

ANALYSIS OF THE GEOMETRIC DESIGN OF THREE WIRE CHAIRS

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ABSTRACT

Wire chairs, starting from the designs of Charles and Ray Eames (DKR Wire Shell, 1951) and Harry Bertoia (Diamond Chair 1952, Side Chair 1952), are a particular field of investigation for both the design historian and the designer. The geometry of their “shell” and supporting structure is still able to puzzle and charm. They are “sculptures made of air”, as Bertoia used to say, yet they are made of a simple industrial material. As true works of art, they fit in any kind of interior. They are often sought as precious vintage collectors’ items.

The authors seek to identify the general and particular features of these mid-century modern classics that had an iconic role in setting new forms and concepts, and to follow a part of their influence upon 21st century design. The analysis itself is allowed to develop into a design process, set between the spatial geometry of an artwork and the functional requirements of the chair.

Key words: wire chair, geometric design, Charles and Ray Eames, Harry Bertoia.

1. INTRODUCTION

**1.1. DESIGN EAMES/
DESIGN BERTOIA**

The analysis of the furniture creations of the two designers starts from the historical

and professional context in which they expressed their visions and ideas. Table 1 presents moments and relational juxtapositions between the two that supposed at least a dialogue of ideas, as well as common activities related to certain themes and projects.

Table 1: Professional circumstances and definition of the conceptual context (after Neuhart and Neuhart 2010b, www.interaction-design.org)

CHARLES EAMES (1907 - St. Louis, Missouri – 1978 – St. Louis, Missouri) Studied architecture at Washington University. 1930, Opened his own architectural office; <i>Architect, Furniture and Graphic designer, Fine Artist, Film maker.</i>	HARRY BERTOIA (1915-San Lorenzo, Udine, Italy–1978–Barto, Pennsylvania) Studied at Detroit School of Arts&Crafts and Cranbrook Academy of Art, Michigan. <i>Sculptor, Furniture and Jewellery Designer, Graphic Artist and Metalsmith.</i>
1937-1940	
1 year fellowship at Cranbrook Academy of Art; Instructor then head of Industrial Design Department at Cranbrook;	2 years scholarship at Cranbrook Academy of Art; Instructor for metalwork at Cranbrook, then head of the Metal workshop
1942-1943	
Organizes a legal partnership called Plyform Wood Company; '43, Sells Plyform Wood Company to Evans Products Company (EPC), turning it into Molded Plywood Division of EPC;	'43, Joins the Molded Plywood Division of EPC, where he works with Eames to develop the plywood chairs;



Figure 1: Organic chairs (Hermanmiller 2018)
www.hermanmiller.com



Figure 2: Three-legged side chairs – Bertioia proposed to separate the seat from the back and worked various models with metal legs
Authors' photos and drawings

1946

Plywood chair made at EPC, exhibited in New York; Leaves Evans Production Company (EPC)

1948- 1950



La Chaise



DAX chair



DAW chair



DAR chair



DSW chair



Rocking chair

Figure 3: “It is the chair that’s made tomorrow” (said Eames Demetrios, Eames’ grandson, Drexler 1973), Fiberglass chairs manufactured by Herman Miller

1951-1953

Developing the resistance welding technology for the Wire Mesh Chair and Wire Sofa, for Hermann Miller;

‘50-‘52, Furniture design for Knoll Associates, in Pennsylvania: Diamond Lounge Seating, Side chair, Bird Lounge chair and Ottoman.

