic contours.(figure 3.3) This adaptability emphasized versatility through flexibility and universality in garment design. These pleats function like architectural facades—independent yet inherently responsive—adapting to various forms, much like Renzo Piano's IBM Pavilion (1982–1986), a mobile and expandable structure designed to accommodate diverse environments. Both Miyake's designs and Piano's pavilion exemplify how modularity and transformation can generate adaptable, user-responsive spaces.

Fig 2.8 Pleated polyester ensemble by Issey Miyake



Miyake further advanced his exploration of folding with the 132.5 collection (2010), a project that reimagined clothing through computational design and origami-inspired construction. The title of the collection referred to its concept of transformation through folding. The process involved a single, planar piece of fabric that acquired a three-dimensional volumetric form through a unique folding pattern. This form could subsequently be collapsed back into two dimensions. Ultimately, the garment transcended these physical dimensions as it was worn, entering a metaphorical "fifth dimension"—a dynamic state where it interacted with movement, the human body, and spatial perception (Önal & Karakoç, 2019).

The core of Issey Miyake's work is the concept of the garment as a spatial entity—a structure that exists independently of the body yet interacts with it. Its form, adaptability, and transformation are enabled by folding, which grants fabric both structural integrity and flexibility. While these garments serve as personal and intimate expressions of space, the same design strategies could be applied to larger-scale architectural surfaces to create responsive and adaptable environments that engage with multiple bodies while responding to the complexities of the built environment.

II.III.III

IRIS VAN HARPEN

Iris van Herpen stands at the forefront of contemporary fashion design, pioneering a new paradigm where technology, material innovation, and craftsmanship converge (Kalaitzi, Papachristou, and Papadimitriou 2022). Her work bridges fashion and architecture, crafting garments that extend the body into sculptural, interactive forms (Smelik 2017). Drawing upon advanced digital fabrication techniques, such as 3D printing and parametric modeling, van Herpen constructs complex, sculptural forms that respond dynamically to movement and interaction. Her approach aligns closely with the Deleuzian notion of "becoming," wherein identity and form are understood as fluid, continuously shifting states rather than static entities (Smelik 2017).

Her Shift Souls (2019) and Hypnosis (2019) collections highlight the role of computational patterning in shaping dynamic, responsive garments. Shift Souls employed thermoformed laser-cut patterns to dictate structural behavior, allowing fabrics to fluidly expand, contract, and morph in response to movement. This interplay between material rigidity and flexibility created an exoskeletal effect, reinforcing the garments' architectural qualities. Hypnosis advanced these explorations through wave-like laser-cut motifs applied to NASA-developed Mylar, generating a rhythmic transformation between density and openness (Smelik 2020). Her ability to design garments that expand, contract, and redefine the wearer's form mirrors the architectural concepts of adaptability and transformation explored in this research.

II.IV

MAKING

The process of making the pleated textile started from mold design and fabrication and . Paper is used for prototyping, while fabric requires extra steps to hold its pleats properly.

Digital Pattern Generation

The process begins with designing folding patterns in Rhinoceros (Rhino), a digital modeling software that allows precise control over geometric shapes. The tessellations are adjusted to ensure proper alignment and folding when translated from digital to physical form.

Cutting and Engraving Prototypes

There are two ways to create prototypes: automated laser cutting and manual tracing. If the pattern fits within the laser cutter's bed, the Speedy 300 laser cutter is used, with power set to 50 for cutting and 3 to 6 for engraving fold lines, depending on the paper's thickness (Fig 2.9). To prevent tearing, engraving lines stop just before intersections, avoiding multiple passes over the same point.

For larger patterns that don't fit in the laser cutter, the design is plotted onto paper, and fold lines are traced manually with a precision tool. While effective, this method is more time-consuming, especially for intricate designs.

Mold Fabrication for Fabric Pleating

When shifting from paper to fabric, molds are needed to maintain the pleats. Two identical paper molds are created from the tessellation, ensuring a perfect fit. These molds go through the same cutting and engraving process as the prototypes. Since fabric doesn't hold folds as paper does, the molds are essential for shaping the pleats.

Fabric Placement and Folding

Once the molds are ready, the fabric is placed between them while they are fully expanded . This step is crucial—if the molds aren't completely unfolded, the pleats won't align correctly (Fig 2.11). After positioning the fabric, the molds are refolded(Fig 2.13), pressing

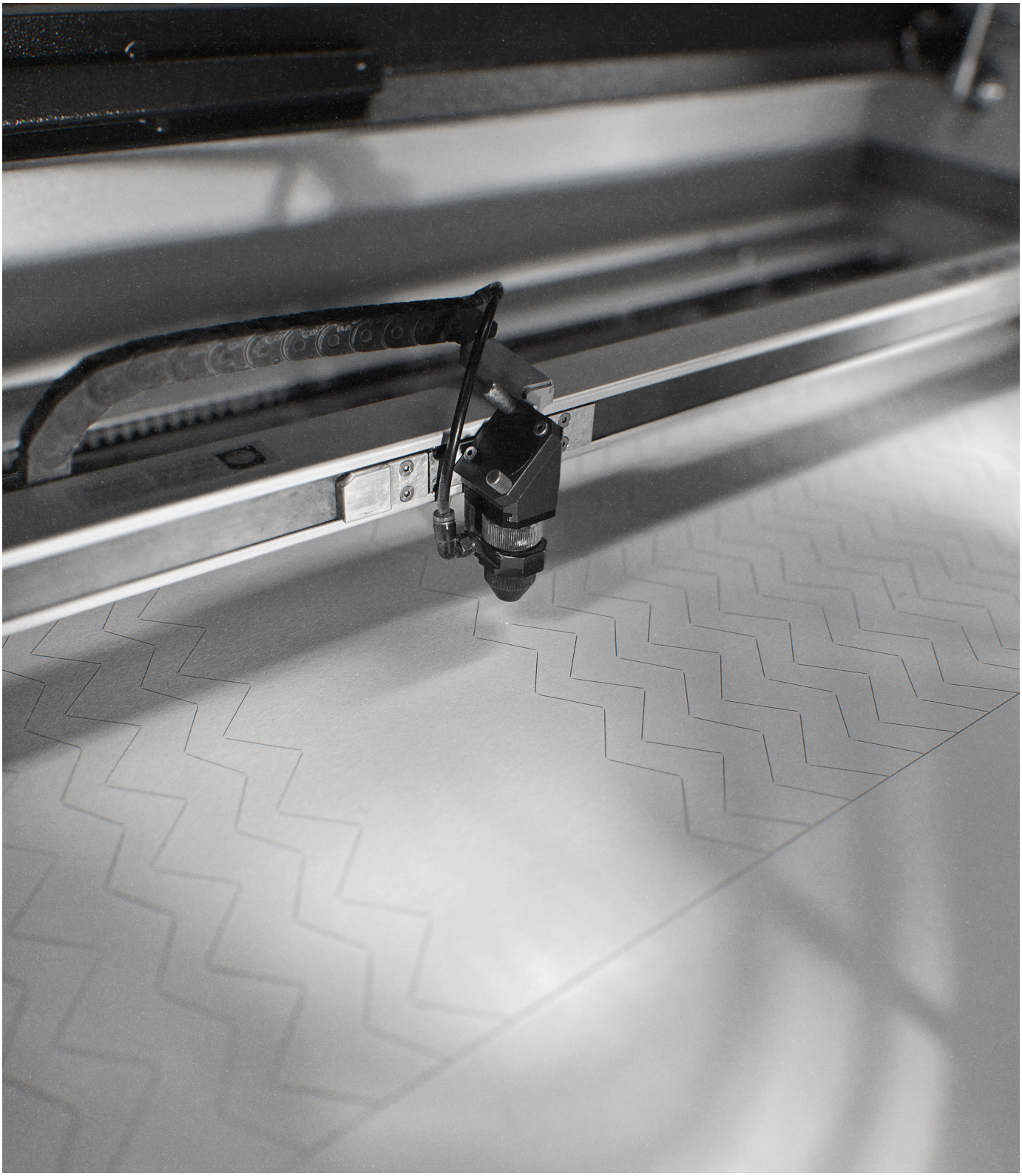


Fig 2.9 Engraving the pattern on fabriano 120gr paper using speedy 300 Laser cutting machine.

the fabric into shape. The assembly is then tied and secured to hold everything in place before the pleat-setting process (Fig 2.16).

Heat Setting the Pleats

The final step is applying heat to permanently set the pleats (Fig 2.17). The temperature and duration depend on the type of fabric. Once the heating process is complete, the mold is carefully removed, revealing a structured textile with crisp pleats. This approach ensures accuracy and consistency, creating a flexible yet stable pleated fabric suitable for various applications (Fig 2.18).

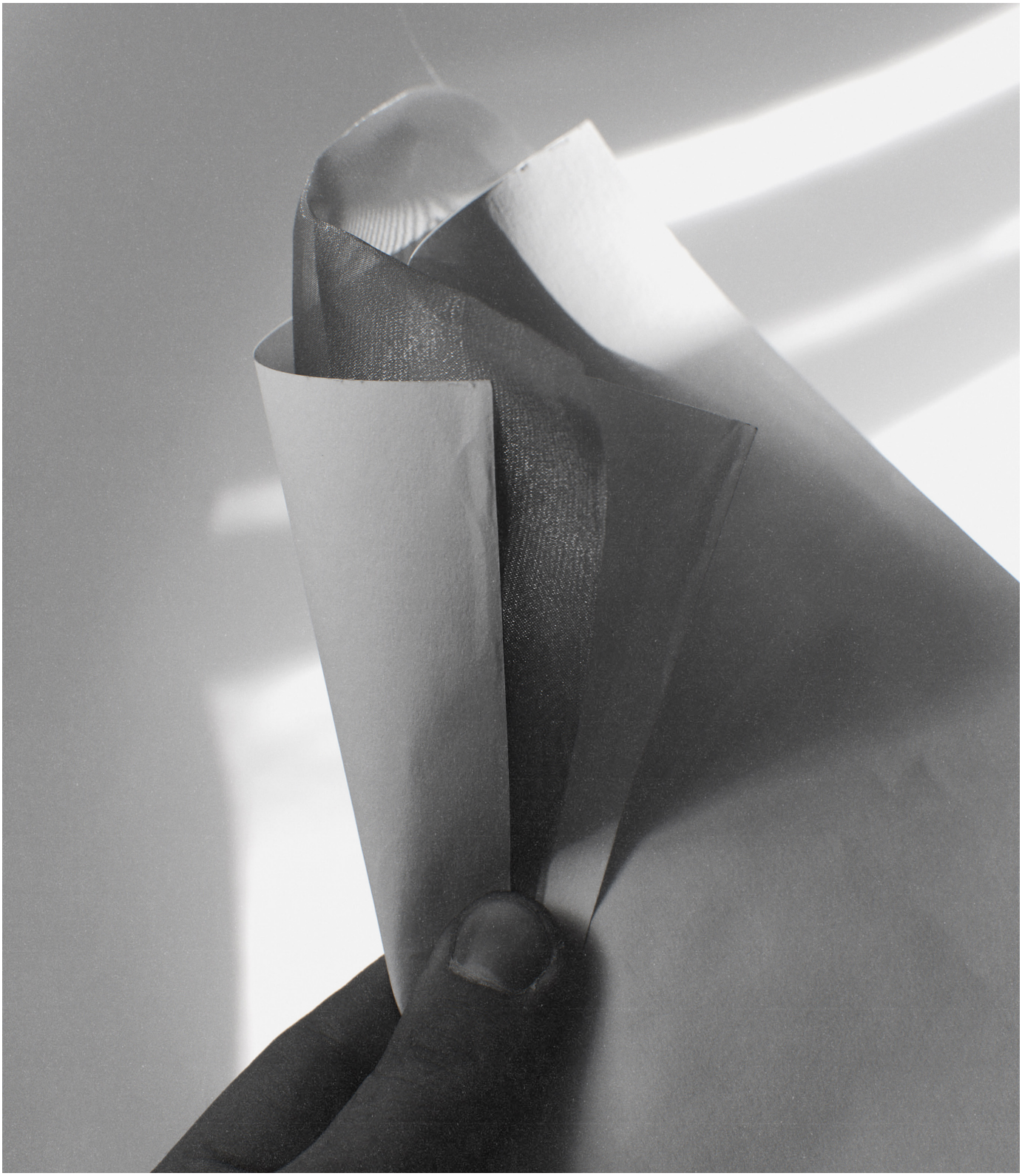


Fig 2.10 Placing the Organza between two layers of engraved paper.

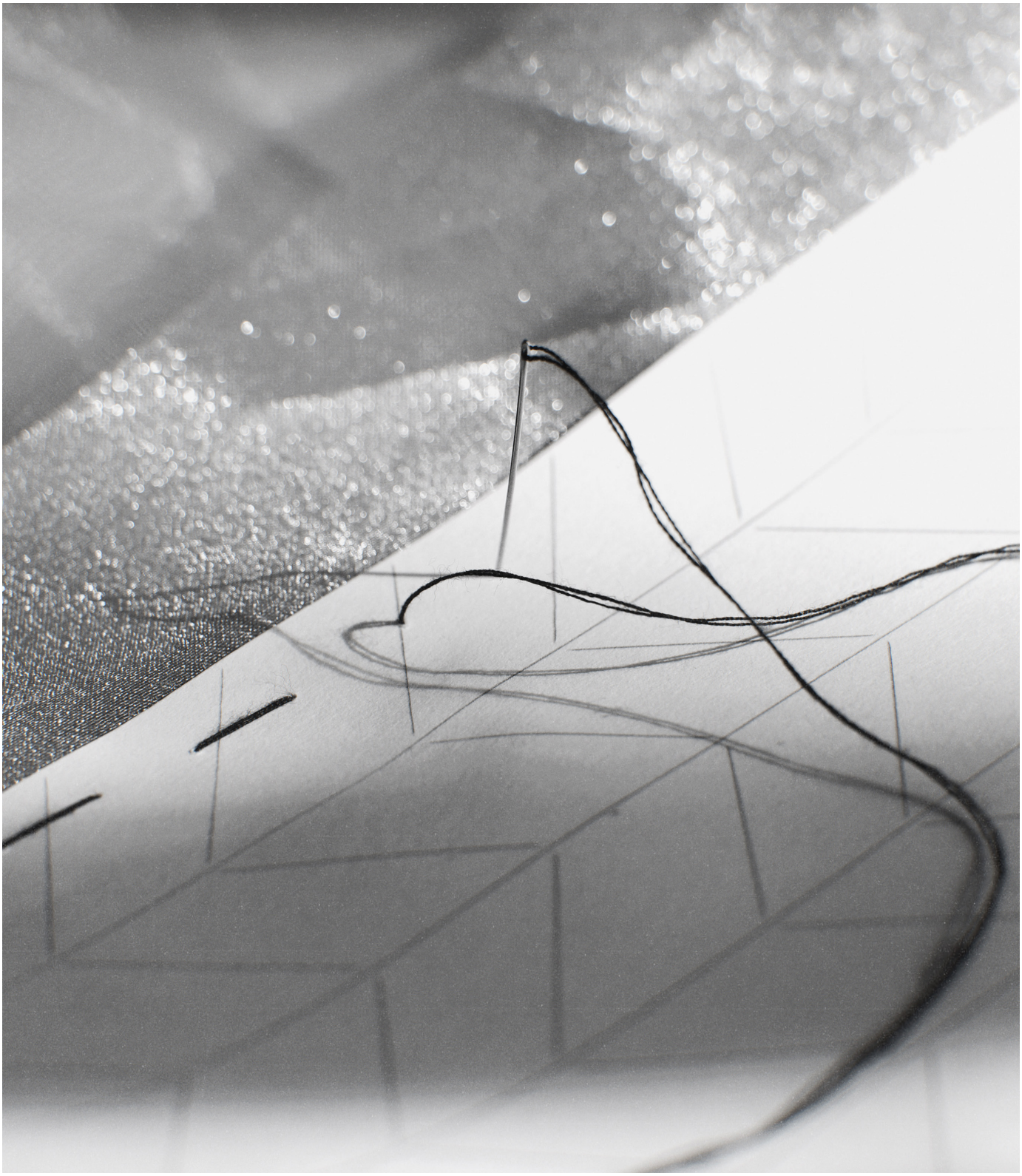


Fig 2.11 Sewing the layers to fix the fabric between the paper mold.

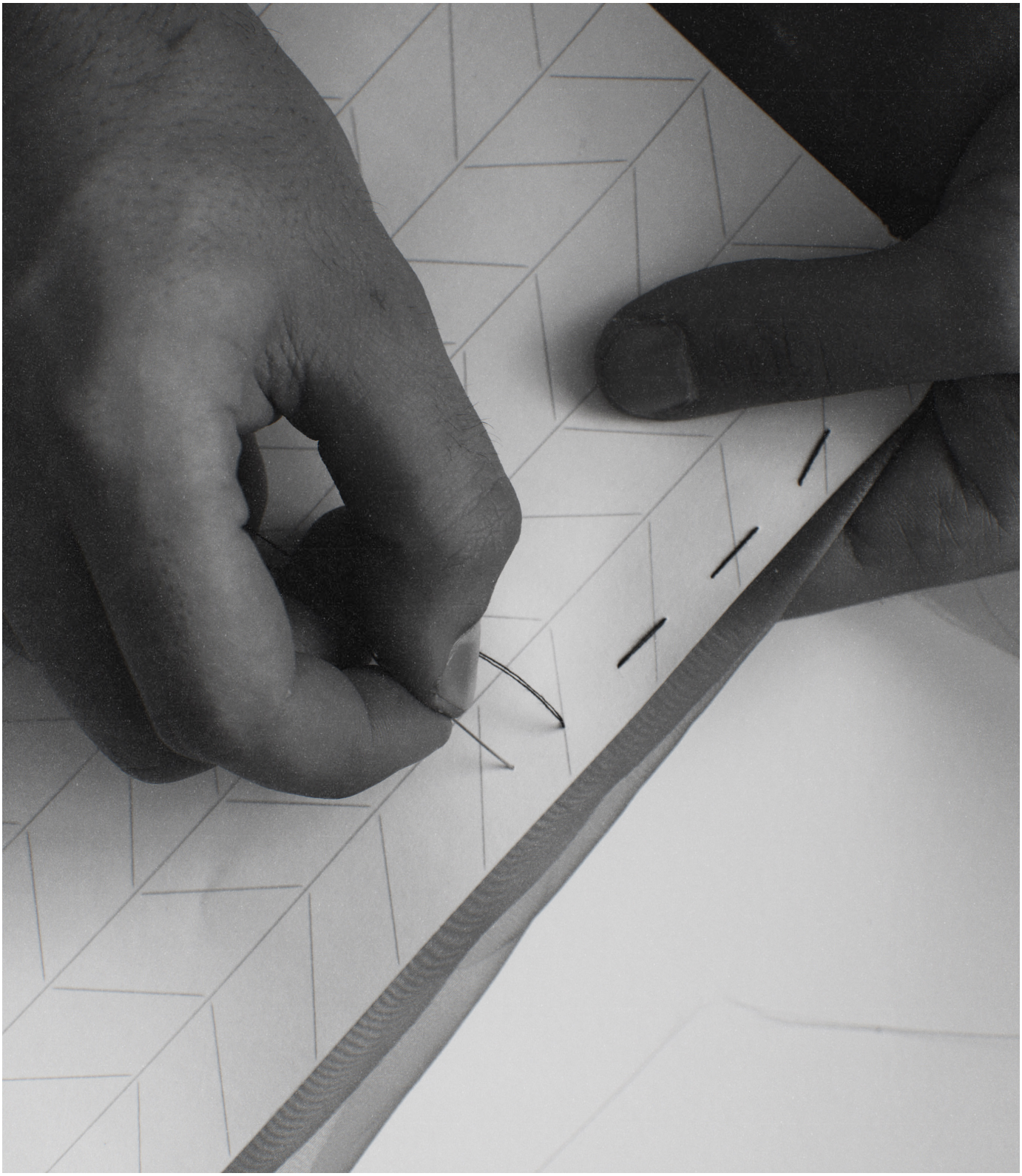
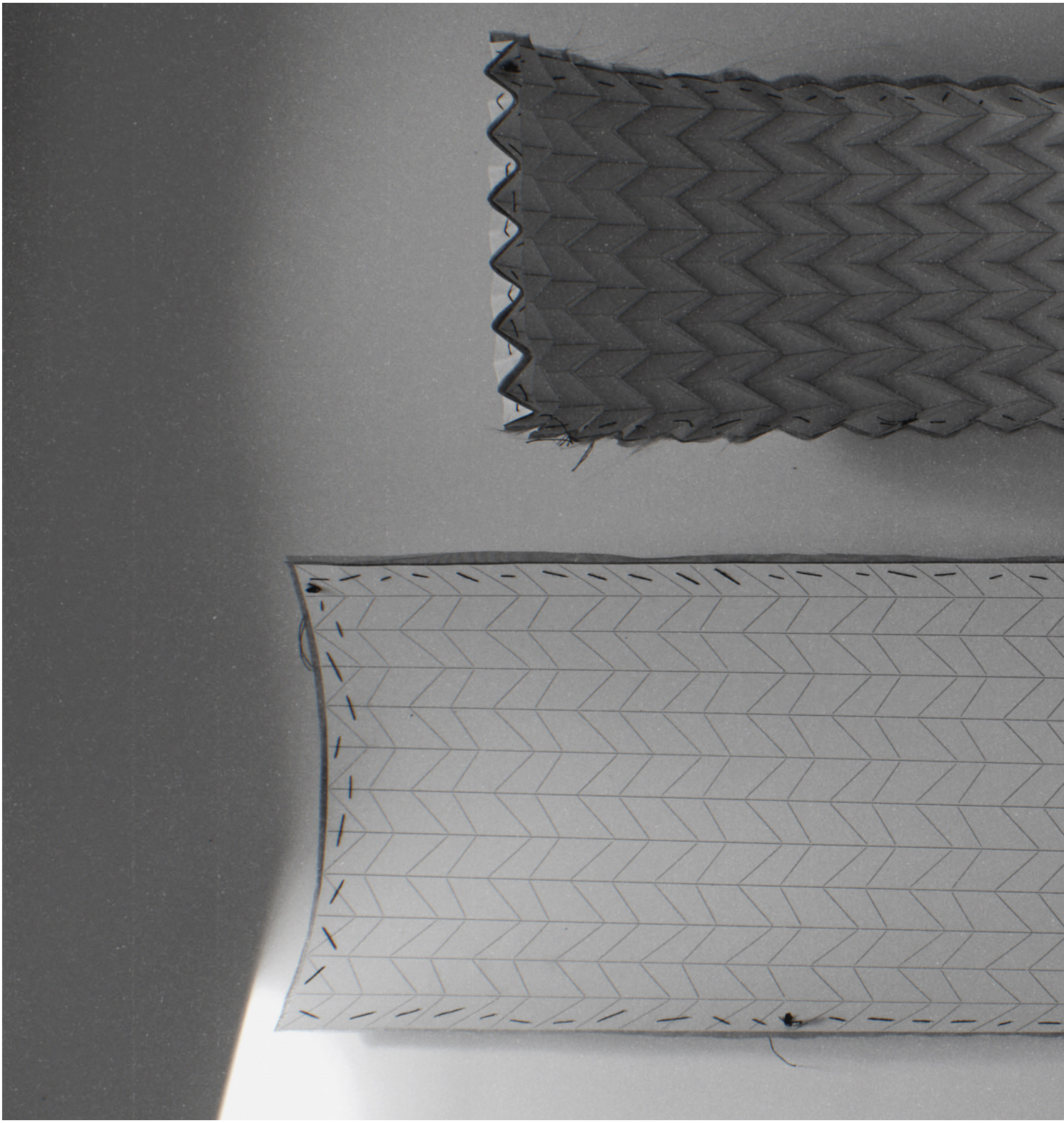


Fig 2.12. Sewing the layers together to fix the fabric in between the paper mold.



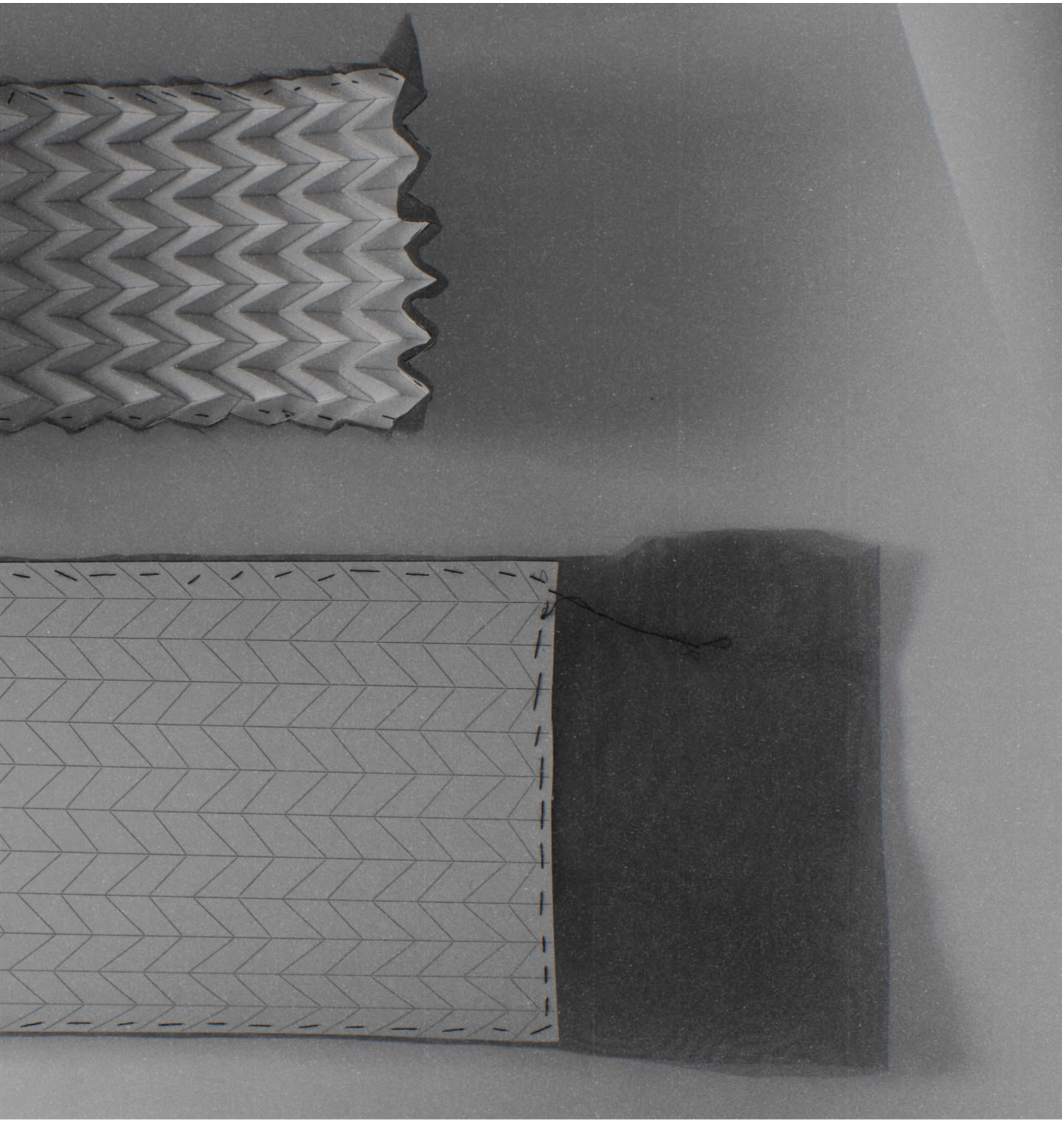


Fig 2.13 The unfolded and folded mold.

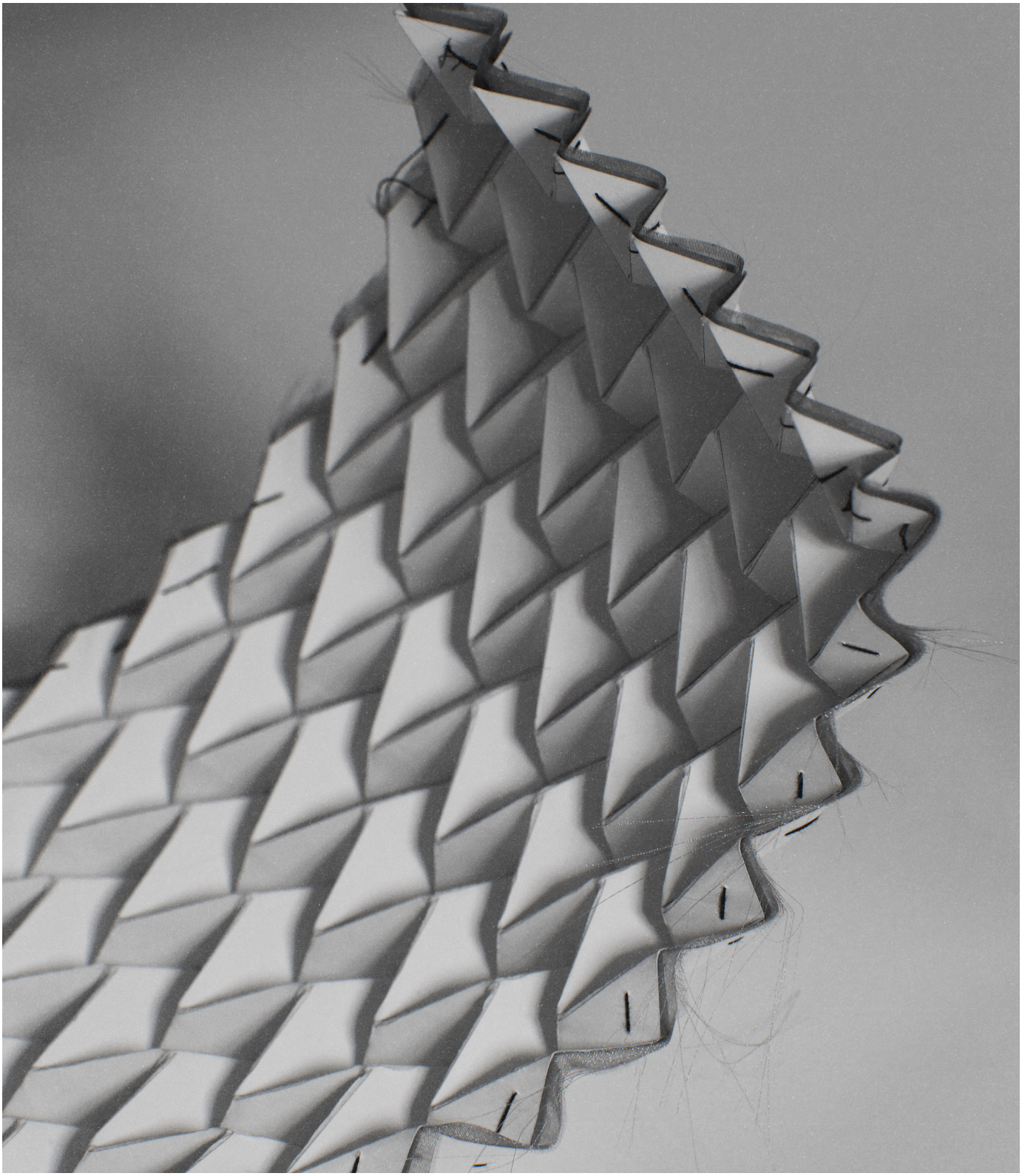


Fig 2.14 Folded mold with two layers of organza in between.

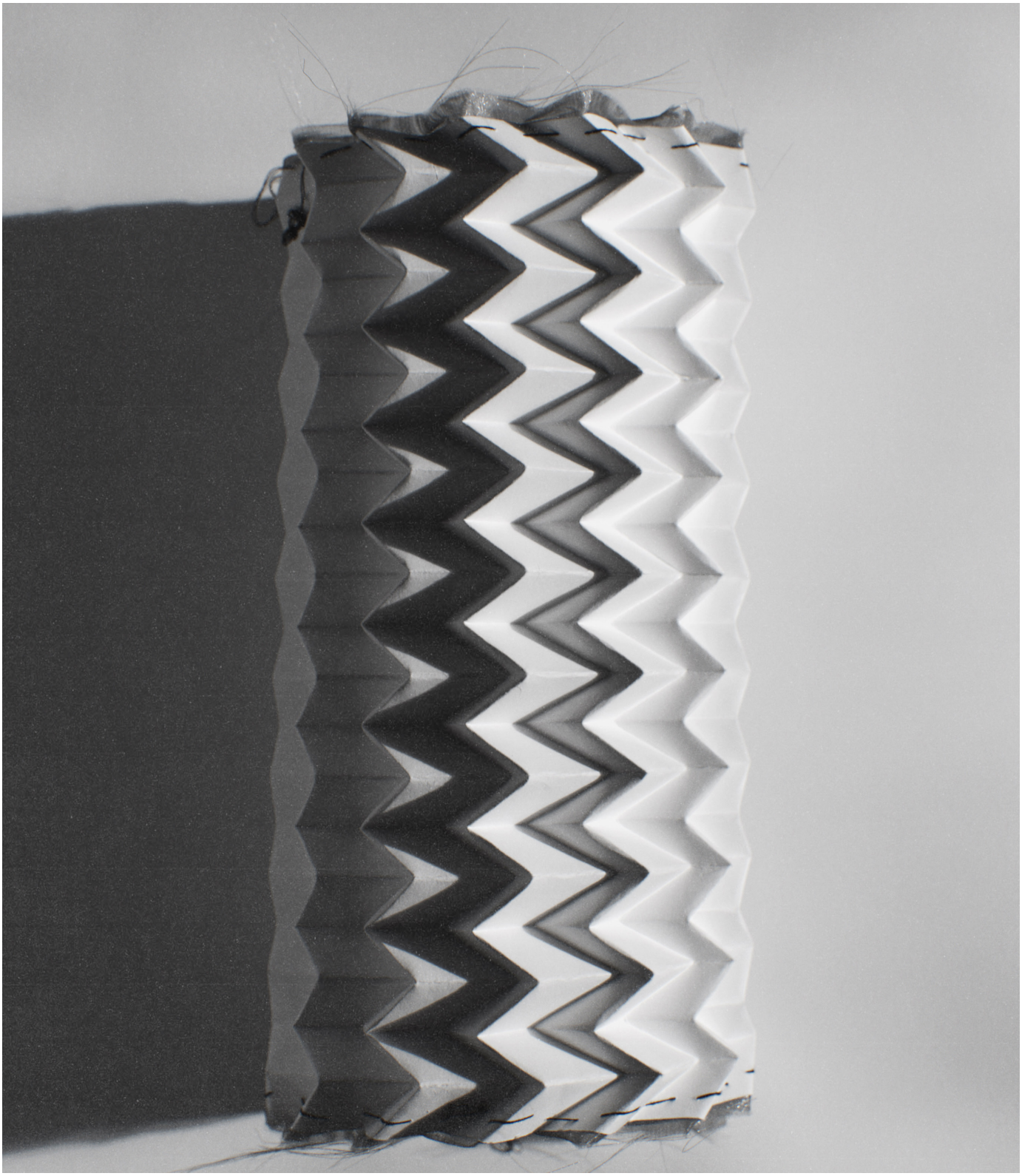


Fig 2.15 Folded mold with two layers of organza in between.



Fig 2.16 Folded molds tied for maximum compression on the fabric in between.



Fig 2.17 Introducing heat to the tied molds.

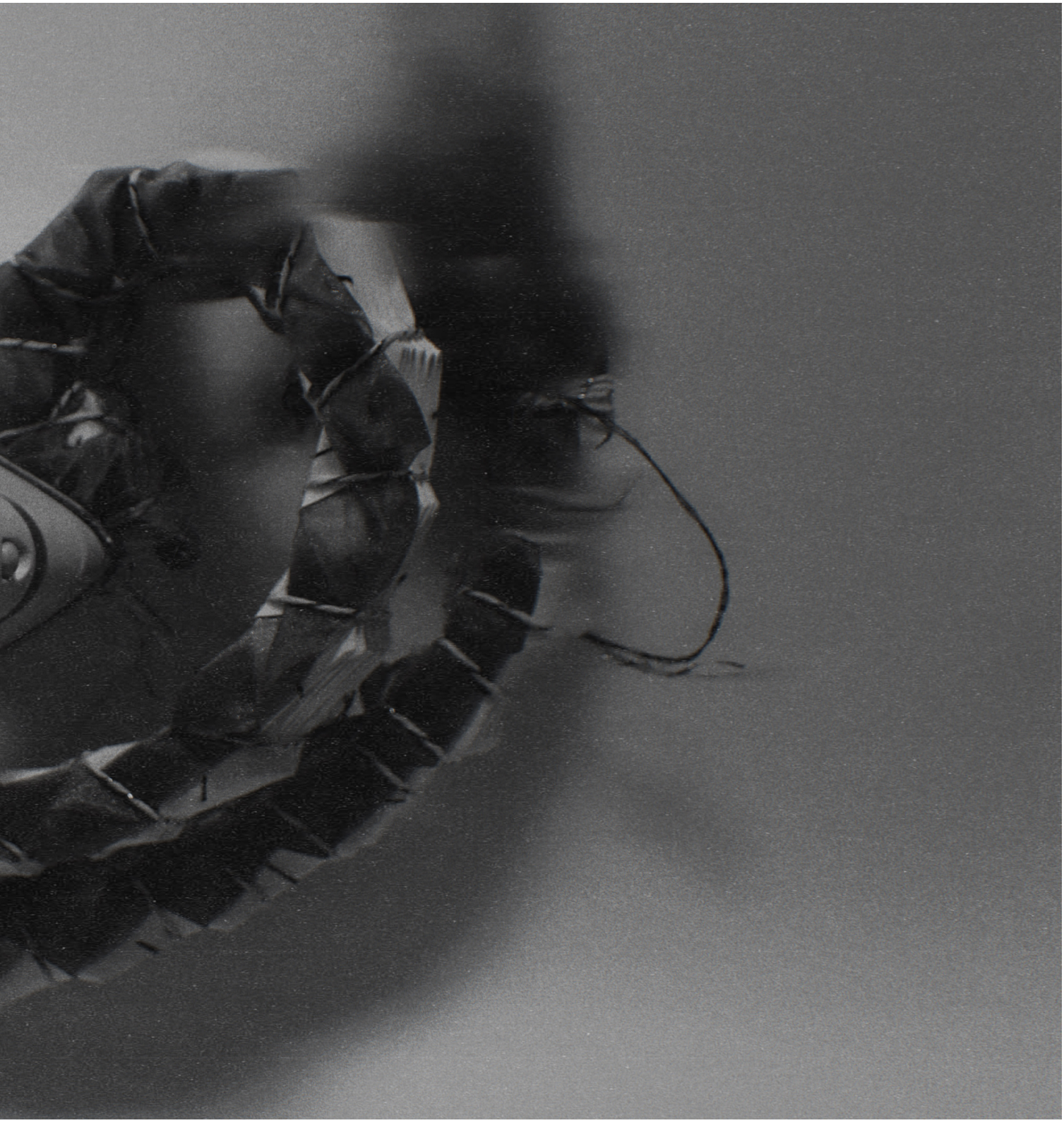
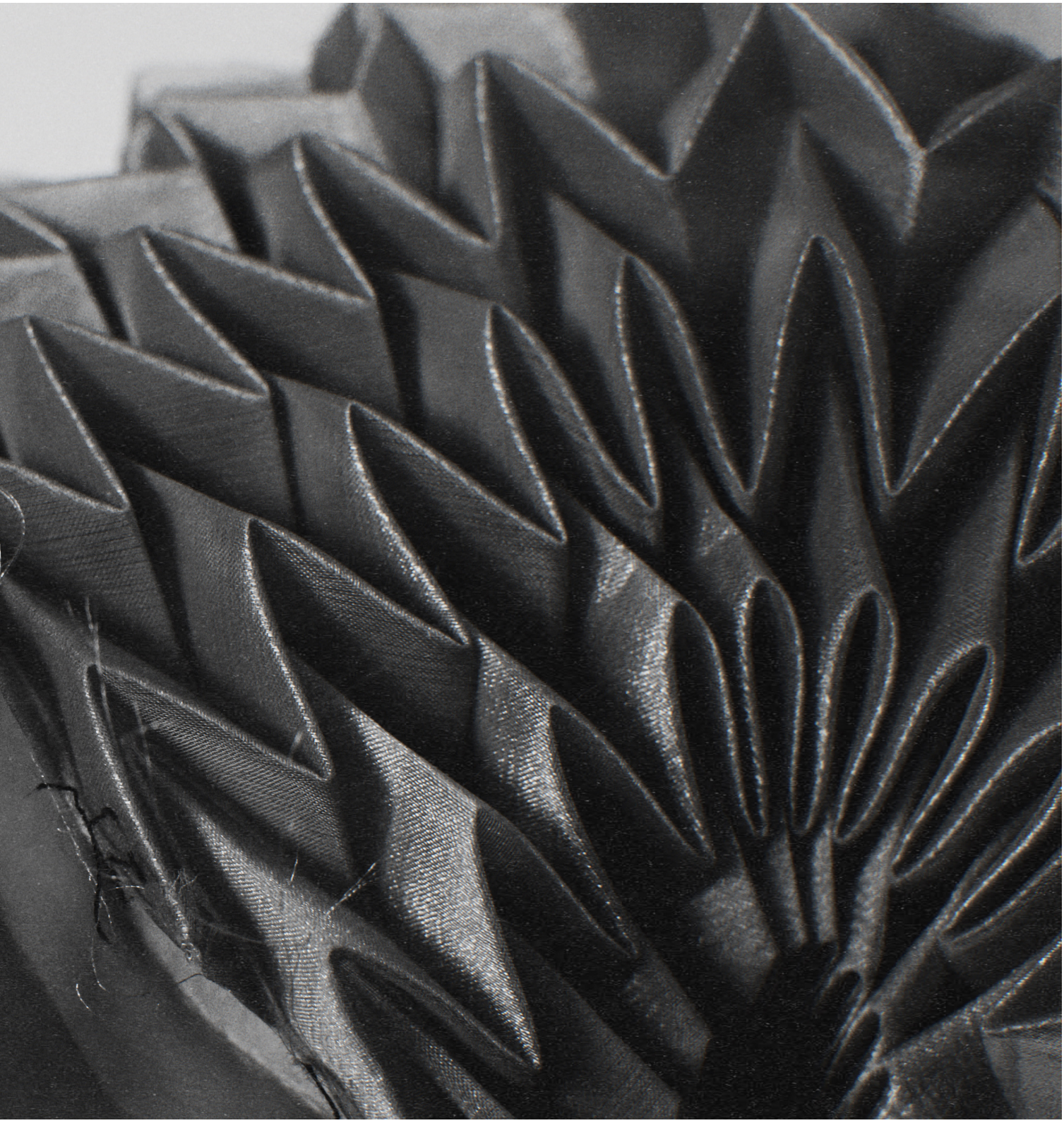




Fig 2.18 Pleated organza.



