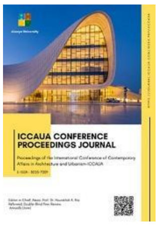

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Hybrid Material Use in Architectural Hardware: Glass Bonding Technology and Surface Analysis in Aluminum Door Handles

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Abstract

The objective of this study is to analyze the effects of glass bonding technology on the mechanical and aesthetic performance of aluminum door handles. The methodology includes integrating glass onto a curved aluminum body using bonding technology and examining the resulting hybrid structure's corrosion resistance and ergonomics. A significant aspect is the rarity of this technology in the hardware sector, which facilitates total surface integrity. Main findings show that bonding technology significantly increases product durability while creating a continuous visual language with the door surface. Ultimately, this research offers an alternative solution for architectural hardware designs by demonstrating that material innovation can enhance structural resilience while presenting a minimal and contemporary aesthetic.

Keywords: Glass Bonding Technology; Aluminum Design; Handle Ergonomics; Surface Integrity; Architectural Hardware.

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Hybrid Material Utilization in Architectural Hardware: Glass Bonding Technology and Surface Analysis in Aluminum Door Handles

Abstract:
The aim of this study is to analyze the effects of glass bonding technology on the mechanical and aesthetic performance of aluminum door handles. Within the scope of the methodology, glass was integrated into a curved aluminum body using bonding technology, and the corrosion resistance and user ergonomics of this hybrid structure were examined. A significant aspect of this approach is its ability to provide surface integrity through a relatively uncommon application within the door handle industry. The findings indicate that bonding technology enhances product durability while creating material continuity between the handle and the glass surface, thereby establishing a seamless visual language. This study contributes to the literature by offering an alternative solution for architectural hardware design, emphasizing material innovation and the integration of minimalist aesthetics.

Keywords: Glass Bonding Technology; Aluminum Design, Door Handle Ergonomics; Surface Integrity; Architectural Hardware.

1.Introduction

Door handles used in contemporary architecture are no longer regarded merely as functional elements for opening and closing doors; rather, they are increasingly considered architectural accessories that contribute to the aesthetic value of a space. Over time, door handle designs have evolved in terms of material quality, aesthetics, and user experience. Within contemporary architectural approaches, door handles are expected to integrate seamlessly with the door itself and become a meaningful component of the overall design language.

Throughout history, the materials used in door handle production have undergone significant changes as a result of evolving architectural trends and advancements in manufacturing technologies. While wood and cast metals were predominantly used in earlier periods, modern door handle production increasingly incorporates materials such as stainless steel, aluminum, brass, and various composite materials. Influenced by changing design perceptions, considerations have expanded beyond ergonomics and durability to include the aesthetic qualities created through the combination of different materials.

However, many door handle products currently available on the market have not fully embraced this design-oriented approach. It took time for architects and designers to recognize that door handles are among the most frequently used architectural accessories in daily life. As the first physical point of contact between users and a space, a door handle serves not only an ergonomic function but also plays a significant role in establishing visual harmony between architectural design and user interaction. As this perspective has become more widely accepted, a variety of innovative door handle designs have emerged. These designs differ in terms of material selection, ergonomic considerations, and advanced manufacturing and assembly methods enabled by modern technologies.

This study focuses on a door handle design in which material innovation and ergonomics are key design parameters. The proposed approach utilizes bonding technology to integrate a glass surface onto the product, creating a modern and refined appearance. Glass bonding technology is widely employed in industries such as automotive manufacturing, façade systems, and interior design applications. By eliminating the need for visible mechanical fastening elements, this adhesive-based technology enables the production of clean and seamless surfaces. Consequently, greater design freedom can be achieved while simultaneously enhancing surface quality.

The first stage of this research involved a comprehensive literature review on door handle design. The historical development of door handles was examined alongside studies investigating manufacturing techniques, changing design trends, the influence of ergonomics on handle design, and the role of door handles in safety and security considerations. The evaluation of previous studies helped establish the scope and boundaries of the present research.

In the second stage, the door handle design process was initiated using mind mapping and morphological analysis methods. Through mind mapping, the subcomponents of the design problem were identified and analyzed. Relationships between user requirements, technical constraints, and problem areas were established. Morphological analysis was subsequently employed to generate alternative design solutions through different combinations of design parameters, leading to the development of the fundamental characteristics of the proposed concept.

The third stage investigated the suitability of glass bonding technology for door handle applications. Particular attention was given to the advantages provided by this technology. The adhesive layer positioned between the two materials creates a high-strength connection, thereby improving the overall durability of the product. In addition to enhancing structural performance, glass bonding technology contributes significantly to the aesthetic quality of the door handle. The glass layer conceals assembly details and eliminates the visual presence of fastening components. As a result, no visible mechanical connection exists between the aluminum body and the bonded glass surface.

