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MID 20TH CENTURY INNOVATIONS IN CHAIR DESIGN

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Abstract:

The main objective of the research was to create, develop and experiment a scientific method to visualize the concepts and design process of three major designers, Charles Eames, Eero Saarinen and Harry Bertoia, by means of a newly created instrument, the synoptic comparative analysis of their form, structure and ergonomics as reflected in the subsequent use of materials and technologies.

The research work aimed at the identification of the dynamics of the creative process of the three designers.

Two side chairs and three lounge chairs, created between 1941 and 1958, were selected and investigated by direct collection of data, measurements of dimensions and angles were made, followed by the representation of the sitting positions, components and construction details. The results of the measurements were compared to the recommended dimensions and angles specific for side and lounge chair sitting positions. The style and composition of each chair were defined, followed by short discussions regarding the characteristics of their respective material (molded plywood, plastic and wire mesh) and specific technology. Unfolding the illustrated synoptic features of the creative process of the three designers is expected to be a beneficial method for the good understanding of innovative industrial design. Their comparative approach to form, ergonomics, materials and their contribution to the evolution of the technological stages in view of the industrial production are expected to be a useful instrument for interior and furniture designers, for manufacturers as well as for design historians.

Key words: *Chair design; Eames; Saarinen; Bertoia; comparative analysis.*

INTRODUCTION

A number of requirements have to be met to a reasonable extent to be able to qualify as design: functionality, originality and innovation. Innovation refers to form, function, material or production technique. The chair design activity of Charles Eames, Eero Saarinen and Harry Bertoia, important representatives of American design, has been widely recognized and discussed. Their groundbreaking contribution to the history of 20th century industrial design and manufacturing (Dewey Eames 2006) has been frequently researched, through a thorough biographic approach (Neuhart and Neuhart Book 1 2010), as well as through their integration in the flow of strong 20th century furniture design innovations (Albus *et al*. 2009, Dewiel 1999), by handling new materials and adapting or improving materials and techniques for the industrial production (Neuhart and Neuhart Book 1 2010). A comparative and direct analysis of some of their most representative chair design concepts and characteristics such as form and composition, aesthetic and emotional value, user-friendliness, comparative functionality and ergonomics, structure and constructive details, together with a synoptic presentation of their approach of the design process is less present in literature. Their comparative concepts of form, materialized in molded plywood, plastics and wire, viewed through the proposed usability and parameters of the seating positions may prove to be useful for interior and furniture designers, for manufacturers and for design historians.

OBJECTIVES AND METHOD

The paper aims at deepening the understanding of several specific design concepts of Eames, Saarinen and Bertoia, members of the same generation of American designers, and their related design process, from biographic as well as professional angles, in order to achieve a synoptic comparative analysis of their contribution at the development of innovative form, structure, materials and technologies of mid-20th century chair design and manufacturing.

The research work started with theoretical investigations regarding the dynamics of the creative process of the three designers, followed by the identification of the targeted synoptic information: the chronological order and typology of their designs, as related to the chairs which were to be analyzed. These five chosen chairs belong to a modern classics chair collection (Cionca 2013). The analysis was carried on through direct collection of data, measurements and visual investigations, for the dimensions, angles, sitting positions, interactions with the human body and stability, followed by detailed technical sketching and drawing. Functionality and ergonomics, components and construction details, materials and technologies, style and composition were also analyzed and compared. Unfolding the illustrated synoptic features of the design and manufacturing stages is expected to be beneficial for the good understanding of innovative industrial design. The chairs that were investigated were created between 1941 and 1958.

SYNOPTIC COMPARATIVE ANALYSIS

The genesis and development of chair design by Eames, Saarinen and Bertoia is part of a larger story about a “diverse group of people who came together for a short time and who ultimately turned contemporary design in a new direction” (Neuhart and Neuhart Book 1 2010). A few of their biographical highlights are closely knitted with striking design renewal concerning form, functionality, material and technique. It is hardly possible to investigate, understand and comment upon the steps of their design process, if a few synoptically viewed moments of their life and work are not taken into account. Figure 1 provides highlights for the origins of the similarities between their creations, as well as for some production details.