Part II outlined different layers of this research, introducing the methodology to analyze the geometrical behavior of the Miura-Ori pattern. The material study identified the selected materials and their relevance to this investigation, while the medium positioned the body as a dynamic site for this experimentation where clothing acts as an architectural form, defining space through its interaction with the body. Finally, the making process illustrated the fabrication techniques for translating digital patterns into physical prototypes. Together, these elements formed a cohesive framework for studying and applying folding as a strategy for adaptive and responsive design.

PART III | DESIGN EXPERIMENTATION

This section studies the Miura Ori pattern to demonstrate how it can be modified to enhance its formal adaptability and allow control over its structural behavior. The component study focuses on adjusting different features of individual folding units to test their flexibility, stability, and geometric behavior. The growth study examines the interaction and integration of components within irregular tessellations, analyzing how grid systems structure and regulate their variations. Together, these studies reveal the underlying principles that govern the geometrical behavior of patterns and establish a framework for encoding controlled behavior into tessellations.

Building upon Rachel Philpott's perspective on playful making in practice-led design research, this study integrates an approach where intuitive exploration and structured analysis coexist. Philpott discusses play as a generative design method, arguing that while playful experimentation may appear purposeless, it fosters unexpected discoveries by allowing materials and geometries to reveal new behaviors (Philpott 2013, 2). She suggests that play within a design process is not directionless but a mechanism for discovering unforeseen potentials (Philpott 2013, 3). By incorporating this notion into the study, various modifications to the Miura-Ori pattern are tested iteratively, with each variation revealing new insights into its folding behavior.

The investigation identifies key principles governing the tessellation's behavior through playful adjustments of variables such as fold lengths, node placements, and pleat introduction. These findings provide a broader framework for integrating folding strategies into various design applications.

III.I

COMPONENT STUDY

This section modifies individual folding units and tessellates them to examine how local adjustments influence the overall folded surface. Prototypes were fabricated to observe these changes in action and evaluate their impact on geometrical and structural performance.

SYMBOLS

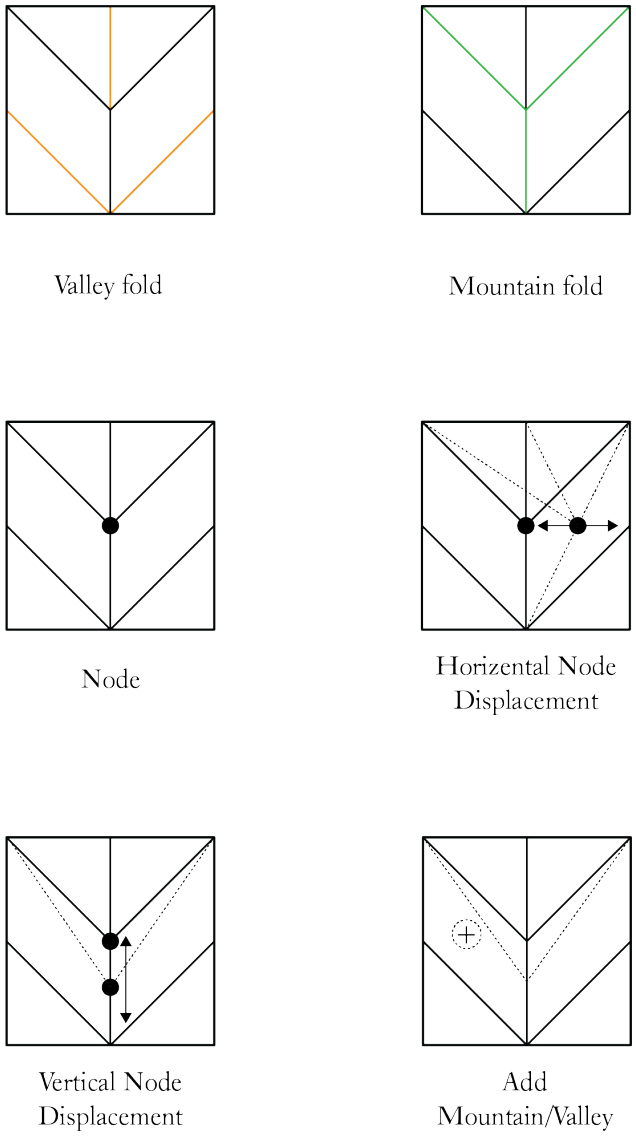


Fig 3.1 Symbols representing different features and functions.

TERMINOLOGY

Crease: A fold line that dictates how a surface bends, forming the fundamental structure of a folding pattern.

Mirror: A symmetry operation where a folding pattern or module is reflected across an axis to maintain structural consistency.

Gradient: A gradual transition in a parameter (such as fold angle, stiffness, or density) across the surface, enabling controlled variations in movement or responsiveness.

Grid: An underlying framework that organizes the placement of creases and nodes, governing the overall structure of the folding pattern.

Tessellation: A repeated geometric pattern of folding units that creates a continuous, structured surface, allowing for scalability and modularity.

Node: A key point in the folding system where multiple creases intersect, often acting as a control point for movement and transformation.

1.Mountain Node Displacement In -Y Axis

Feature modified : Mountain node
Axis of change : -Y
Flexibility : Consistent flexibility
Compactability : Fully compactable
Bending : Convext
Bending intensity : High

This iteration shifts the placement of the highlighted node in the component, progressively reducing the length of mountain folds while increasing the following valleys. As a result, when the component is tessellated and folded, the surface begins to exhibit curvature. This curvature results from the new correlation between shorter mountain folds and elongated valley folds, altering the equilibrium of the pattern. In the base component, mountains and valleys are equal, maintaining a balanced, planar state through the tessellated pattern. However, as this equilibrium is disrupted—shortening the mountains and extending the valleys—the surface deforms, introducing curvature.

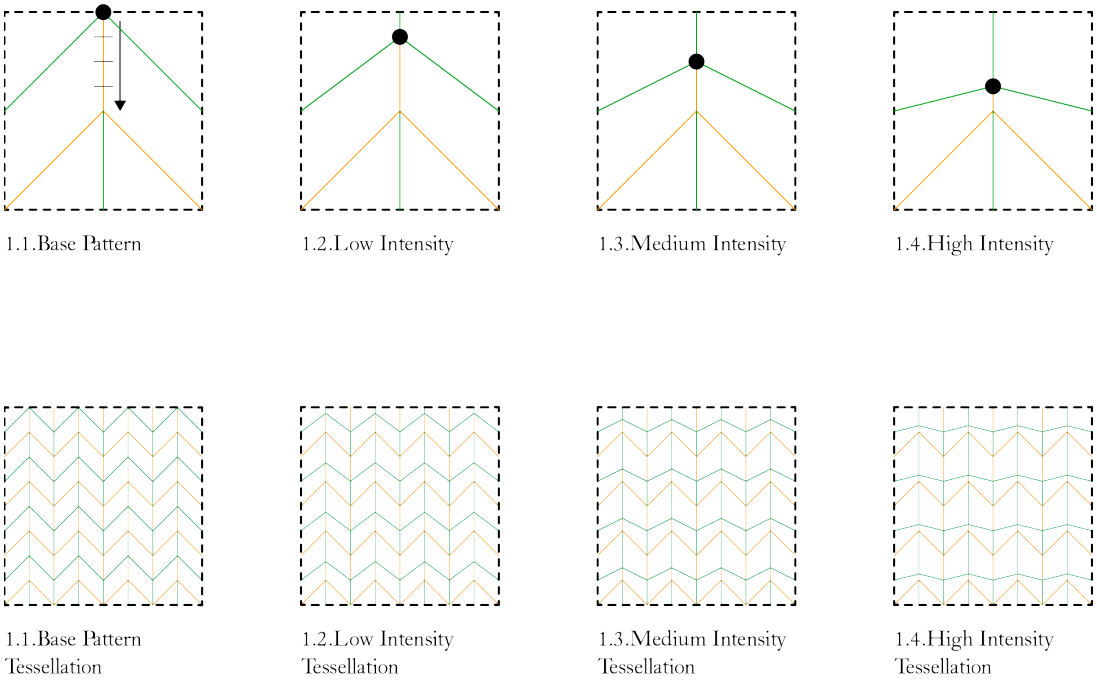
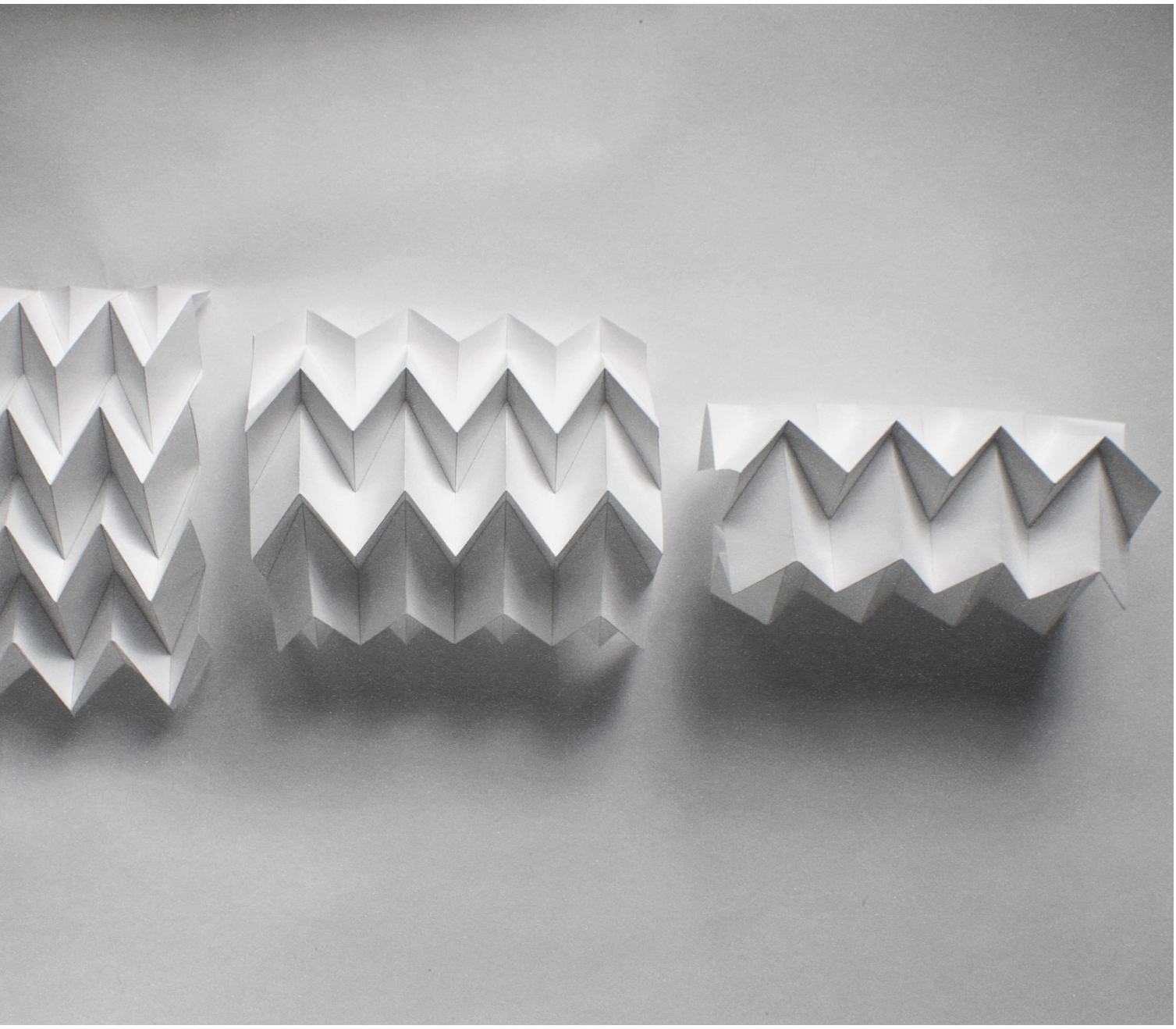


Fig 3.2 Sequential displacement of mountain node in -Y axis and their 4x4 tessellation.



Fig 3.3 Change in surface beh through sequential displaceme mountain node in -Y axis.

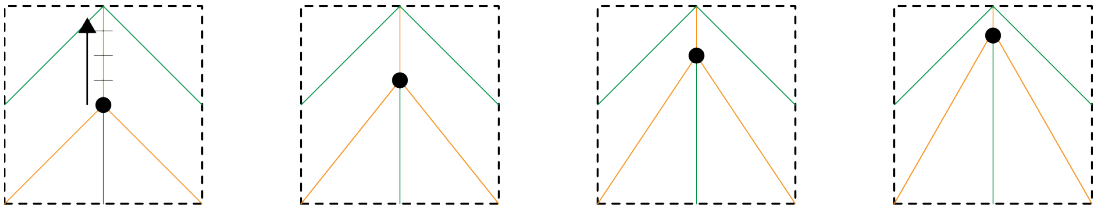


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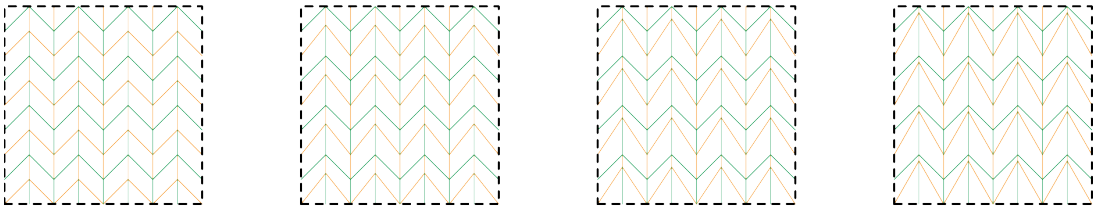
2.Valley Node Displacement in +Y Axis

Feature modified : Valley node
Axis of change : +Y
Flexibility : Consistent flexibility
Compactability : Fully compactable
Bending : Convext
Bending intensity : Low

By shifting the placement of the highlighted node closer to the following node, the valley reduces as the mountain increases, introducing curvature to the surface. The significance of this pattern is revealed when integrated with Component No.1. The key difference between this component and Component No.1 lies in the direction of curvature. While Component No.1 bends the surface inward, creating a concave effect, this component bends it outward, producing a convex curvature.



3.1.Base Pattern | 3.2.Low Intensity | 3.3.Medium Intensity | 3.4.High Intensity

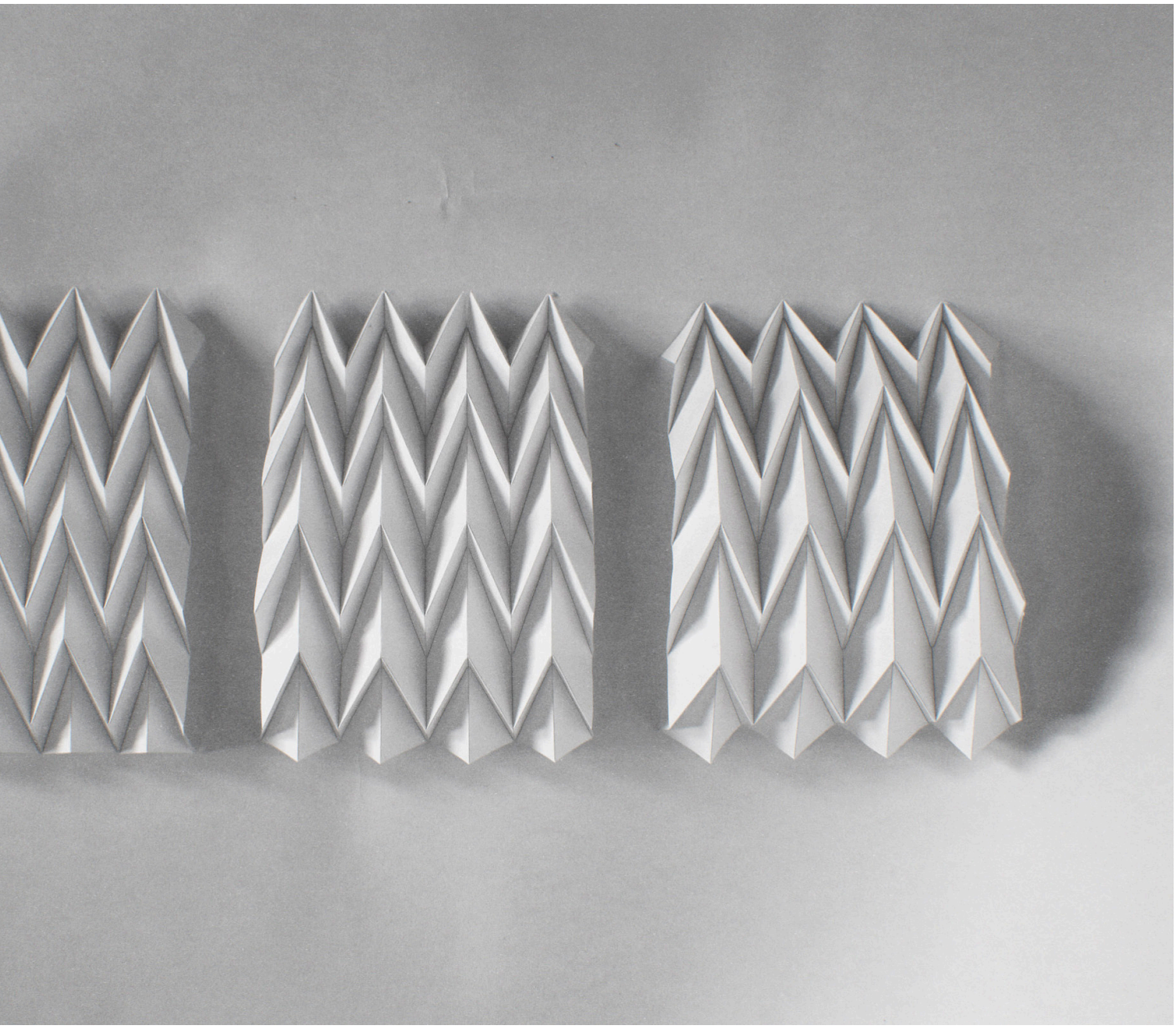


3.1.Base Pattern Tessellation | 3.2.Low Intensity Tessellation | 3.3.Medium Intensity Tessellation | 3.4.High Intensity Tessellation

Fig 3.4 Sequential displacement of valley node in +Y axis and their 4x4 tessellation.



Fig 3.5 Change in surface beh through sequential displaceme valley node in +Y axis.



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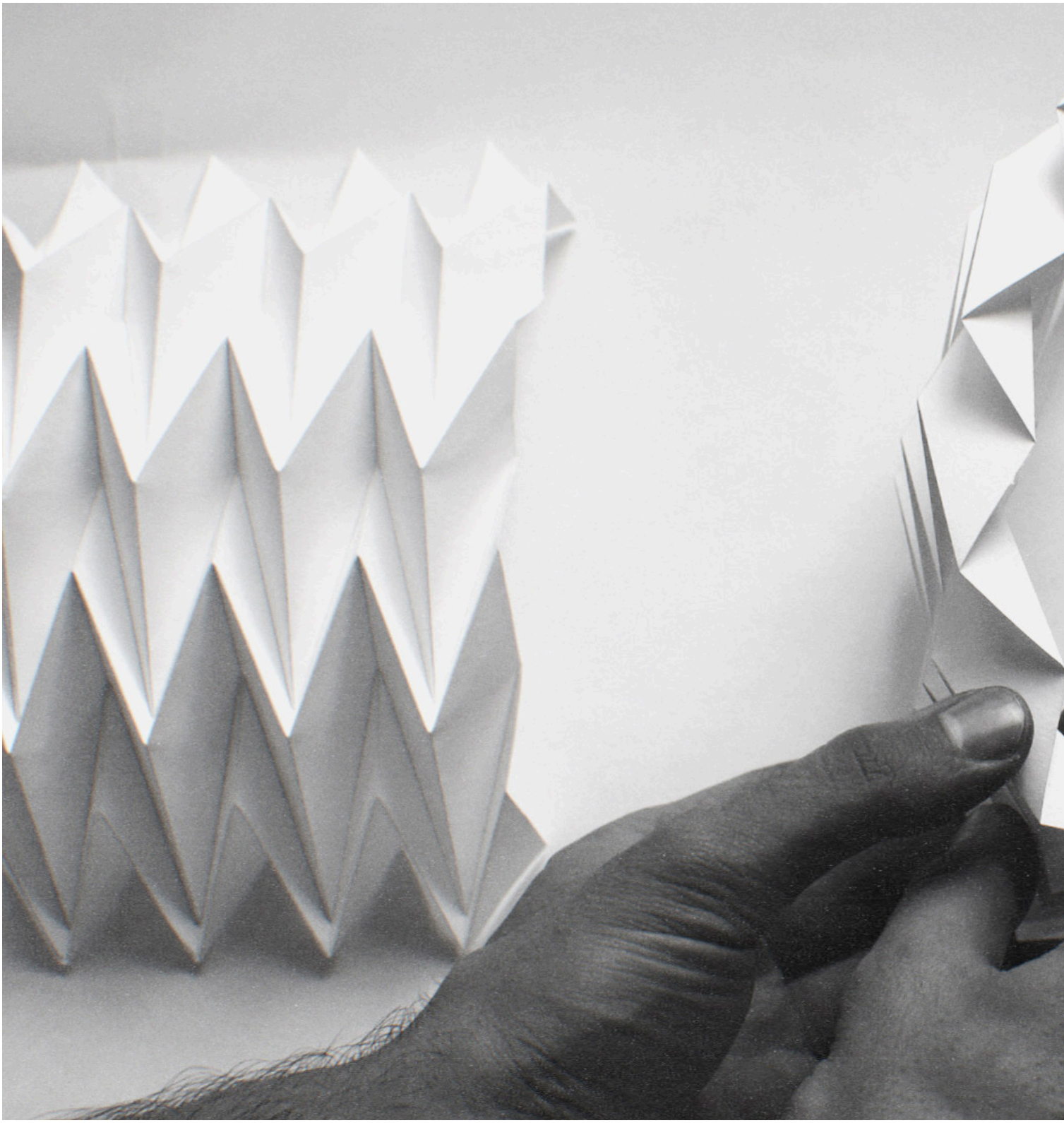
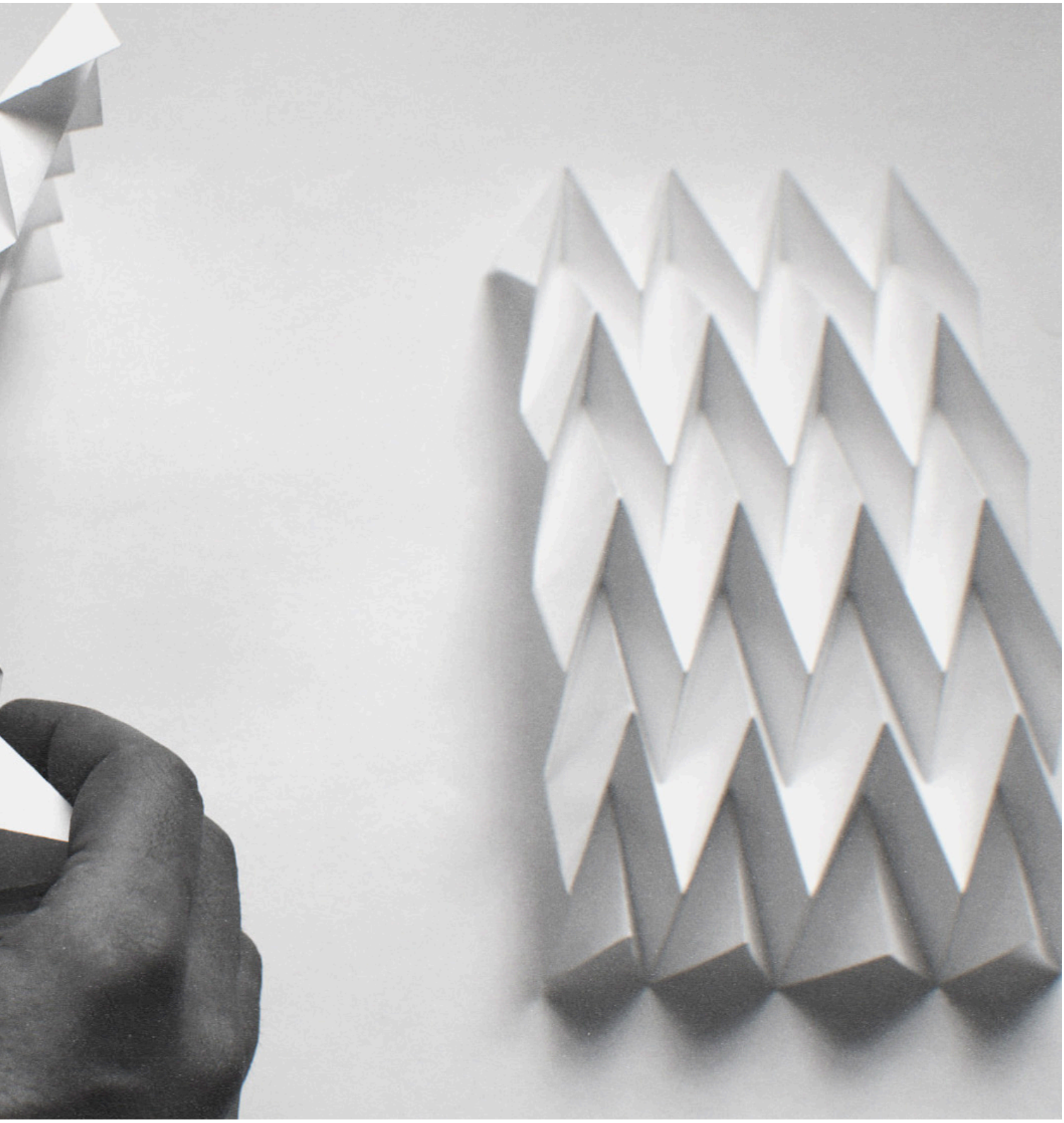


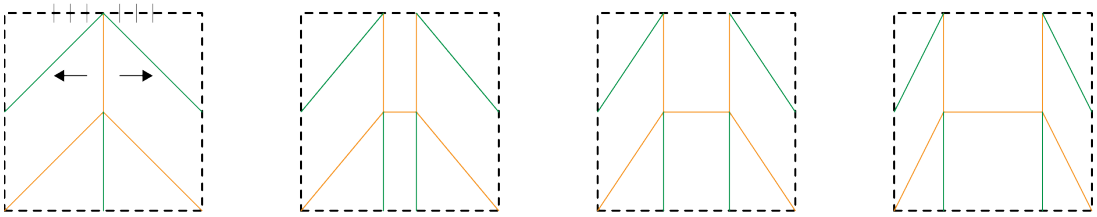
Fig 3.6 Folded surface bending through the displacement of valley node in +Y axis.



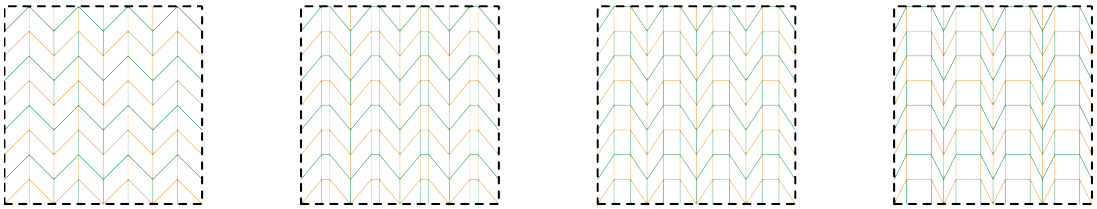
3.Centerline Offset in X Axis

Feature modified : Centerline
Axis of change : +-X
Flexibility : Consistent flexibility
Compactability : Partially compactable
Bending : None
Bending intensity : N.A

The centerline offset introduces space pockets between V-pleats when folded. While the overall component size remains unchanged, this effect simultaneously reduces the size of the V-pleats and decreases the angle between them. As a result, the space pockets progressively enlarge, while the surface's deployability decreases. The original component can fold into a fully flat state, whereas the modified version cannot. This modification indirectly reveals V-pleats' potential to control the spacing between a series of panels, lines or points, with the pleats acting as a homogenizing mechanism that maintains uniform separation.



4.1.Base Pattern | 4.2.Low Intensity | 4.3.Medium Intensity | 4.4.High Intensity



4.1.Base Pattern Tessellation | 4.2.Low Intensity Tessellation | 4.3.Medium Intensity Tessellation | 4.4.High Intensity Tessellation

Fig 3.7 Sequential centerline offset and their 4x4 tessellation.

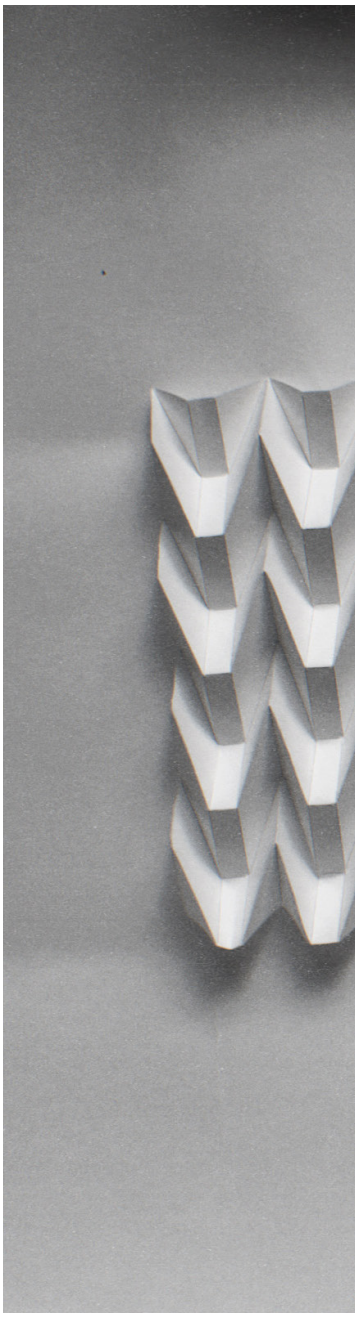
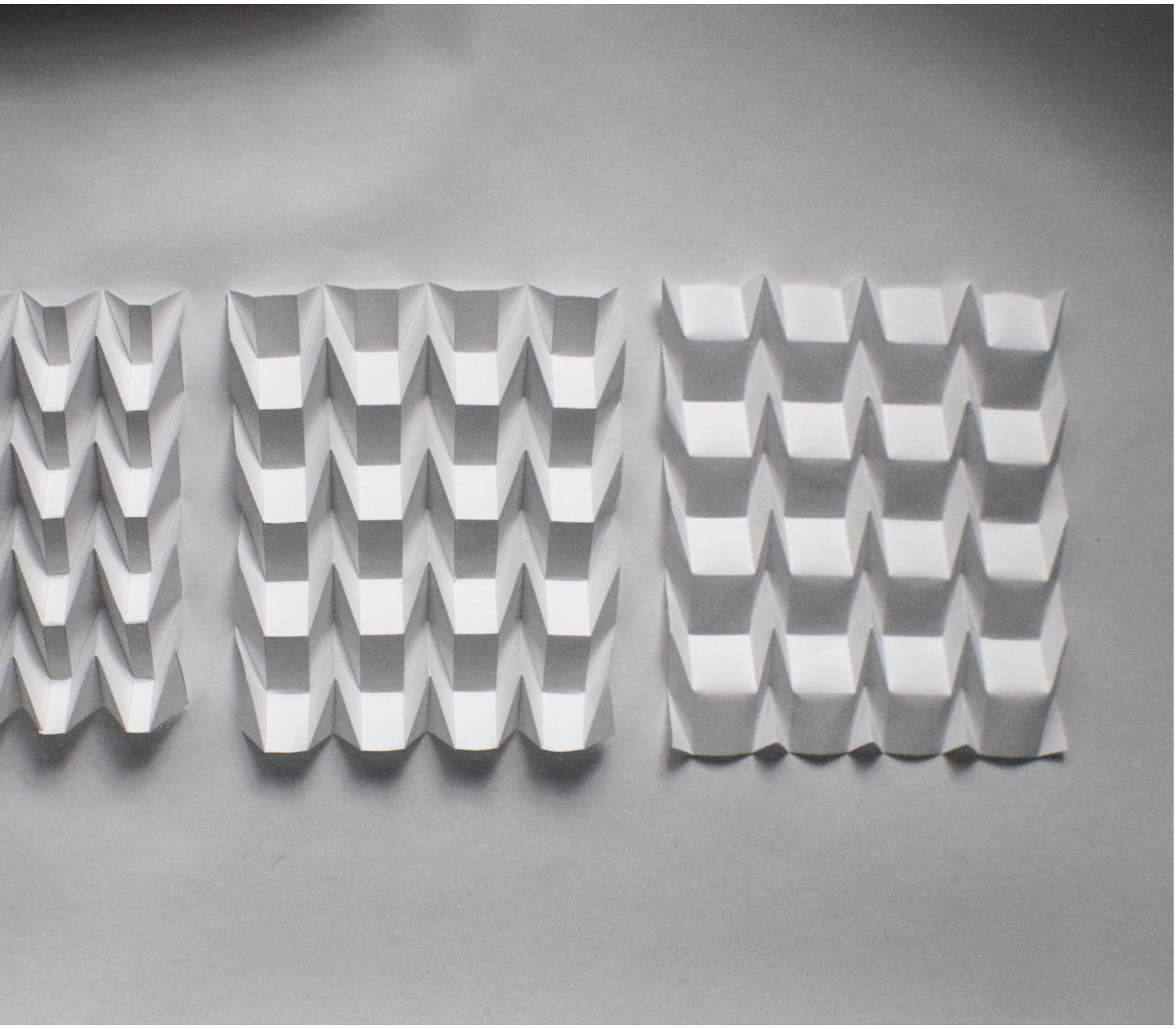


Fig 3.8 Change in surface beh through progressive offset of c in X axis



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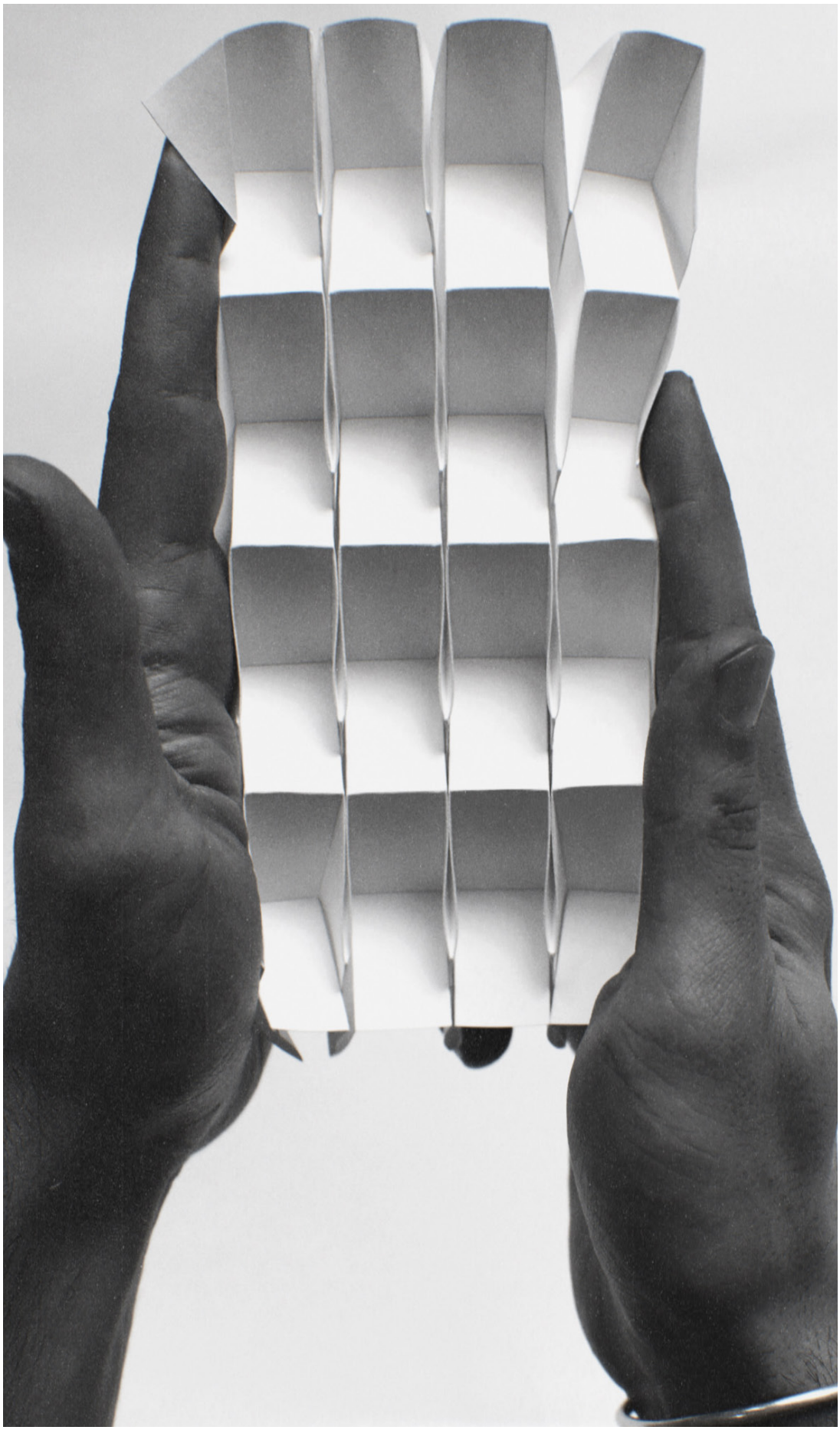


Fig 3.9
Compaction of space pockets through v-pleats between them in a tessellation.

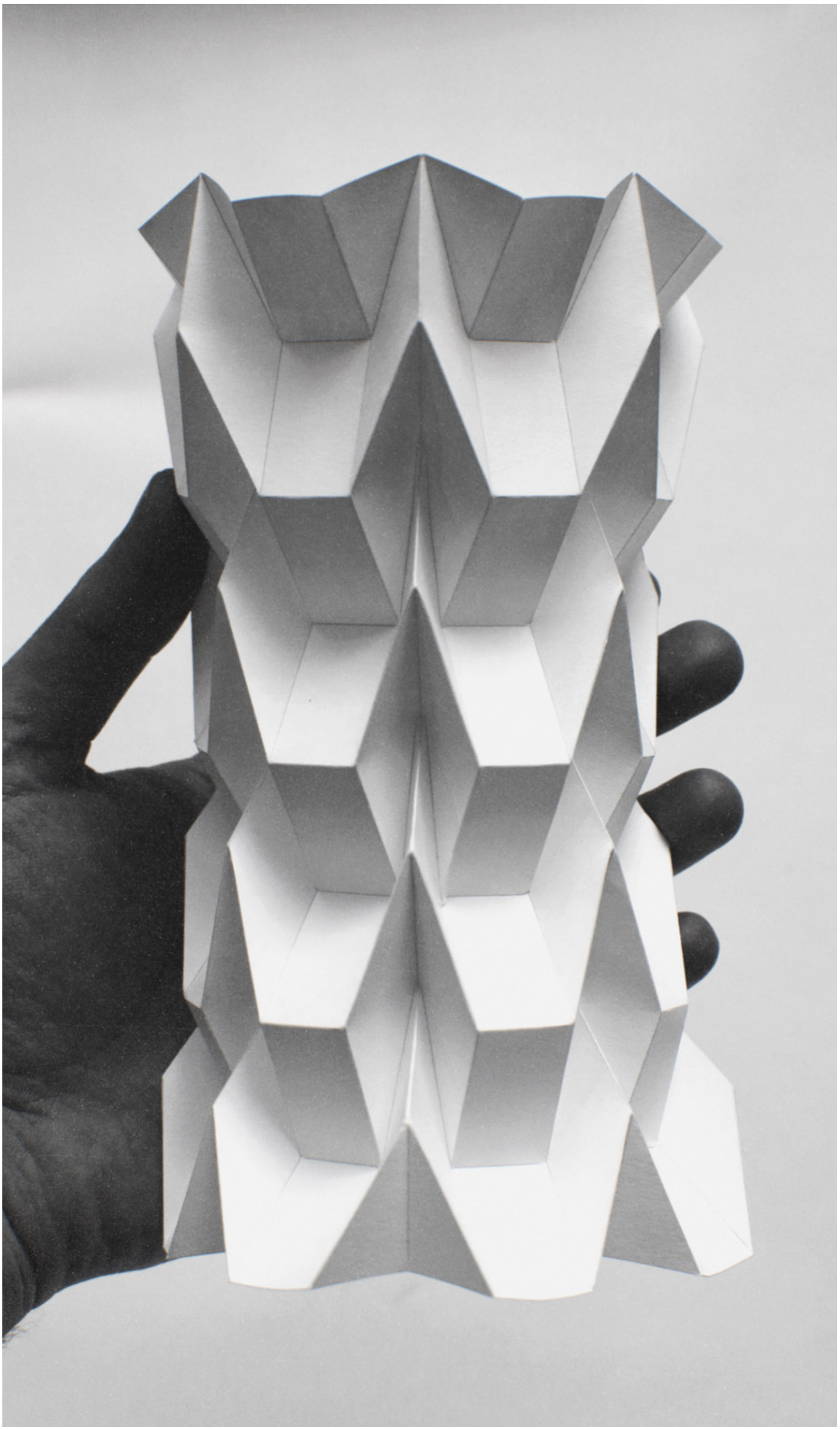
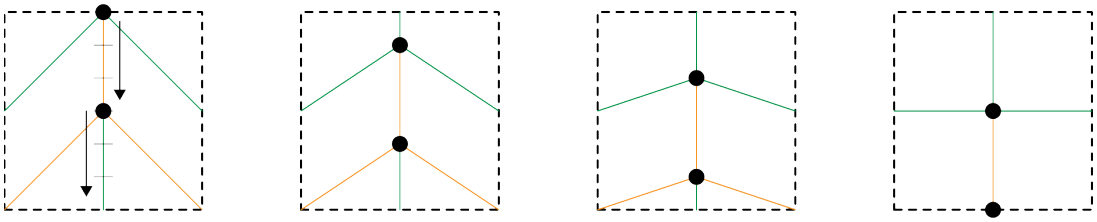


Fig 3.10 Formal flexibility of the modified pattern.