Finally, the conceptual design was refined based on the findings obtained throughout the study. Evaluated from both aesthetic and functional perspectives, the final design distinguished itself through its manufacturability, material performance, and user experience. The outcome is a door handle design that aligns with contemporary architectural principles while emphasizing innovation in both material selection and production techniques.

This study contributes to the broader application of glass bonding technology by extending its use beyond conventional industrial fields and exploring its potential within the domains of architectural hardware and product design.

2. Materials and Methods

2.1 Methodology and Design of Door Handles

The methodology adopted in this study for door handle design was based on the integration of user experience and emerging technologies. During the initial stage of the process, a problem definition was established, revealing that existing door handles exhibit shortcomings in terms of technical performance, aesthetics, and ergonomics. It was determined that many currently available door handle designs fail to harmonize with contemporary architectural approaches and are unable to meet modern design expectations. Accordingly, the primary design objective was defined as improving product durability, hand ergonomics, and manufacturing processes through the development of an aluminum door handle incorporating glass bonding technology on its surface.

Following the problem definition stage, a mind mapping study was conducted as the first step of the design process. Subcategories related to manufacturing processes, material selection, ergonomics, user expectations, and functional requirements were identified and analyzed. The mind map enabled the design problem to be evaluated from a broader perspective, facilitating the exploration of a wider range of potential solutions.

Supported by the findings of the mind map, morphological analysis played a significant role in determining the form of the door handle. Through the generation of different combinations of design parameters, innovative design alternatives were developed and evaluated.

To address the technical integration of different materials, glass bonding technology was investigated in detail. The joining principles of two dissimilar materials, adhesive alternatives, and the advantages offered by the technology were examined. Although glass bonding technology is commonly employed in large-scale applications, its applicability at the scale of a door handle was assessed. The study aimed to enhance product durability while introducing innovation to the sector by eliminating the visual presence of mechanical fastening components.

2.2. Historical Development of Door Handles

A door is composed of several complementary elements, including door handles, knockers, rings, peepholes, locks, hinges, thresholds, canopies, and frames (Kılıç, 2022). Among these components, door handles represent one of the oldest architectural hardware elements that directly interact with users. Originating in Ancient Egypt and continuing to evolve to the present day, door handles have undergone significant transformations in response to technological advancements and developments in material usage. Early door handles were manufactured using wooden bolts, leather straps, and simple gripping elements. Over time, increasing material diversity and changing requirements related to frequency of use, ergonomics, and manufacturability led to a wide variety of door handle designs.

During the Ancient Egyptian period, advancements in metalworking enabled the production of door handles made from bronze and iron. In the Middle Ages, evolving design perceptions transformed door handles into decorative architectural elements. Door handles used in palaces, castles, and religious structures reflected the craftsmanship of the period through increasingly elaborate aesthetic details. The growing need for security during this era also contributed to the development of locking mechanisms. Decorative features produced through wrought-iron techniques became widespread in Gothic and Romanesque architecture, while the Baroque and Renaissance periods introduced more elegant forms and ornamental details through the use of bronze, brass, and precious metals.

The Industrial Revolution enabled door handles to reach broader markets through mass-production techniques. With continuing technological developments, door handles became increasingly integrated with mechanical locking systems. During this period, ergonomics and ease of use emerged as key considerations within the design process.

Today, with the advancement of contemporary architecture, door handle designs have become more simplified and function-oriented. Influenced by the Bauhaus movement, geometric and minimalist forms have become dominant, replacing excessive decorative elements. The use of aluminum, stainless steel, and various alloys has significantly improved product durability. Furthermore, advances in science and technology have enabled ergonomic factors such as hand dimensions, grip force, and accessibility criteria to be systematically incorporated into the design process.

As a result, door handles are no longer regarded solely as devices for opening and closing doors but are increasingly recognized as important components that contribute to the overall coherence of contemporary architectural design. Ünlükal, Ertan, and Sert emphasize that a door handle is not merely a functional tool for operating a door but also a significant design element that directly influences user satisfaction and overall user experience (Emel Unlukal Ilhan, Rukiye Ertan, Kenan Sert, 2025).

2.3. Design Objectives

The primary objectives of this study are as follows:

1. To enhance material durability,
2. To introduce innovation into door handle design through the application of emerging technologies,
3. To ensure ergonomic suitability for different age groups and genders,
4. To facilitate ease of manufacturing and assembly.

Material durability is achieved through the application of glass bonding technology. By utilizing specialized adhesives, glass and aluminum components are bonded together to form a unified structure. The adhesive layer contributes to the overall structural strength of the aluminum component while simultaneously eliminating the visual complexity associated with conventional mechanical fastening systems. As a result, a clean and refined surface finish is obtained.