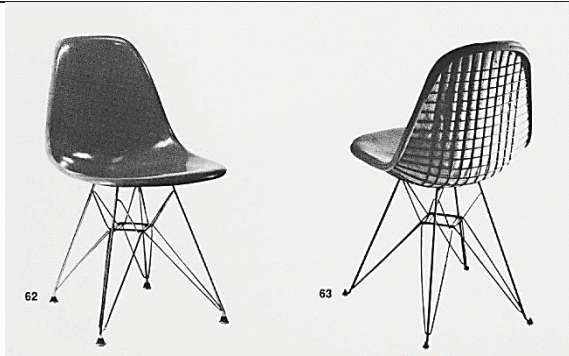


Figure 4: Wire Mesh Chair. 1950, Molded polyester; wire; 1951, Formed black wire; padded tan leather, Drexler 1973



Figure 5: a. Wire “Bird” chair and stool; 1952. b. The Bertoa Collection, 1952, knoll.com/designer/Harry-Bertoia

1.1.1. Eames philosophy

The Eames design philosophy is a speaking trumpet of the 50’s decade, with a strong accent for human needs, not particularised needs but needs extended at social level (Drexler 1973): this open attitude shows a fine preoccupation for the industrial product which defines and identifies itself in Eames’s vision according to the design diagram shown in Fig. 7, as a dynamic harmony of vibration between the designer’s preoccupation and the desire of the beneficiaries. Can



Figure 6: Coffee table, 1946. Molded plywood circular tray top, legs made of steel rod, Drexler 1973

this idea be anything else than the axiom of a social, moral design?

Anyway, all Charles’s beside his design studio team materialised in creations impregnated by conceptual and technological efficiency “to give the most with the least in every product” (Drexler 1973). This orientation represents a continuation of what was sown in the philosophy of world design by Adolf Loos (1870-1933), Peter Behrens (1868-1940), and Frank Lloyd Wright (1867-1959).

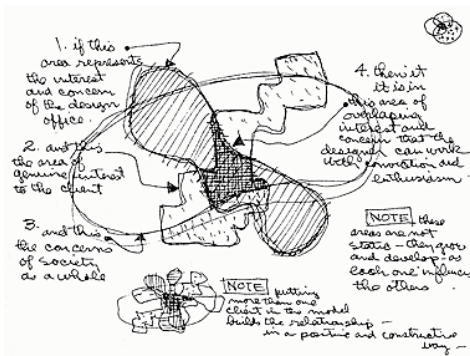


Figure 7: Charles Eames, Design Diagram Design Diagram, created for a 1969 exhibition at the Louvre, entitled, *What is Design?*

The concept of simple and clear furniture in Eames' vision is represented by the coffee table shown in Fig. 6 composed of elements that are going to be identified in the future design of Eames-branded chairs manufactured by Herman Miller.

The conceptual affinities between Eames and Eliel Saarinen (1873–1950) or Eero Saarinen (1910–1961) who contributed at the refreshing of a philosophy of creation impregnated by simplicity, efficiency, attention to ergonomics, functionality and rationalism cannot be denied. The connection related to influences and conceptual similarities in design within certain historical periods cannot be detoured or dismissed. Here there are to be taken into account similar possible visual connections between the geometry of Buckminster Fuller's structures and shell network and/or supporting structure of Eames'

chairs. This affirmation may be possible but not necessarily conclusive. Geodesic domes answer a strict geometry of equipartition controlled by triangles. For the wire shell there is a squares network resembling a reinforcement of construction elements.

1.1.2. Bertoia philosophy

To define a creation philosophy Bertoia-branded cannot be separated from his studies and education in the field of the art of sculpture, jewellery and design. It may be stated that Bertoia design is "feeling-design", in which the product comes close to the sculptural object. Some of the artist's sculptures presented in Fig. 8 support this fact (Knoll 2018).

This kind of thinking and action substantially defines Bertoia's chair design methodology.