4.Mountain and Valley Node Displacement In -Y Axis

Feature modified : Mountain & valley node
Axis of change : -Y
Flexibility : Consistent flexibility
Compactability : Fully compactable
Bending : None
Bending intensity : N.A

The simultaneous downward displacement of both nodes, progressively increasing the x-angle, directly influenced the pattern's packaging feature, with the third iteration exhibiting a dramatic surface compaction. Additionally, this displacement alters the width of each panel, further impacting the overall structural behavior. This effect can be strategically utilized in scenarios where the final size of the compacted surface is a critical factor.



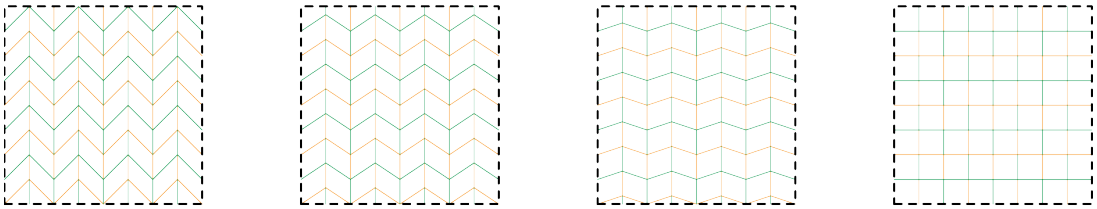
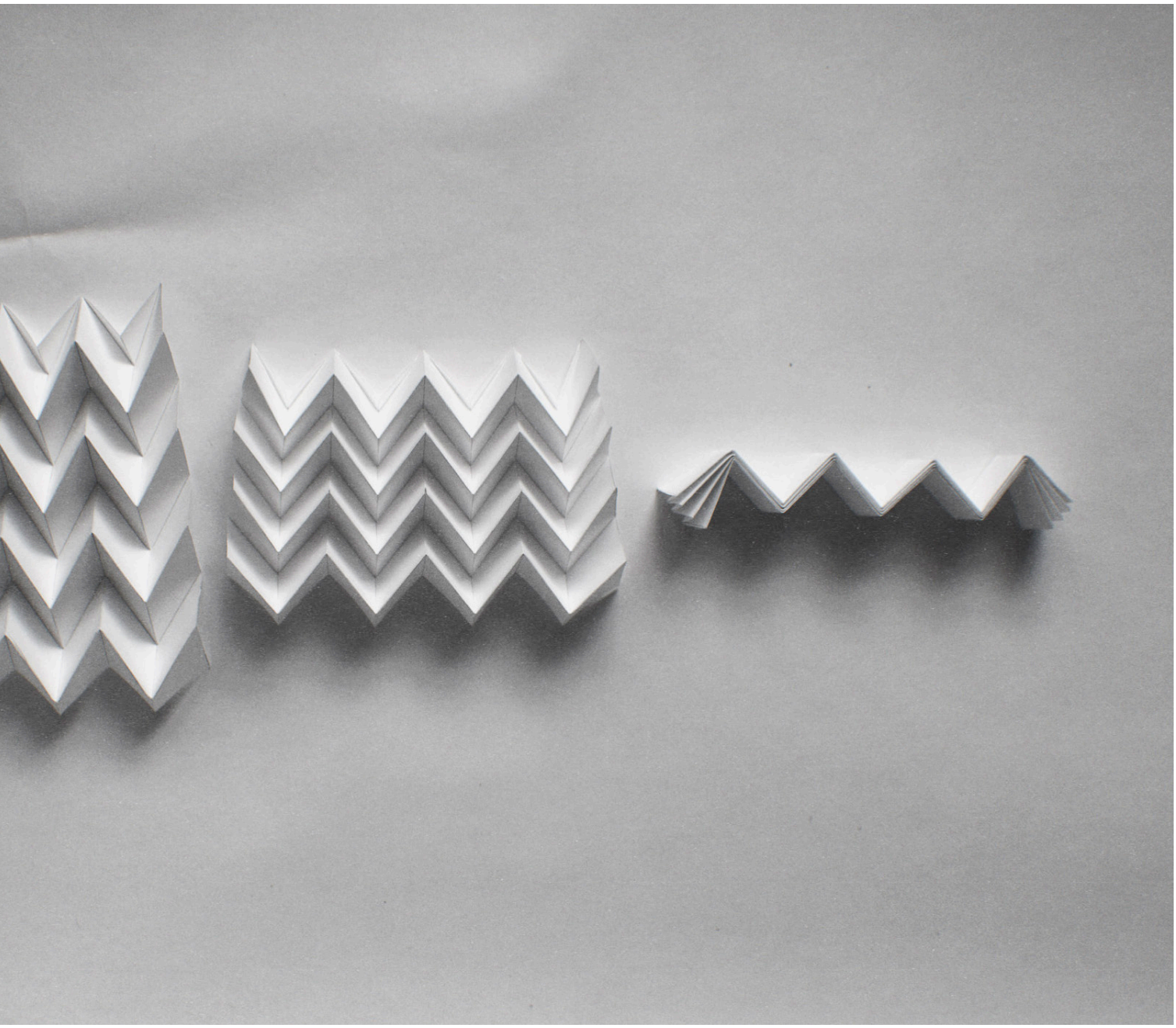


Fig 3.11 Sequential displacement of mountain and valley node in -Y axis and their 4x4 tessellation.



Fig 3.12 Change in surface be through progressive mountain valley node displacement in -Y

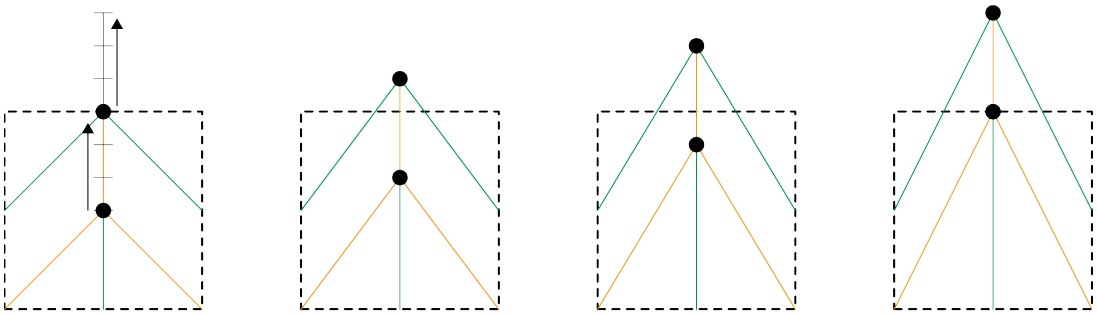


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5.Mountain and Valley Node Displacement In +Y Axis

Feature modified : Mountain & valley node
Axis of change : +Y
Flexibility : Consistent flexibility
Compactability : Fully compactable
Bending : None
Bending intensity : N.A

The simultaneous upward displacement of both nodes progressively reduces the x-angle and expands mountains beyond the component's original boundaries. This extension increases the length of each mountain and valley fold. Given that structural changes in a surface primarily occur through modifications in its mountains and valleys, and the surface remains relatively straight along them, the transformation rate is dictated by component length. When the mountains and valleys are elongated, changes propagate more gradually across the surface. On the other hand, shorter folds result in more frequent transformations, as deformations occur at a higher rate. This relationship suggests that adjusting tessellation parameters can serve as a mechanism to control the periodicity of change through a tesselation.



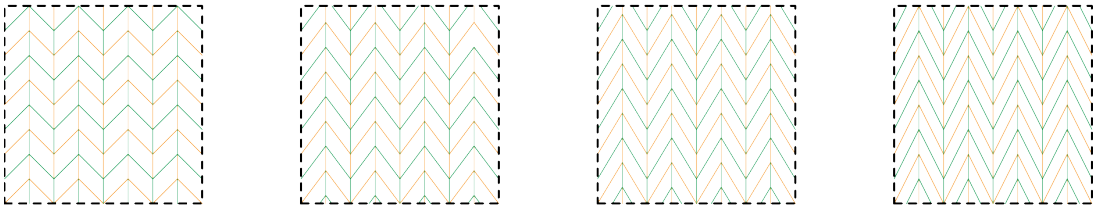
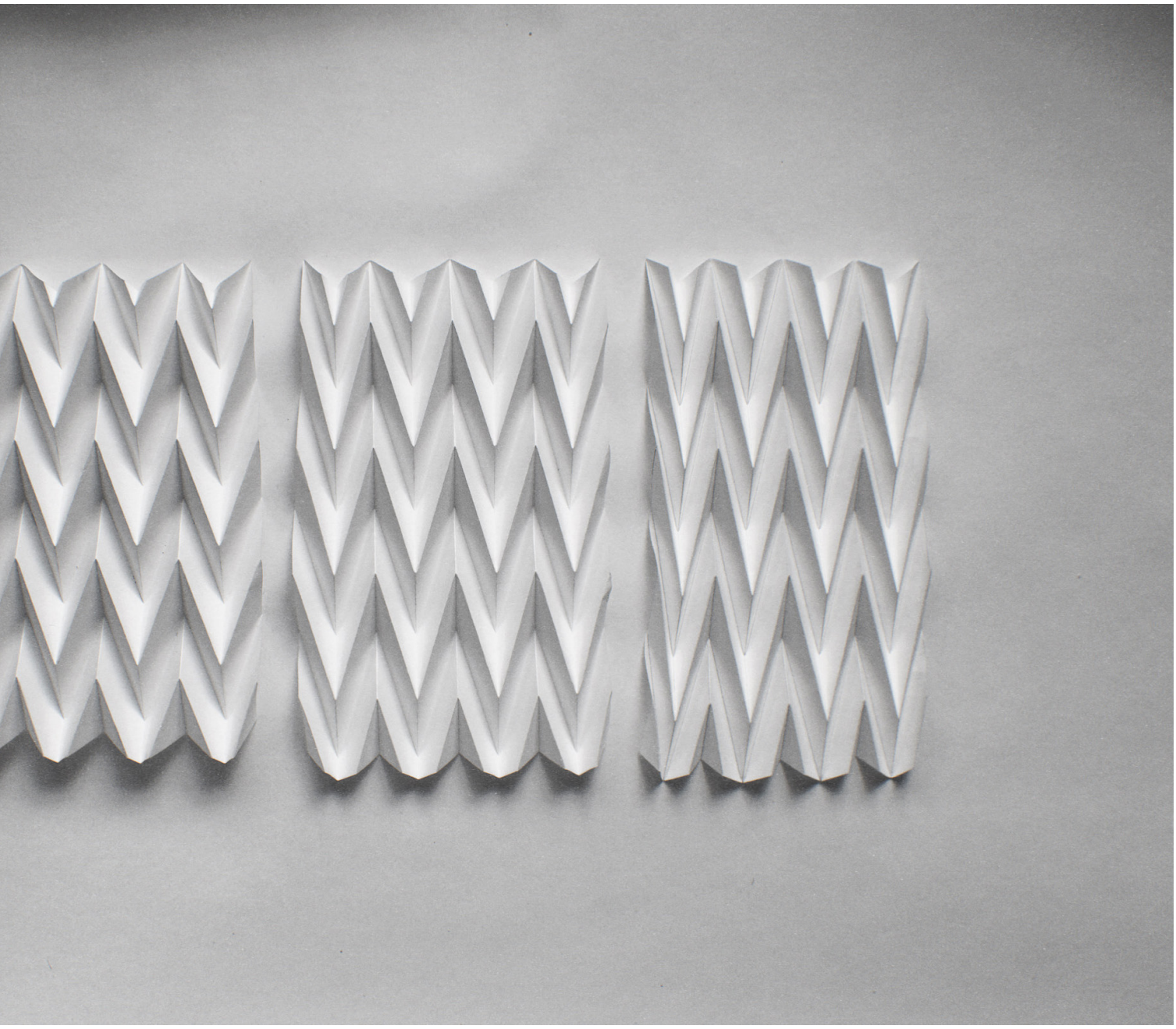


Fig 3.13 Sequential displacement of valley node in +Y axis and their 4x4 tessellation.



Fig 3.14 Change in surface be through progressive mountain valley node displacement in +

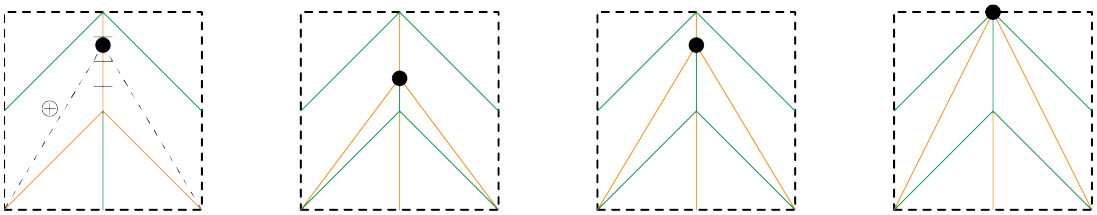


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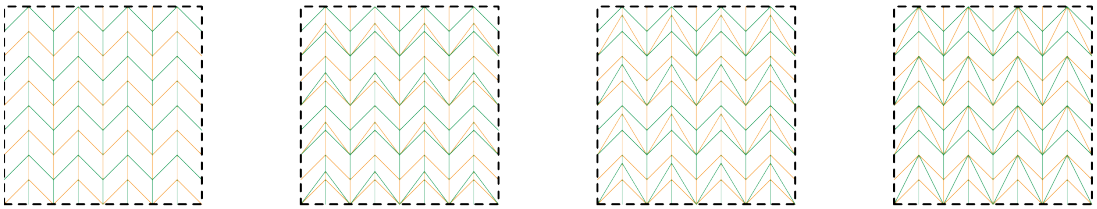
6.Introduction of a new V-pleat and Node Displacement in +Y

Feature modified : Mountain/valley & node
Axis of change : +Y
Flexibility : Consistent flexibility
Compactability : Fully compactable
Bending : Convext & Concave
Bending intensity : High

This iteration combines two effects: introducing a new mountain or valley while progressively shifting its node along the centerline of the component. Considering the foundational rule that a mountain always follows a valley, the introduced pleat requires a change in the nature of either the mountain or the valley in the initial component. Since the new component begins and ends with either two mountains or two valleys, this necessitates a periodic shift in the arrangement of mountains and valleys in every row of the tessellation. Such a modification in pleat structure can be useful in instances where a shift in surface behavior is required. For example, when a surface is experiencing concave curvature and an instant switch to convex curvature is needed, reversing the pleats—where mountains become valleys and valleys become mountains—induces the opposite behavior in the surface.



7.1.Base Pattern | 7.2.Low Intensity | 7.3.Medium Intensity | 7.4.High Intensity

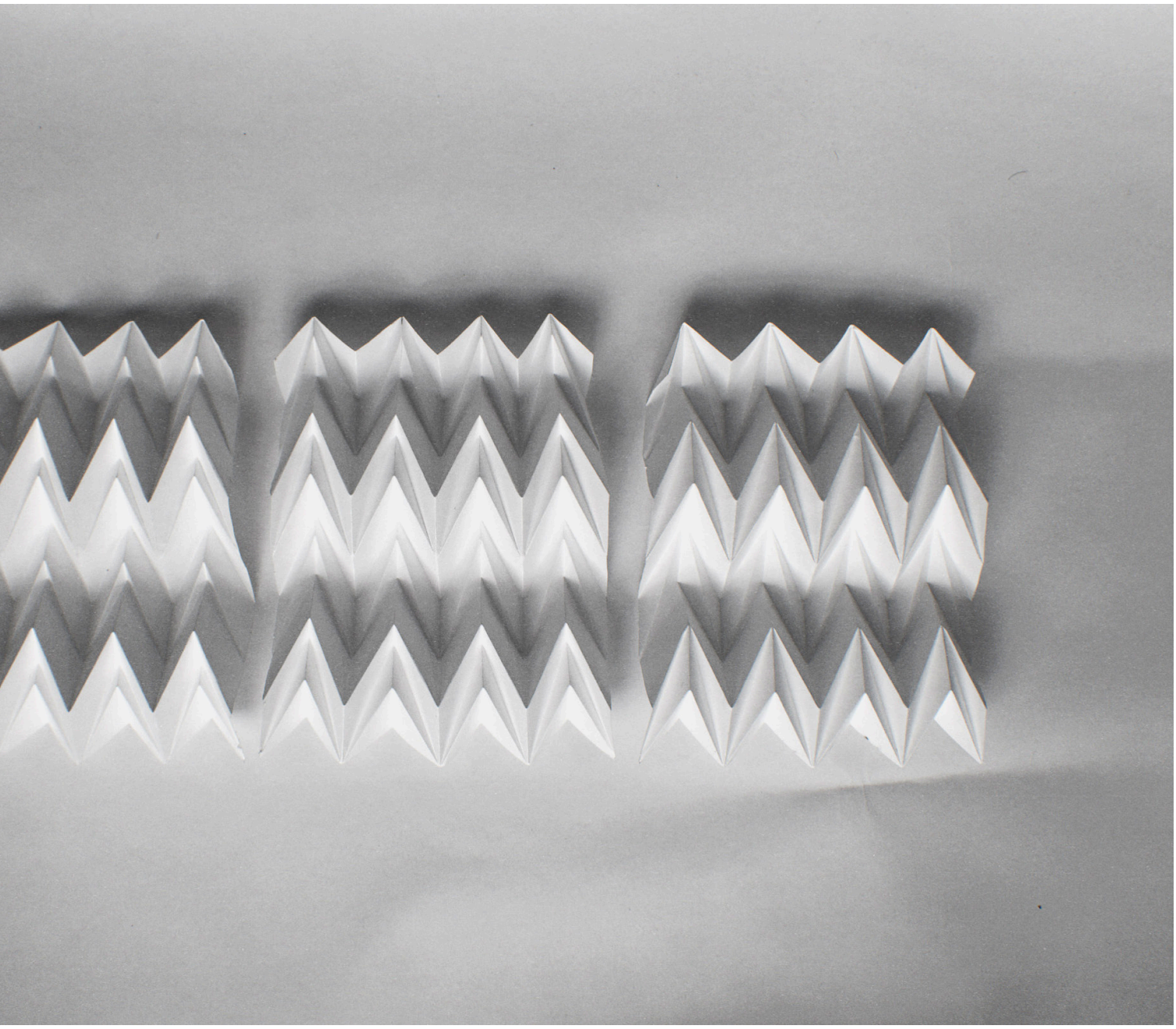


7.1.Base Pattern Tessellation | 7.2.Low Intensity Tessellation | 7.3.Medium Intensity Tessellation | 7.4.High Intensity Tessellation

Fig 3.15 Introduction of new v-pleat and sequential displacement of mountain/valley node in +Y axis, along their 4x4 tessellation.



Fig 3.16 Change in surface be by introducing a new pleat an displacement.



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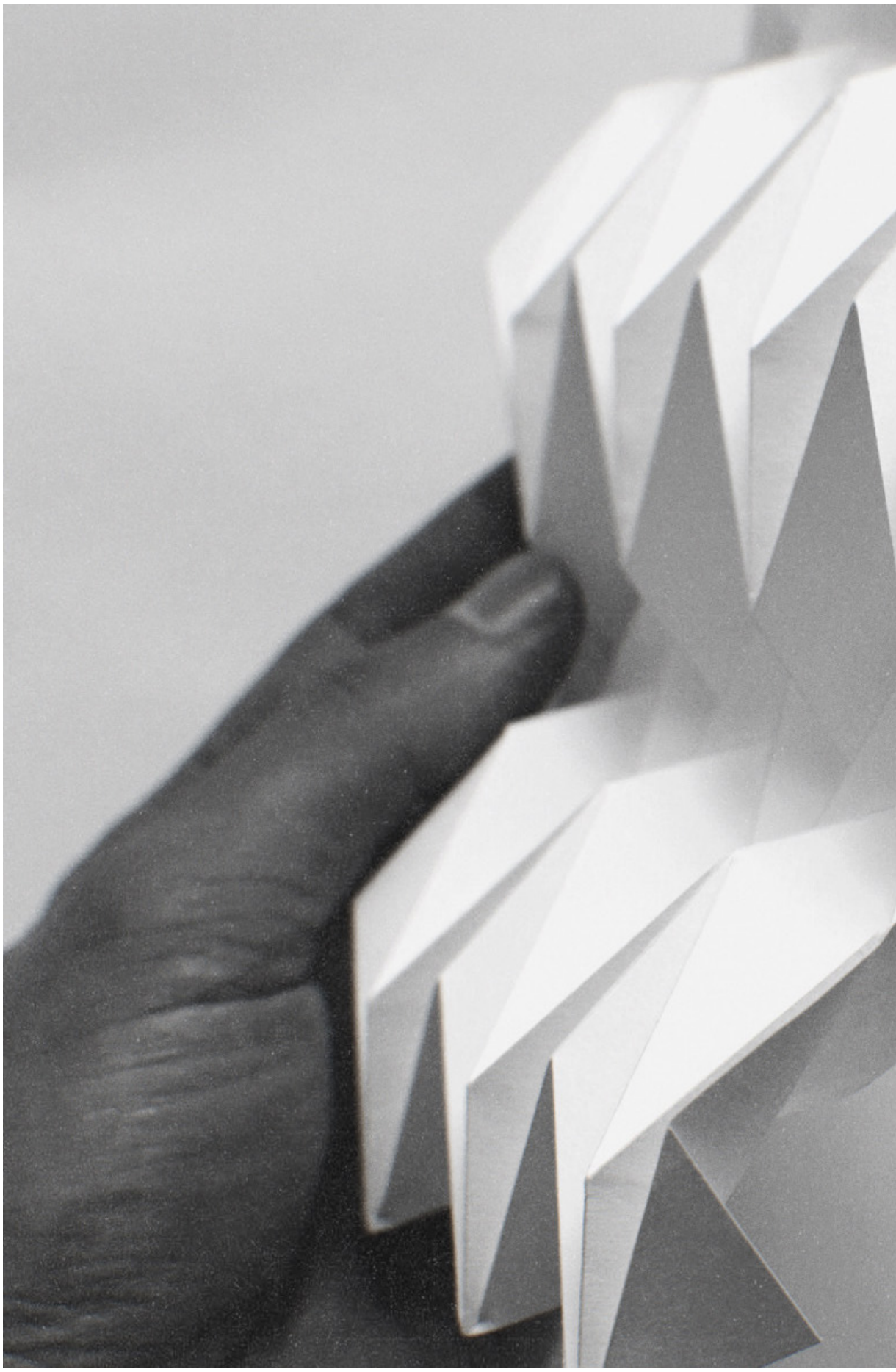


Fig 3.17 Periodic change in convex and concave bending.



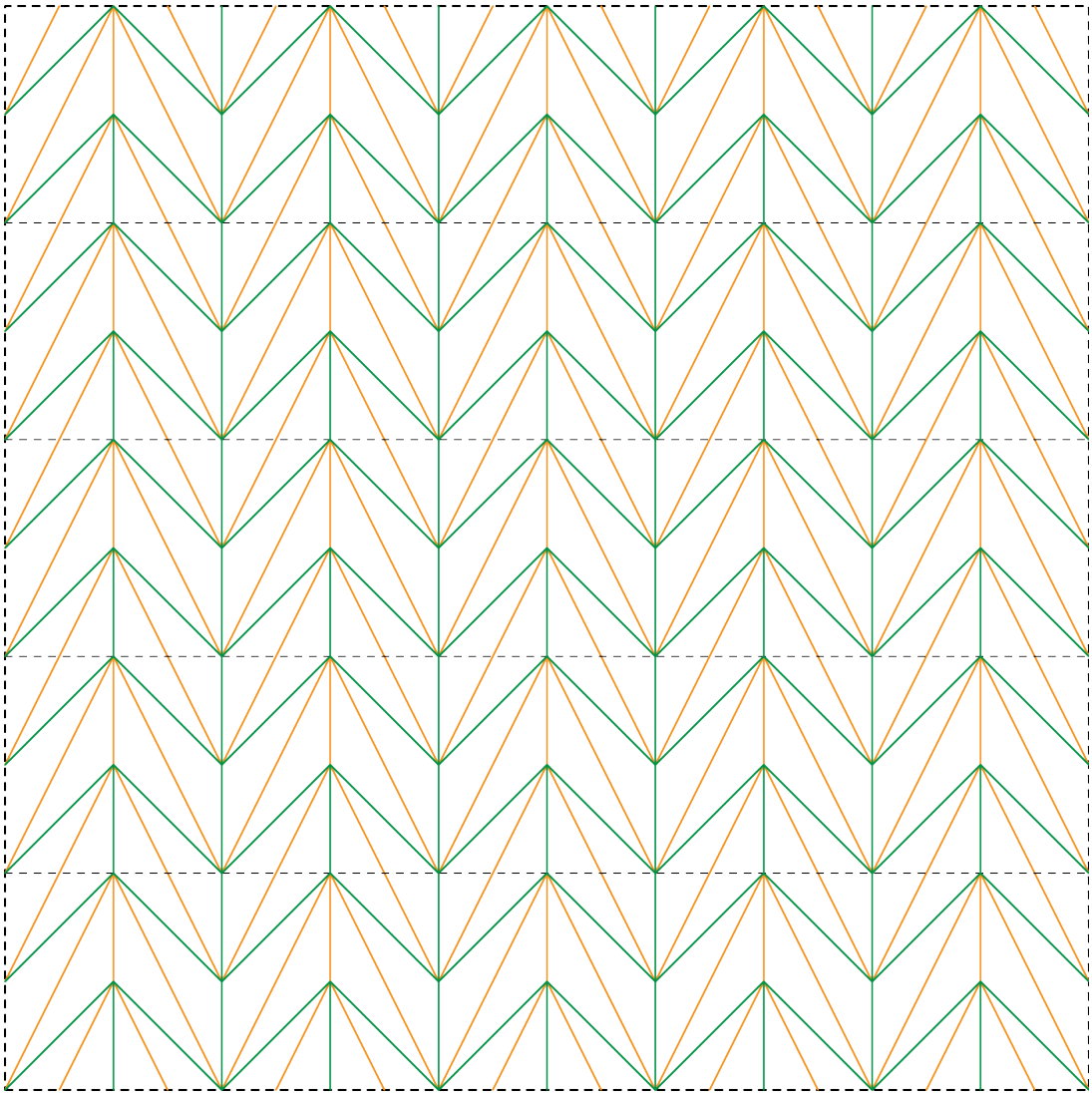


Fig 3.18 Introduction of new pleat in between every mountain and valley.

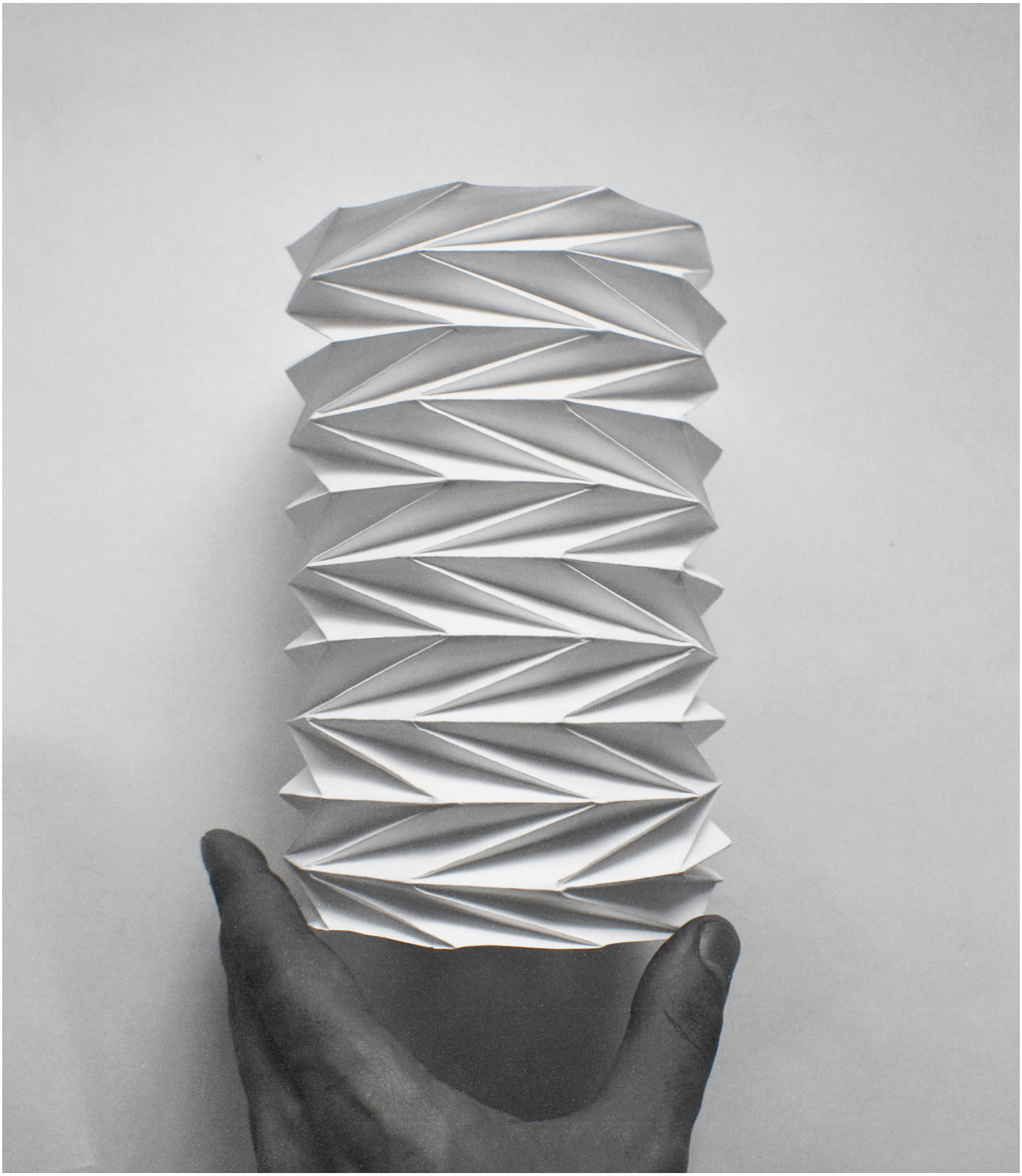
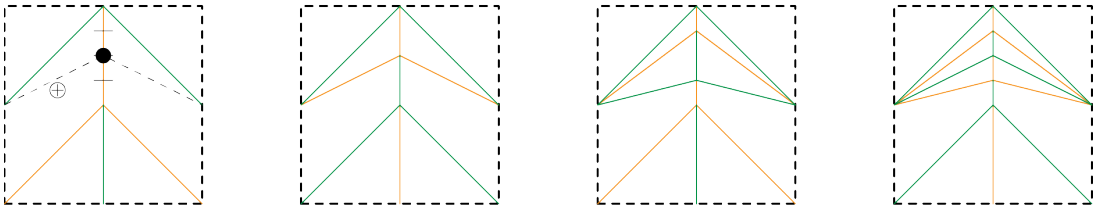


Fig. 3.19 Folded tessellation transforming the surface into cylindrical geometry.

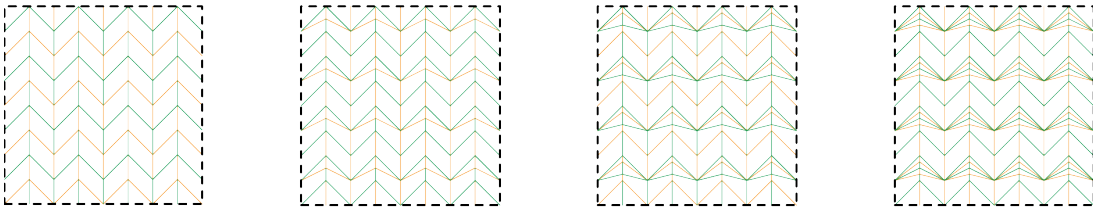
7.Pleat introduction

Feature modified : Mountain/valley
Axis of change : N.A
Flexibility : Consistent flexibility
Compactability : Fully compactable
Bending : Convext/Concave
Bending intensity : Medium

This iteration progressively introduces new pleats, altering the nature of the existing pleats each time a new pleat is added. The addition of a single pleat changes the assigned folding direction of the existing pleats, as a mountain must always follow a valley. However, adding two pleats allows the component to maintain its previously assigned folding direction. The introduction of new pleats results in surface curvature due to the corresponding changes in the length of centerline mountains and valleys. Surface curvature occurs where these lengths are unequal along the centerline.



8.1.Base Pattern | 8.2. One Additional Crease | 8.3.Two Additional Creases | 8.4.Three Additional Creases

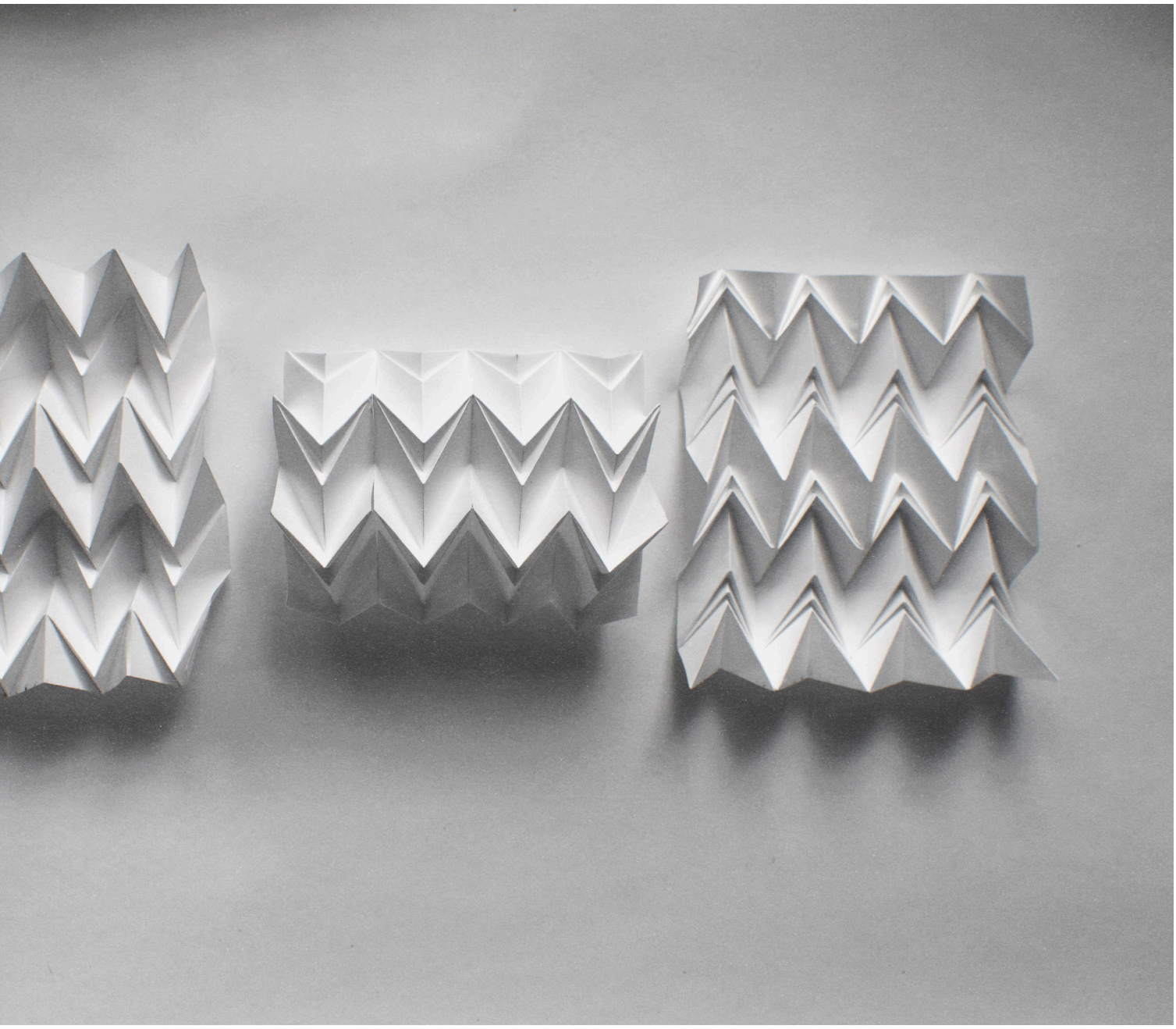


8.1.Base Pattern Tessellation | 8.2. One Additional Crease Tessellation | 8.3. Two Additional Creases Tessellation | 8.4.Three Addtional Creases Tessellation

Fig. 3.20. Sequential introduction of new pleats and their 4x4 tessellation.



Fig 3.21 Folded tessellations p geometry.



progressively transforming the surface into cylindrical

8.Valley Displacement In -X Axis

Feature modified : Valley node
Axis of change : -X
Flexibility : Low flexibility
Compactability : Flat compactability
Bending : None
Bending intensity : N.A

This iteration shifts the entire valley pleat, enabling flat foldability in the tessellation—a new characteristic with potential applications in packaging and deployment. However, folding it within a large tessellation can be challenging, as every single crease must fold simultaneously for it to achieve a fully flat state.

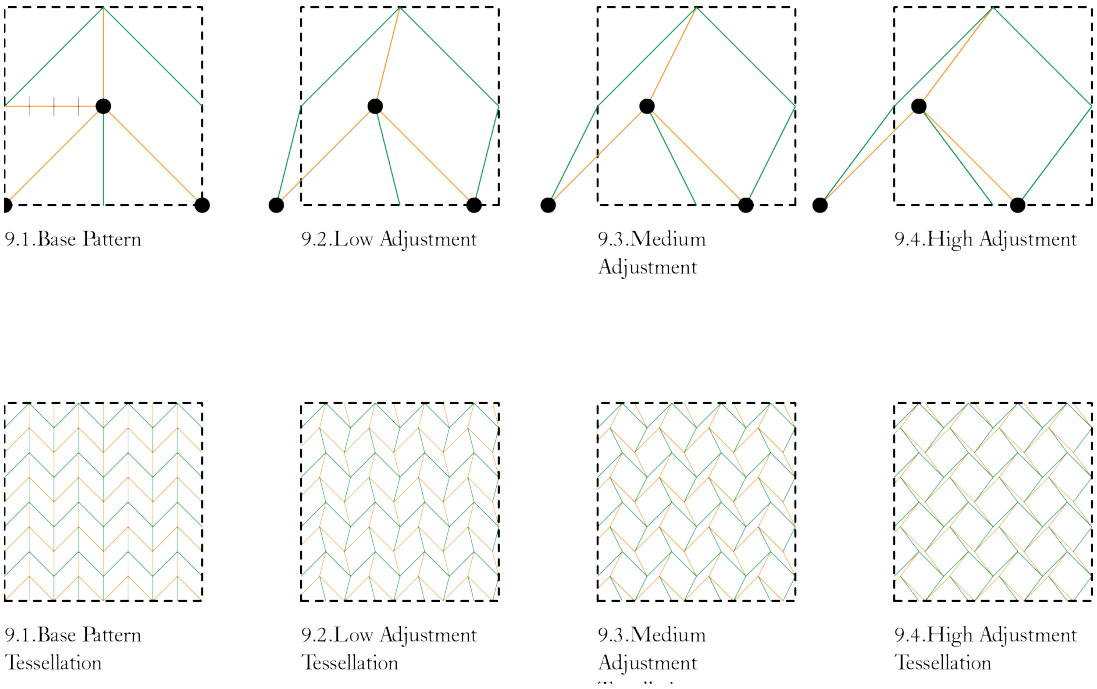
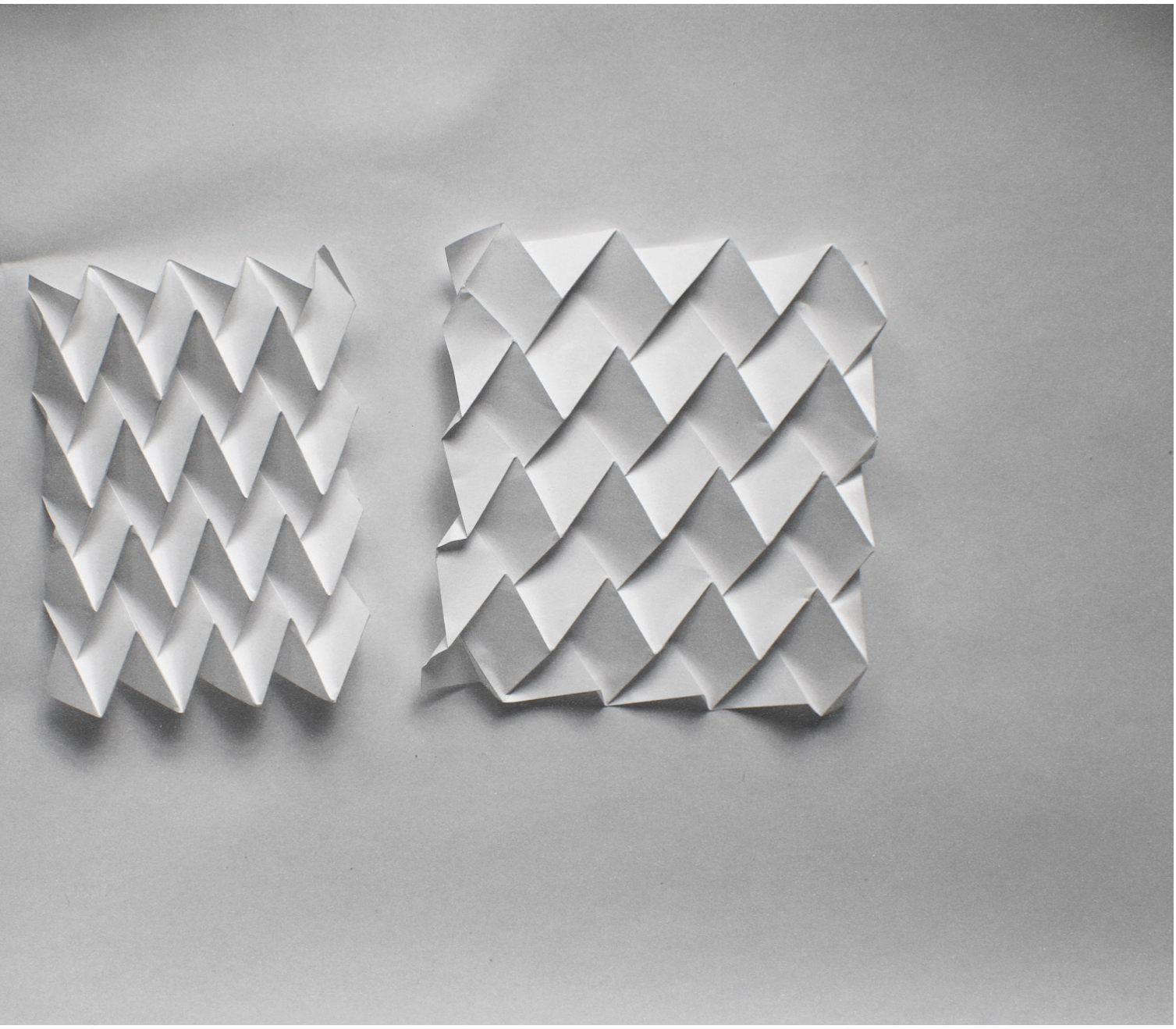


Fig 3.22 Sequential displacement of valley node in -X axis and their 4x4 tessellations.