Innovation in door handle design is introduced through the application of glass bonding technology. Although this technology is generally employed in large-scale applications, the present study investigates its feasibility and effectiveness at the scale of a door handle.

Caggiano, Kocakuşak, Kumar, and Tier (2023) emphasized that the use of multidimensional evaluation approaches during design and planning processes can contribute significantly to the development of comprehensive and user-centered solutions. Accordingly, morphological analysis was employed to improve ergonomic suitability across different age groups. This approach generated various design alternatives optimized for hand ergonomics. In a study conducted by Paschoarelli et al. (2012), the physical effort exerted by users on door handles with different geometries was investigated. The findings demonstrated that door handle geometry has a substantial influence on accessibility and usability. Furthermore, ergonomically optimized designs were associated with lower perceived effort and improved user experience.

Ease of manufacturing and assembly is also supported through the use of glass bonding technology. Conventional mechanical fastening elements commonly found in traditional door handles are concealed through the bonding process. In addition, various form explorations were conducted to facilitate efficient mass production while maintaining design integrity.

2.3.1. Summary of Design Decisions

2.3.1.1. Mind Map Analysis

Mind mapping is a visual technique used to represent insights related to a central topic and establish relationships between concepts (Buzan & Buzan, 2002; Buzan, 2018). According to Buzan (2002, p. 4), mind mapping is a powerful information organization and structuring technique in which each branch originates from a central visual element, allowing information to be arranged systematically. A mind map is constructed around a central idea, from which subordinate concepts and themes emerge. Its primary purpose is to reveal associations generated within the human mind. These subordinate themes are commonly represented through symbols, colors, and concise keywords.

As a graphical method that organizes information in a non-linear manner while preserving conceptual relationships, mind mapping facilitates the structuring and comprehension of complex networks of information (Kefalis, Skordoulis, & Drigas, 2025). Consequently, the primary subject becomes more simplified, understandable, and holistic.

Mind mapping can also be described as a visual note-taking technique that enables individuals to organize knowledge and ideas systematically. This structure consists of a central visual element, major thematic branches extending from the center, and interconnected sub-branches containing keywords, images, and associated concepts (Tee et al., 2014). By linking multidimensional perspectives, mind maps contribute to a deeper understanding of a given topic (Gupta & Kumar, 2022). These relationships are organized hierarchically in a tree-like structure consisting of primary, secondary, and tertiary levels (Biktimirov & Nilson, 2006).
The use of mind maps is particularly effective in strategic thinking processes, including problem-solving and idea generation. Within the design process, developing a mind map plays a crucial role in clarifying the design problem and identifying the parameters that require attention. Although these parameters vary depending on the product, they typically include factors such as material selection, manufacturing techniques, ergonomics, user experience, and production cost.