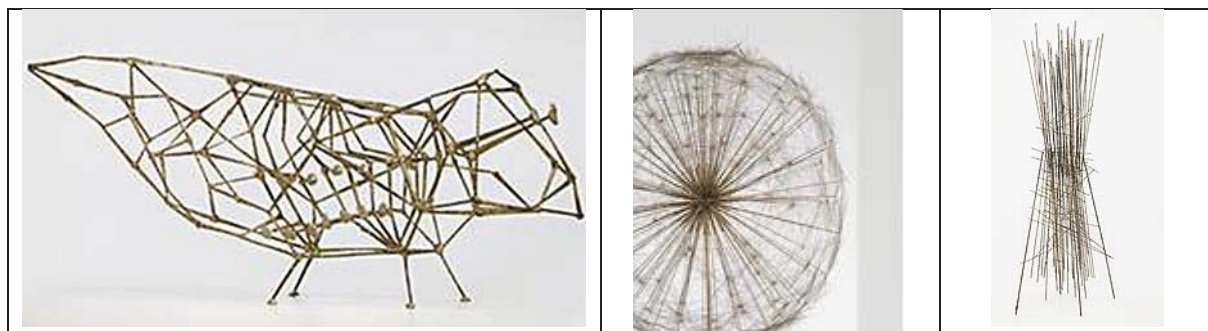


Figure 8: Bertoia's art of sculpture, Design Diagram, created for a 1969 exhibition at the Louvre, entitled, *What is Design?*

Some of his ideas and concepts are going to be highlighted now. A chair's destination is also meant to attract attention, to express feelings and qualities related to the perfection of the vision. He used to say that "Always some chair is calling for attention, improvements (Knoll 2018). But once we understand that, it is not possible any more to avoid the idea of a control of the relationship between the object and the space manifestation of the significant general form, and their harmonisation with the material that was uti-

lised. Regarding the triggering mode of a creation deed, Bertoia himself declares that, the feeling of an idea, the opinion upon the image of a product are the result of a careful introspection. It is a creation option that does not exclude research but for him this is not a purpose. For Bertoia the concept of an object that is defined by line, contour, figure, results from modelling and manipulating the material, "I was delighted to take a rod and bend it, it was part of my nature" (knoll.com). Modelling the material, controlling the construction and the expressivity are actions that

get the object formatted and defined functionally. This creation model presents, as previously stated, features that are specific to the art of sculpture or to a manufacturing process that follows the harmony between material and form. To bend a wire was for Bertioia a true discovery of a primordial working method.

Using his classic Arts & Crafts heritage, Bertioia highlights the priority of the object's vision against the thinking and manufacturing process, and then the result of applying this process. This point of view may be extrapolated also to the very creation step where the vision upon the product supposes the definition of certain thinking and imagining instruments as well as the result of their use.

2. OBJECTIVES AND METHOD

The main objectives of our study and research were:

- Clarifying the historical context and the values expressed by the two creators, Charles Eames and Harry Bertioia.
- Identifying a possible conceptual continuity within the frame of the operational and thinking process for similar products or of products responding other needs.
- Highlighting new materials, new constructive and technological solutions for seating furniture related to their historical context.
- Highlighting the relationship of the object with its end-user by making the seating posture analysis and the investigation of ergonomics.

The analysis was carried on through direct collection of data, measurements and artefact analysis regarding dimensions, angles,

sitting positions, followed by detailed technical sketching and drawing. Functionality and ergonomics, components and construction details, materials, style and composition were also analysed and compared.

3. ANALYSIS OF THE CHAIR DESIGN PROCESS

3.1. ORIENTATION AND CONTROL OF THE CONCEPT

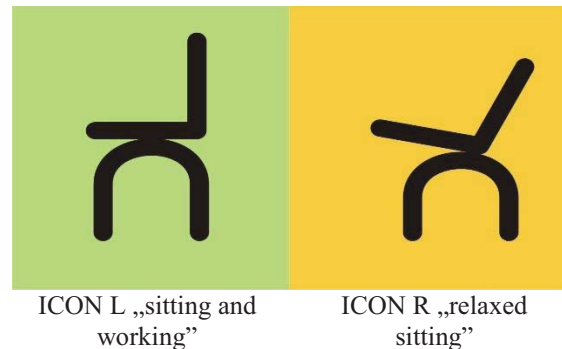


Figure 9: Structural icons, Authors' photos and drawings

The constructive, ergonomic and qualitative characteristics are invariants that lead to a certain result. The outline of the general aspect of the object becomes a formal synthesis, a sign which orients the position of the body on the chair and designates a structural icon (Fig. 9).