Fig 3.23 Flat foldability of the axis.



e tessellation through the displacement of valley node in -X

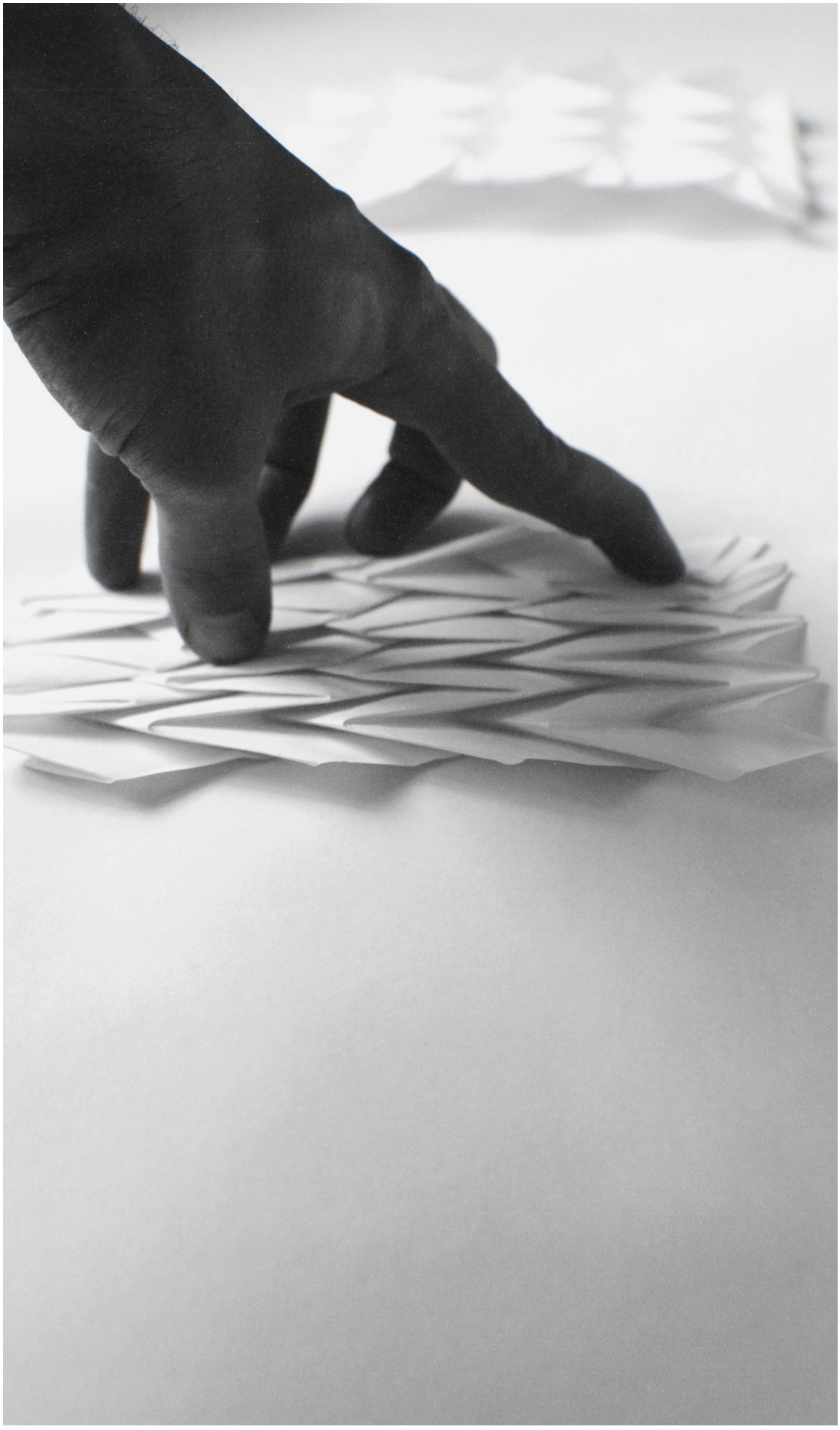


Fig 3.24 Surface folding flat.

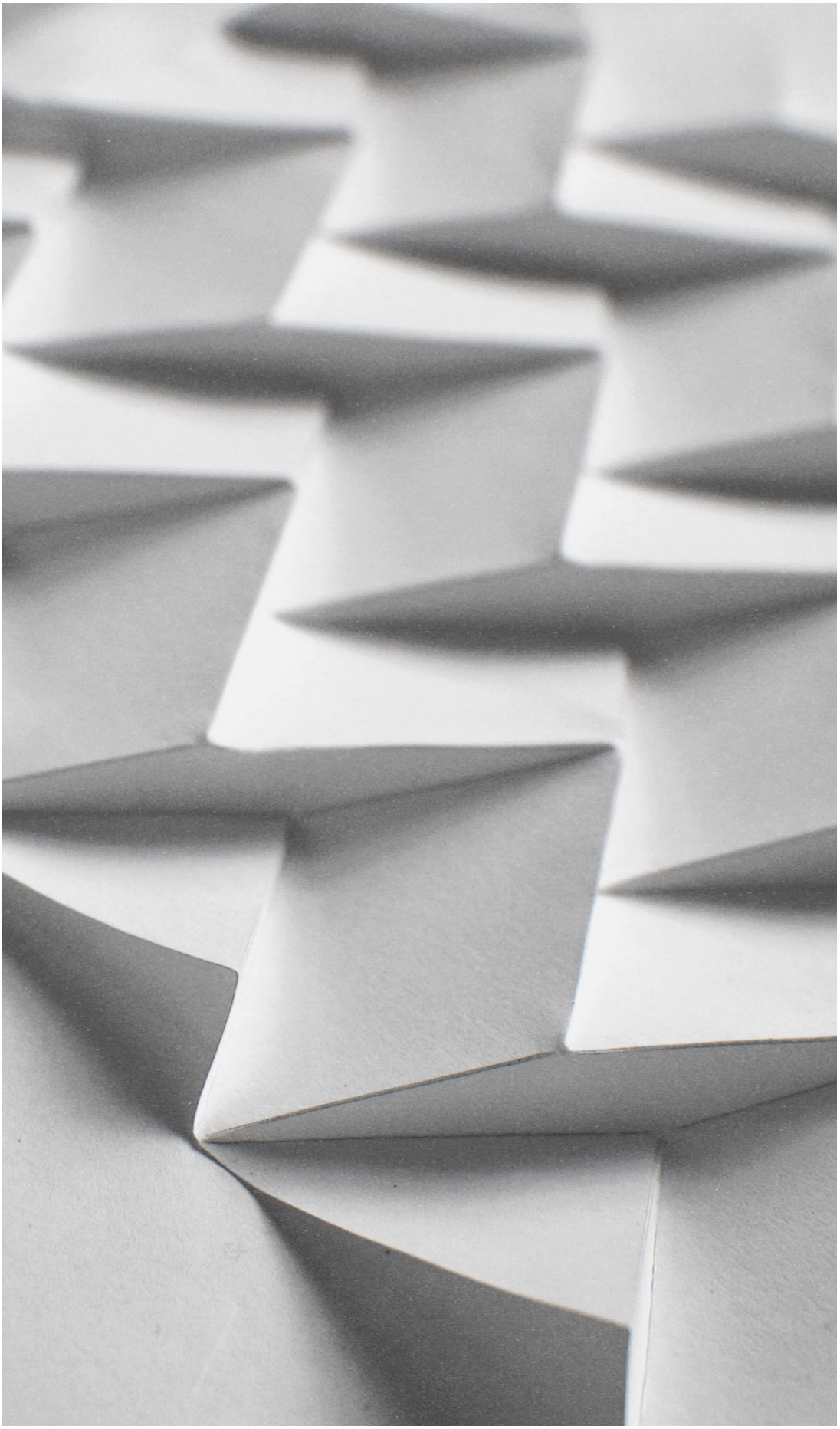


Fig 3.25 Details of flat foldable tessellation.

III.II

GROWTH STUDY

This section introduces different modes of tessellation, emphasizing the role of grids in guiding component variations within a tessellated surface. A grid can take multiple forms: it may be constructed from perpendicular lines (Jackson 2019, 29), forming square or rectangular patterns, or it may adopt diagonal and circular configurations. For instance, a diagonal grid emerges from sequentially rotating diagonal lines, which can then be subdivided and connected through polylines.

By understanding grid systems as frameworks for surface division—where each grid cell serves as a placeholder for a single component—any surface can be tessellated using diverse components. This framework is central in the development of the wearable surface, where grids initially function as guiding structures for generating complex and irregular tessellations. Additionally, this section introduces effects such as the gradient effect, in which transformations within the grid occur gradually and progressively. This approach enables smooth transitions within the system, creating a dynamic interplay between order and variation.

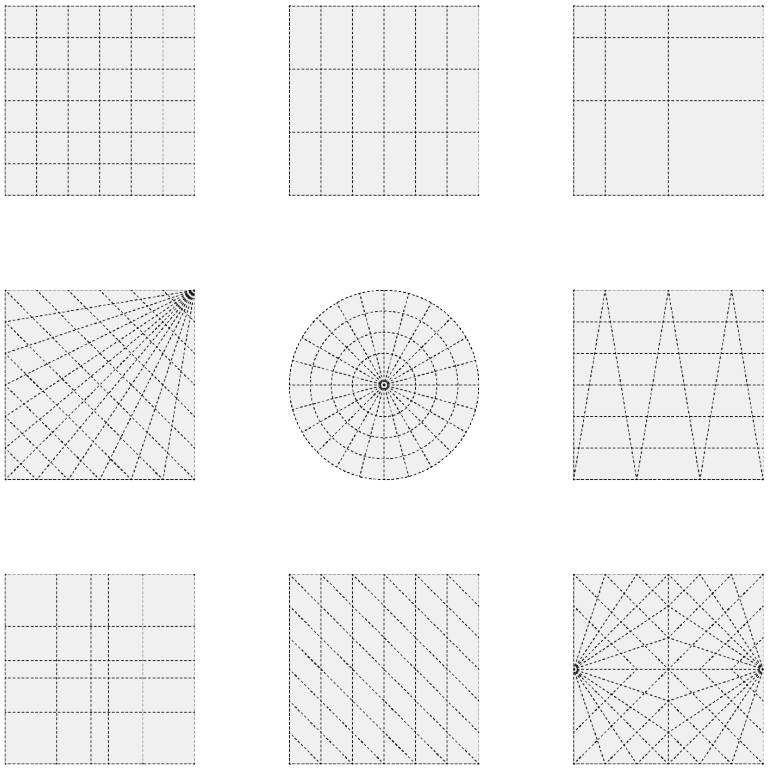
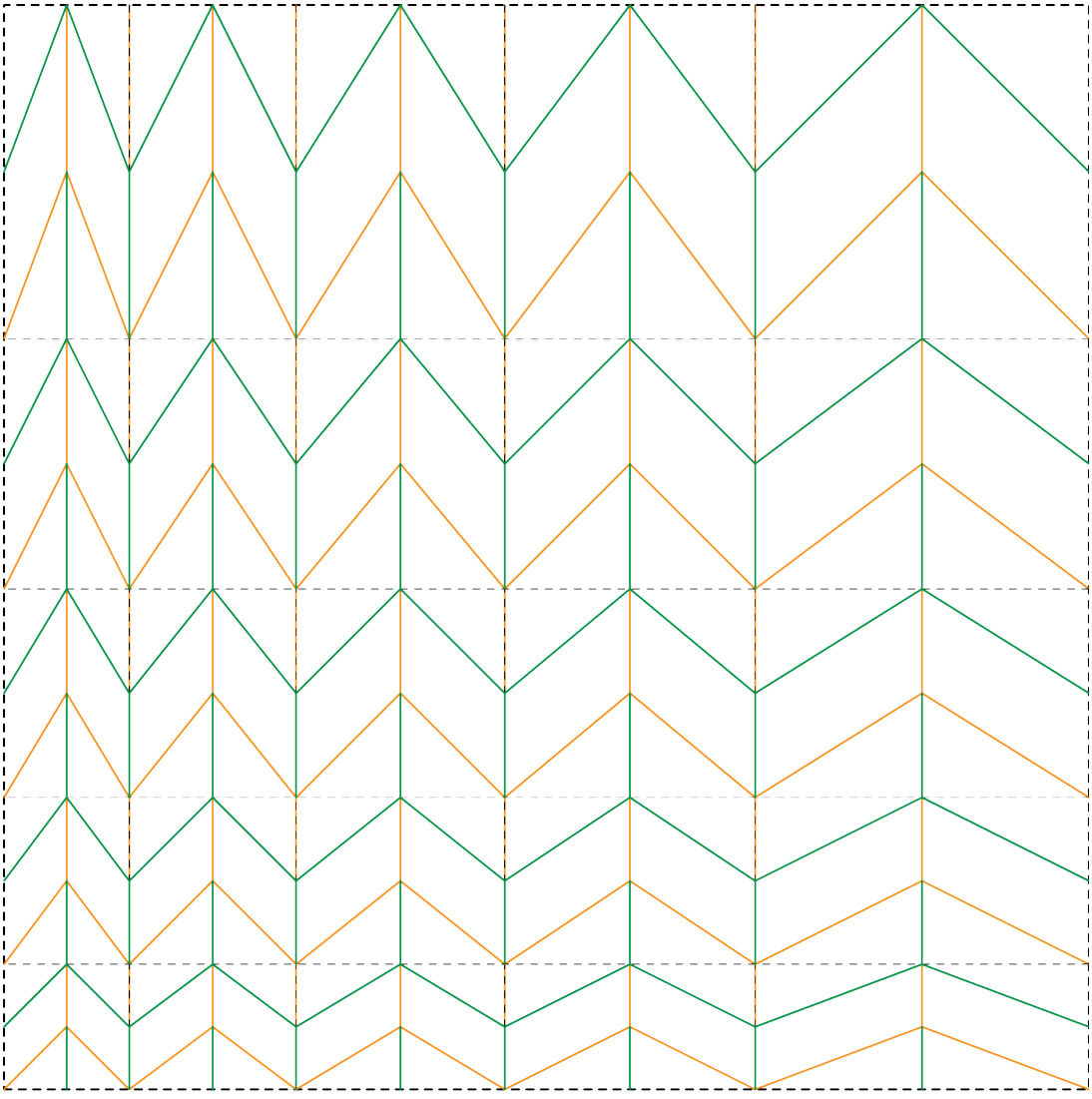
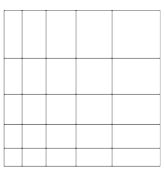


Fig 3.26 Instances of grid systems.

1. Gradient effect

By progressively increasing the size of components along both the x and y axes, the grid of components transitions gradually. This effect enables a smooth size shift within a tessellation; however, it compromises deployability, preventing the surface from folding into a flat state. While this approach can be useful for connecting tessellations of different sizes, it also introduces challenges in situations where compactness is required.





1.Gradient Effect Grids

Fig 3.27 The base component structured by an underlying grid system with progressively increasing unit sizes, generating a gradient effect.

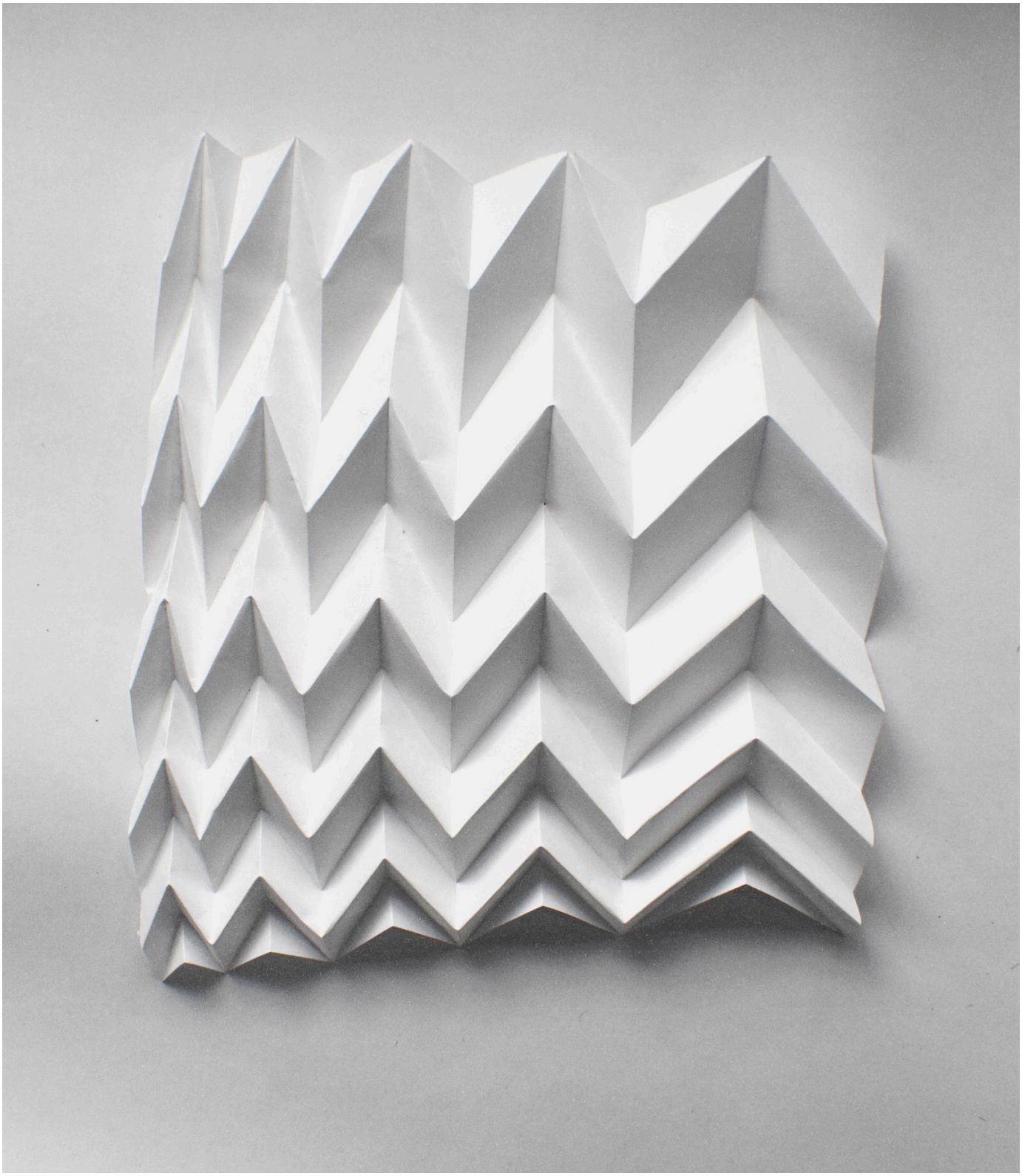
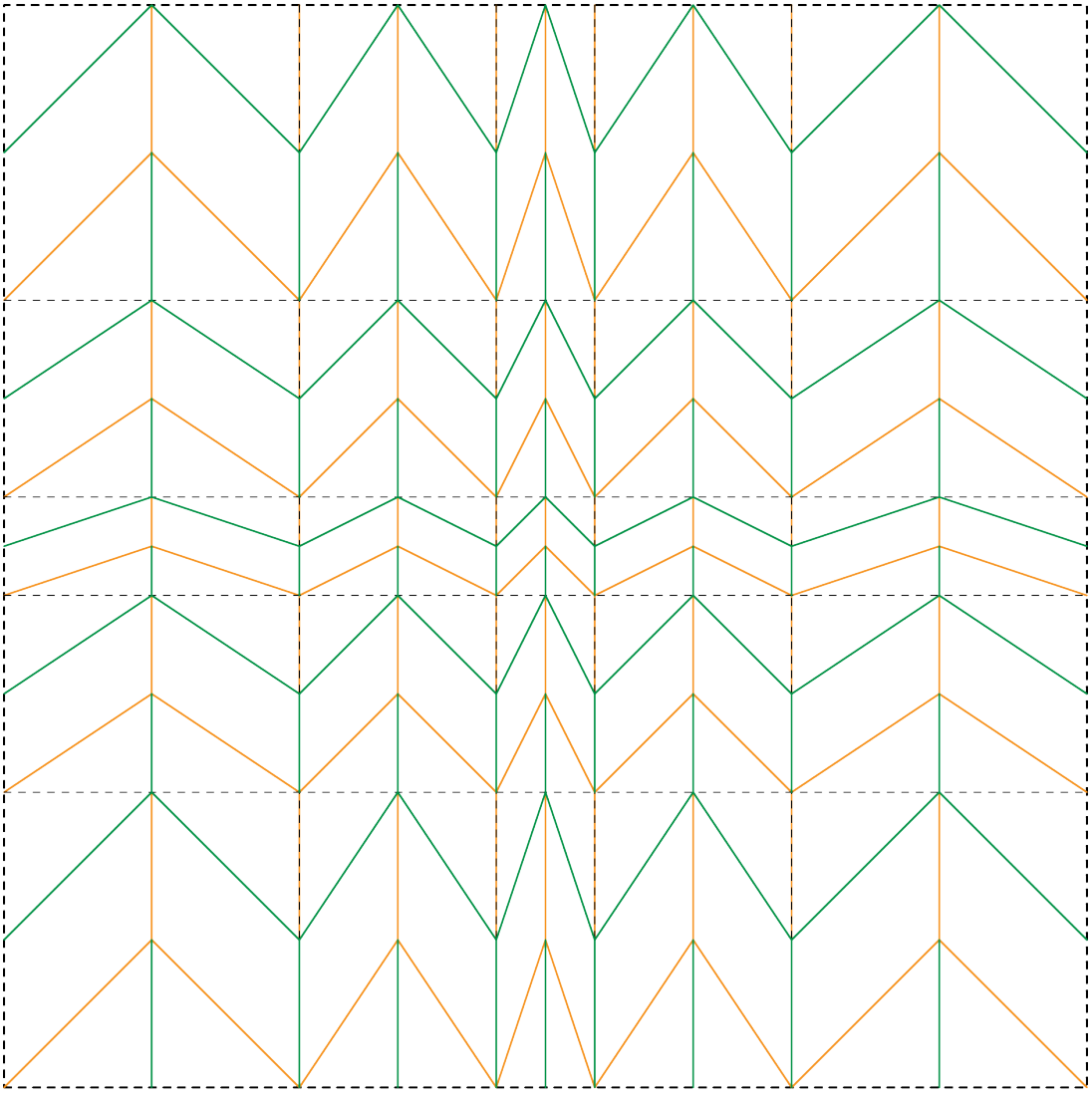
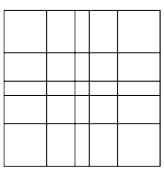


Fig 3.28 Folded tessellation with gradient effect.

2. Mirrored Gradient effect

Referred to as "*Reflection*" by Paul Jackson, a component can be repeated in one direction as a mirrored version of the previous component (Jackson 2019, 36). In cases where modifications to a component are asymmetrical—applied only to one side—mirroring ensures that the displaced nodes align properly, maintaining continuity within the tessellation and increasing the complexity of the overall pattern.





2.Gradient Effect Mirrored

Fig 3.29 Paul Jackson's 'Reflection' technique mirrors components to maintain alignment, ensuring continuity and enhancing pattern complexity.

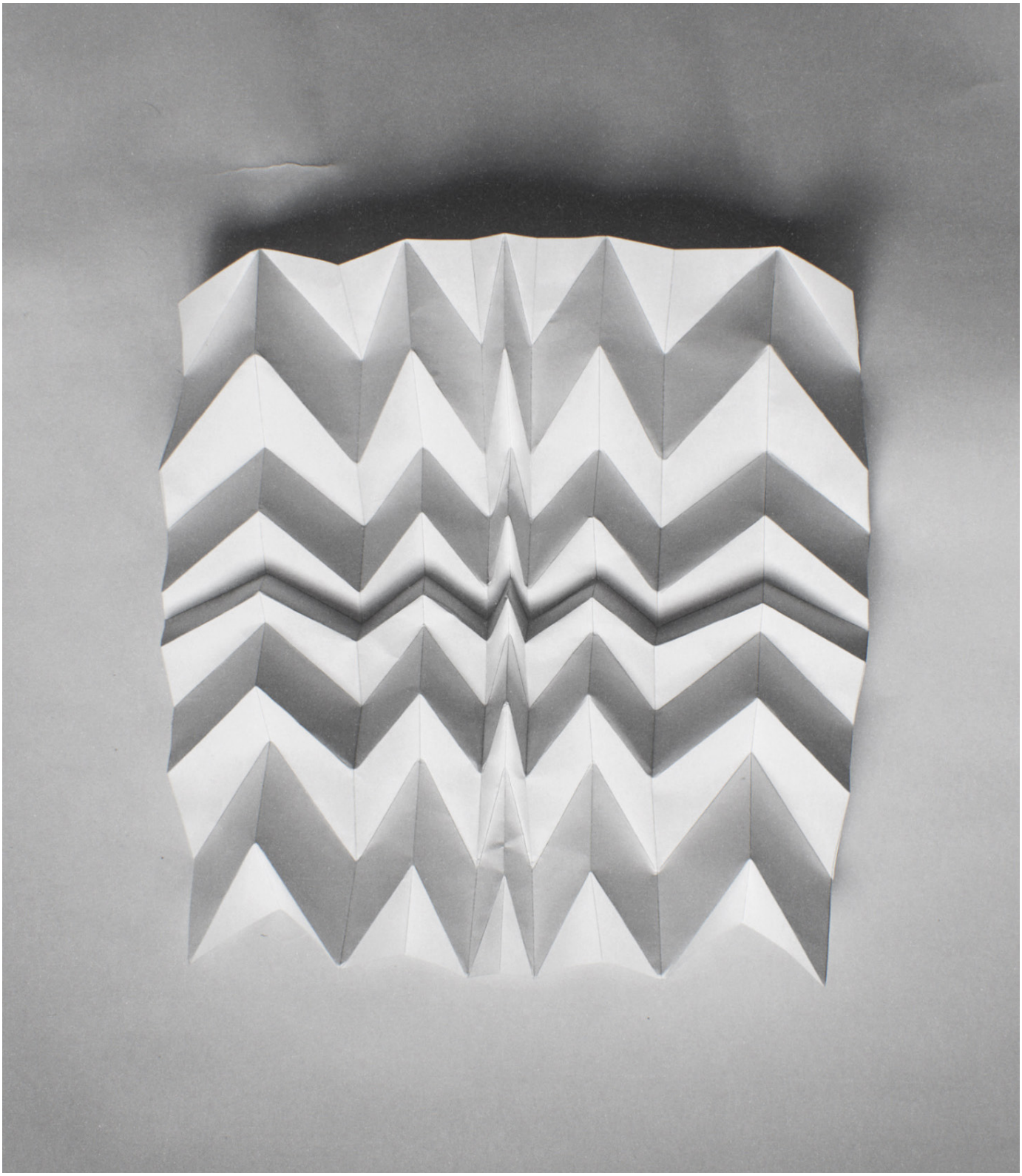
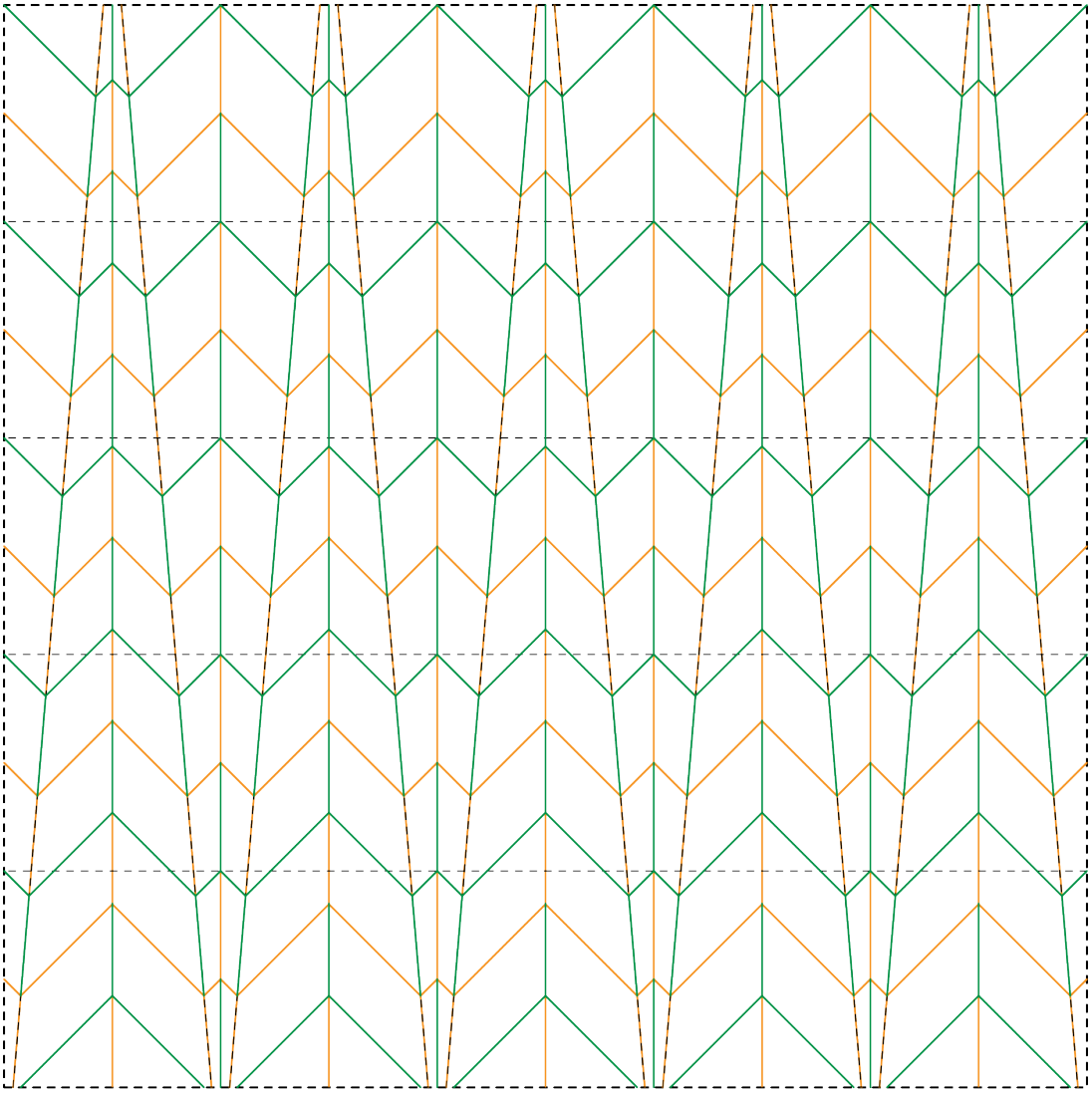
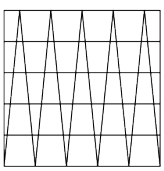


Fig 3.30 Folded model of mirrored gradient effect.

3.Symmetry lines Disorientation | First Variation

Lines of symmetry shift from parallel to diagonal orientations while the horizontal lines remain unchanged. This transformation increases the visual complexity of the pattern while preserving the surface's ability to fold into a compact state.





4.Diagonal Grid

Fig 3.31 Disorientation of symmetry lines. First variation.

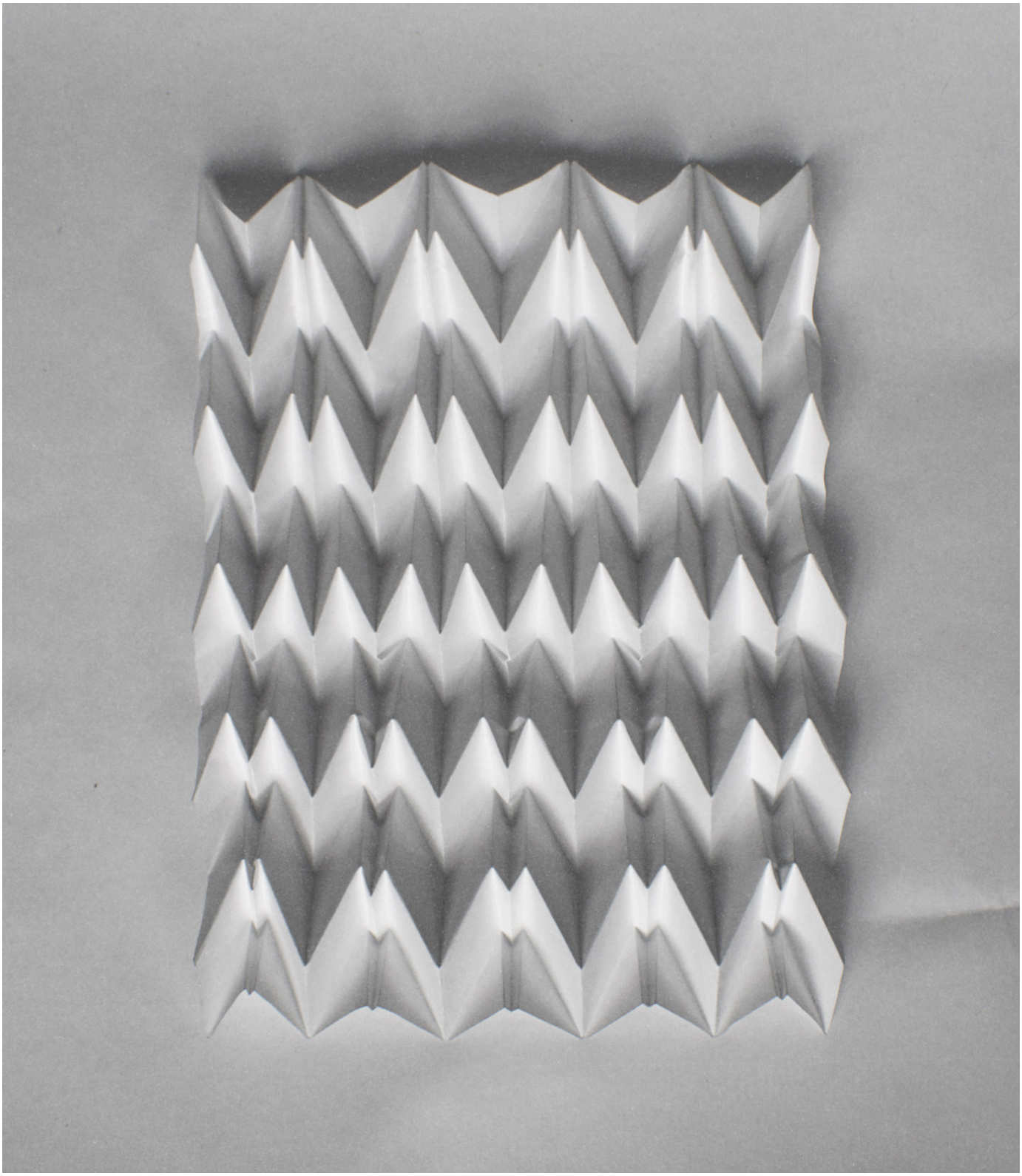
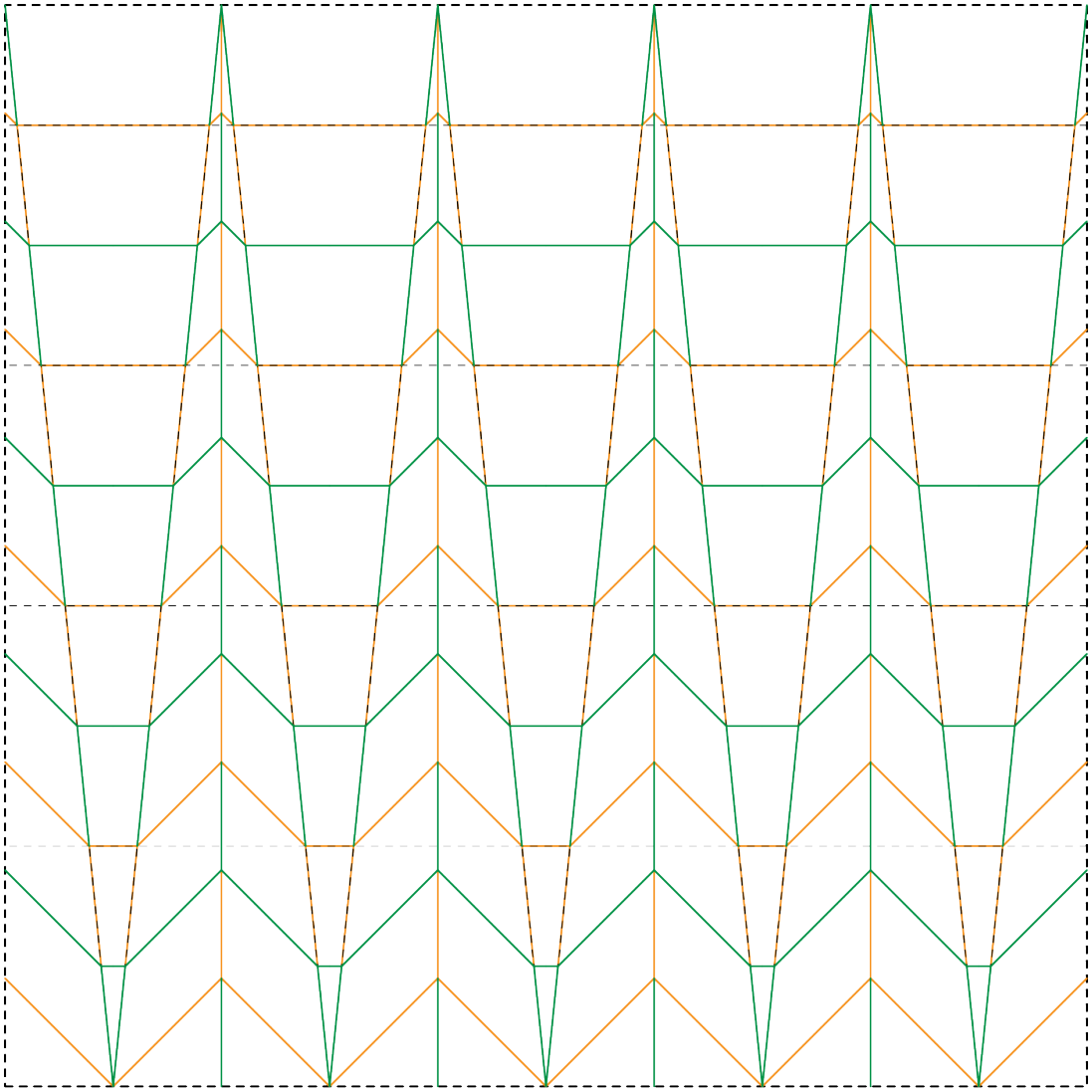
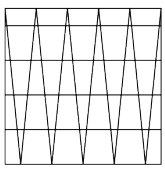


Fig 3.32 Folded model of tessellation with disoriented lines of symmetry. First variation.

4.Symmetry lines Disorientation | Second Variation

Such an effect can be utilized to rotate any given component. For instance, the iteration below illustrates diagonal rotation in Component Study 3, allowing the space pockets to rotate around a central point.





3.Diagonal Grids

Fig. 3.33. Disorientation of symmetry lines. second variation.