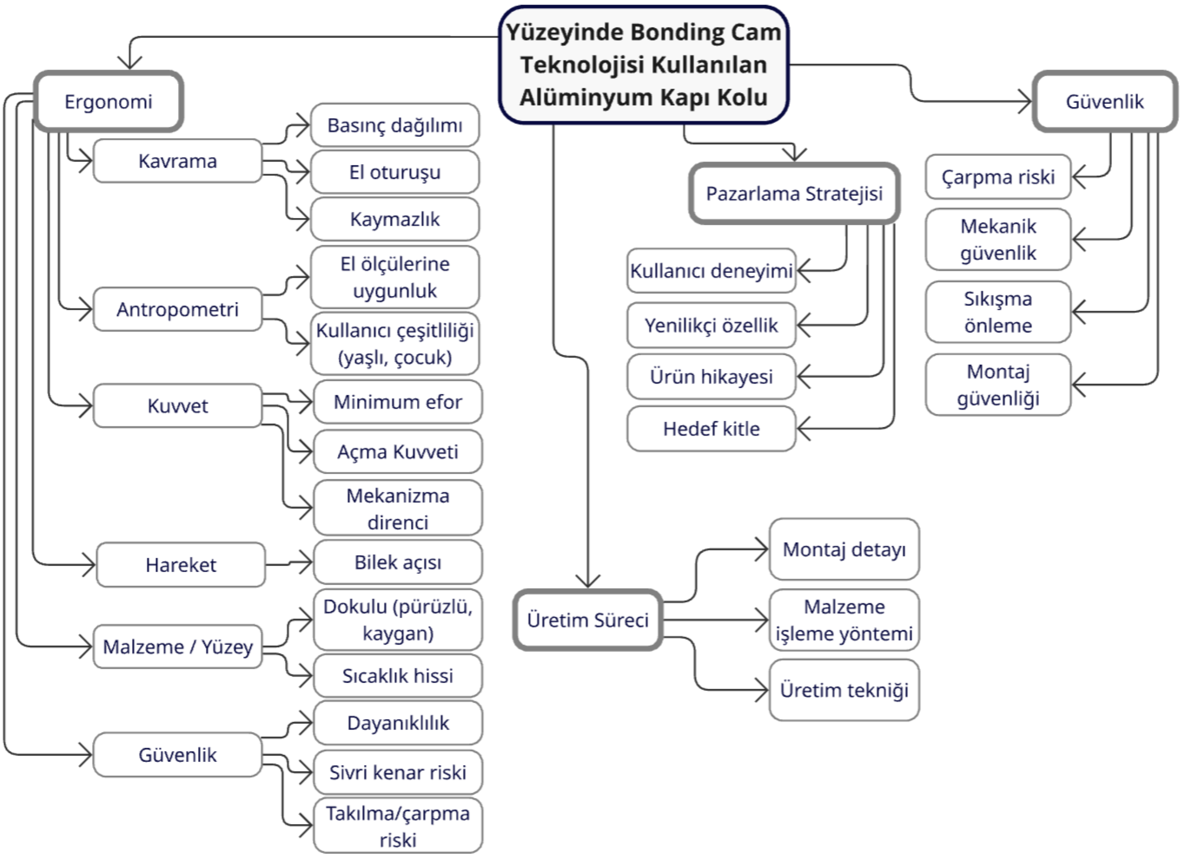

Figure 1. Mind Map.

The mind map developed at the beginning of the door handle design process played a significant role in guiding design decisions (Figure 1). The main categories identified within the mind map developed for the proposed door handle design were Ergonomics, Manufacturing Process, Marketing Strategy, and Safety (Figure 1).
The topics included under the Ergonomics category were:

1. Grip; the pressure exerted by the hand on the door handle, the hand's contact with the surface, the possibility of the hand slipping from the handle surface, and compatibility with the natural form of the hand,
2. Anthropometry; suitability for different user groups, including children/elderly users and women/men, based on hand dimensions,
3. Force; the resistance of the mechanism against opening and closing actions associated with pushing and pulling forces while requiring minimal effort,
4. Movement; wrist angles generated during the opening and closing movements performed on the door handle,
5. Material/Surface; the sensation and tactile perception created by the material used on the door handle surface,
6. Safety; considerations related to preventing accidents such as impacts, snagging, and cuts during use.

The topics primarily included under the Safety category were:

1. Impact risk; the possibility of colliding with sharp edges resulting from the form of the door handle,
2. Mechanical safety; safety issues that may arise from performance degradation of the mechanism due to prolonged use during opening and closing operations,
3. Pinch prevention; the possibility of finger entrapment during opening and closing movements,
4. Installation safety; evaluation of resistance to external interventions and the possibility of loosening at mounting points over time as a result of use.

Under the Manufacturing Process category:

1. Assembly details; integration of the door handle into the door structure and the integration of glass bonding technology onto the aluminum surface,
2. Material processing methods; processing techniques for aluminum and glass materials in accordance with the design requirements,

3. Production technique; the suitability of the selected manufacturing method for the chosen materials was examined.

Under the Marketing Strategy category:

1. User experience; the impact and impression left on the end user after product use,
2. Innovative aspect; the differentiation of the proposed design from existing door handles through its material selection and contemporary design approach,
3. Product story; potential user perceptions regarding the design process and manufacturing methods,
4. Target audience; architects, interior architects, and end users were considered.

2.3.1.2. Morphological Analysis

Morphological analysis is a method used to separate the subcomponents of design topics or problems within a table, combine these components through different configurations, and evaluate the resulting outcomes. This analytical approach was introduced by Fritz Zwicky in the mid-twentieth century to structure and analyze all possible relationships within complex problems that are multidimensional and difficult to express quantitatively. From an engineering perspective, Morphological Analysis (MA) is a method that enables the acquisition of design knowledge, the creation of an abstract design representation space, and the systematic generation of potential design solutions through the utilization of this space (Arciszewski, 2018). Its primary purpose is to generate new ideas by categorizing different product characteristics and combining alternative options across these categories. In this respect, it constitutes one of the fundamental components of Inventive Engineering, which is defined as a new engineering discipline focused on conceptual engineering design studies aimed at generating innovative design concepts (Arciszewski, 2016). In this method, a table is generally constructed in which design parameters and alternative options are systematically organized. Mouratidis (2024) stated that design problems should be evaluated through multiple parameters, including functionality, accessibility, and user requirements, rather than relying on a single criterion.

In this study, various design alternatives were generated through morphological analysis (Figure 2). In the analysis table, the main component and body categories were positioned in the rows, while alternative options related to these categories were placed in the columns. Variations in dimensions and ergonomic differences in hand grip played a significant role in the development of the design. Considering anthropometric factors, particular attention was given to hand ergonomics, taking into account the needs of elderly users and children.