These icons may be interpreted as essential images of constructive-functional visions that define certain characteristics and typological variants of the chair. Playing with the components may guide us towards new constructive-structural expressions, with influences upon ascribing new materials and manufacturing technologies. At the same time, these icons have a suggestive force in which we can recognise various influences or inspiration sources that may be identified and explored in Table 2, after having analysed the Wire Chair and the Diamond Chair, presented in Fig. 10 and 11.



Figure 10: Charles Eames, Wire Chair,
Authors' photos and drawings



Figure 11; Harry Bertoia, Diamond Chair,
Authors' photos and drawings

Table 2: General requirements for two chair concepts: side chairs and lounge chair

	ICON L	ICON R
<i>Need</i>	- active sitting	- relaxed sitting
<i>Posture</i>	- Upright posture sitting with minimal angles of the seat and back	- Sitting with considerable angles between the seat and the back
<i>Ergonomics</i>	- correctly defined seat height; - vertical backrest; - movement freedom of arms and legs	- seat – back over 100°; -the simultaneous shifting of the seat-back ensemble according to the vertical axis; - Rest for the main body segments.
<i>Construction</i>	- Possible adjustment adaptation and transformation of constructive parts according to the implicated human body segments.	- high degree of modellation and adaptation of the constructive parts to the implicated human body segments; - the chair typology migrates towards the armchair.
<i>Materials</i>	-optimal characteristics and qualities for the sitting comfort and for the elements that are in contact with the human body;	- higher qualities of the sitting comfort of the elements that are in contact with the human body.
<i>Intensity of expression of the needs</i>	- average and high intensity with major influence upon the entire concept. It is correlated with ergonomics and construction of the product.	- high intensity with major influence upon the entire concept. It is correlated with ergonomics and construction of the product.
<i>Width of needs</i>	- average influence upon concept;	- major influence upon concept.

3.1.1. A conceptual dialogue between the two chairs

In most cases it is good to look towards defining a product concept with new valences, that is a change of what already exists.

Even in case of a system of products with restrained typology as is that of chairs, the creative searches follow this desire of the particular, belonging to a unique vision often defined by a simple “otherwise” (Table 3).

Table 3: Conceptual dialogue between the two chairs: technically and structurally

<i>Similarities</i>	<i>Differences</i>
As manufacturing process	Number of elements of component parts
Two principal parts (shell + supporting system)	Dimensional construction of parts
Dismountable system between the main parts	Sitting posture
Elements made of wire	Wire mesh for the shell
Seat pad	Geometric forms of main parts
Four protection elements for the contact between the supporting system and the floor	Wire diameter at supporting structures
Products perfectly framed by the requirements of industrial manufacturing	Material and colour of the protection element of the seat

Beyond this engineering level everything gets individual. The concepts of the two chairs don't seem to dispute from the formal and stylistical point of view, but seek per-

sonal formulas through the expressive language of geometric structures, of semantic terms and of communication through the general form (Table 4).

Table 4: Conceptual dialogue between the two chairs: stylistically and semantically

<i>Similarities</i>	<i>Differences</i>
Orientation of the concepts towards functionality	As functional destination by the sitting posture
Stylistical inflexions of organic type in the concept of the ensemble	The overall form of the shell as graphical significations and expressivity
Preoccupation for formal efficiency through sufficient elements	Functional and volumetric expression of the geometry of the supporting structure
Simple and airy parts through structural and content clarity	Product development and diversification potential

After this analysis, the following may be synthetically expressed:

- Both concepts are perfectly answering the manufacturing needs of the post-war society.

- The similarities between the two products are prevalent design features and values through which, in a historical moment, a fusion succeeds, between the Arts & Crafts and the Bauhaus visions (Fair 2006).

- Expression of a structural unity of the entire product by replacing the opaque seat

shell – the impression of a rigid carapace, with a light, airy shell.