Evolution, Style and Composition

For the accuracy of the investigations, a thorough comparative chronology of Eames’s, Saarinen’s and Bertoia’s chair designs had to be built up and presented. The fact that most aspects of their furniture designs emerged from only one major event, their participation and winning of the 1st Prize at the Organic Furniture Competition organized by the New York Museum of Modern Art (MoMA) in 1940-41, is revealing for the specific approach of their later design process (Fig. 1, Fig. 2).

The following stylistic and compositional analysis of the five chairs is based on their expression of form, structure and construction and also on the identification of the values that are communicated and signified in the product ensemble.

The Plywood LCW chair (Charles Eames 1948) shows independent formal elements made of molded plywood, integrated in a functional ensemble and a seamless composition, in the spirit of the Bauhaus school. These elements define a logical and ergonomic structure, expressing formal accuracy, spatial developments with aesthetic values and proportional qualities. The curvilinear joints and the lay-out of the edges and planes recall rigorously built compositions, according to the rules of artistic creation. It is an ergonomic and highly expressive chair.

The Rocking chair (Charles Eames 1950) strongly recalls the organic design concept of the MoMA design competition in 1940-41. The fiberglass and resin seat shell is supported by a linear structure, with a pyramidal volume made of steel to which two curved wooden runners are added. This contrasting association of elements offers a heterogeneous ensemble of forms and materials leading at functionality, comfort and technical-economical solutions, with a lesser preoccupation towards rigorous formal language and stylistic unity. The Rocking chair is indeed the expression of the serial product targeting the middle-class consumer.

The Wire chair (Charles Eames 1951) is armless and may be used as a dining-room or desk chair. The seat-back element is ergonomically modeled and made of steel wire mesh. The general form is light, simple and practical. The leg system is a linear structure similar to that of the Rocking chair and its spatial composition supports the seat like an elegant pylon, in a slender, functional, resistant and stable geometric construction. The chair has an evident conceptual and stylistic unity, through material, structure and constructive expression.