Through this analysis, different body forms and main fixed components were combined in an effort to achieve an effective design solution. Various door handle forms were matched with one another to create different design combinations. The final design decision was reached through the combined use of both morphological analysis and mind mapping techniques (Figure 3).

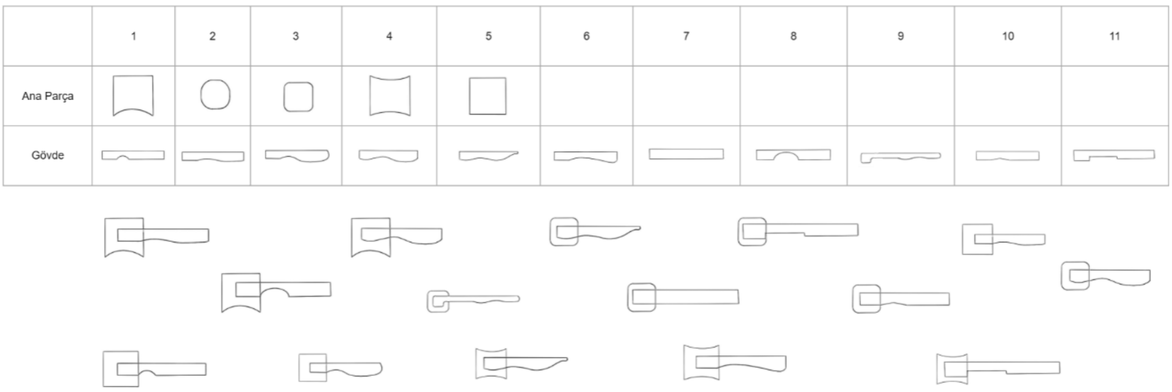

Figure 2. Morphological Analysis.

2.3.1.3. Effects of Ergonomics On Design Decisions In Door Handle Design

The integration of ergonomic principles into product design is one of the fundamental factors determining a product's accessibility and usability. Devices intended for manual use must be designed in accordance with ergonomic principles; otherwise, users may encounter various limitations and discomfort during operation (Luis Carlos Paschoarelli, Raquel Santos, Paula Bruno, 2012). To provide effective design solutions, designers must consider various factors, one of which is ergonomic values (Jasmin Kaljun, Bojan Dolsak, 2011). In this study, ergonomics emerges as a supporting discipline in door handle design by examining human movement habits and physical characteristics. When door handles are designed according to appropriate ergonomic principles, they not only enhance user satisfaction and comfort but also contribute to the aesthetic values of contemporary architectural environments. Due to the effects of handle design on user safety, comfort, and operational performance, numerous studies have been conducted to determine optimal handle dimensions. Handles designed with appropriate dimensions improve the interaction between the user and the product, thereby providing a safer and more efficient user experience (Gregor Harih, Bojan Dolsak, 2013). The proposed door handle is intended to provide maximum control with minimum effort while simultaneously ensuring user comfort and safety. Through the examination of human physical characteristics, it was determined that the handle should be designed in accordance with the natural gripping motion of the hand. Therefore, the design process focused on facilitating door opening and closing actions through a handle form compatible with natural hand movements. In this way, the objective was to reduce the physical load exerted on the hand, wrist, and arm.

The primary function of handles is to enable the safe, efficient, and controlled transmission of force generated by the user's musculoskeletal system to the relevant product or mechanism according to its intended purpose (Pheasant & Haslegrave, 2006). Handle size is one of the most important parameters in ergonomic handle design, as it directly influences both the user's grip span and force generation capacity (Yuh-Chuan Shih, Mao-Jiun J. Wang, 1998). The length, width, and depth of the door handle body are therefore of considerable importance for effective hand grip. Door handles with excessively thin or excessively thick cross-sections can create difficulties during use. Due to the diversity of users, door handles should be designed with dimensions that accommodate different hand sizes. These evaluations provide opportunities to identify design decisions that improve the ergonomic performance of the product and support design optimization (Jasmin Kaljun, Bojan Dolsak, 2011).

Another factor affecting ergonomic performance is the surface texture of the door handle. For this reason, the use of aluminum as the primary body material was considered during the design process. By applying glass to the aluminum body through glass bonding technology, a hybrid structure combining aluminum and glass materials was developed. Although the smooth texture of glass may be perceived as reducing grip security, the aluminum body was intended to reinforce the user's sense of control and grip stability.

Contemporary door handles are designed according to universal design principles due to their broad user base. Therefore, factors such as operating force, installation height, and usage method should be considered for elderly users, children, and individuals with physical limitations.