4. EXPERIMENTAL METHODS

4.1. ERGONOMICS DATA - SITTING POSITIONS, DIMENSIONS AND ANGLES

The study of the sitting positions started from the necessity of comparing the dimensional and angular characteristics of the two chairs with those recommended by various specialists, preceded by the evaluation of the degree of comfort offered by each of them.

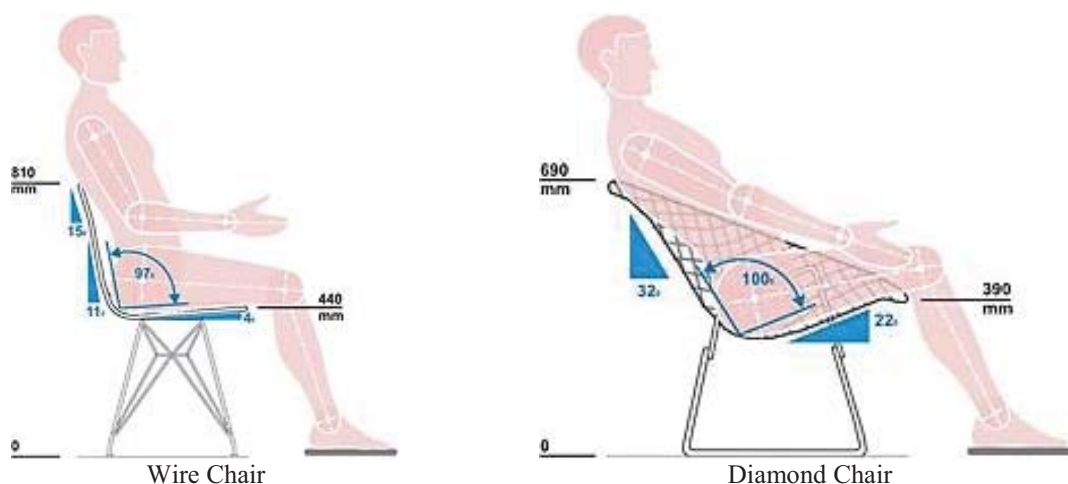


Figure 12: Ergonomics of seating positions (simulation created by the authors), Authors' photos and drawings

The analysis of their ergonomics is shown in Fig. 12, where the position of the average (50% of percentile) human being is represented as sitting on the respectively scaled side view of each chair.

The results of the sitting postures analysis are synthesized in Table 5 and compared to the specific recommendations. The seat and seat-backrest angles show important differences, concerning sitting parameters.

Table 5: Ergonomics data (after Grandjean and Kroemer 1997, EN 1335-1:2000)

	Wire chair	Recommended for side chairs	Diamond Chair	Recommended for lounge chairs
Seat height (frontal measurement), mm	440	400–450	390	375–400
Seat depth, mm	400	380–450	470	450–500
Height of chair, mm	810	–	690	–
Seat angle	4°	5–8°	22°	5–10°
Seat-backrest angle	97°	105–115°	100°	110–120°
Backrest angles	11°/15°	13–15°	32°/37°	25–38°

4.2. CONSTRUCTION, MATERIAL AND TECHNOLOGY

The **Wire Chair** has two components, the seat and the supporting structure. The seat actually constitutes a seat and backrest surface, made of a wire mesh inscribed in a double curve that defines its outline. The supporting structures may be volumetrically interpreted as being made of four prisms with triangular surfaces, united towards of the center of the structure, following the shape of the square (Fig. 13 a). The constructive solution of this part comprises a structure modeled by the edges of the component prisms.

The edges respect the idea of a modular composition and finally represent two pairs of typo-dimensions of the same linear element being doubled by mirroring forms the upper and the lower parts. These groups of modules reinforce four linear elements made of thicker wire that define the four supporting legs.