CHARLES EAMES (1907 - St. Louis, Missouri - 1978)		EERO SAARINEN (1910 - Kirkkonummi, Finland - 1961)	HARRY BERTOIA (1915 - San Lorenzo, Udine, Italy - 1978)
1925-1930, Studied architecture at Washington University. **'30,** Opened his own architectural practice;	1925	**1925-1930,** Studies sculpture in Paris and architecture at Yale University Works for Norman Bel Geddes;	**1925-1930,** Studies at Detroit School of Arts & Crafts and Cranbrook Academy of Art/Bloomfield Hills, Michigan
	1937		**1937,** 2 years scholarship at Cranbrook;
1938, 1 year fellowship at Cranbrook Academy of Art/Bloomfield Hills, Michigan;	1938		
1939 - '40, Instructor then head of Industrial Design Department at Cranbrook;	1939	**1939,** Instructor at Cranbrook, for architecture;	**1939,** Instructor for metalwork at Cranbrook, then head of the Metal workshop
1940, Eames and Saarinen signed up at The Organic Design in Home Furnishing Competition at the Museum of Modern Art (MoMA); Bertoia and other staff and students from Cranbrook join in for helping them; **1941,** Eames and Saarinen are awarded 1st Prize at two categories: A. Seating for a living room; B. Other furniture for the living room. **USA enter World War II .**			
1941, Starts building a pioneering molding device at his home;	1941	**1941-1947,** Partner at architecture firm Saarinen, Swanson and Saarinen;	
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 Dividion of EPC;	1942		
	1943	**1943,** Signs for furniture design with Knoll. Wins first prize in the competition Designs for Postwar Living, of the Arts & Architecture magazine;	**1943,** Joins the Molded Plywood Division of EPC, where he works with Eames to develop the plywood chairs;
1944 -1949, Manufactures plywood furniture at EPC; '45, Molded Plywood Children's Furniture;	1944		
1946, Plywood chair made at EPC, exhibited in New York;	1946		**1946,** Leaves EPC;
1947, Signs for furniture design with Herman Miller; **1947-1988,** The Eames Office, in Venice-California;	1947		**1947-1950,** Graphic design, San Diego, and research work at Naval labs
1948, The Eames Office signed up at the International Competition of Low-Cost Furniture Design sponsored by the Museum of Modern Art (MoMA) and won 2nd Prize;	1948	**1948,** Womb chair, inspired and asked for by Florence Knoll;	
1949, Developing the molded reinforced fiberglass technology in collaboration with Zenith Plastics;	1949		
1950-1951, Fiberglass armchair and side chair mass production, for Herman Miller;	1950	**1950,** Furniture design for Knoll;	**1950,** Sculpture works; **1950-1952,** Furniture design for Knoll Associates, in Pennsylvania: Diamond Lounge Seating, Side chair, Bird Lounge chair and Ottoman, a.o.
1951-1953, Developing the resistance welding technology for the Wire Mesh Chair and Wire Sofa, for Hermann Miller;	1951		
	1958	**1958,** Tulip chairs and tables Collection, furniture design for Knoll;	
	1963		**1963,** Sculptures created for Dulles International Airport, architect Eero Saarinen;
1968, Experimenting a new technology with the incorporation of molded polyurethane foam into the upholstery of chairs and sofas;	1968		

Fig. 1
Comparative biographical highlights for Charles Eames, Eero Saarinen and Harry Bertoia (after Neuhart and Neuhart, 2010).

Fig. 2
Evolution of chair design concepts of Eames, Saarinen and Bertoia 1940-1958 (after Neuhart and Neuhart, 2010, Von Vegesack et al. 1996).

The Diamond chair (Harry Bertoia 1952) enters a competition with the Wire chair, regarding the concept and the stylistic expressivity. The seat is lushly modeled as a rhomboidal unified shell volume obtained by cambering of a regular wire mesh. The plane and spatial deformations express sinuosity and tapering with the solving of the comfort of sitting, keeping simultaneously the visual structural signification of a mineral form. The supporting system describes through linear edges a simple and supple pyramidal volume, which is well integrated stylistically and constructively to the ensemble.

The Tulip chair (Eero Saarinen 1958), an organic and symbolic chair, offers through the formal shaping of its parts the concept of a growing structure. The seat and back shell opens up like a flower with a single petal, supported underneath by a stem-like leg. This is how the product concept strongly expresses the compositional and constructive unity, where the components develop one from the other just like natural growth. The horizontal rotation system of the seat enhances the functional character. It may be used as a dining-or meeting room chair.

The five chairs show two sitting typologies: work position (upright sitting) and reclined position (relaxed sitting). The Wire and Tulip chairs are meant for the work position, and the LCW, Rocking and Diamond chairs are meant for reclined sitting, specific to lounge chairs.

Sitting positions, dimensions and angles

The study of the sitting positions started from the necessity of comparing the dimensional and angular characteristics of the five chairs with those recommended by various specialists, preceded by the evaluation of the degree of comfort offered by each of them. The results of the measurements are presented in Table 1, together with the normative recommendations (Neufert 2004, Grandjean and Kroemer 1997, EN 1335-1:2000). The analysis of their ergonomics is shown in Fig. 3, 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 drawings of Fig. 3 were meant to highlight the sitting posture, the tilt of the torso, the leaning position of the legs as well as the freedom of arm movement. The Rocking chair sitting position is represented in three specific postures, vertical, frontally tilted and reclined, as allowed by this kind of chair.