In this study, a curved geometry was incorporated into the body of the door handle to provide a dedicated placement area for the thumb. This design enables the user's thumb to rest naturally within the curved section of the body during gripping, allowing the applied force to be transferred efficiently for door operation. The curved form, developed to enhance user experience, also creates a favorable angle for palm placement. Since glass is incorporated into the handle surface, concerns regarding the safety of potentially slippery surfaces may arise. To address this issue, the primary structural material of the handle was designed as aluminum, with the intention of increasing user confidence and improving perceived grip security.

2.3.2. Application Of Glass Bonding Technology to The Door Handle Surface

The use of transparent structural elements has become an important design approach in modern architecture due to the aesthetic advantages and visual continuity it provides (J. Belis, D. Callewaer, D. Delince, R. Van Impe, 2008). Bonding technology refers to the process of fixing a glass surface to metal, composite, plastic, or another glass surface through the use of high-strength adhesives and advanced technologies. As an alternative to traditional joining methods such as screwing and welding, adhesive bonding technology has become widely accepted and established in industrial applications, particularly since the second half of the twentieth century (Benjamin Schaaf and Markus Feldmann, 2024). This system, in which glass is bonded to aluminum frames, has undergone significant development over time through technological advancements and innovative improvements (Pierre Descamps, Valerie Hayez, Mahmoud Chabih, 2017).

Adhesive bonding technology is preferred over conventional fastening elements due to several important advantages, including uniform stress distribution within the bonded region, effective load transfer through the adhesive layer, lightweight performance relative to the applied load, superior vibration and impact damping compared to mechanical fasteners, corrosion resistance resulting from sealing properties, the ability to accommodate various structural and design configurations, ease of assembly, economic and time-saving benefits, and the capability of joining components manufactured from different materials. Owing to these advantages, adhesive bonding is widely used in numerous industrial fields, particularly in the aerospace and aviation industries (Bilge Yılmaz, 2020).

Silicone-based adhesives, UV-curing adhesives, and high-performance epoxy resins are commonly used in bonding technology. Several factors must be considered before selecting an adhesive. For example, the adhesive must be compatible with the materials being bonded, suitable for the manufacturing process, and capable of withstanding the calculated service loads and environmental conditions (Bilge Yılmaz, 2020). Factors such as adhesive type, the quality condition of the bonded surfaces, surface preparation techniques, and adhesive layer thickness are also taken into consideration during the design process (Bilge Yılmaz, 2020).

In this technique, the bonding surface of the material must be properly prepared. Before the bonding process is carried out, careful and controlled preparation procedures are implemented to enhance material performance and prevent potential damage. Surface preparation methods include:

1. Degreasing,
2. Mechanical Abrasion,
3. Chemical Etching,
4. Primer Pretreatment.

Since aluminum sheets are relatively ductile materials, surface abrasion must be performed carefully. To achieve suitable bonding conditions, the oxide layer on the aluminum surface must be adjusted to the desired film thickness. For effective bonding, aluminum surfaces generally undergo four treatment processes: sulfuric/chromic acid etching, chromic acid anodizing, phosphoric acid anodizing, and sulfuric acid anodizing.

Through this technology, material strength is improved while providing a strong and aesthetically pleasing connection. One of the most significant advantages of bonding technology is that frame elements and mechanical fasteners (such as screws and rivets) remain invisible after the glass is bonded to the substrate, resulting in a modern and visually clean appearance (Doğan Cam, n.d.; Enez Cam, n.d.). In this system, the glass is bonded to the frame of the supporting material through adhesive connections and fixed to the underlying structural support responsible for load transfer (C. Richter, B. Abln, A. Gebler, M. Feldmann, 2014). Bonding technology is commonly used in façade systems, staircases, and glass balustrades. Other application areas include electronics, household appliances, the automotive industry, and interior design. Due to the invisible connection details it provides, its use has become increasingly common in minimalist and contemporary design approaches.

In this study, glass and aluminum materials are joined through specialized adhesives in the door handle design. The process begins with the cleaning of both glass and aluminum surfaces to remove dust and contaminants. To improve adhesive performance, the aluminum surface is roughened through sandblasting or sanding. An appropriate surface preparation chemical (primer) is then applied to enhance adhesion performance, after which the selected adhesive is applied in a controlled manner between the two surfaces and allowed to cure.

In this design, the curved geometry incorporated into the door handle form was replicated in the glass component. Previous studies have indicated that sharp door handles installed at standard heights may pose a significant risk of eye and facial injuries, particularly for young children (Chaudhry et al., 2005). Therefore, to prevent potential impacts, cuts, and accidents, the edges of the glass component were rounded and protected during the design process.