Herman Miller introduced the chair in 1951. Full use of industrial techniques was made in this chair design and resistance welding technology was used to bond the vertical and horizontal wires together at each intersection. This technology was used for the first time in 1949 at Herman Miller, for

the bases of the fiberglass chairs and for other products. (Neuhart and Neuhart Book 2 2010)





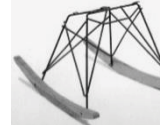
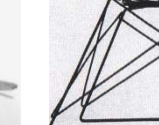
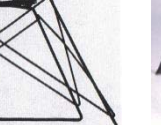

Figure 13: Formal-constructive analysis of the chairs, Authors' photos and drawings

“The Wire Mesh chair is a translation of the fiberglass chair into wire” (Neuhart and Neuhart Book 2 2010). It may be stated that the wire mesh chair is able to represent a kind of highlighting of the glass fiber fabric, a visualization of the fiberglass fabric as a functional, simple, rational and light component. This transition from opaque to transparent is indeed to be found in the concept of Buckminster Fuller’s geodesic domes and was

taken by Eames as an inspiration from the fiberglass shell.

This idea of the supporting structure called Eiffel Tower of the Wire Chair was not the only one that was studied in Eames’ studio. The development of the chair concept comprised a variety of possible such structures. Table 6 presents six constructive ideas adopted by Eames for this chair.

Table 6: Types of legs for the Wire Mesh Chair (after Neuhart and Neuhart Book 2 2010)

Eiffel Tower base	Wood legs and wire	Wire legs and rocker base with wooden runners	Low wire legs	X-base tubular steel	H-base tubular steel
					

The Diamond chair is also composed of two parts, the seat and the supporting structure. The seat constitutes a seat + backrest spatial surface made of a wire mesh in a closed outline curve that becomes the symbol of the precious mineral, the diamond.

Modeling the shell and its dimensional amplitude did not need a doubling of its outline like the Wire Chair. The supporting part may be understood and volumetrically interpreted as being formed by two prisms with trapezoidal surfaces that compose a compact ensemble (Fig. 13 b). The constructive solution in this case is similar to that of the Wire

Chair, the differences consist in the fact that the part cannot be viewed as modular and is formed only of two open welded prismatic contours.

4.3. DIALOGUE WITH A NEWCOMER

This analysis could not have avoided a fresh dialogue between what gets relevant as

a contemporary idea and what represents a conceptual certainty of the near modern.

The Carbon chair, designed by Bertjan Pot and manufactured by Moooi, Netherlands in 2004, is made of epoxy-coated carbon fibre. It is an extremely “lightweight product updated with contemporary materials. ...It is made entirely of hand-wrapped carbon fiber soaked in epoxy resin” (Fairs 2006).