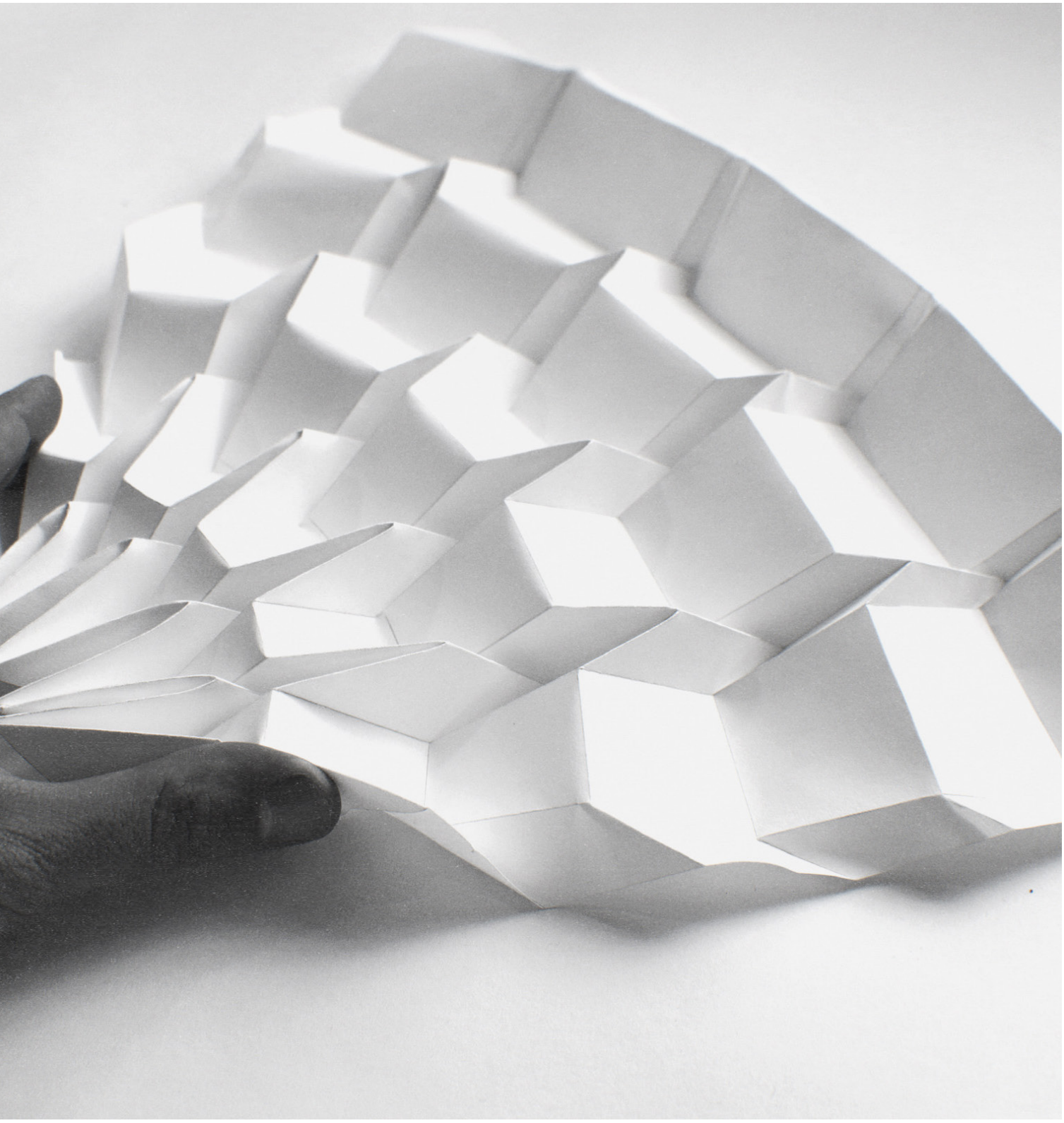


Fig. 3.34. Folded model of tessellation with disoriented lines of symmetry. Second variation.

5.Radial Growth | First Variation

In radial growth, lines of symmetry rotate around a central point, forming a pattern that expands outward in a circular motion. This transformation generates a dynamic and organic arrangement, where components gradually shift orientation relative to their distance from the center. Such a system allows for smooth transitions between elements, making it particularly useful for adjusting the orientation of components within a tessellation. This controlled change in orientation becomes essential when different regions of a surface require distinct component alignments to achieve a specific effect.

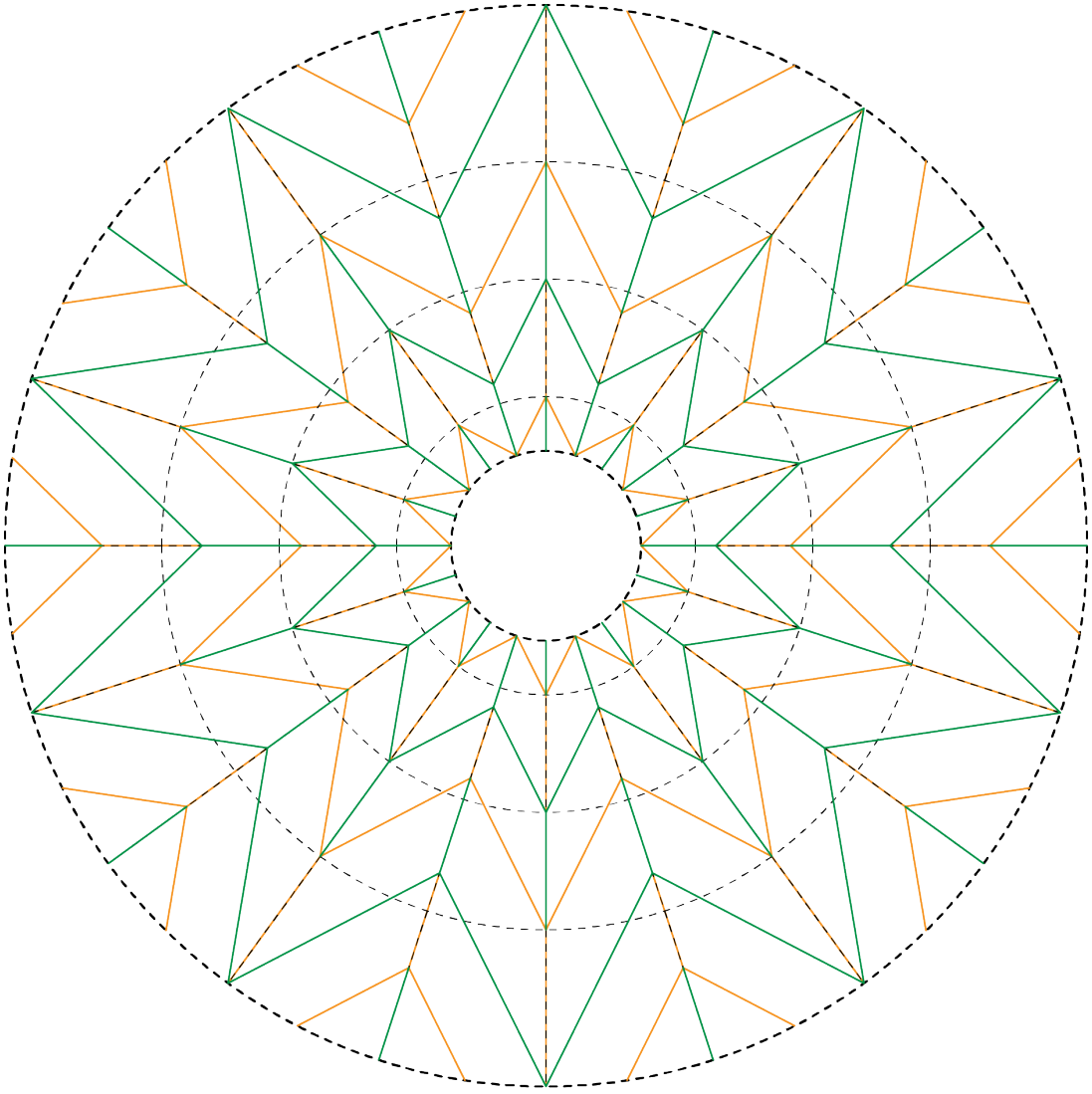
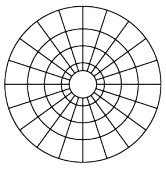


Fig 3.35 Radial Growth, Fisrt variation.



5.Radial Tessellation

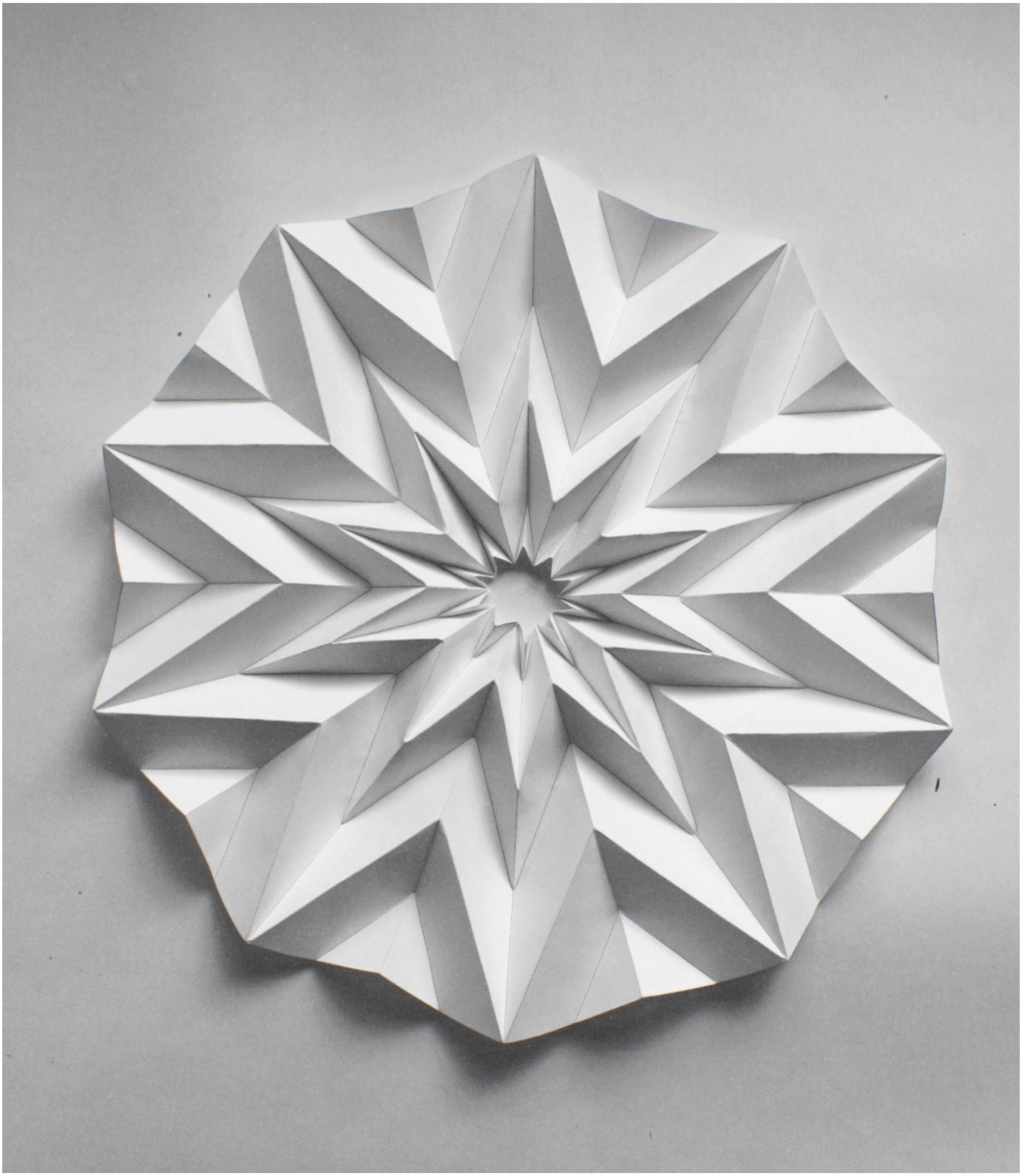
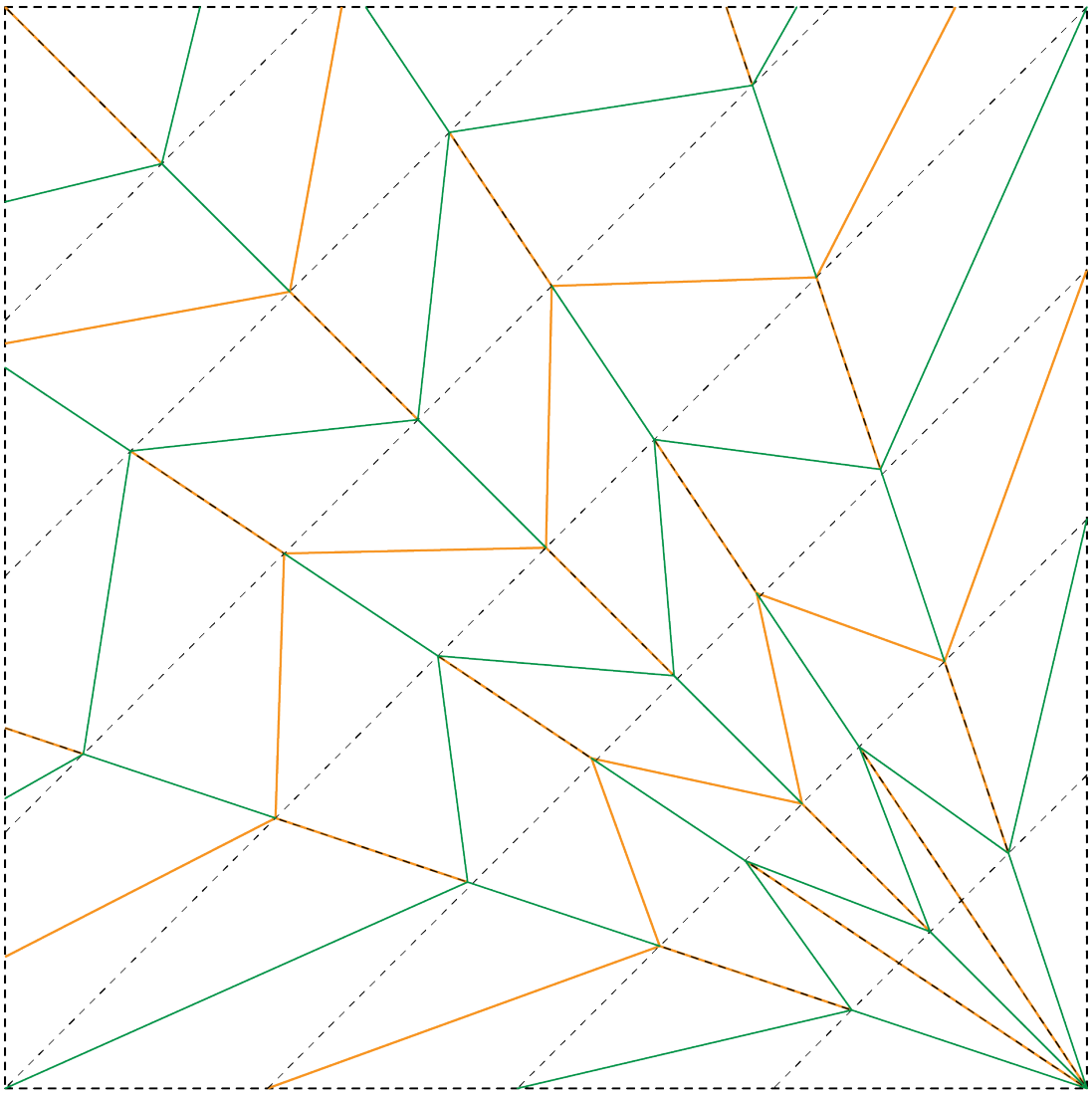
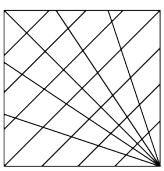


Fig 3.36 Folded prototype of Radial Growth, First variation.

6.Radial Growth | Second Variation

Similar to radial growth, the centerlines in this pattern rotate around a central point. However, unlike the previous effect, the lines that intersect them to form grids are straight rather than curved.





6.Diagonal Grid Tessellation

Fig 3.37 Radial Growth, second variation.

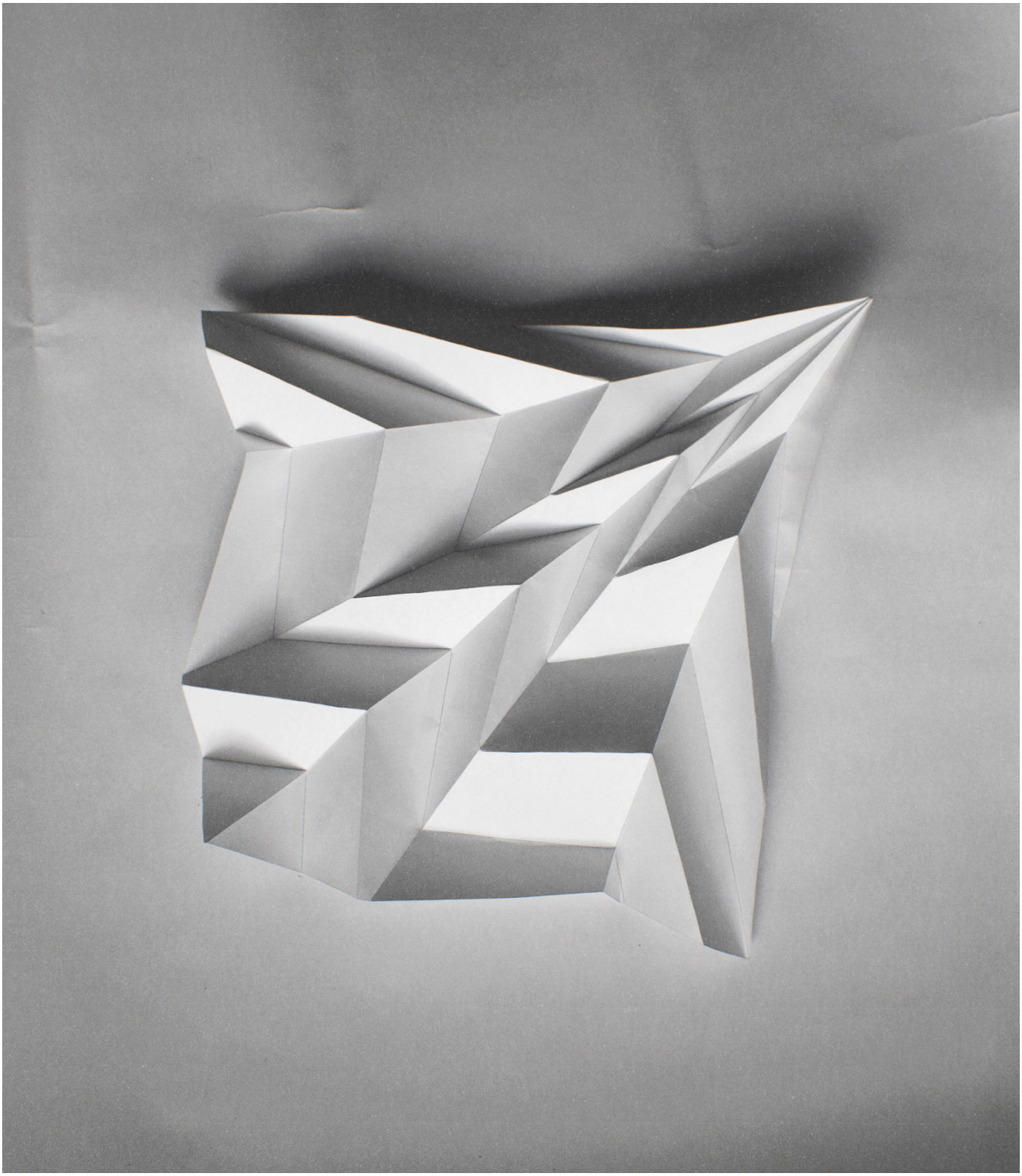


Fig 3.38 Folded prototype of Radial Growth, second variation.

PART IV | DESIGN IMPLEMENTATION

IV.I

DESIGN PROPOSAL

"If there is a single effect produced in architecture by folding, it will be the ability to integrate unrelated elements within a new continuous mixture." (Lynn, 1993)

Drawing from Deleuze's interpretation of Leibniz and Greg Lynn's discourse on continuity, this thesis positions folding as a strategy for integration rather than fragmentation. Both Deleuze and Lynn conceptualize folding as a means of reconciling disparate elements within a continuous system. The artifact in this thesis builds upon this idea, proposing folding as a generative process that produces spatial definition through a homogeneous surface that follows its logic of pliancy. Rather than relying on assemblage or juxtaposition, it embodies a structural and formal continuity, where spatial conditions emerge from the inherent dynamics of a single manipulated surface.

While numerous architectural precedents employ folding as a means of reconfiguration and adaptation, these applications typically remain as single elements, serving isolated functions—such as walls or roofs— attached to a static structure rather than parts of a unified responsive system (Wierzbicki, 2014). In contrast, this design proposal integrates multiple functional elements into a continuous surface that adapts its behavior across different regions while conforming directly to the body's form. It demonstrates how folding introduces formal adaptability, allowing the surface to shift between multiple configurations, and structural transformability, enabling it to maintain integrity while dynamically responding to movement within an architectural space as intimate as clothing (Fig 4.1). After all, our clothes are the first space we inhabit; they respond to challenges similar to buildings, yet they require a higher level of flexibility and adaptability across their entire form.



Fig 4.1 A continuous surface wraps around the body and defines space.

The torso, with its complex anatomical motion and multi-directional deformations, serves as the primary site for this exploration (Fig 4.2). It imposes unique design challenges and strictly dictates the desired surface behavior that could respond to its form and movements. By integrating insights from component studies and growth systems on the Miura-Ori Pattern, this project encodes surficial deformations directly into the textile, allowing for fluid yet structurally coherent transformations.

The wearable is not just an object but a machine—a mathematical function capable of producing infinite variations. Giving it different bodies manifests endless iterations of the same essence. As Deleuze described, it becomes an *objectile* (Carpo , 2017, p.15), a form defined not by its finality but by its potentiality. The photographed artifact, whether the unfolded pattern on a flat sheet or the folded form as a wearable, is insignificant compared to the countless, unphotographed states that give it its true meaning. What matters is not the static stages but the infinite uncaptured frames of existence through which the dress gains significance. It becomes an organic machine, as Greg Lynn envisioned, one that undergoes continuous, asexual reproduction to generate limitless variations (Lynn 2004). This constant state of transformation is what imbues the dress with its erotic and desirable dimension. It is not simply a wearable or a functional item but a system, alive in its ability to adapt, evolve, and recreate itself. This infinite generativity becomes its essence, its allure, and its power.

The following sections will explore the development process of the wearable, illustrating how these principles materialize through folding.

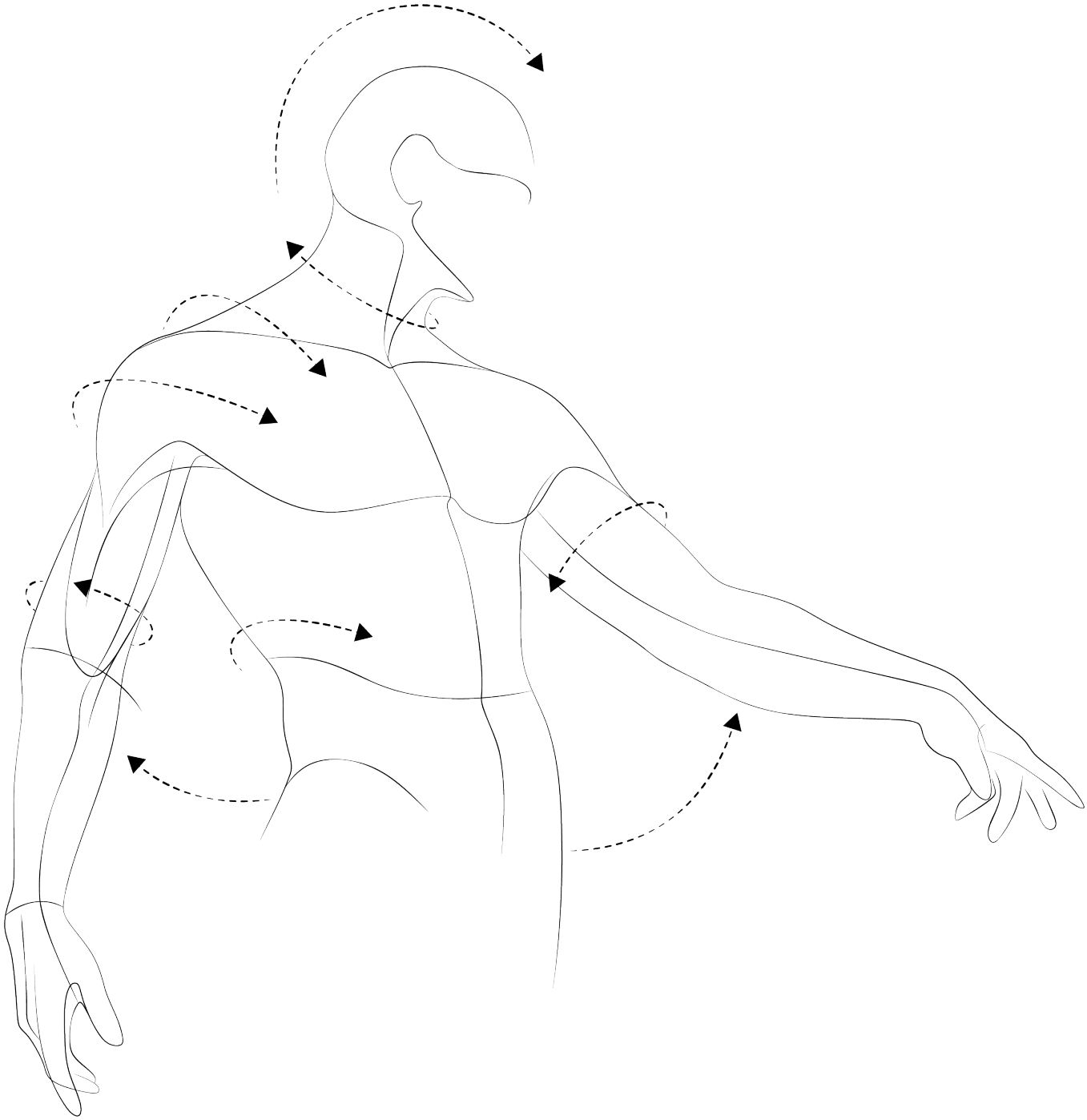


Fig 4.2 Formal complexities of the torso in motion.

IV.II

PARTS

The garment consists of three interconnected elements: the sleeves, the bodice, and the hood, each designed to promote adaptability and responsive transformability. The sleeves are designed to facilitate fluid motion, accommodating the dynamic positions of the arms while exhibiting bistable behavior—allowing them to transition between short and long configurations. The hood extends this principle of bistability, offering varying states of shelter and wearability. The bodice acts as the structural mediator, connecting the sleeves and hood while adapting to the complex contours of the torso. Collectively, these different parts merge into a synthesized system that reimagines garment construction beyond the conventional cut-and-sew method. Rather than assembling discrete fabric panels, this wearable is conceived as a continuous surface where structure, movement, and adaptability emerge from an encoded system of folds.

However, to integrate these different parts into a homogeneous system, it is essential first to develop and analyze the basic structural configuration of each part individually based on its intended function. This preliminary exploration provides a foundational understanding of the structural configuration of each system part and later informs the development of smooth tessellation transitions between them. As discussed in the previous chapter, the development of each element begins with establishing its underlying grid—a system of accordion pleats—along which V-pleats are subsequently introduced. Figures 4.3 and 4.4 illustrate the required orientation of the underlying accordion structure in the sleeves and hood, enabling their bistable transformations.

IV.II.I

SLEEVE

To form the sleeve, the surface must bend by a full circle, creating a long cylindrical structure. This transformation results from the varying heights of pleats—each mountain fold is shorter than the next valley fold—causing the surface to bend and reconnect to itself. As the mountains and valleys align, the loop closes, forming a self-supporting, auxetic structure that is highly adaptable in all dimensions(Fig 4.6).

Unlike conventional fabrics that rely on material elasticity, this sleeve's compactability is purely structural. Its auxetic pattern enables expansion in three dimensions, allowing it to adjust to different sizes while maintaining integrity. The sleeve's length is adjustable, offering multiple configurations. As it approaches the shoulder, the structure gradually increases in diameter, creating extra space for enhanced comfort and mobility around the arms. This transition also ends the sleeve with matching component to the one used for the shoulder part, allowing a seamless transition of sleeve pattern to the sholder's patten(fig).This built-in adaptability ensures that the sleeve remains functional, ergonomic, and seamlessly integrated into the garment's overall structure.

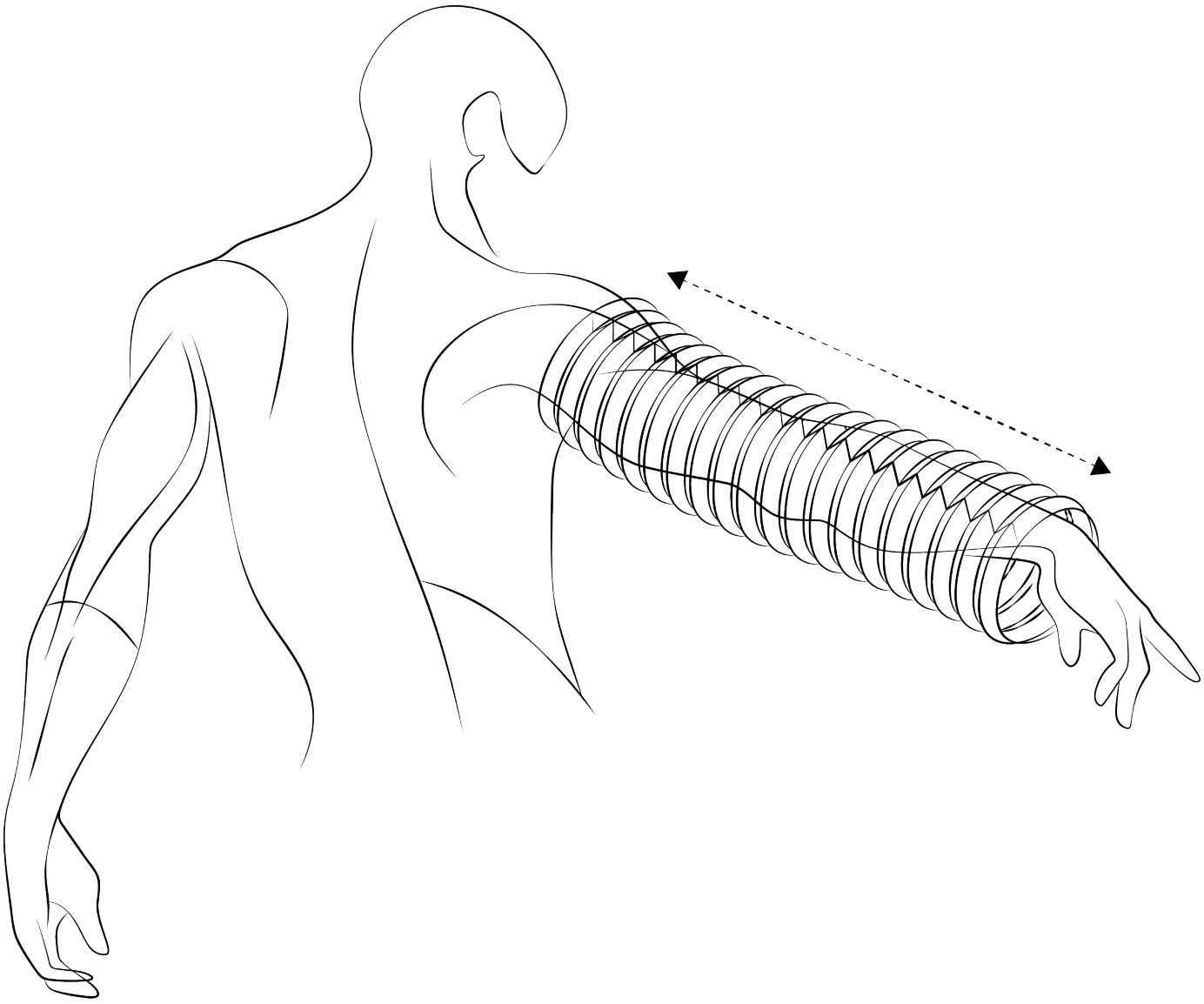


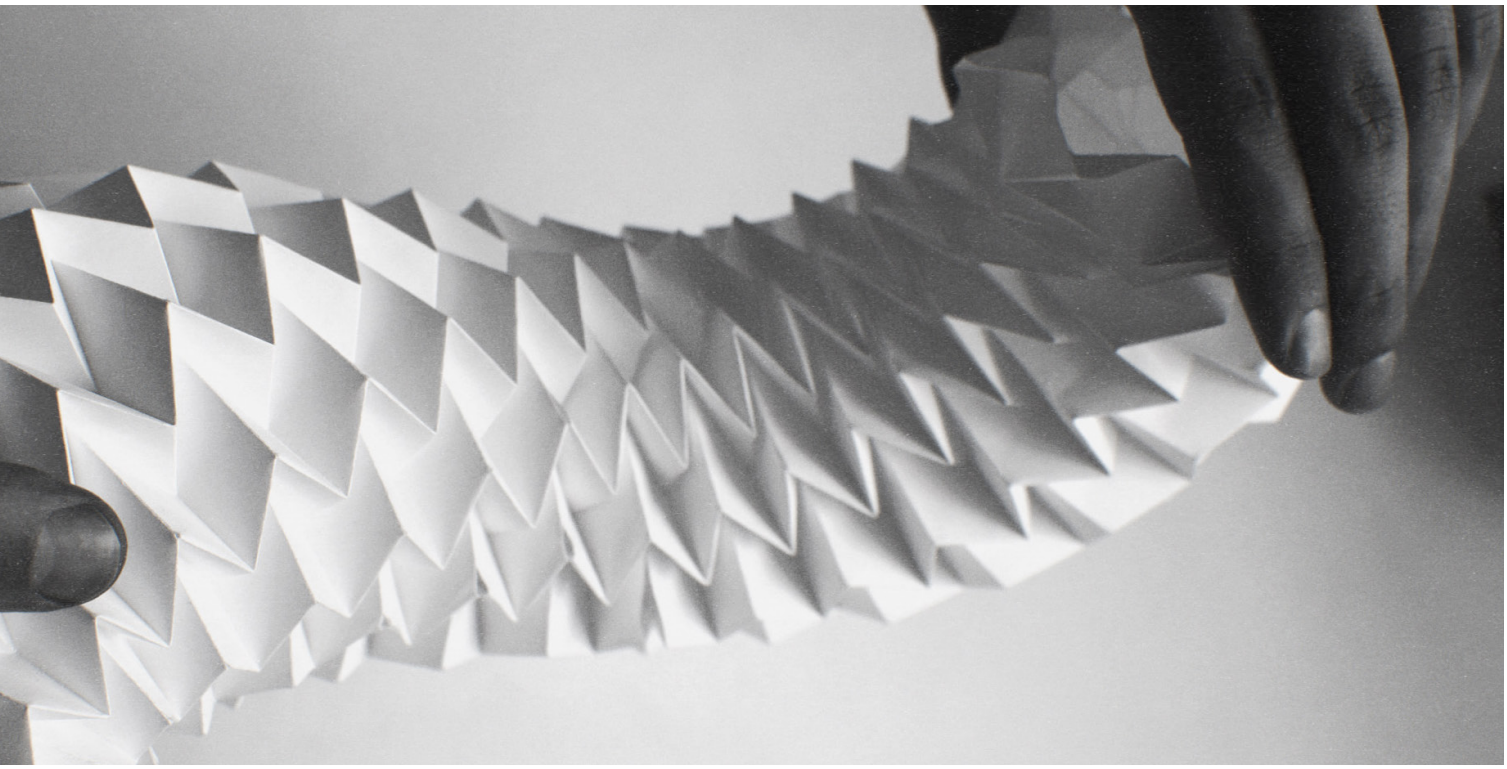
Fig 4.3 Sketch illustrating the direction of accordion folds in a flexible sleeve.

In Component Study No.1, displacing the mountain node along the Y-axis causes the surface to bend, forming a continuous arc. When this component is tessellated in a repeating sequence, the pattern loops back onto itself, creating a cylindrical surface. The degree of this bending is directly related to the degree of displacement in the mountain node. Meaning that greater displacement results in shorter valleys and longer mountains, leading to more pronounced curvature. This relationship directly affects the radius of the resulting cylinder, making it a key design consideration to ensure the sleeve fits the arm in both its expanded and compacted states. As previously mentioned, Miura-Ori exhibits auxetic behavior in three dimensions. Consequently, when the cylindrical surface contracts, its radius decreases proportionally.

Multiple prototypes were developed to determine the optimal component for a sleeve that effectively adapts to the arm's size and movements, analyzing the relationship between node displacement and curvature to optimize the performance and the overall fit.



Fig 4.4 Flexibility of the cylindrical folded surface.



First Prototype

The sleeve is structured from a single component; however, multiple iterations were developed using different component variations, resulting in folded sleeves with varying diameters. Through this iterative prototyping process, the sleeve's dimensions were optimized to ensure functional adaptability, allowing for controlled expansion and contraction while maintaining a precise and secure fit, preventing excessive looseness.

The tessellation of the sleeve is directly influenced by the behavior of its components, as this determines the number of components required to complete a full turn and loop back onto itself. Components that introduce higher bending intensity in the surface create tighter loops, requiring fewer repetitions to complete the cycle. Conversely, components that generate a lower curvature intensity produce larger loops, necessitating a greater number of repeated arrays to form a cylindrical structure.

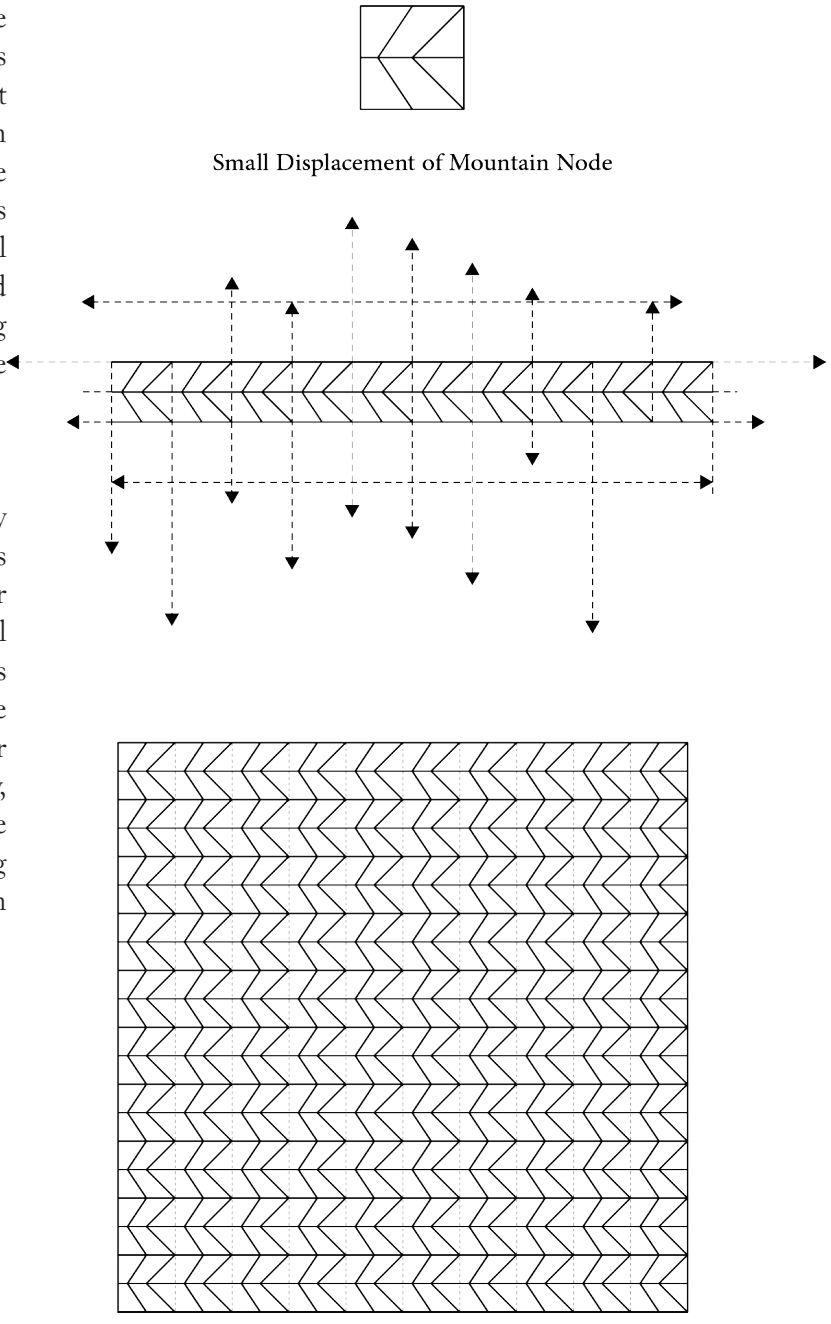


Fig 4.5 Small displacement of the mountain node applied to the entire tessellation to shape the sleeve.