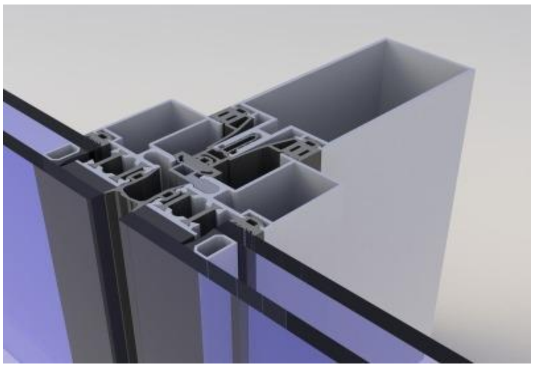

Figure 3. Glass Bonding Cross-Section Detail.

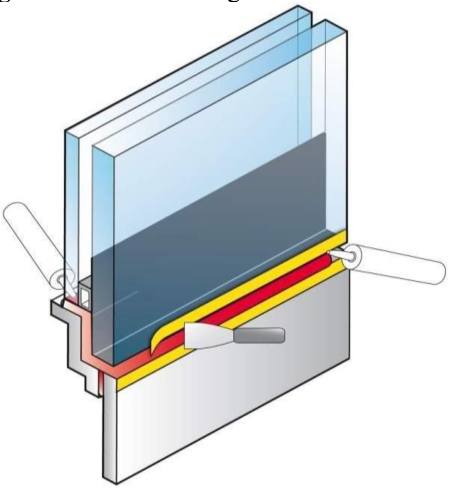

Figure 4. Glass Bonding Application Stages.

Figure 5. Perspective View of the Door Handle .

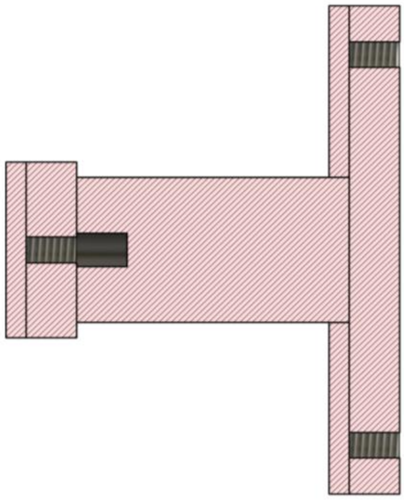

Figure 6. Cross-Section of the Door Handle .

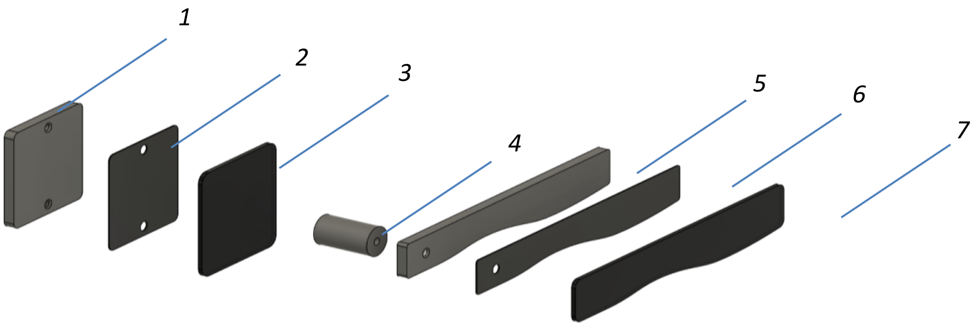

Figure 7. Exploded Perspective View of the Door Handle .

Table 1. Material Components of the Door Handle.

NUMARA	MALZEME ADI
1	Aluminum Base Component
2	Adhesive Bonding Material
3	Glass
4	Aluminum Tube Profile
5	Aluminum Body
6	Adhesive Bonding Material
7	Glass

3. Results

The evaluations conducted throughout the research and design processes revealed that the application of glass bonding technology to the surface of a door handle can provide significant advantages from both aesthetic and technical perspectives. Compared to conventional door handles, the integration of two different materials was found to create a holistic surface perception compatible with contemporary architecture. The findings indicate that glass bonding technology not only enhances the visual value of the door handle but also improves its structural durability and perceived material quality.

Through the use of the mind map method, the factors influencing door handle design were identified. The results demonstrated that user expectations regarding ergonomics, manufacturing processes, safety, and contemporary design principles constitute important design criteria. Consequently, the conceptual framework of the door handle design was established.

The morphological analysis process revealed that both the body and the main component of the door handle could be designed in various forms. The fundamental forms of the handle body and the main component were determined, and numerous combinations were generated through alternative configurations of these two parameters.

When the design alternatives generated through mind mapping and morphological analysis were evaluated from an ergonomic perspective, it was observed that user comfort was as important as aesthetic appearance. Factors such as ease of grip, force applied to the handle, and contact surface characteristics were identified as critical considerations. The handle was therefore designed with sufficient grip area and thickness, while sharp edges were minimized in accordance with ergonomic criteria. As a result of the analyses and evaluations, some design alternatives were found to be ergonomically inadequate, whereas ergonomically optimized alternatives demonstrated superior user experience performance.