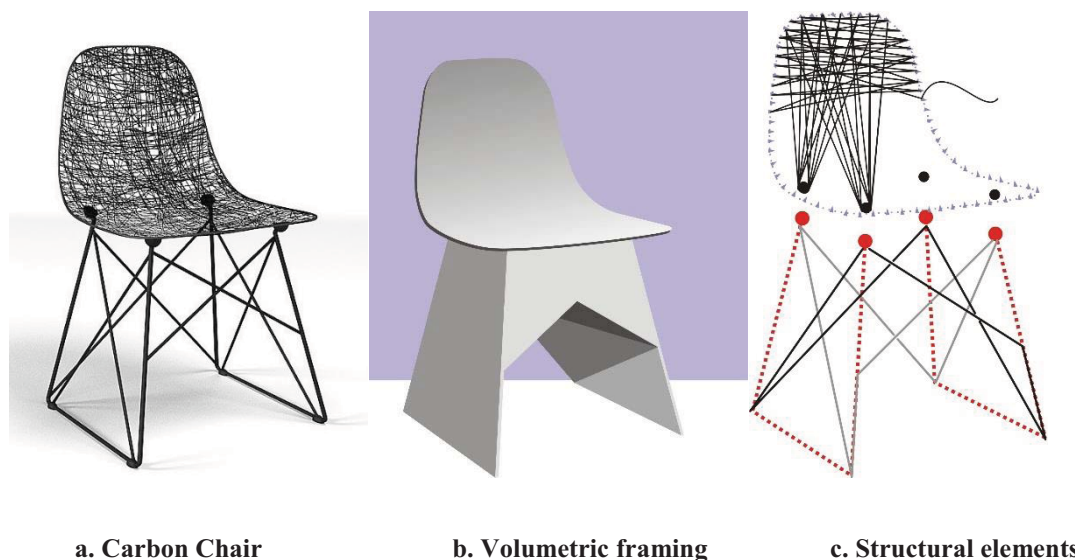


Figure 14. Carbon chair: the formal constructive analysis, Authors' photos and drawings

The Carbon chair is the one that pushes us towards this dialogue, accompanied by the following comments (Fig. 14):

- The concept represents a conversion of the Wire Chair in terms of a new material and technology.

- The structure is defined just like the Eames model, with the two principal dismountable parts, the shell as a dense textural network, the linear supporting structure composed of simple linear elements, identical dimensional and ergonomic characteristics.

- A substantial difference between the Wire Chair and the Carbon Chair is that the Carbon Chair seat is handcrafted by weaving a single carbon thread that is pushed into the punctured contour. The woven thread respects two overlapping composition rules,

the progressive geometric one and the network that converges towards the four principal assembly knots.

- The supporting structure is composed of two main parts that are doubled by mirroring, an idea somehow similar to the Diamond Chair.

Finally, the Carbon Chair looks like being the answer of the contemporary style to a historical personage, even if this answer gets defined from the perspective of the aesthetic: ghostly coming into being of a carbonized skeleton.

5. CONCLUSIONS

The concepts of the two chairs hold attributes tied up to the historic context of the post-war era, a well-developed rationalism without stylistic or ornamental demands: a

preoccupation for the industrial product which is an “expression of a purpose”, a fruitful search for efficiency. Eames’ and Ber- toia’s education and creativity illustrate their end-products: the general form, its geometric description, functional elements and visual-expressive imprint.

Their visions are not contrasting; on the contrary, their features get them into a conceptual and technological unity, but with particular expressivities: modularity and mirroring multiplication idea, simplicity of manufacturing specific to the industrial process. A development of the components by the flexibility of wire geometry is a consequence of anterior products (1948-50), when fiberglass helped develop non-transparent shells. The metallic structures vouchsafe attributes and values that are not easy to reach otherwise: lightweight impression, visual diminution of volume, constructive regularization, strength of the structure, indoor and outdoor usability.

The Carbon Chair, this already famous actor on the stage of contemporary design, consolidates the idea of conceptual continuity, plays the charms of old handicrafts in a stunning new key with a new material. The three chairs, as star protagonists in a still contemporary play, seem to formulate a timeless statement.

REFERENCES

- DREXLER, A. 1973. Charles Eames: Furniture from the Design Collection, The Museum of Modern Art, New York, Museum of Modern Art Publisher, New York.
- EN 1335-1:2000 Office Furniture – Work Chairs Part 1: Determination of Dimensions
- FAIR, M. 2006. 21st Century Design. New Design Icons, from Mass Market to Avant-Garde, Goodman Fiell, London.
- GRANDJEAN, E., KROEMER, KHE. 1997. Fitting the Task to the Human. A Textbook of Occupational Ergonomics, 5th edition, CRC Press, Taylor & Francis, London.
- NEUHART, M., NEUHART, J. 2010a. The Story of Eames Furniture. The Early Years, Book 1. Die Gestalten Verlag GmbH&Co KG, Berlin.
- NEUHART, M., NEUHART, J. 2010b. The Story of Eames Furniture. The Herman Miller Age. Book 2. Die Gestalten Verlag GmbH&Co KG, Berlin
- NEUFERT, E., NEUFERT, P. 2012. Architects' Data, Wiley-Blackwell; 4th edition, Bognor Regis, West Sussex.
- WWW.KNOLL.COM.



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