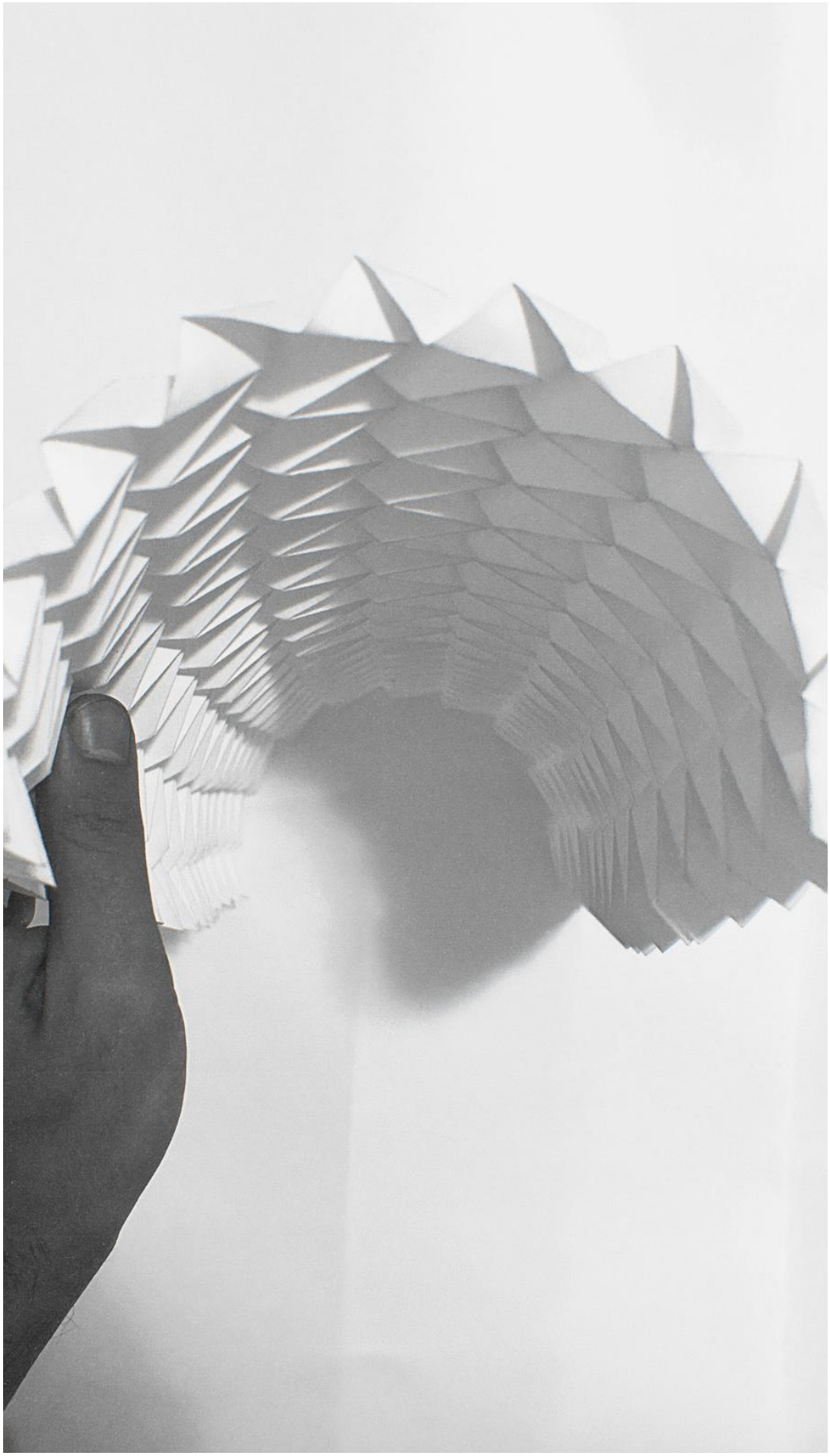


Fig 4.6 Section of the Sleeve, illustrating how the surface loops back onto itself.

Second Prototype

While this iteration accommodated the arm when in its folded state, it did not allow for contraction, as the diameter decreased upon contraction, preventing the arm from fitting in its contracted form. However, a minor adjustment could resolve this issue, provided that the modification was systematically repeated to ensure the completion of the loop.

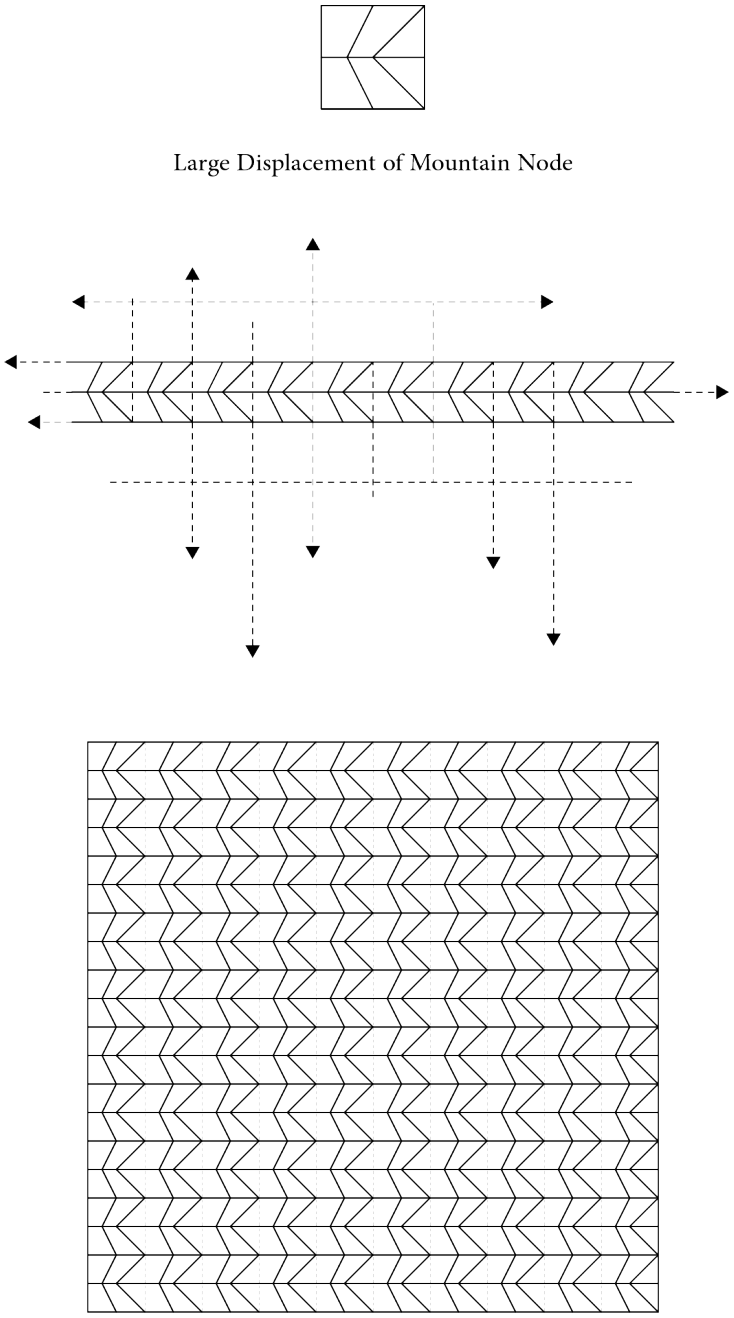


Fig 4.7 Repetitive tessellation of the component with large displacement in its mountain node.

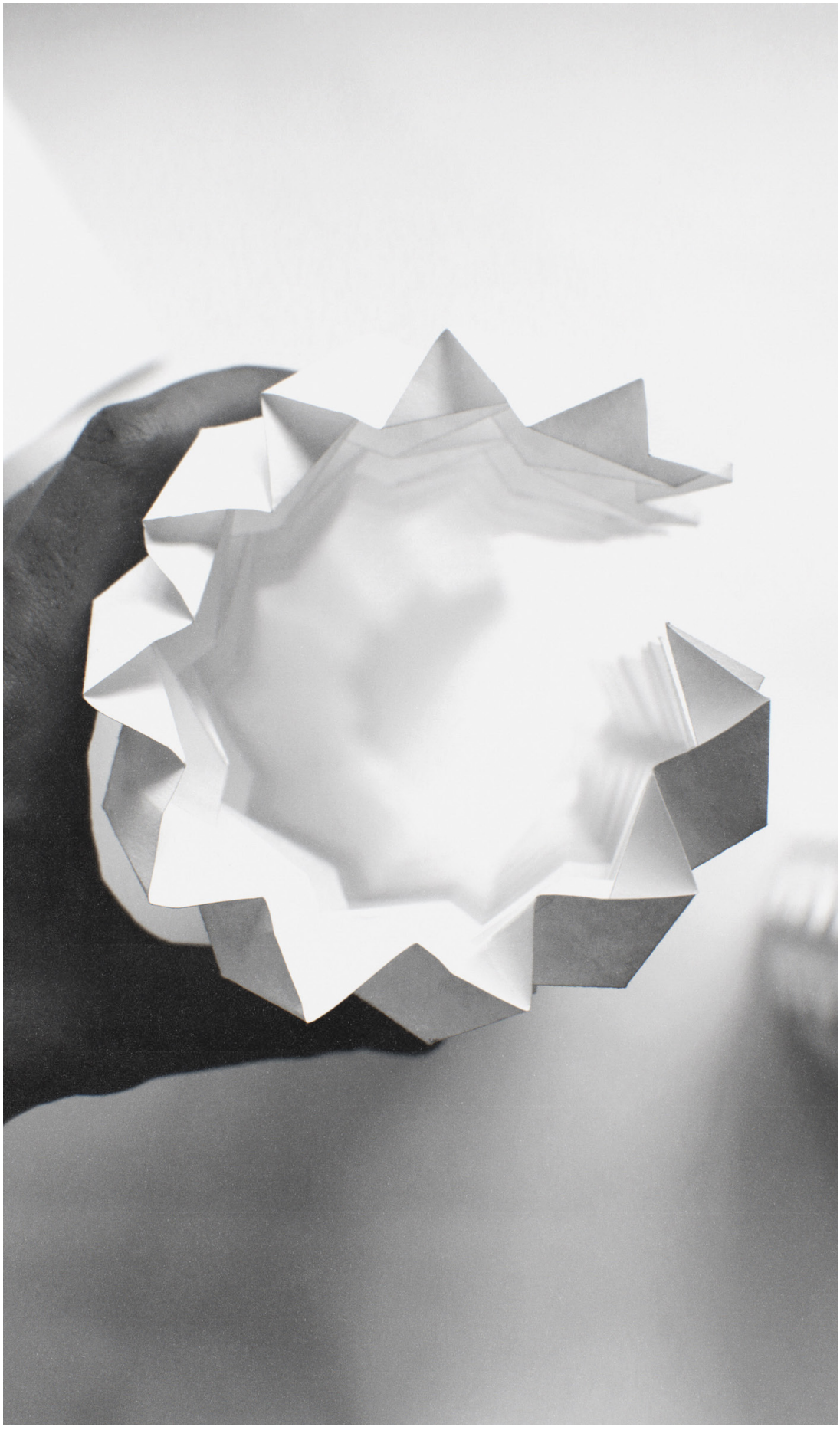
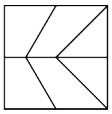


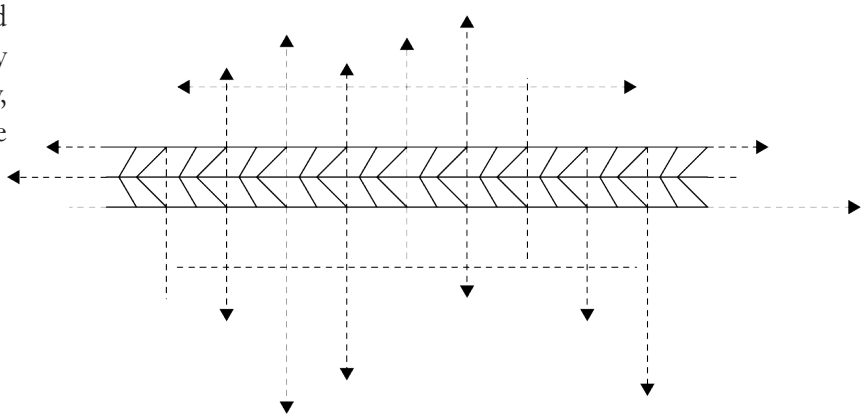
Fig 4.8 Section of the Sleeve, illustrating how the surface loops back onto itself.

Third Prototype

By mediating between the first two prototypes, the structure generated a cylindrical surface that accommodated the arm in both its contracted and expanded states, thereby fulfilling its functional purpose while ensuring an optimal fit. As illustrated in Figure 4.x, the pattern can be infinitely repeated in both directions. Consequently, to achieve the desired sleeve length, the structure must also expand vertically.



Medium Displacement of Mountain Node



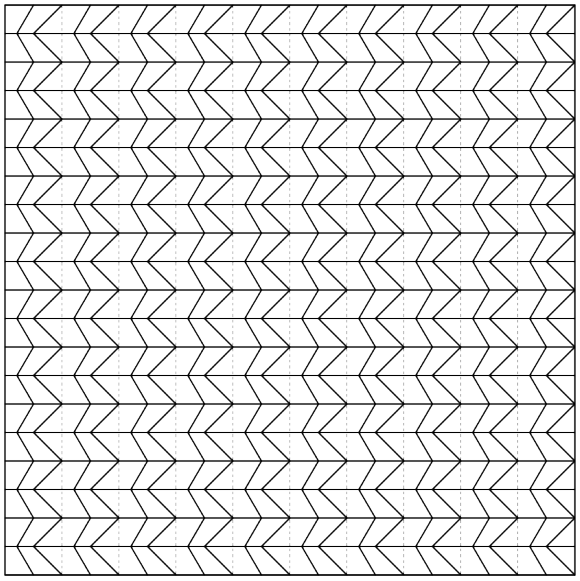


Fig 4.9 Repetitive tessellation of the component with large displacement in its mountain node.

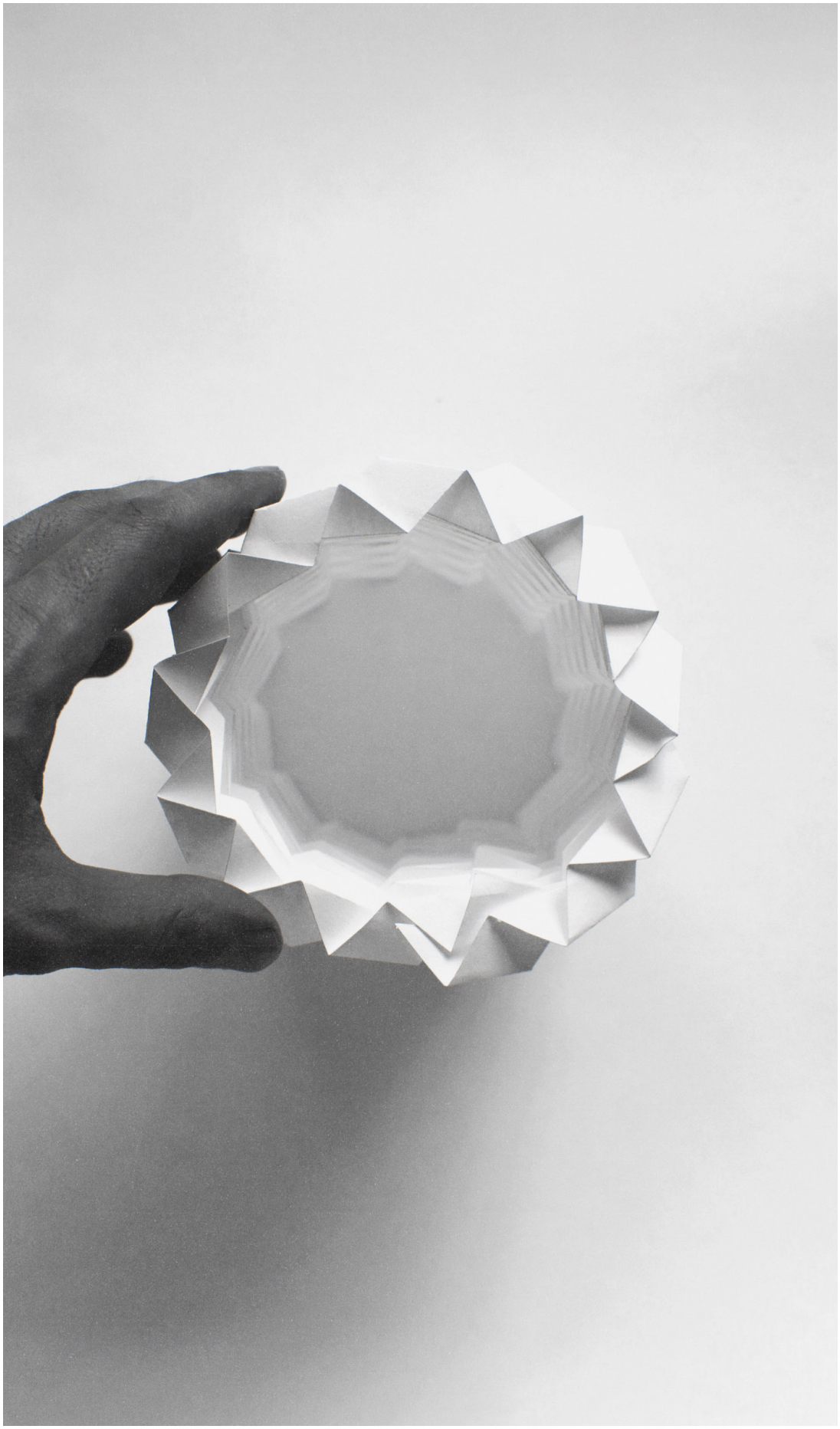


Fig 4.10 Section of the Sleeve, illustrating how the surface loops back onto itself.

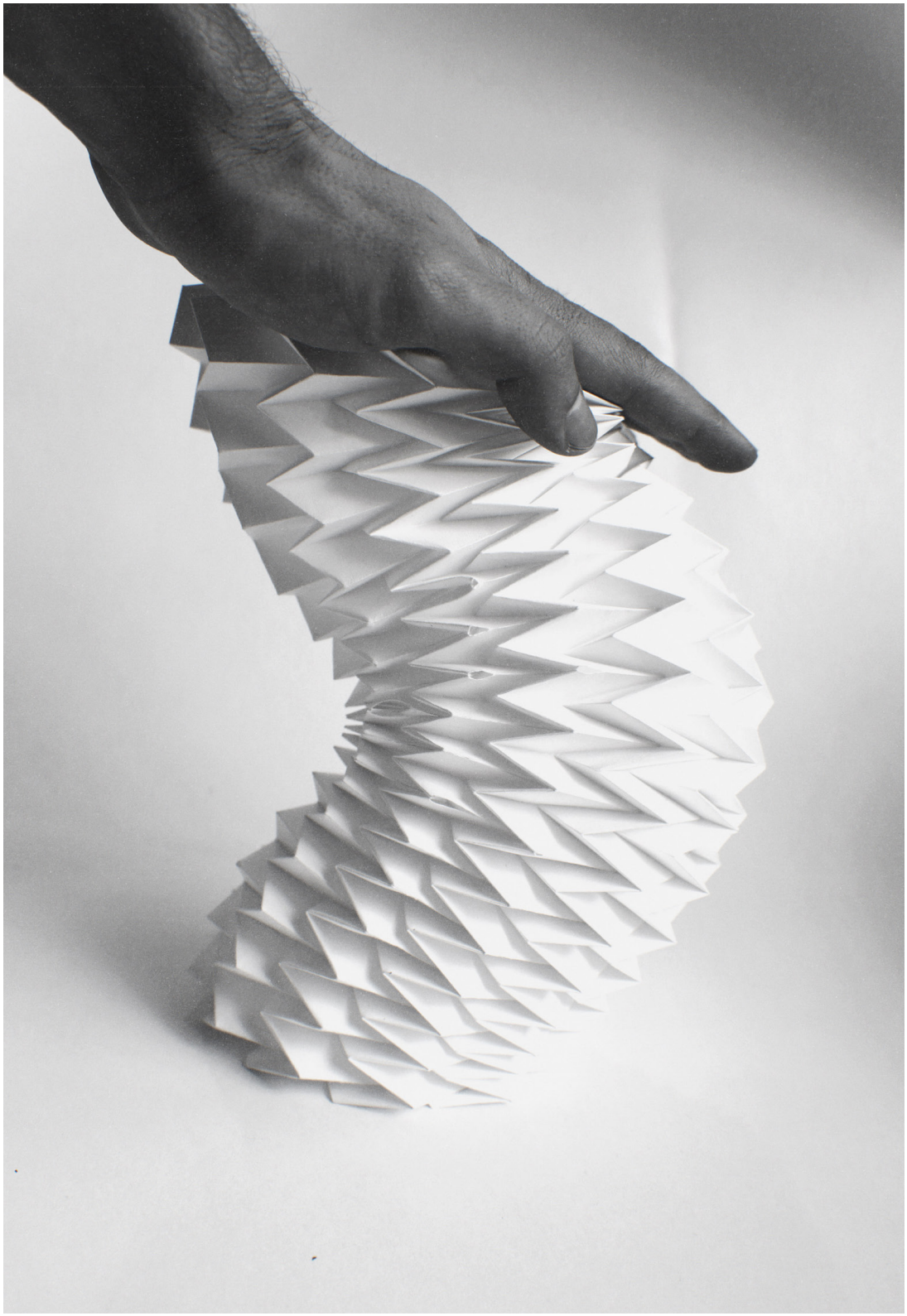


Fig 4.11 Flexible behavior of the sleeve structure achieved through folding.



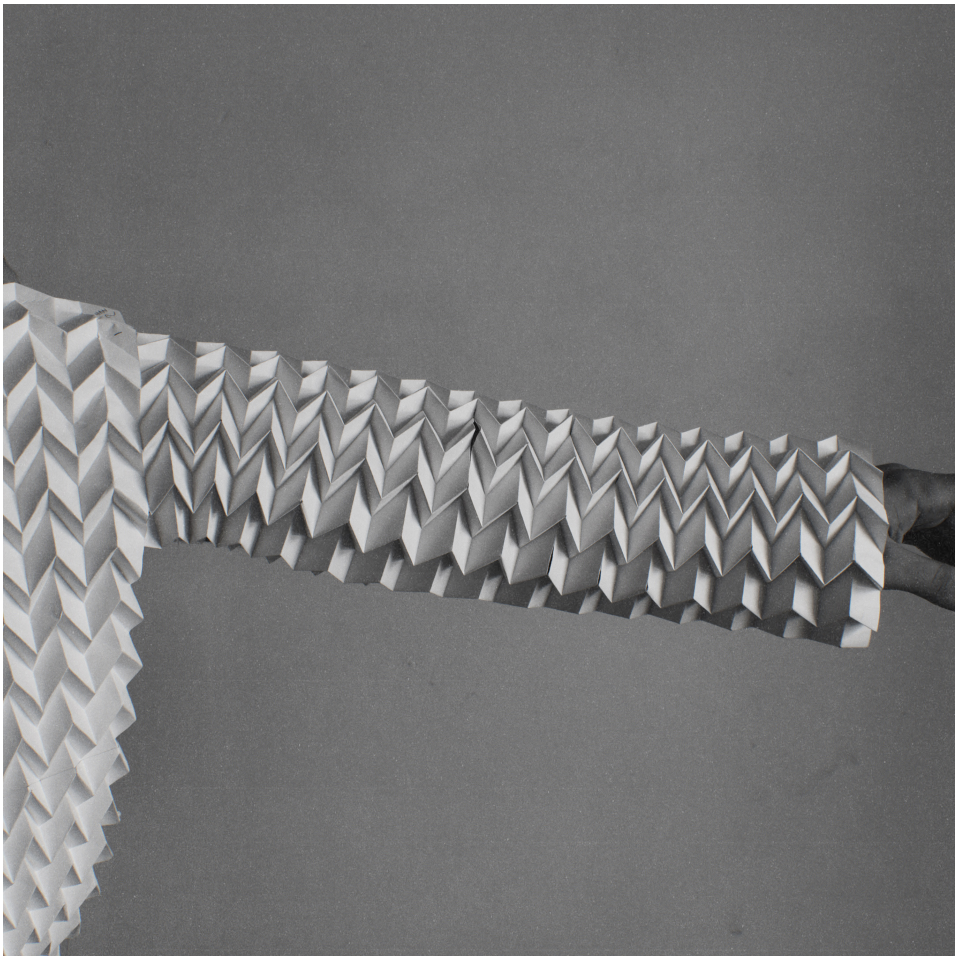
Fig 4.12 Flexible behavior of the sleeve structure achieved through folding.



Fig 4.13 Compactability of the sleeve structure achieved through folding.



Fig 4.14 Compactability of the sleeve structure achieved through folding.



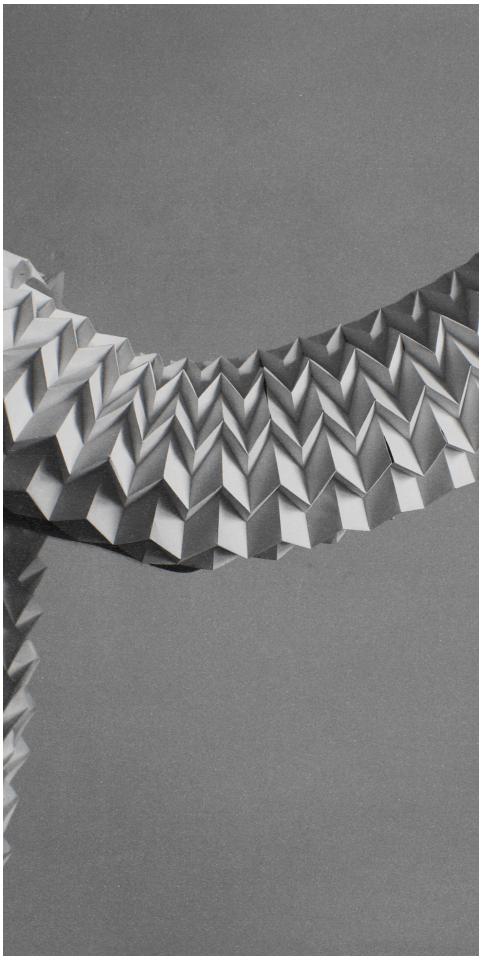
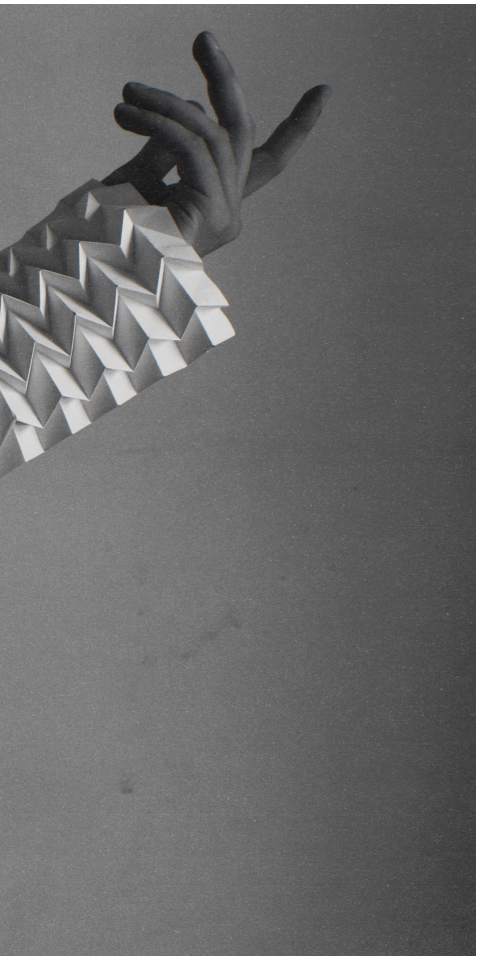
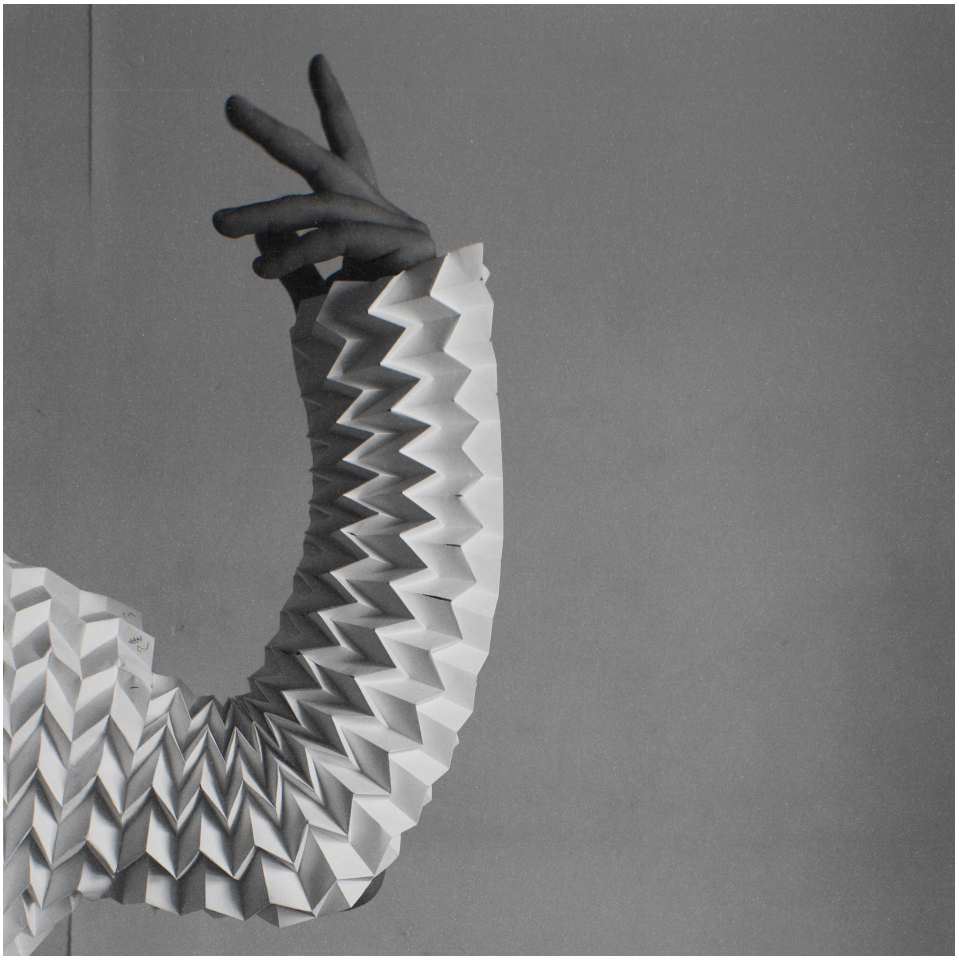


Fig 4.15 Flexibility of the sleeve in relation to arm movement.





IV.II.II

HOOD

The hood was the first part of the wearable I explored. It resembles a temporary shelter structure that could function across multiple scales—from an outdoor public shelter to a personal-scale hood in clothing. Unlike a standard hood, which is often composed of three stitched-together fabric pieces that rely on fabric elasticity for flexibility, this design introduces a structurally flexible form. The wearable's collar transitions smoothly into a retractable dome to cover the head.

Achieving this transformation required a precise manipulation of the folding pattern. The transition from the collar into a dome-shaped hood involved progressive adjustments to the mountain and valley folds of the V-pleats to introduce gradual curvature. These modifications allowed the surface to grow, bend, and form the dome structure. Such a changing behavior requires the use of different component variations throughout the tessellation. However, mixing multiple components can create excessive complexity in the system. To simplify the system, we begin by assigning numerical values to components with varying modification intensities and distributing these numbers across the grid. By dividing the surface into a grid system and assigning numbers representing different variations to grid units, the process of developing this multi-behavioral surface becomes manageable, allowing the designer to understand and implement smooth transitions between multiple component variations. Figure 4.8 illustrates the development of the grid system and coding it with different components.

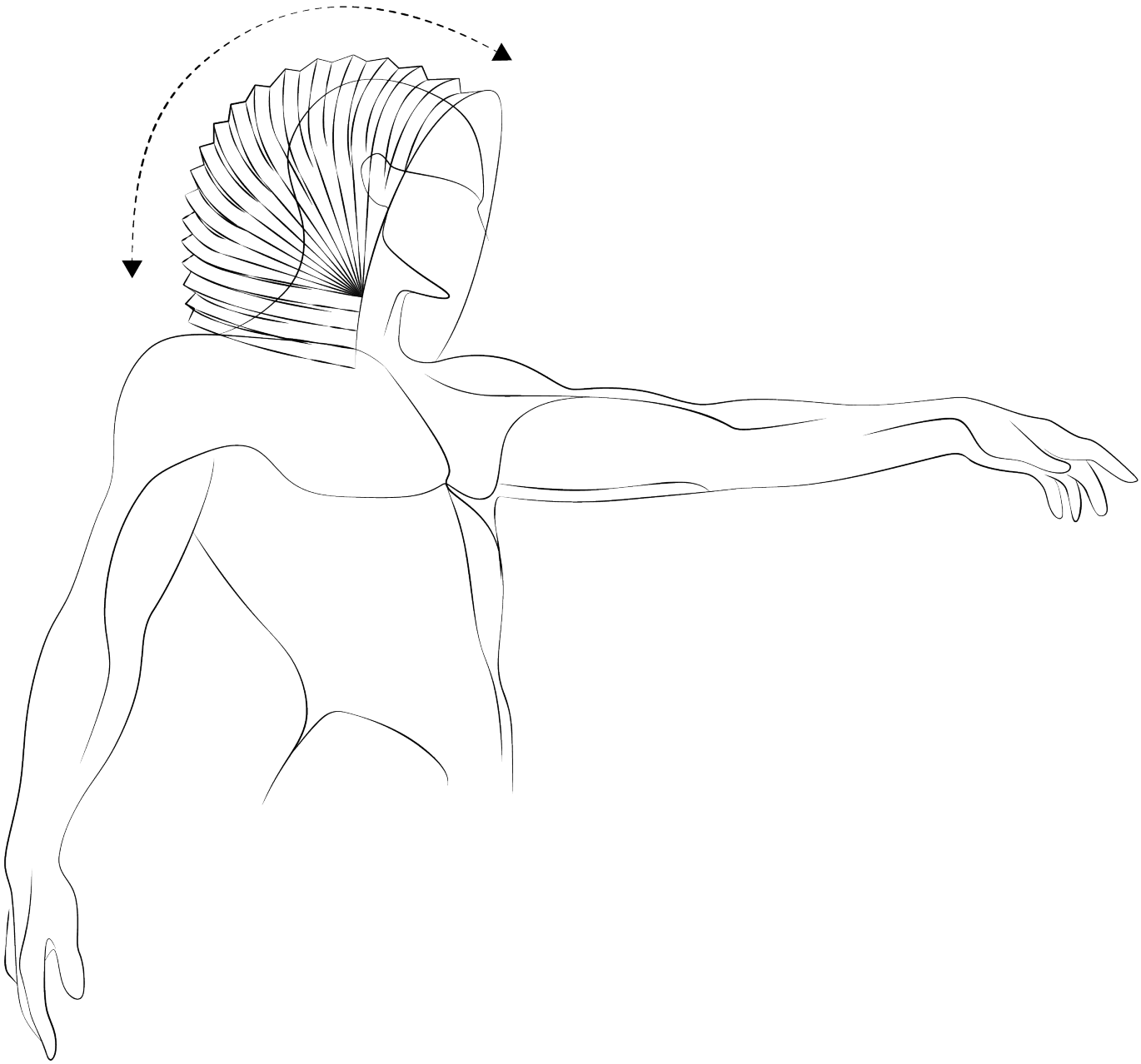
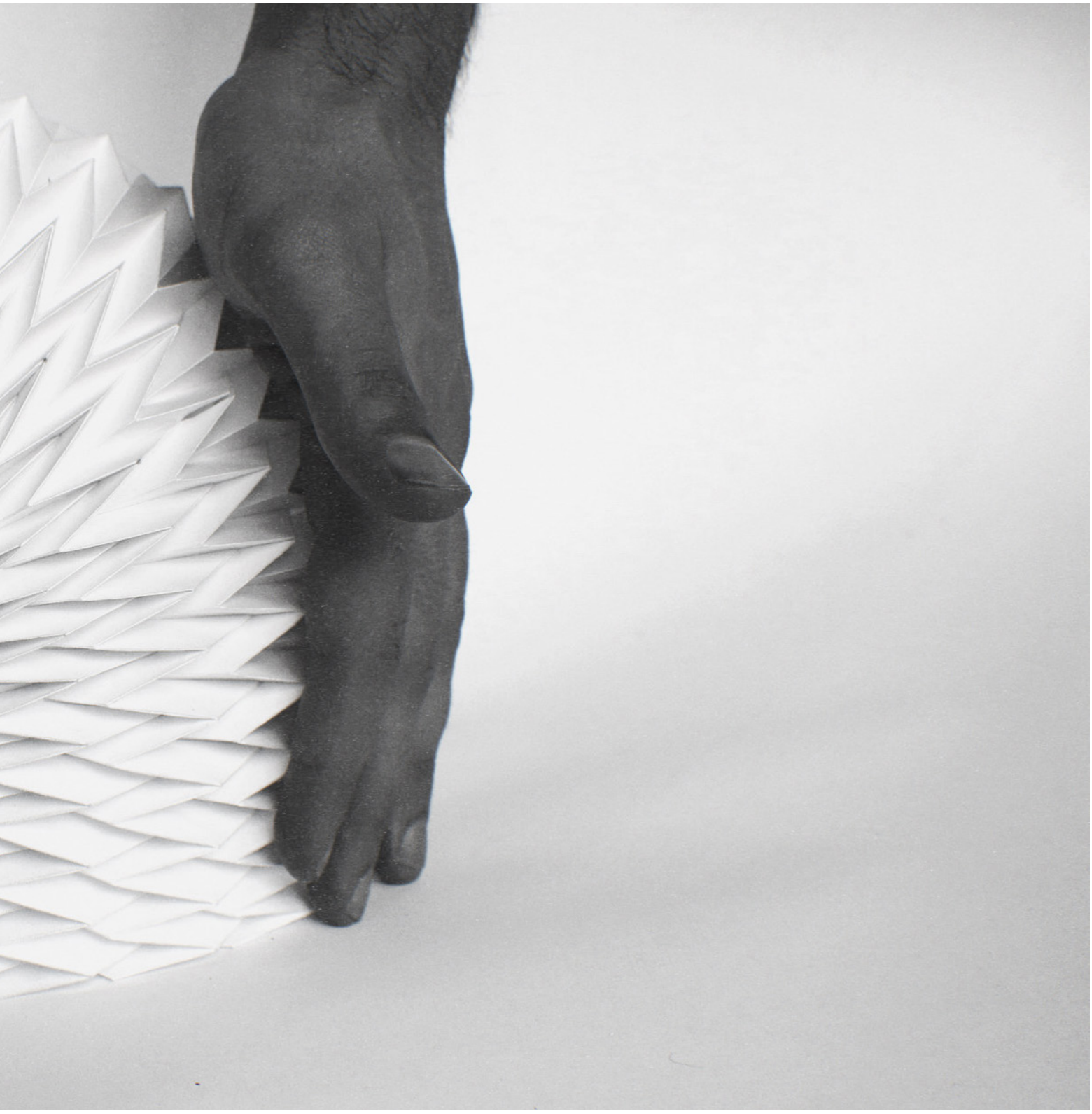


Fig 4.16 Sketch illustrating the direction of accordion folds in a flexible Hood.



Fig 4.17 Small scale prototype of the hood.



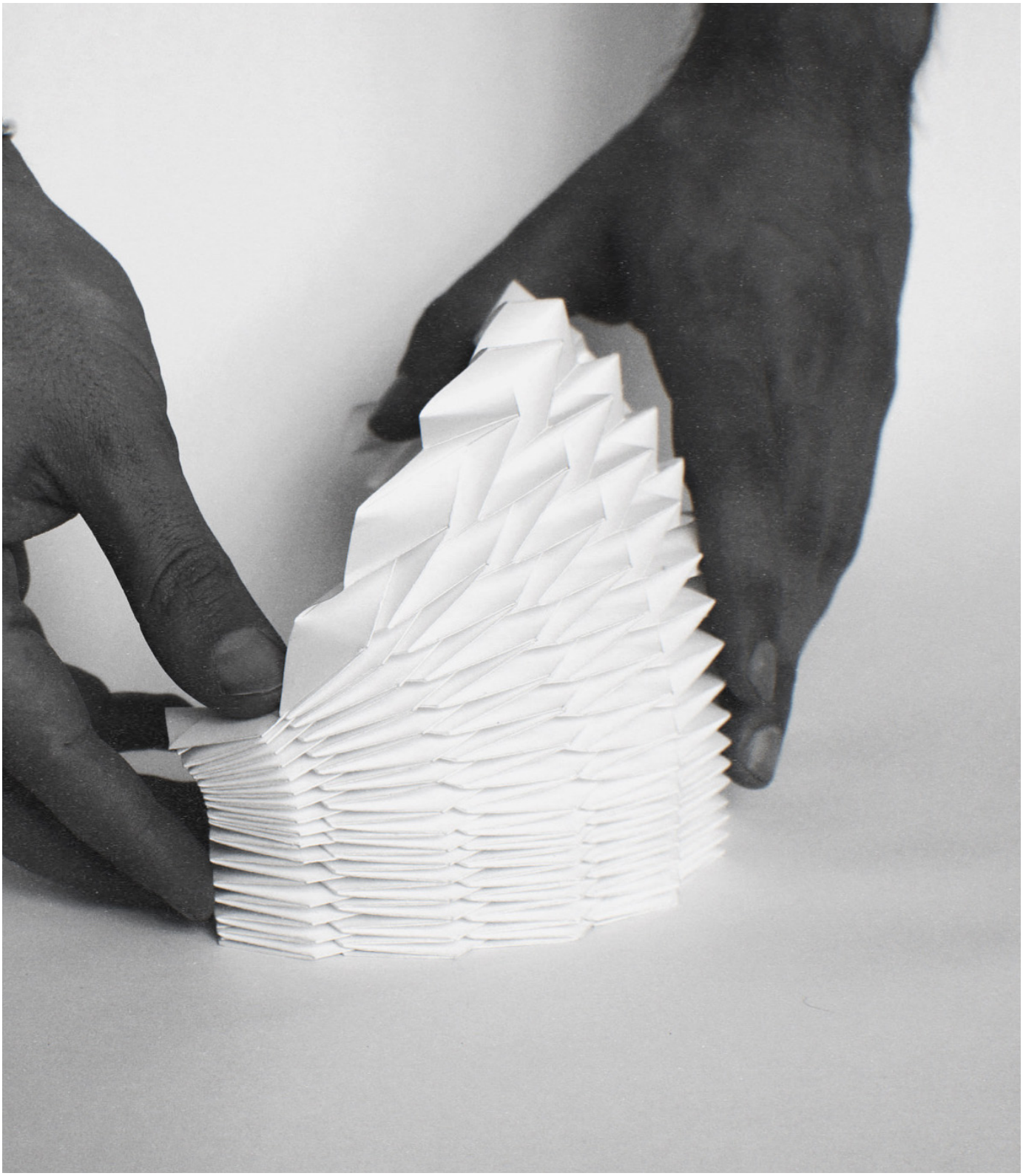


Fig 4.18 Compactability of the hood prototype.