The seat height of the LCW is 10mm above the maximum recommended height for lounge chairs, and the Tulip chair seat height is 20mm above the recommended maximum seat height for work chairs, while the seat height of the Rocking chair is below the recommended minimum seat height (Neufert 2004). The seat depth of the LCW is 30mm above the recommended value for lounge chairs. The seat angles of the LCW (17º), Rocking (13º) and Diamond (22º) chairs are beyond the recommended seat angle limits (5 -10º). The Diamond chair has its seat angle value of 22º, which is more than the double of the recommended maximum value, while its seat-backrest angle is situated between the recommended limits. The seat-backrest angles of the Wire and Tulip chair are below the recommended minimum limit of 105 -115º (Neufert and Neufert 2012).

Despite the incongruities observed at all selected chairs, they offer adequate sitting positions which are certainly not deprived of comfort. Their design concept and form and material requirements allowed the designers to step off limits, without affecting the comfort of sitting.

Table 1

Comparative presentation of the dimensions of the five chairs and the recommended dimensions (Neufert and Neufert 2012, Grandjean and Kroemer 1997, EN 1335-1:2000)

	LCW	Rocking chair	Diamond	Recommended for lounge chairs	Wire chair	Tulip chair	Recommended for side chairs
Seat height (frontal measurement) mm	410	360	390	375-400	440	470	400-450
Seat depth mm	530	450	470	450-500	400	400	380-450
Total height of the chair mm	700	690	690	-	810	820	-
Seat angle	17˚	13˚	22˚	5-10˚	4˚	0	5-8˚
Seat-backrest angle	100˚	97˚	100˚	110-120˚	97˚	97˚	105-115˚
Backrest angles	27˚	20˚/25˚	32˚/37˚	25-38˚	11˚/15˚	7˚/17˚	13-15˚

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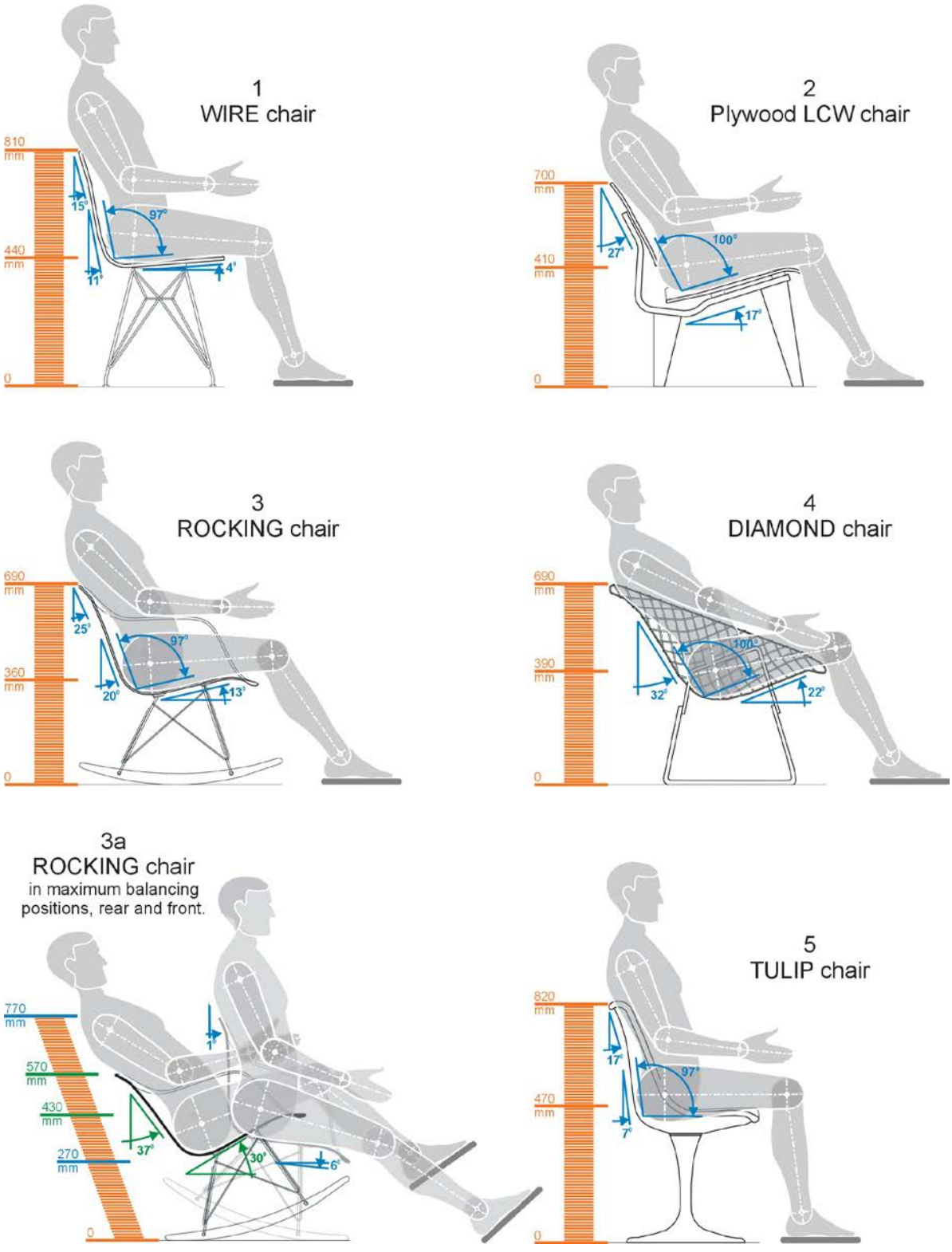