The application of glass bonding technology successfully concealed visible connection details and was found to be compatible with contemporary design principles. The combination of aluminum and glass materials enabled the door handle to integrate effectively with various interior design concepts while enhancing the visual depth of the product.
Although glass bonding technology is generally associated with large-scale applications, the findings of this study demonstrate its applicability to small-scale product designs. The high-strength adhesive used between the glass and aluminum components maintained surface continuity while eliminating the visual impact of assembly details.
Overall, the findings suggest that the implementation of glass bonding technology in door handle design can contribute to the industry as an innovative surface application. The integration of advanced material bonding technologies into architectural hardware creates a contemporary appearance, while the reduction of visible mechanical connections enhances the perception of a modern and seamless surface.

4. Discussion

The findings obtained in this study indicate that the application of glass bonding technology in door handle design represents an innovative approach from both technical and aesthetic perspectives. While conventional door handle designs typically rely on standard surface treatments and visible mechanical fastening elements, this study demonstrates that different materials can be integrated through concealed bonding techniques to achieve a holistic surface concept. The incorporation of glass into the door handle provides a visual appearance that is compatible with contemporary architectural design principles. Furthermore, the combination of different materials highlights that door handles function not only as utilitarian components but also as significant design elements that influence user perception and experience.
The concepts generated through the mind mapping process and the alternative solutions produced through morphological analysis enabled the comparison of different materials, surface treatments, and manufacturing approaches. The combined use of mind mapping and morphological analysis throughout the product design process facilitated a controlled and multidimensional evaluation framework. However, the findings obtained through these methods remain conceptual in nature and should be supported by future user testing and performance-based evaluations.
Although glass bonding technology is generally associated with large-scale applications, the present study demonstrated its feasibility at the scale of a door handle. Nevertheless, additional technical evaluations are required. The long-term performance of the adhesive used between the glass and aluminum components, surface durability, and impact resistance should be investigated in greater detail.
The results also indicate that material and surface technologies have become increasingly important in contemporary architecture and product design. Users are increasingly seeking products that combine technological innovation, strong aesthetic qualities, and high perceived material quality.
Consequently, the application of glass bonding technology in door handle design introduces an innovative approach to architectural hardware by providing a contemporary appearance and enhanced material integration. This study offers a foundation that can be further developed for future door handle design research and manufacturing technologies.

5. Conclusions

This study adopted a comprehensive approach through the examination of product research, design analyses, and contemporary bonding technologies. An investigation of the historical development of door handle design and manufacturing revealed that the product has evolved from a purely functional element into an accessory that contributes to aesthetic coherence within architectural environments. It was determined that many currently available door handles fail to establish visual continuity with surrounding surfaces, do not adequately align with contemporary architectural trends, and are unable to satisfy current design expectations.
During the initial stage of the study, a mind map was developed to identify critical factors related to material selection, manufacturing processes, marketing considerations, user requirements, and user expectations. The use of mind mapping enabled the design process to be examined from a multidimensional perspective and broadened its conceptual framework. Based on the parameters identified through the mind map, morphological analysis was subsequently conducted to generate alternative design solutions. Together, these two analytical methods facilitated the evaluation of diverse design approaches and perspectives throughout the product development process.
The study further investigated glass bonding technology within the manufacturing process and demonstrated that the system is capable of joining dissimilar materials while providing both high structural performance and aesthetic continuity. Since this technology is predominantly used in façade systems and the automotive industry, its application within the door handle manufacturing sector introduces an innovative approach.
The proposed product creates a particularly strong visual impact when applied to lacquered and glass-surfaced doors. Potential application areas include residential projects, villa entrance doors, apartment and residence entry systems, interior doors, hotels, showrooms, and office environments.
This study examined both the manufacturing methodology and design approach of a door handle system intended for contemporary architectural applications. The findings indicate that the aluminum door handle system integrated through glass bonding technology offers significant advantages compared to conventional door handle designs and assembly methods. These advantages arise both from the use of advanced bonding technology during manufacturing and from the ergonomic compatibility of the design, resulting in improvements in production quality and user experience.

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The authors report no conflicts of interest.

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All data generated or analyzed during this study are fully integrated within this published manuscript. Additional requests for specific technical layout details can be directed to the corresponding author.

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Not applicable. This study did not involve experimental interventions on human or animal subjects, focusing entirely on technical hardware design and application methodologies.

Credit Author Statement
Nisa Nur Çam: Conceptualization; Data curation; Methodology; Investigation; Resources; Software; Visualization; Writing – original draft.. **Ahmet İnci** Supervision; Writing – review & editing; Verification. All authors have read and approved the final manuscript.

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