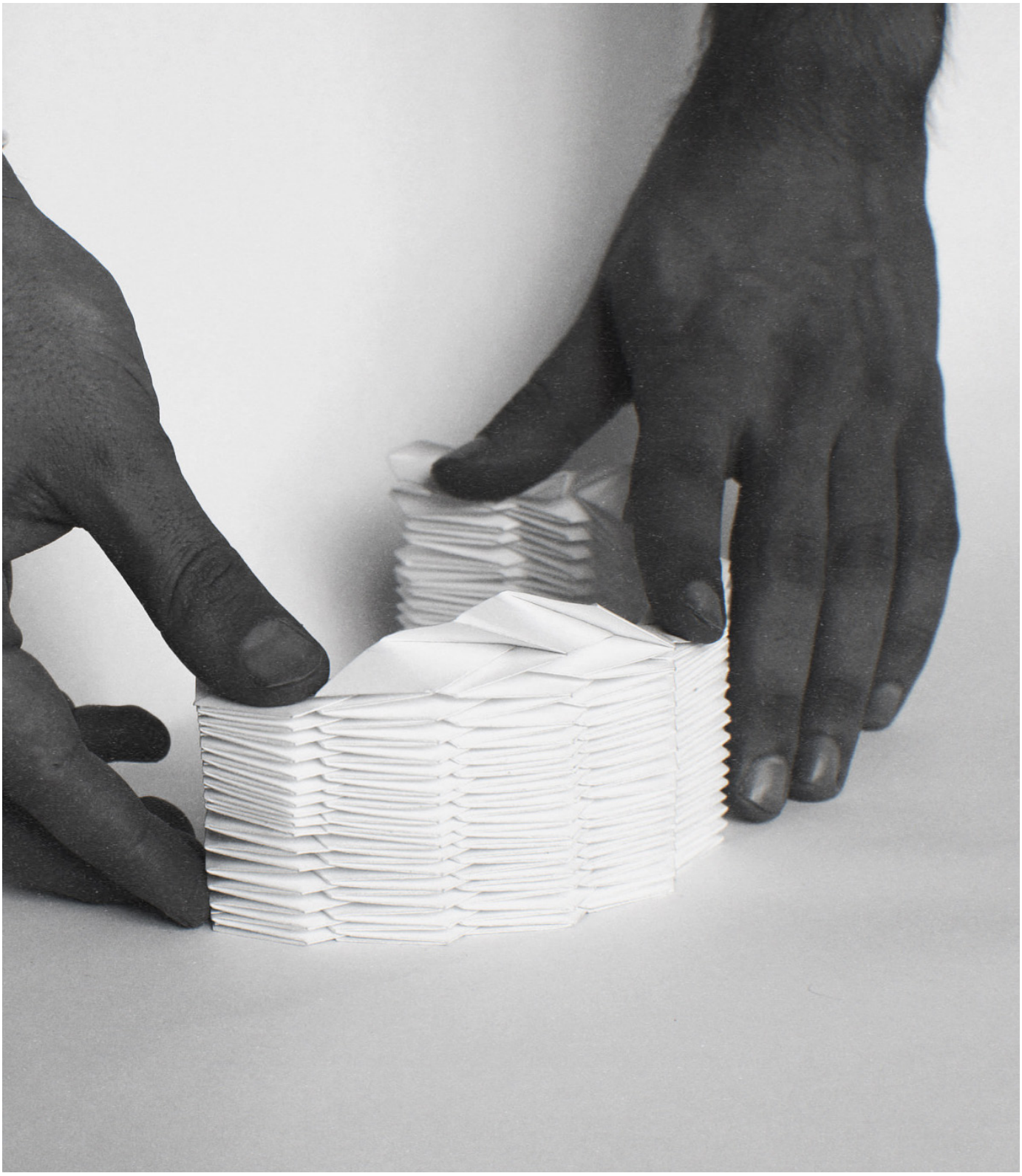


Fig 4.19 Compactability of the hood prototype.

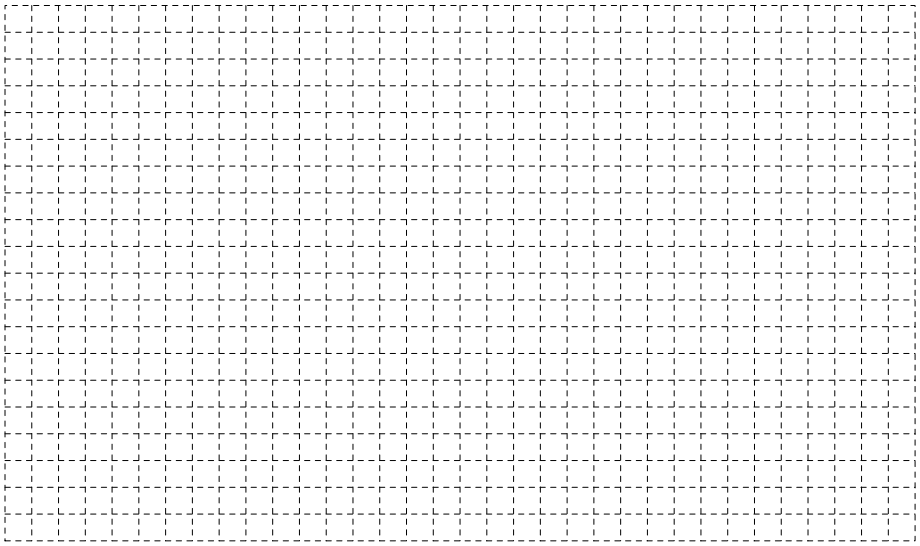


Fig 4.20 Grid division of the surface for component organization.

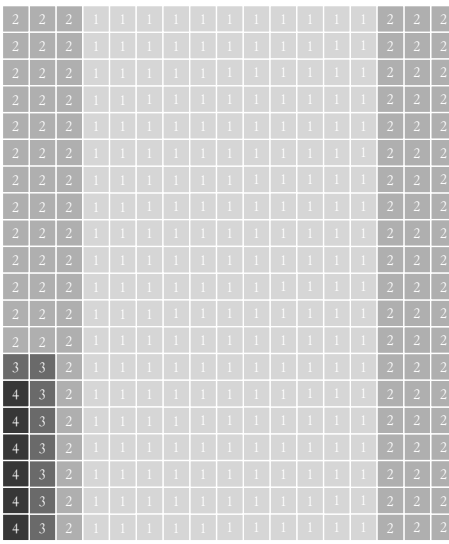
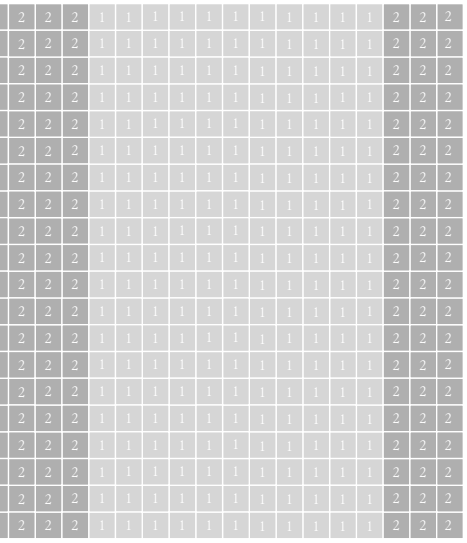


Fig 4.21 Coding the grid with nume assigned to different component varia



erical values and colors
tions.

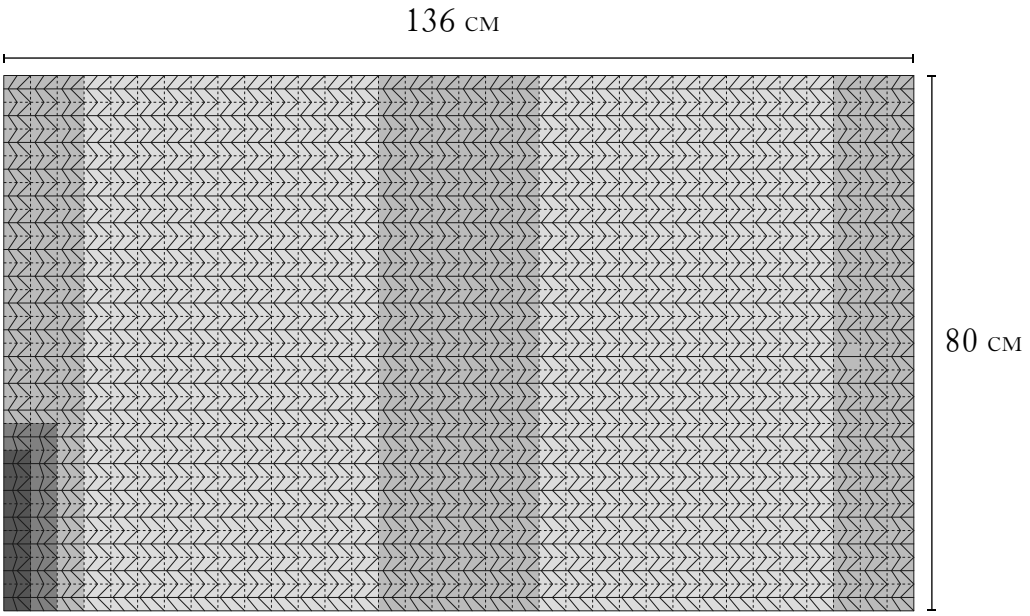


Fig 4.22 Distributing different components across the surface based on the color-mapped grid.

IV.II.II

BODICE

The bodice section of the surface must bend at the shoulders and waist while ensuring that the folds transition correctly to facilitate the dynamic compactability of the hood and sleeves. The primary challenge lies in accommodating these adaptive deformations along multiple directions within a single surface constrained by limited boundaries, which requires multiple optimization phases to achieve a seamless and functional solution. The developed bodice wraps around the body, beginning at the collar and connecting to the hood. From there, it extends over the shoulders, integrating with the sleeves, and continues down to cover the waist. This structural ribbon must bend multiple times as it conforms to the body's complex form, with each bend adapting uniquely to the specific anatomical features it encounters. For instance, the surface bends differently around the shoulders than it does at the waist due to variations in size and the differing angles at which the surface meets these body parts. To simplify this adaptation, the ribbon-like structure covering the torso has been divided into five distinct sections. Each section is designed sequentially, ensuring precise adjustments before merging into a single continuous ribbon in the final design.



Fig 4.23 Sketch of the accordion folds for bodice.

The first section originates at the neck, expanding to envelop the chest and wrap around the shoulder, where it gradually morphs into a sleeve. Figures 4.22 to 4.25 depict the process of mapping various components into a tessellated pattern. Once folded, this pattern transforms a flat sheet into a three-dimensional structure that conforms to the complex topography of the body (Fig.4.21).

The geometry exhibits varying degrees of curvature: bending with higher intensity at the neck as it transitions into the hood, flattening across the chest for a more structured fit, and intensifying its bending again at the shoulder. This transformation continues as the surface wraps around the torso, shaping the bodice of the wearable.

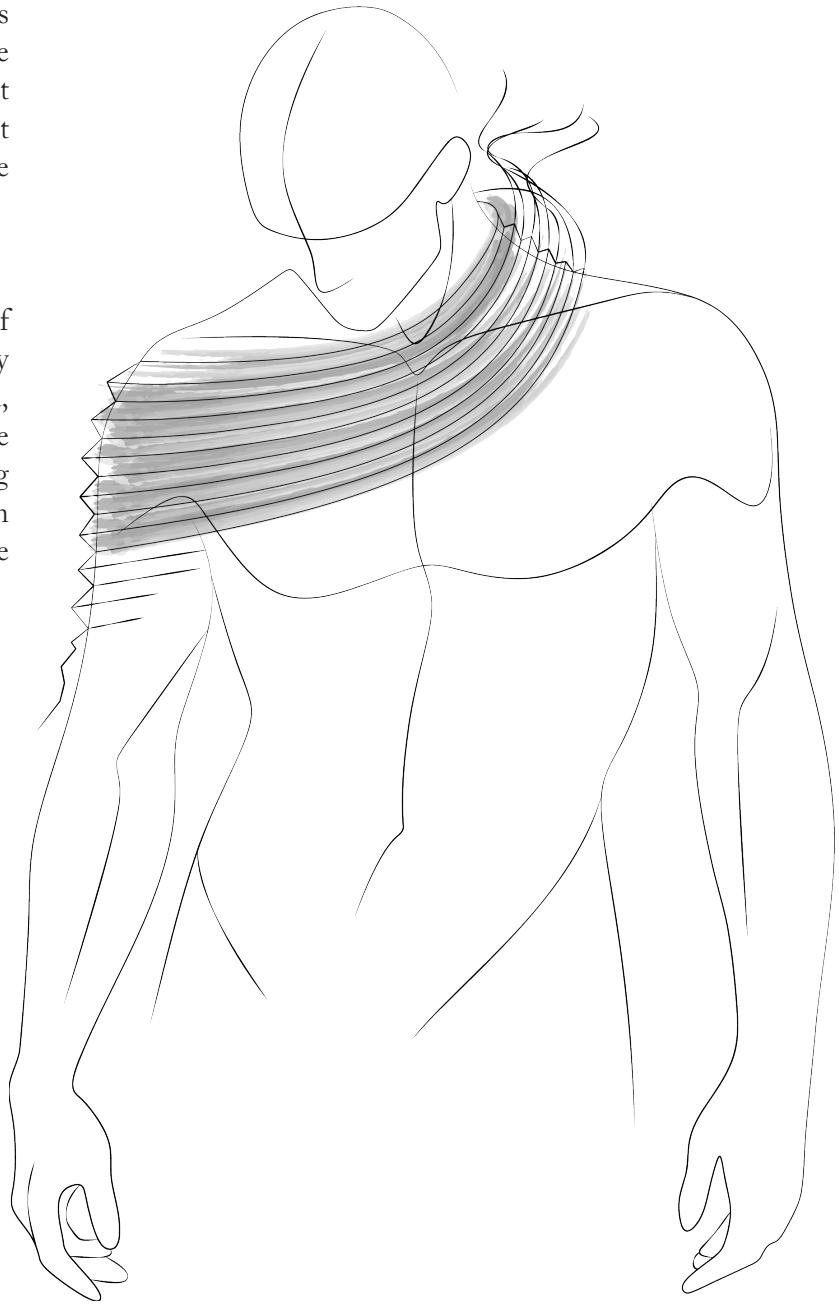


Fig 4.24 Sketch illustrating the bodice section from neck to shoulder.

Fig 4.25 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.

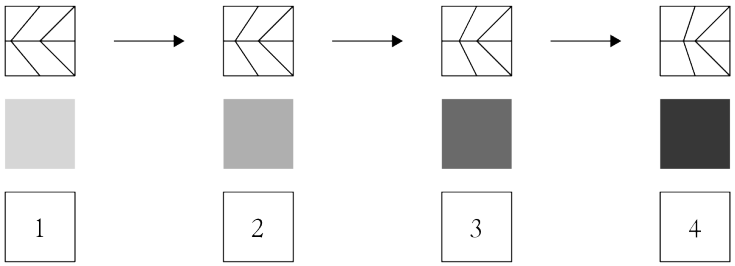


Fig 4.26 Grid division of the surface for component organization.

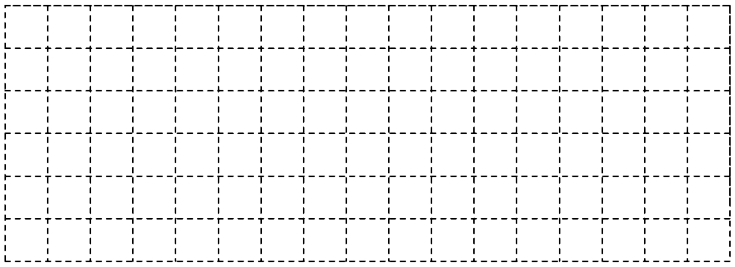


Fig 4.27 Coding the grid with numerical values and colors assigned to different component variations.

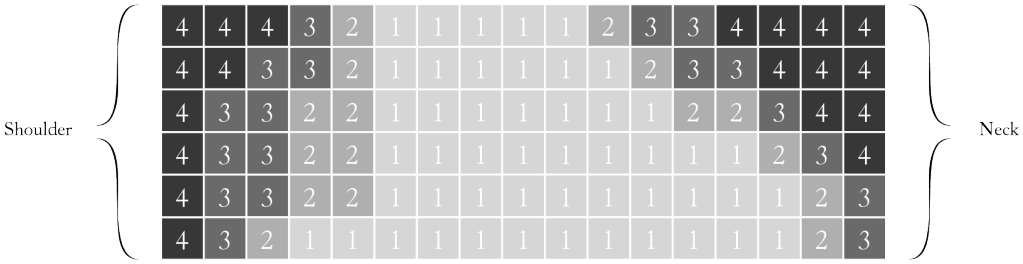
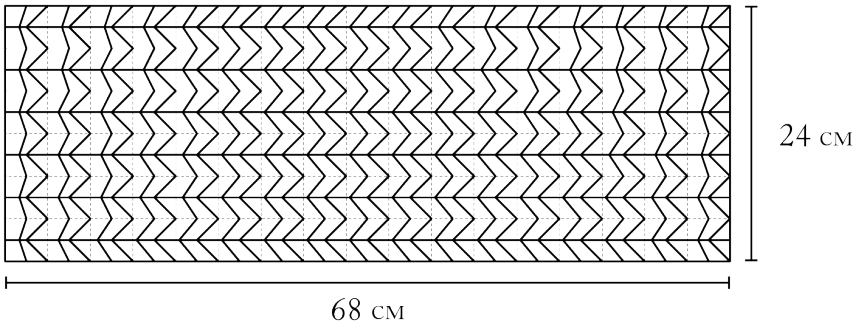


Fig 4.28 Distributing different components across the surface based on the color-mapped grid.



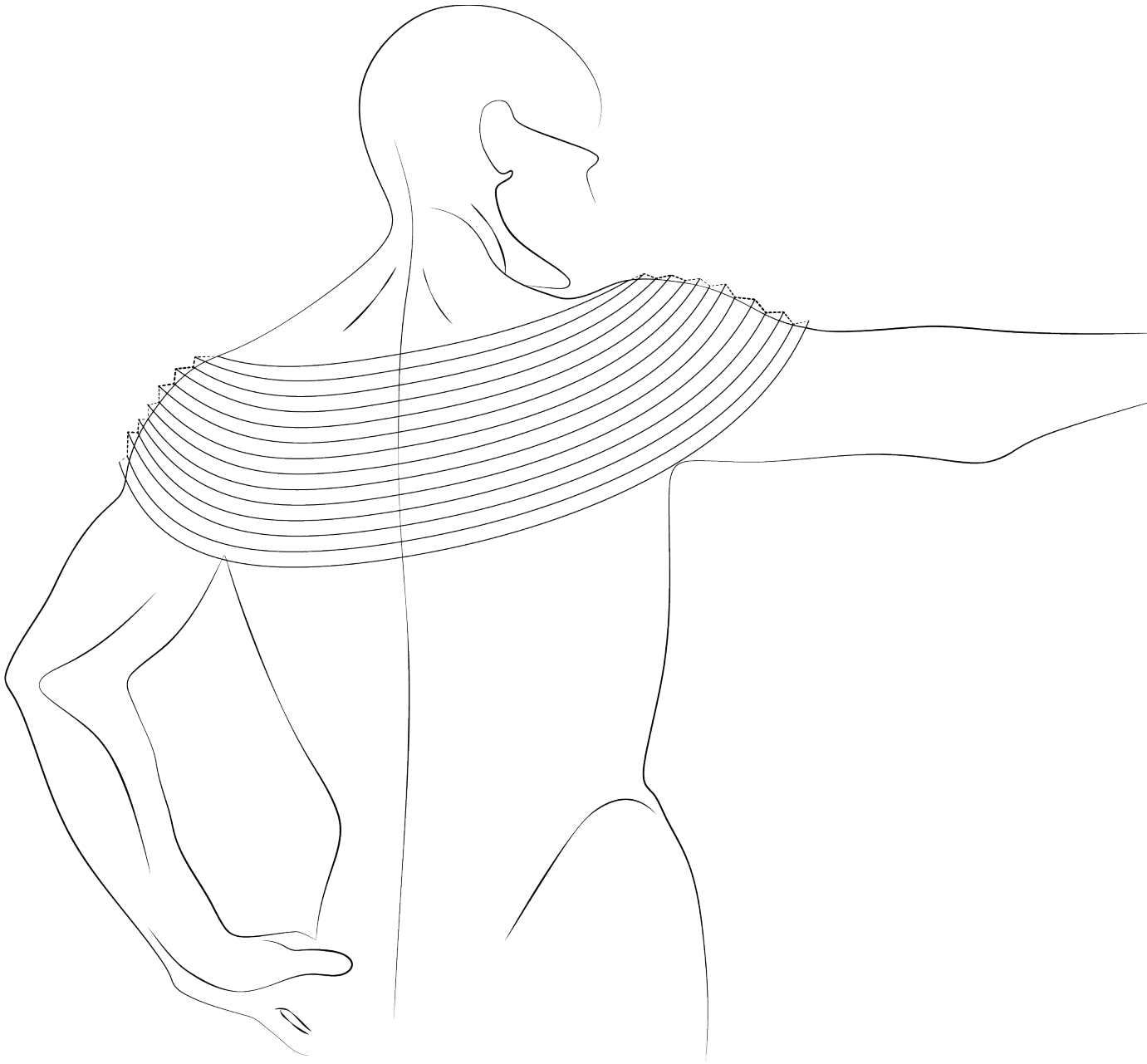


Fig 4.29 Sketch illustrating the bodice section from shoulder to shoulder.

Fig 4.30 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.

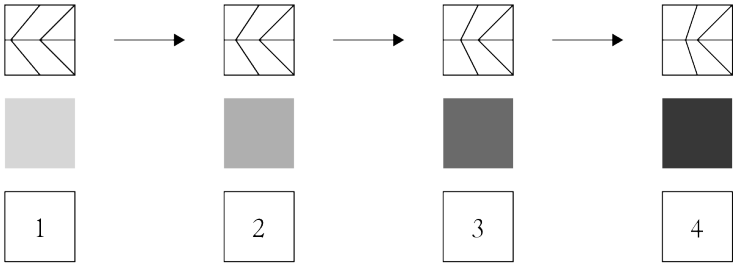


Fig 4.31 Grid division of the surface for component organization.

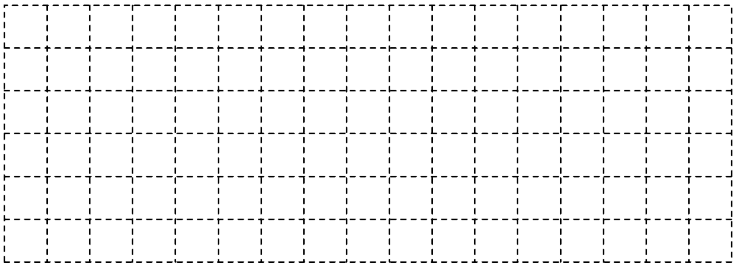


Fig 4.32 Coding the grid with numerical values and colors assigned to different component variations.

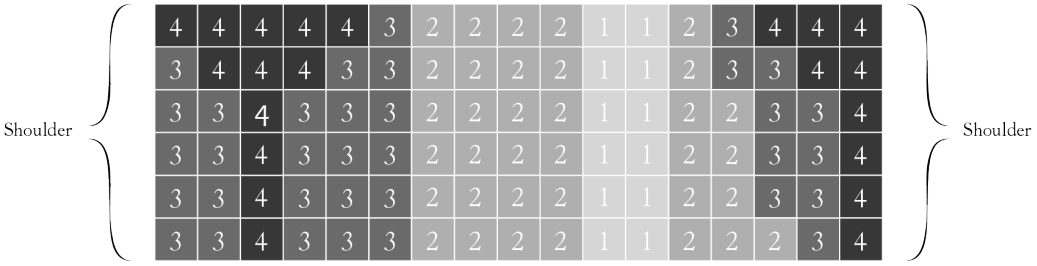
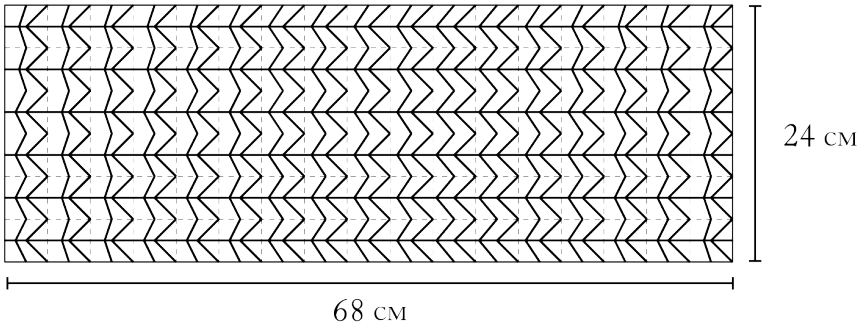


Fig 4.33 Distributing different components across the surface based on the color-mapped grid.



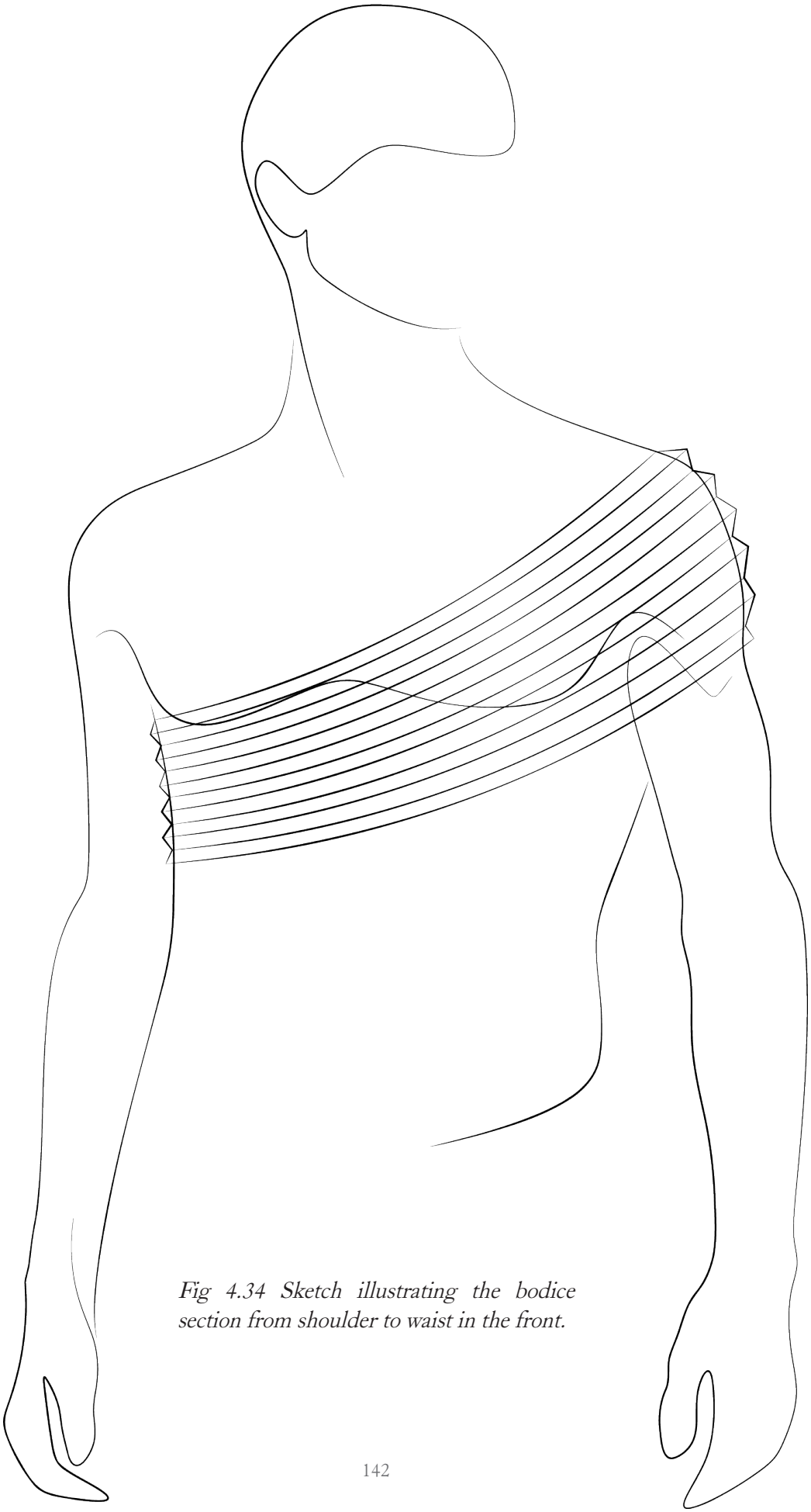


Fig 4.34 Sketch illustrating the bodice section from shoulder to waist in the front.

Fig 4.35 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.

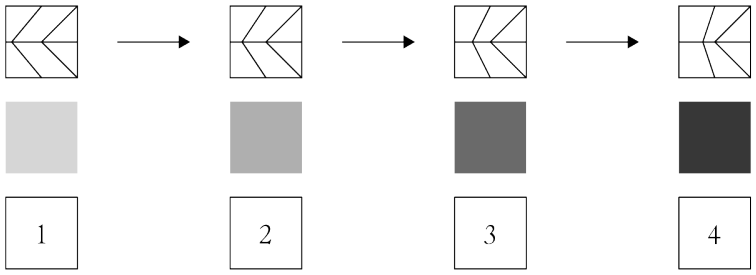


Fig 4.36 Grid division of the surface for component organization.

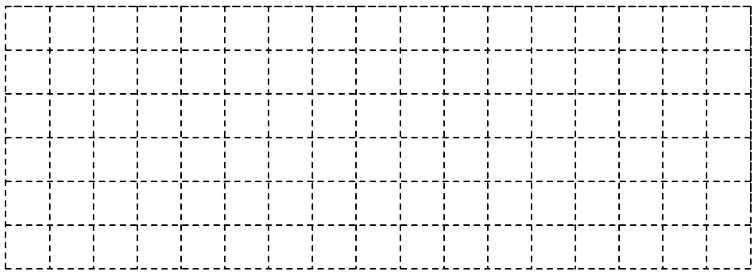


Fig 4.37 Coding the grid with numerical values and colors assigned to different component variations.

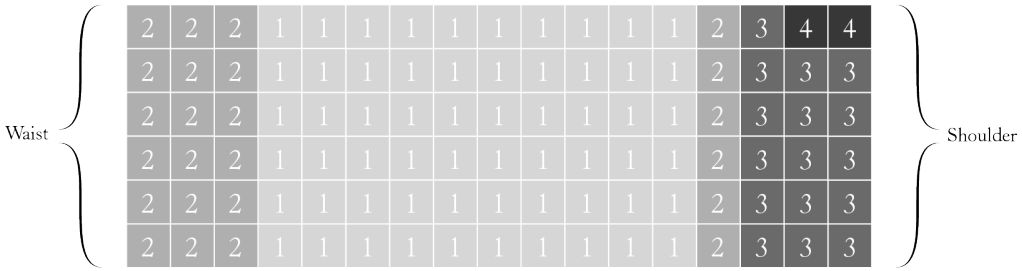
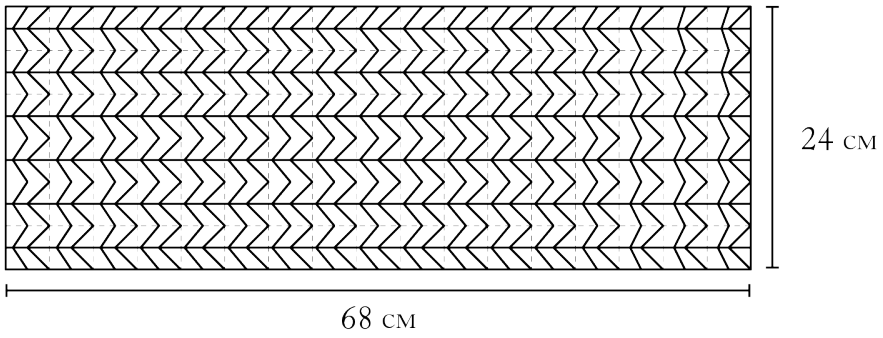


Fig 4.38 Distributing different components across the surface based on the color-mapped grid.



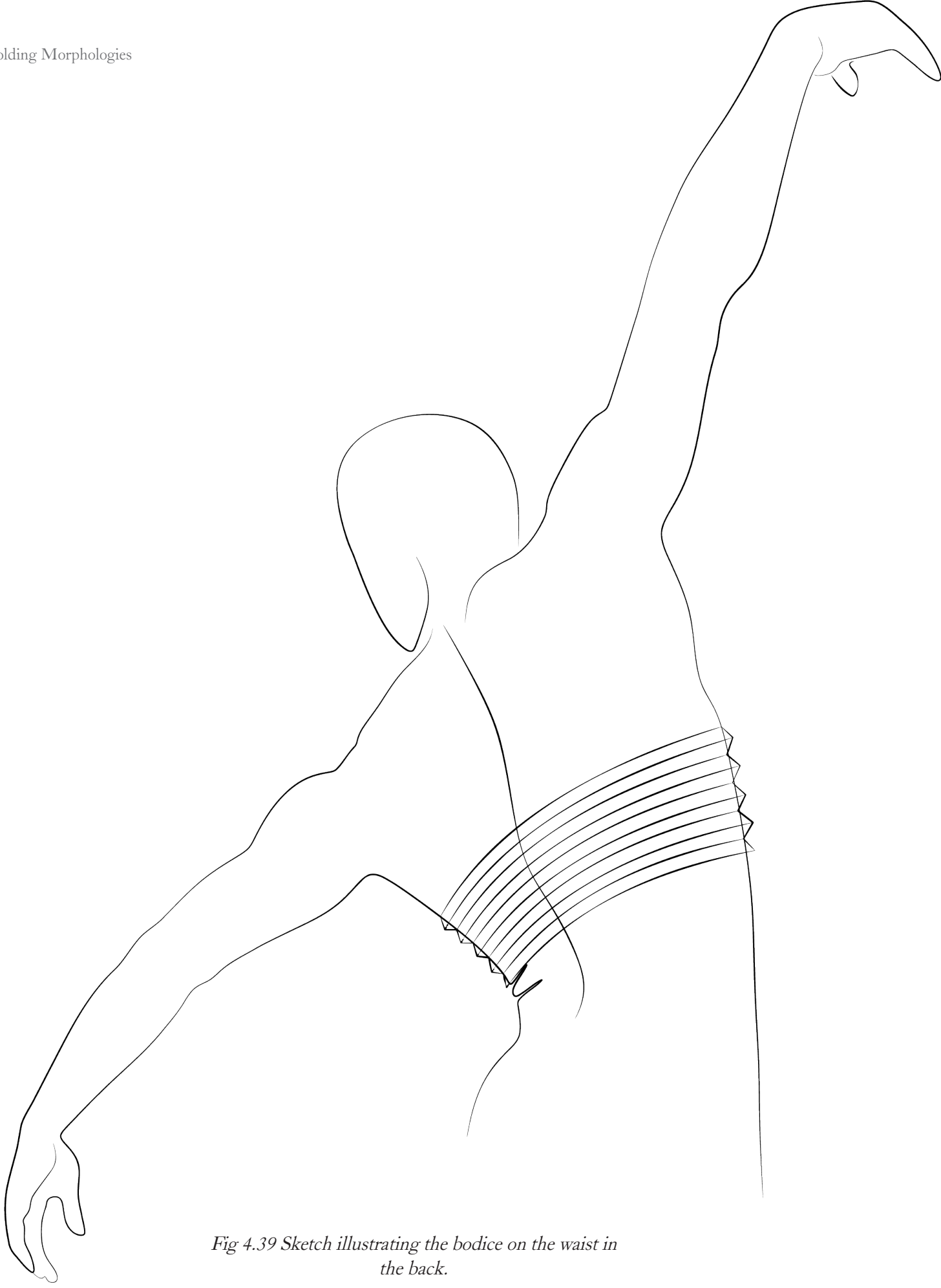


Fig 4.39 Sketch illustrating the bodice on the waist in the back.

Fig 4.40 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.

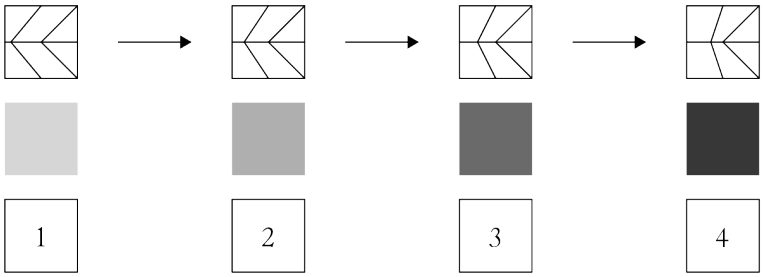


Fig 4.41 Grid division of the surface for component organization.

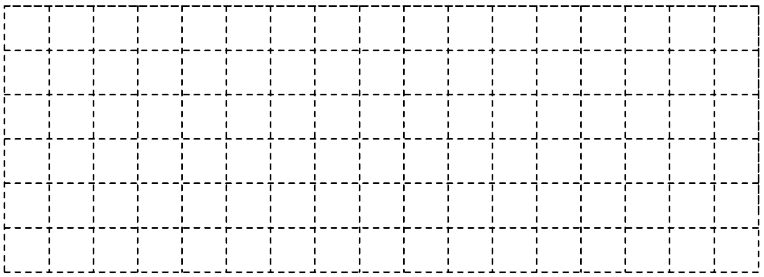


Fig 4.42 Coding the grid with numerical values and colors assigned to different component variations.

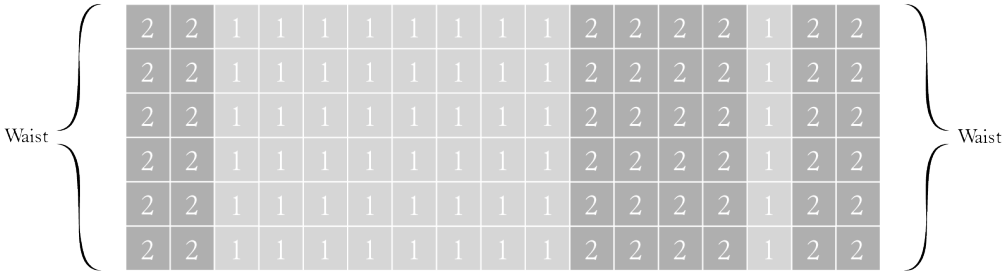
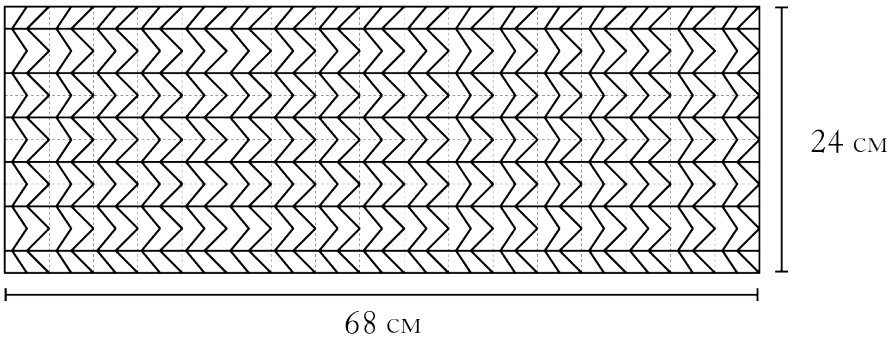


Fig 4.43 Distributing different components across the surface based on the color-mapped grid.



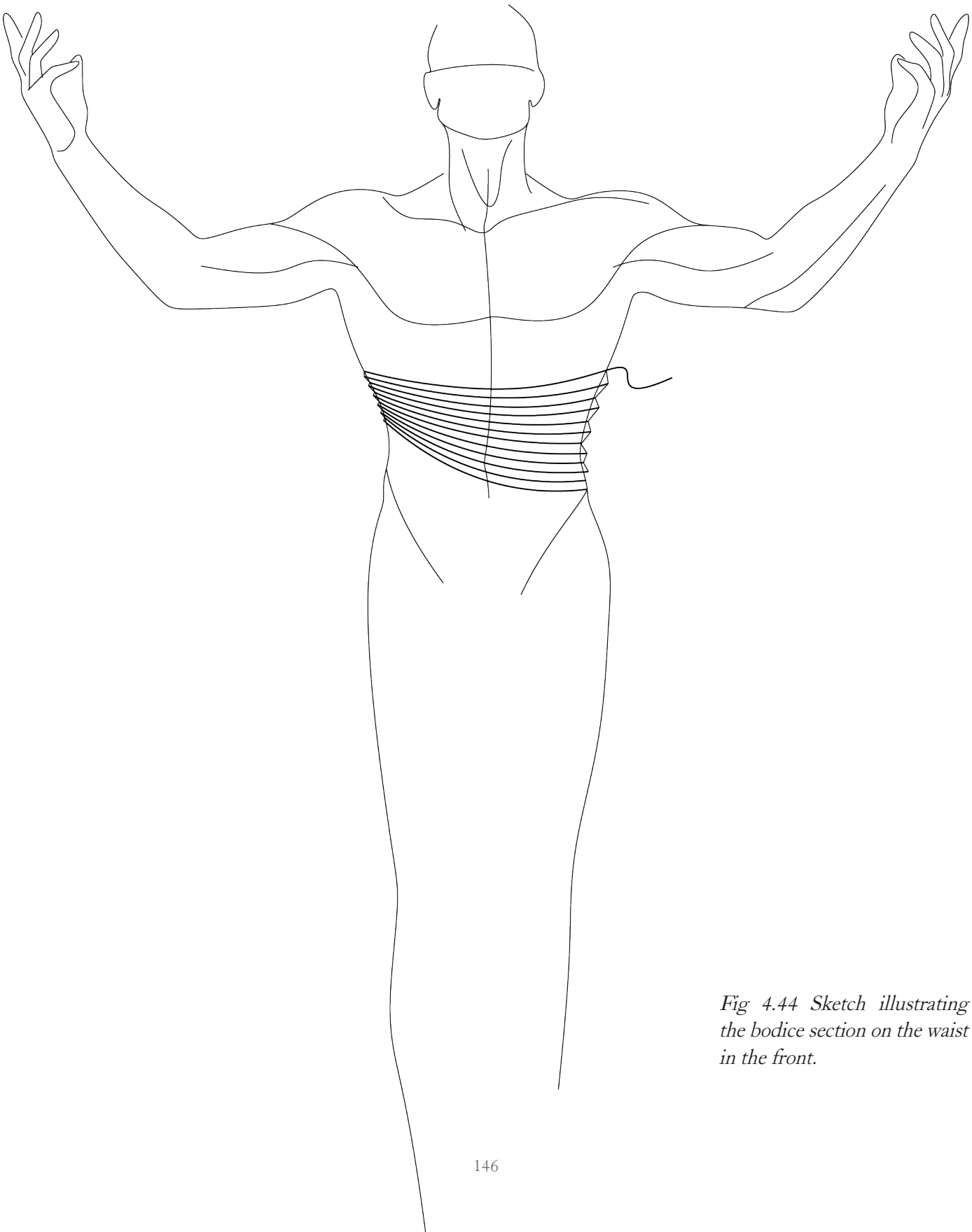


Fig 4.44 Sketch illustrating the bodice section on the waist in the front.