Fig. 3
Sitting positions for the Wire, Plywood LCW, Rocking, Diamond and Tulip chairs.

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Construction Details, Material and Technology

Fig. 4 presents a few construction details of the five chairs. Most of the details illustrate the dialogue with specific manufacturers, a tendency towards industrial solutions, and a highly innovative approach.

"…For the ease of manufacture and reasons of economy, a molded plywood chair could best be realized by linking separate molded-plywood head, back and seat components together by means of a structural spine made of wood and/or metal." (Neuhart and Neuhart Book 1 2010). The seat and the back of the Plywood LCW chair are assembled to the spine with shockmounts and screws, the front and back leg units are assembled with screws to the spine (Fig. 4, 1a,b).

"Some of the most elegant chairs they ever designed were made of plastic…The single shell chairs are masterpieces of economy - there's not a superfluous detail to them. Inexpensive…they sold in huge numbers**."** (Stungo 2000). Plastic shells asked for new construction solutions. In the case of the Rocking chair the legs are mounted at the bottom of the shell with a square metallic plate, welded to the leg, through which the screws reach the shockmounts (Fig. 4, 2a,b).

"From a formal standpoint, the Wire Chair is a „translation" of the plastic side shell in the material of resistance-welded wire mesh. With minimal material requirements a chair was created that is a striking synthesis of strength and transparency" (Von Vegesack 1996). More complex mounting solutions are used for the Wire chair. A rectangular frame welded to the wire mesh at the bottom of the seat is the connector for the leg system (Fig. 4, 3c). The seat pad is assembled with the wire mesh with four rectangular metal plates with semicircular curved edges, screwed into the pad supporting panel (Fig. 4, 3a). The legs end with a steel ball welded at the end of each leg, fitted into a rubber and stainless steel boot glide (Neuhart and Neuhart Book 2, 2010) (Fig. 4, 3b).

"The structure of the Diamond Chair clearly separates the different functions of the chair: the transparent wire shell is bent out of a quadratic lattice into an organically shaped diamond like net frozen in space, and the base of round iron embraces it like a polished diamond." (Von Vegesack A *et al*. 1996). Fig. 4, 4a shows the relationship between the upholstery and the seat wire mesh, Fig. 4, 4b presents the assembling of the leg with the seat wire mesh and Fig. 4, 4c shows the small rectangular rubber sole at the bottom of the leg system.

Saarinen's Tulip chair, with its fiberglass reinforced plastic seat that rests on a plastic coated aluminum base has a spatial sculptural composition. The aluminum leg containing the steel rod is assembled with the bottom of the plastic shell as detailed in Fig. 4, 5b. The steel rod also allows full rotation of the chair. Fig. 4, 5a shows the Velcro seat pad connection.

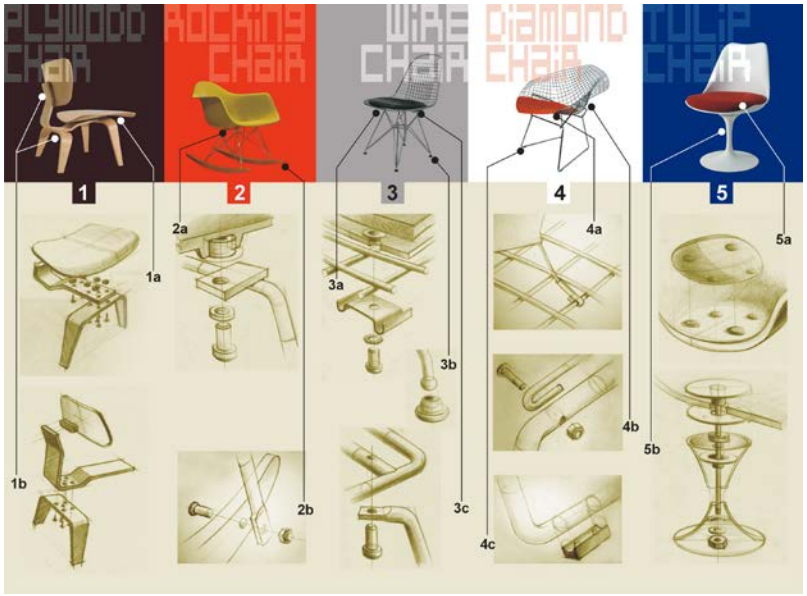

Fig. 4
Construction details.

A synoptic discussion of materials and technologies used for prototyping and later in the industrial production, of the plywood, wire mesh and plastic chairs are presented in Fig. 5, 6 and 7. The main topics of the discussion are synthesized as follows: material, general techniques, inspiration, objective and works targeting mainly the industrial production.

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MOLDED PLYWOOD CHAIRS

The material:

- **In 1930-1940** plywood was adapted for wooden military aircraft, landing rafts, attack boats, railroad and ferry station seating, sleighs, furniture, doors. Various patents had been issued for bonding and molding plywood and/or veneers;
- **In 1937** a urea-formaldehyde resin adhesive was introduced, with rapid curing time under lower temperatures, reducing manufacturing costs;
- **In 1944** phenolic resorcinol glues were introduced, for greater durability;
- In 1945 resorcinol and phenolic, as well as epoxy adhesives were widely used, for superior quality plywood.

The techniques:

- In the early 40's, the Durand and Vidal methods for molding layers of veneers in autoclaves were used for furniture manufacturing.

DCW and LCW Shockmount (1)

The Kazaam (2)

Paimio Chair, Alvar Aalto, 1938 (3)

TECHNOLOGY

Cranbrook , MoMA Competition, 1940-1941, Eames and Saarinen

Inspiration:

- Alvar Aalto, plywood Paimio chair 1938 (3); Marcel Breuer plywood Long chair, 1936 (4).

Objective:

- adapting the veneer laminating process to the designed chair shapes; extending plywood molding beyond one-directional curved components into two-directional compound curves.