Fig 4.45 Sequential modifications of the base unit, with different colors and numbers assigned to distinguish variations.

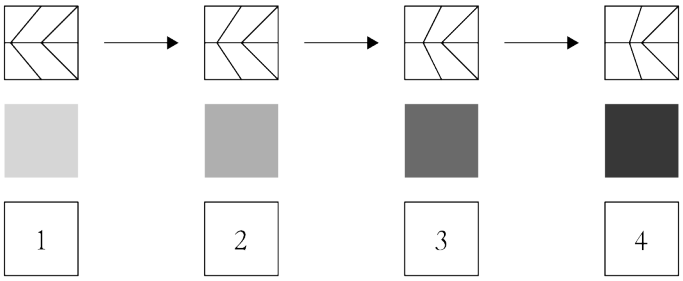


Fig 4.46 Grid division of the surface for component organization.

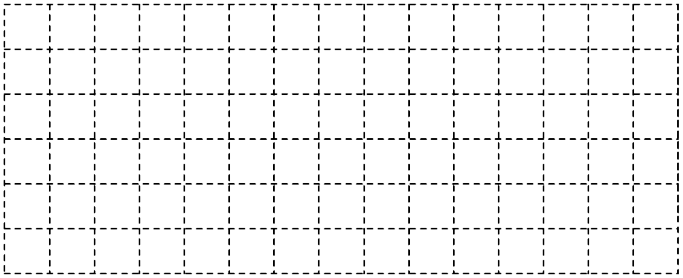


Fig 4.47 Coding the grid with numerical values and colors assigned to different component variations.

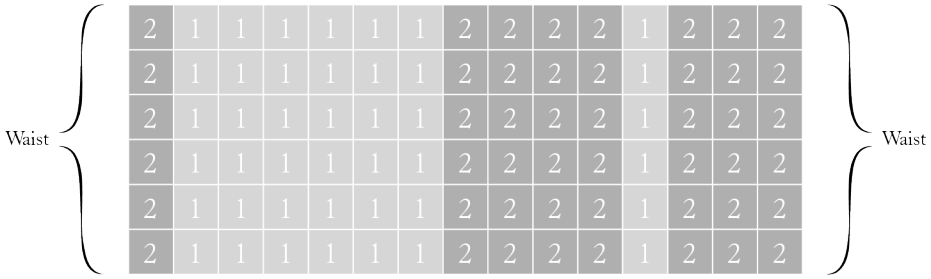
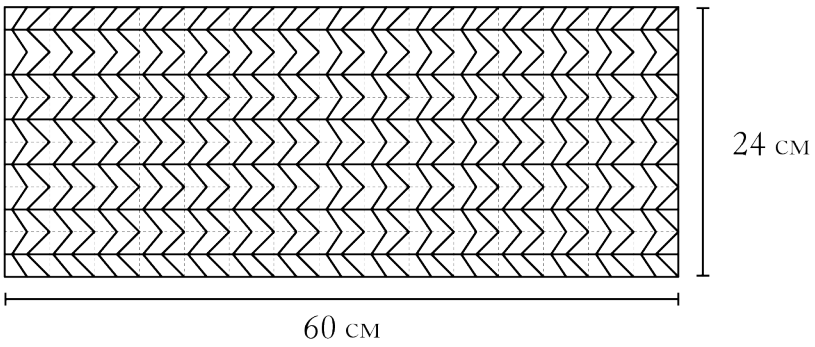


Fig 4.48 Distributing different components across the surface based on the color-mapped grid.



IV.III
WHOLE

Folding, as described by Sancho, is a unitary gesture (Sancho 2014, p. 24), enabling multiple functional elements to integrate into a continuous whole (Lynn 2004). The design process was initiated with the intention of merging all components into a unified system. Each part of the dress was developed with careful consideration of its connection points to the rest of the system, ensuring seamless integration within the overall structure.

The proposed assembly illustrates the continuity of the folding logic throughout the entire system, demonstrating how the design maintains coherence along its structure. However, the fabrication of the dress was inevitably shaped by material and production constraints. Due to the limitations imposed by the available sheet material dimensions and the relatively small working area of the laser cutting machine, the dress could not be produced as a single continuous piece. Instead, it was designed and manufactured in multiple pieces, which were later assembled to form the final wearable structure.

While this segmented approach contrasts with the conceptual foundation of continuity proposed in the design, it also presents an opportunity to explore a different facet of continuity—one that is achieved through meticulous integration rather than material singularity. The process of assembly itself becomes a generative act, where separate tessellated units come together to form a cohesive whole. The following masterplan illustrates the unified tessellation system, which, when folded, becomes a three-dimensional wearable surface.

Fig 4.49 The bodice wrapping around the torso, adapting to its formal complexity.



MASTERPLAN

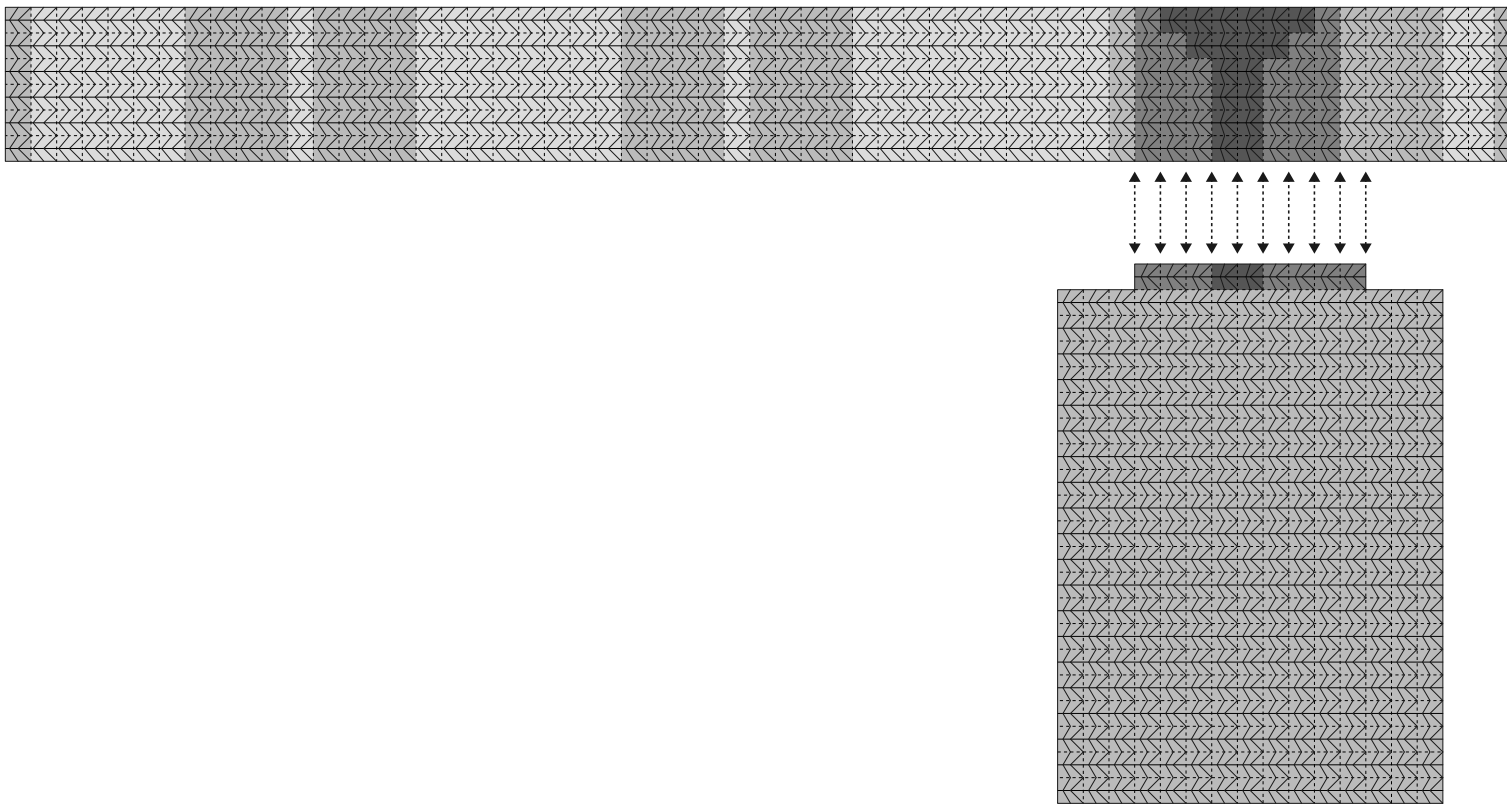
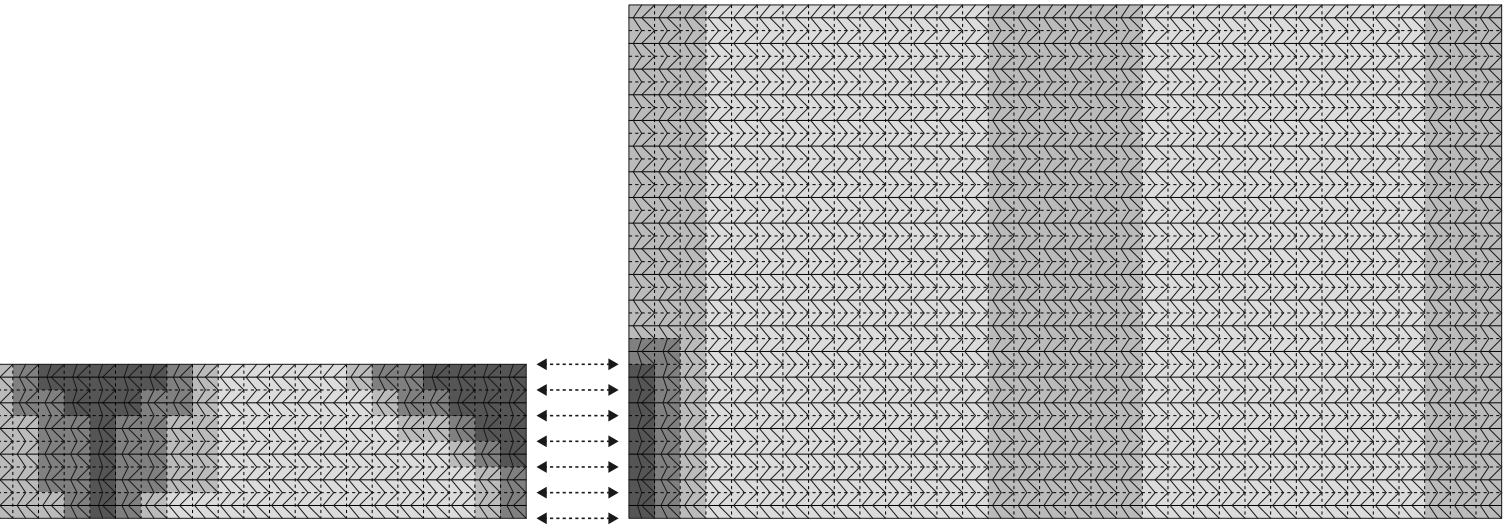


Fig 4.50 Diagram illustrating the complete plan assembly.





BODICE TO HOOD

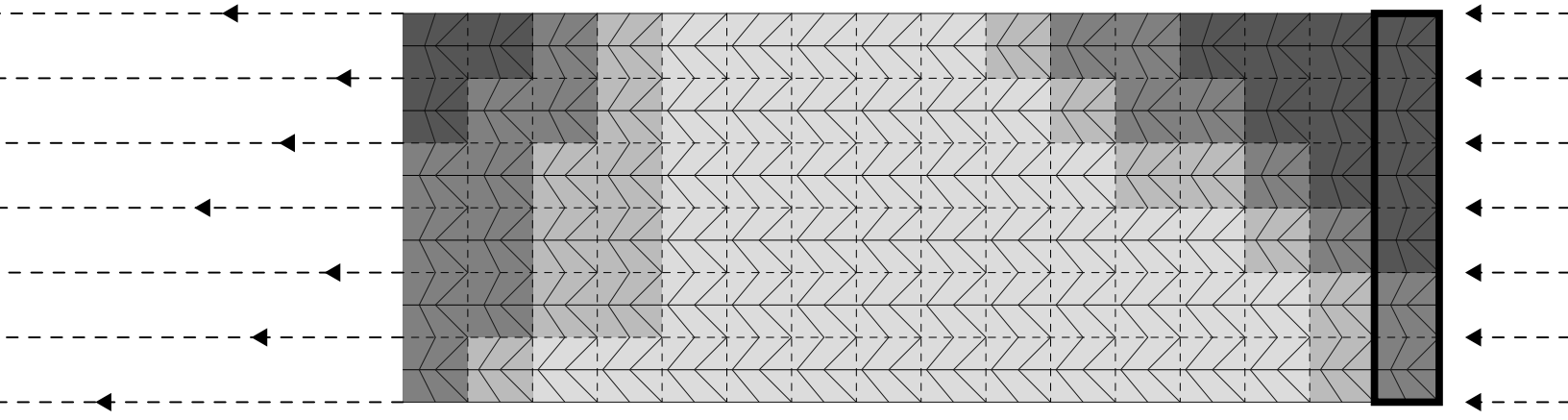
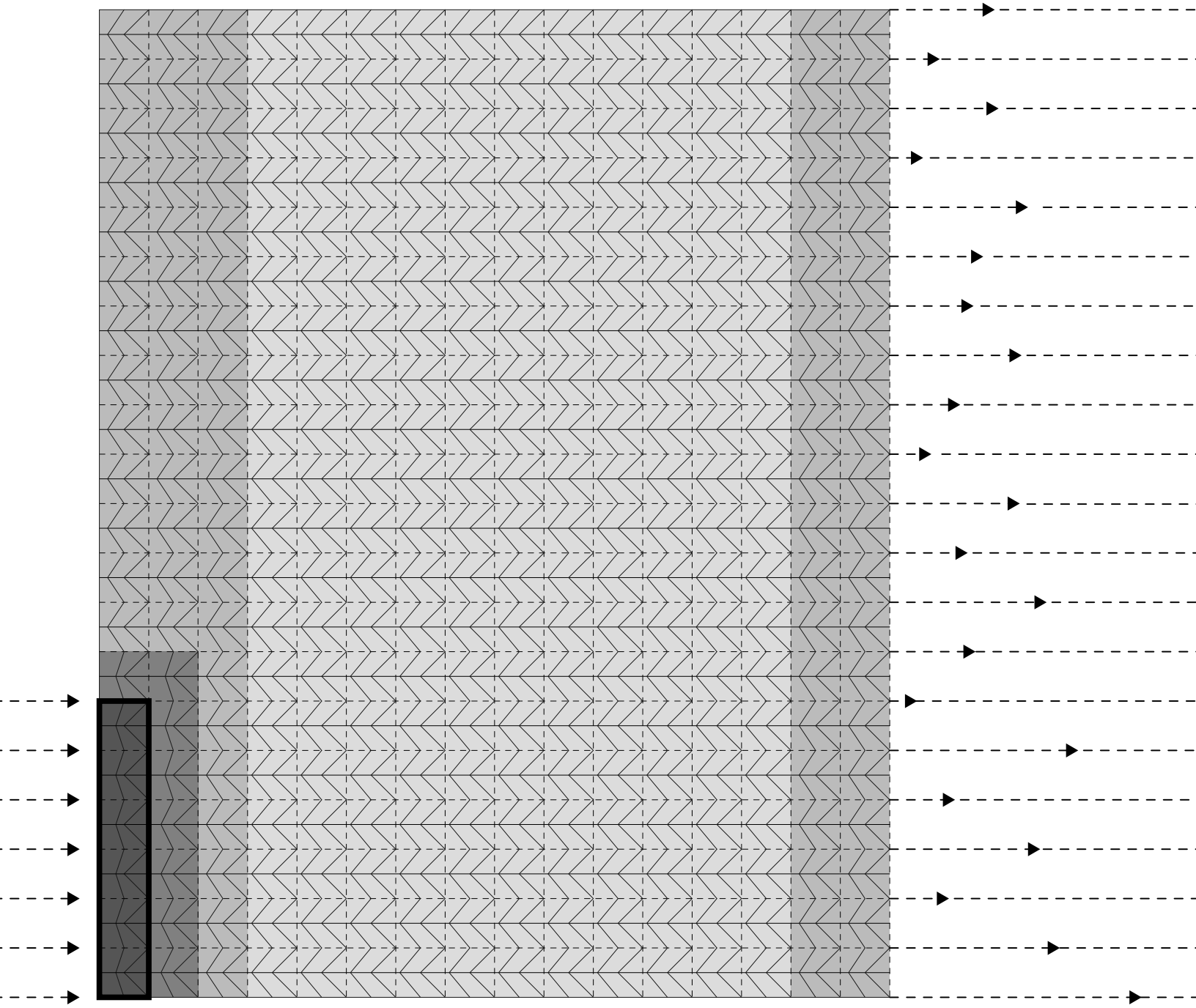
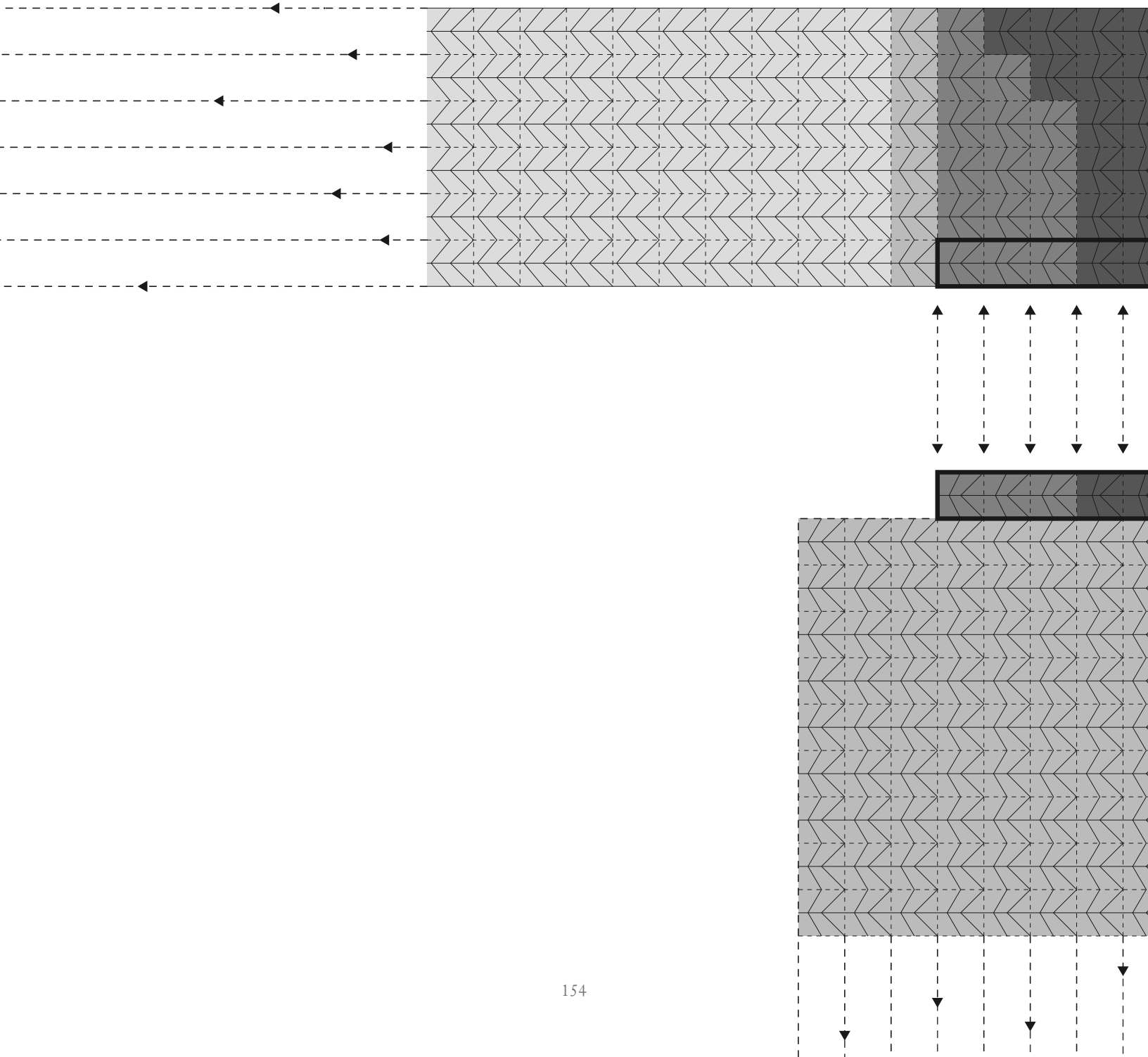


Fig 4.51 Diagram illustrating the overlapping connection between the bodice and hood.





BODICE TO SlEEVE



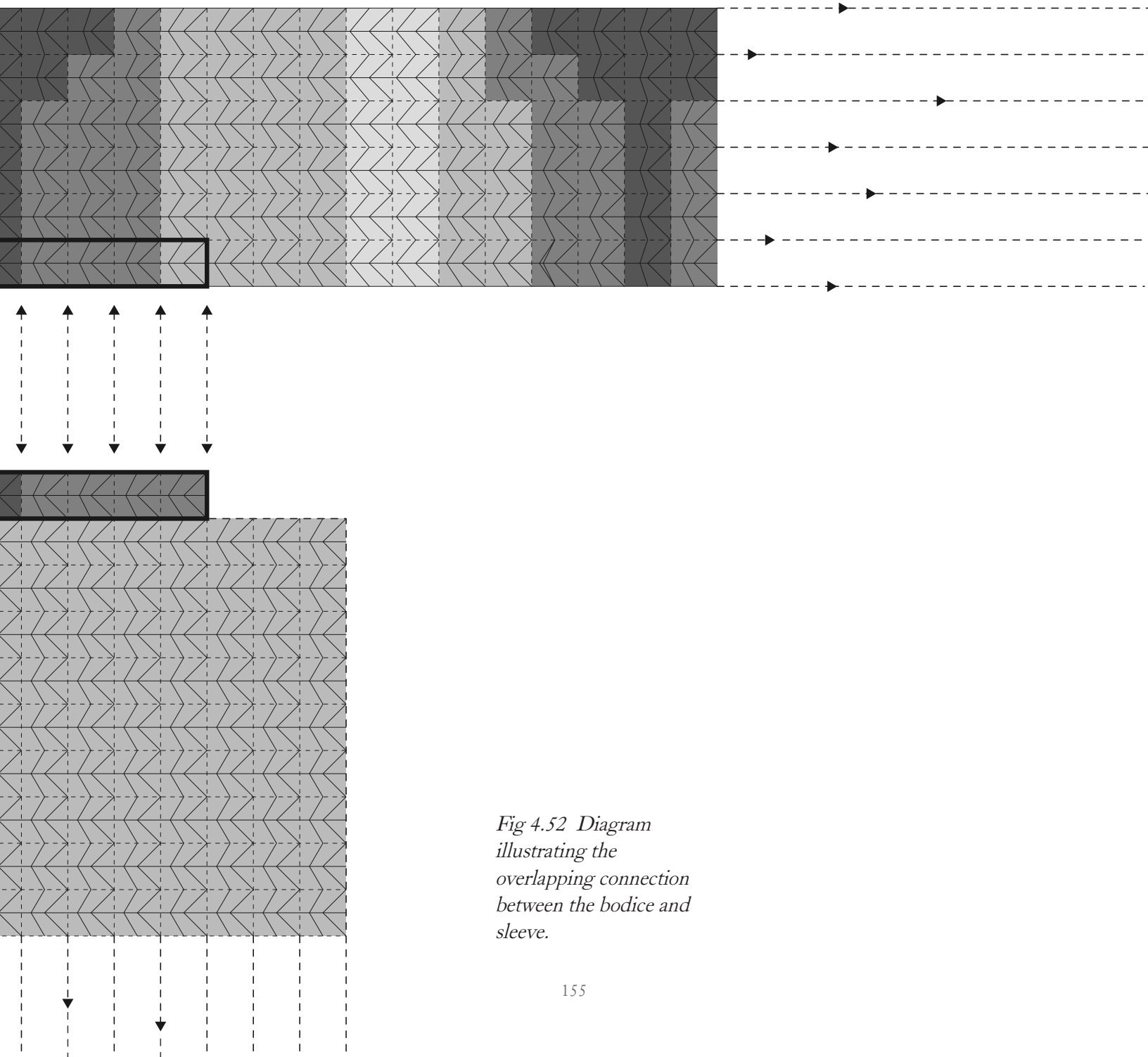


Fig 4.52 Diagram illustrating the overlapping connection between the bodice and sleeve.



Fig 4.53 Wearable surface.



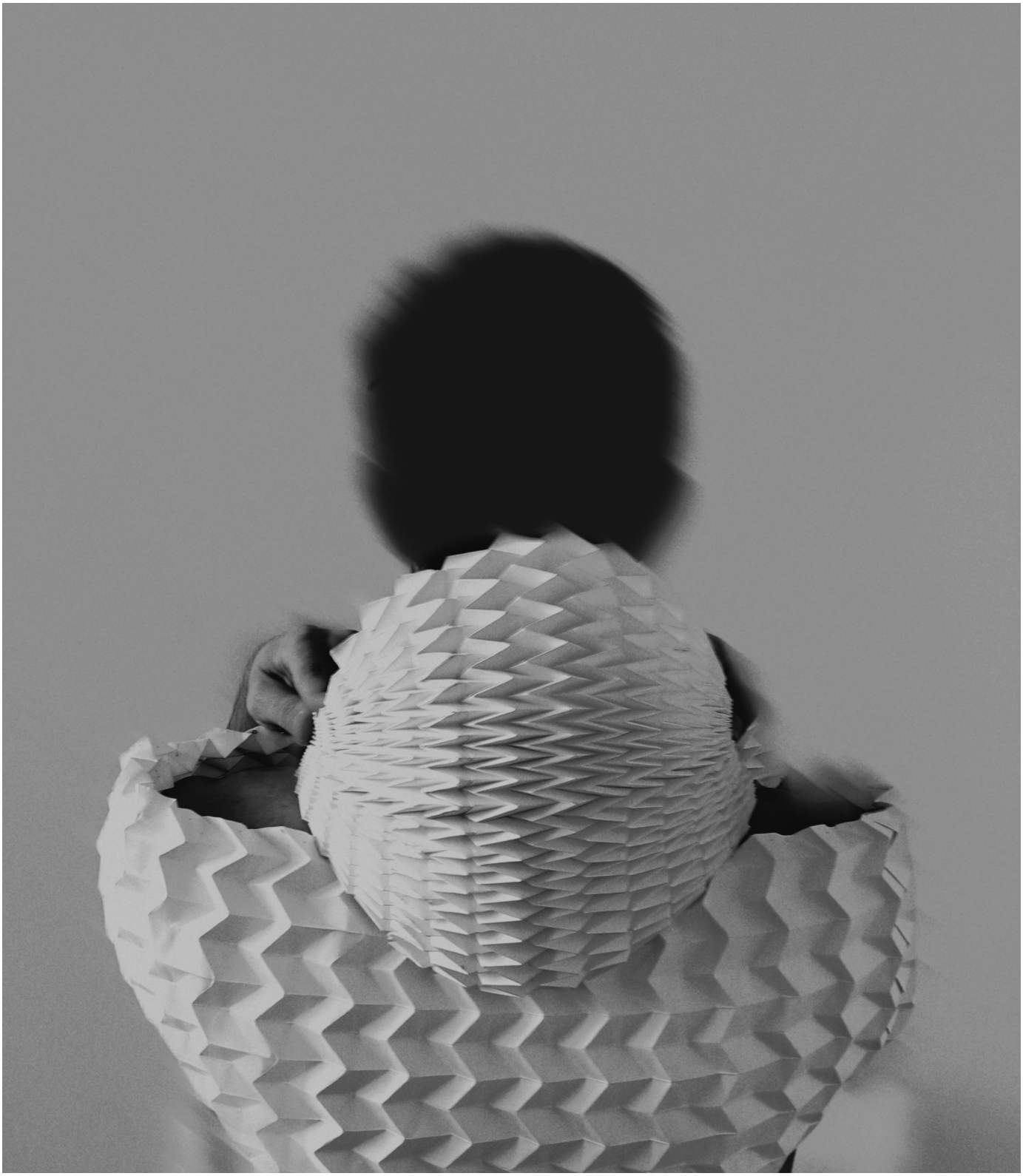


Fig 4.54 Flexibility of the hood.

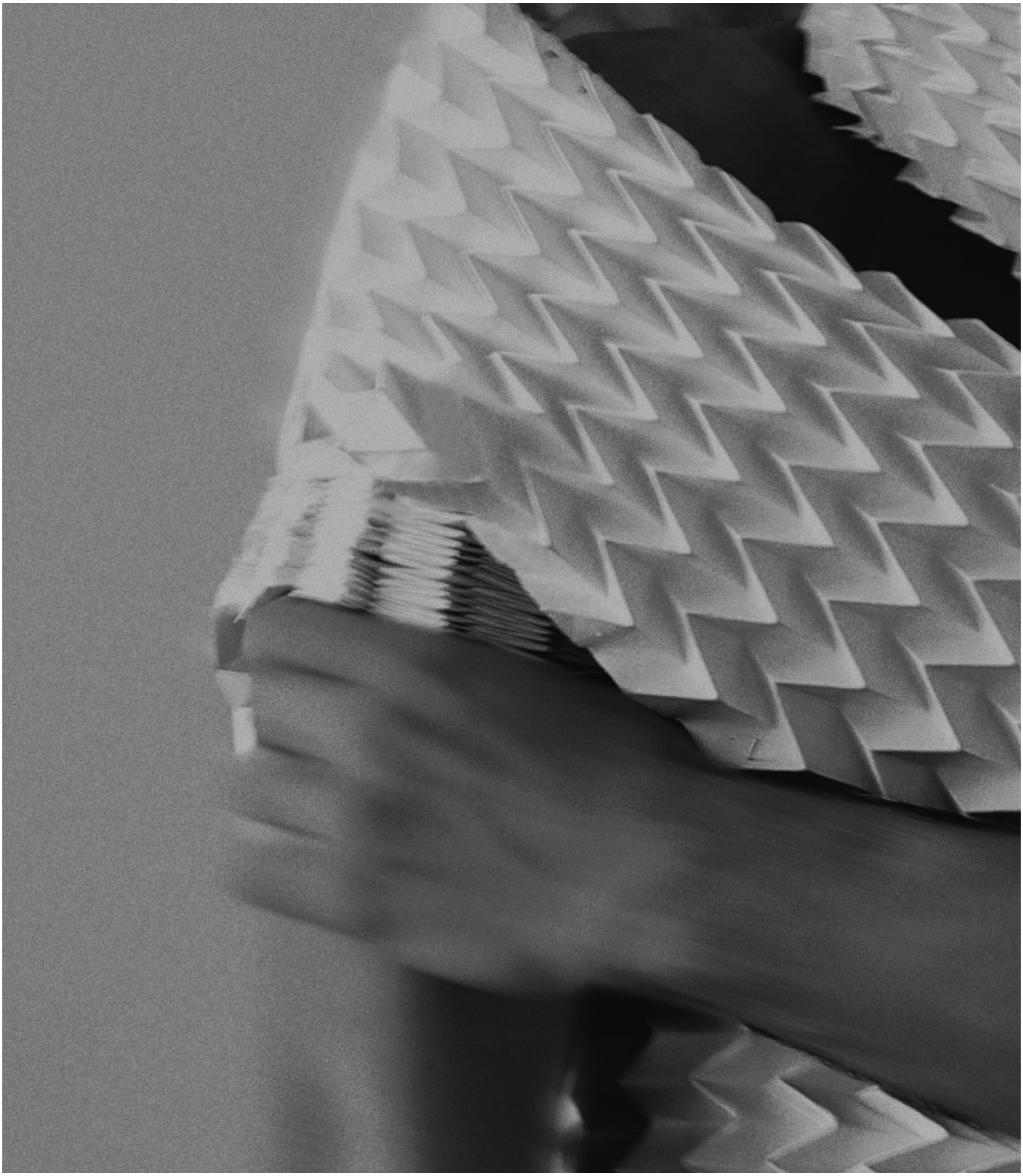


Fig 4.55 Compactability of the sleeve.



Fig 4.56 Wearable surface.





Fig 4.57 Sleeve and hood compacted.



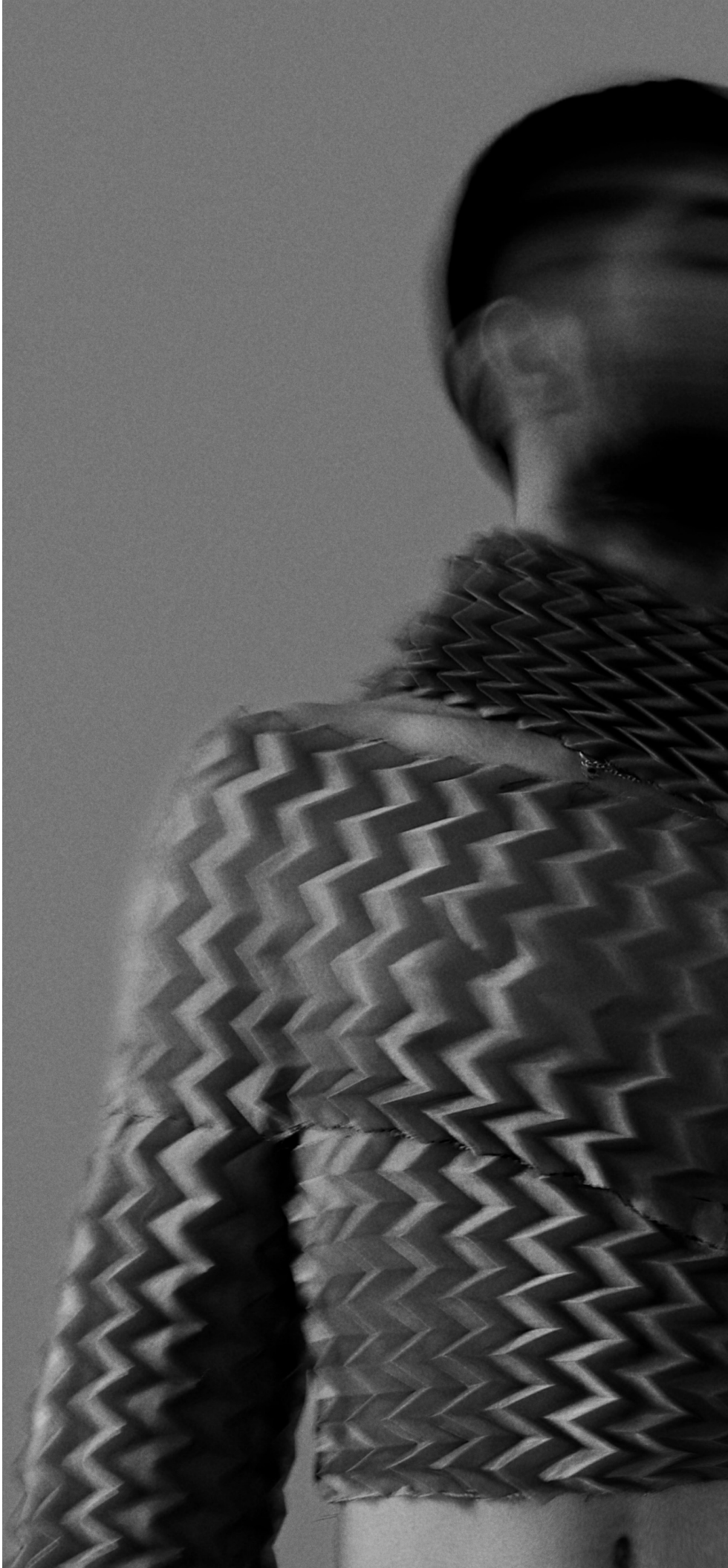


Fig 4.58 Pleated organza prototype.

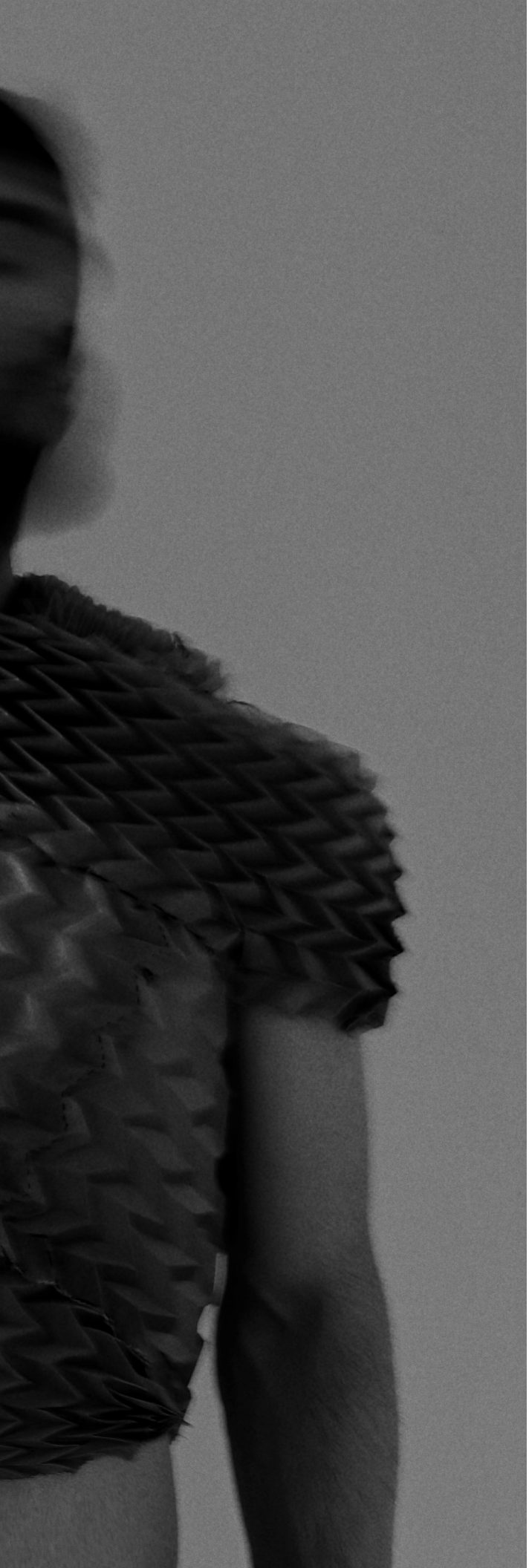




Fig 4.59 Pleated organza prototype





Fig 4.60 Pleated organza prototype.



PART V | CONCLUSIONS

V.I
CONCLUSIONS

The culmination of this thesis—through literature review, Case studies, pattern studies, and prototyping—resulted in a wearable surface that demonstrates the potential of folding as a design strategy for adaptive spatial reconfiguration. Rather than being a static product, folding is explored as a dynamic process that enables continuous spatial transformation. While architects such as Peter Eisenman and Greg Lynn have utilized folding to evoke transformation and generate adaptive forms, their final outcomes remained fixed. This thesis investigates the transformational qualities of folding, revealing its potential for dynamically adaptive and responsive structures.

One of the key contributions of this research is the development of a structured framework for analyzing folding behavior. By integrating component studies and growth pattern investigations, this study has enabled a deeper understanding of how local geometric manipulations influence global surface behavior. This methodology provides designers with a tool to harness folding, not as a functional mechanism for creating spaces that transform in response to users and environmental conditions.

The wearable artifact produced as part of this thesis serves as a proof of concept and an extension of architectural thinking at an intimate scale. While folding can be applied at various scales—from cardiac stents to operable stadium roofs—this research situates it within clothing, where its activation relies on the user's movement rather than motorized intervention. This allows for an immediate and tangible exploration of folding's capacity for movement, formal adaptability, and space formation, fostering a direct interaction between the user and the artifact.

The relevance of this work extends beyond wearable design. As architecture increasingly prioritizes flexibility, sustainability, and responsiveness, the findings of this study provide a foundation for broader applications. From deployable structures to interactive surfaces, the principles outlined in this thesis can inform the next generation of adaptive design strategies. Ultimately, this research underscores the idea that architecture is not merely a fixed entity but a continuous process that unfolds, responds, and evolves. The ability of folding to generate adaptable forms challenges conventional notions of spatial rigidity, proposing a future where built environments are as dynamic as the lives they support.

Future research can expand upon these findings by refining computational simulation tools for interactive folding design, integrating innovative materials that dynamically respond to external stimuli, and exploring large-scale architectural implementations of the principles developed in this study. By continuing to investigate the synergy between form, structure, and function, this work lays the groundwork for an architecture that is not only built but is continuously becoming.

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