Works:

- small scale models made of hammered copper by Bertoia;
- experiments with assembling the legs to the wooden shell without connecting hardware, trying to use "cycle-welding" (a Crysler technology for eliminating rivets, by using a layer of rubber between the connecting elements). Aluminum legs attached to the seats were to be used;
- The Haskelite Manufacturing Corporation was selected to mold the shells, for mass-production;
- cast iron molds were made and the veneer strips glued with U-F were laid upon the mold;
- the mold and veneers were put into a rubber bag, a vacuum drawn on it, and then placed in the autoclave, in which steam pressure and heat were pumped;
- over the plywood, a thin layer of foam rubber covered by upholstery was laid;
- the aluminum legs were replaced by wooden legs attached with a collar, because the "cycle-welding" process couldn't be used (5); in 1942 WWII started and production at Haskelite did not continue.

The *Kazaam*, Los Angeles, 1941, Eames

- Eames built the *Kazaam* device for molding plywood, made of interlocking wooden strips (2), designed for a one-piece chair seat and back. It was heated with electrical resistance wire.
- an inflatable rubber bag was the male component for the mold.
- a vertical cut had to be made in the back of the chair, to relieve the tension of the wood.
- at the end of the molding process, the chair was trimmed and sanded.
- this was the last solitary work in furniture development of Eames, on his way to mass produce his molded plywood chairs.

Plywood chairs at the Evans Product Company (EPC) 1943-1949, Eames

- Eames continues to experiment with molded plywood with the financial support of the EPC; steel molding presses were added to the production line-up, replacing the wooden Kazaams.
- Bertoia successfully proposed to design the plywood chairs with separated head, back and seat components, with a "spine" made of metal or plywood, to support them, succeeding to simplify the molding process (6).
- parts of the molding process could be mechanized, and required less time.
- after the molding was complete, the plywood sections were trimmed using a routing template, then lacquered.
- the seat, back and legs were assembled to the spine with the shock-mount, a rubber disk to be bonded with phenolic resorcinol glue to wood, providing an interface between the components without affecting the exterior appearance of the chair (1). Today epoxy glue is used for the rubber shockmounts.

Laminated plywood long chair, Marcel Breuer, 1936, (4)

Eames and Saarinen, Organic Armchair, MoMA Competition (5)

Eames LCW chair (6)

Fig. 5
Technology discussion for molded plywood chairs (photo (2) Matter and Matter 2010).

Fig. 6
Technology discussion for fiberglass and plastic chairs (photo (1) Steelform).

Fig. 7
Technology discussion for wire chairs.

CONCLUSIONS AND DISCUSSIONS

For the carrying out of the major objective of the paper, which consisted of the five chairs' synoptic comparative analysis, the following stages were set up and resolved: 1) the identification of a few biographical highlights regarding the professional evolution of three designers, Charles Eames, Eero Saarinen and Harry

Bertoia, for the subsequent understanding of their related careers in the field of innovative chair design; 2) the analysis of the evolution of form, style and composition in their design process, as related to the five chairs which were selected; 3) the comparative analysis of the chairs' ergonomics – dimensions, angles and sitting positions; 4) the comparison between the results of the measurements and the recommended dimensions and angles; 5) an investigation of the structure, components and significant constructive details of the five chairs; 6) short synoptic discussions regarding the contribution of each of the three designers to the evolution of innovative materials and technologies of the 40's and 50's. Stages 1) to 6) may be seen as the self-developing method structure.

The results of the comparative analysis of the Wire and Tulip side chairs and the Plywood LCW, Rocking and Diamond lounge chairs highlighted at first their common features and later on allowed the identification of their specific and unique design approach. The synoptic presentation of the various sitting positions shown in Fig. 3 allows a good understanding of the anatomical interaction and helps designers have an overview of the chair design process. Due to the measurements results compared with the recommended parameters in Table 1 it becomes visible that none of the five chairs has all dimensional and angular parameters within the recommended limits, nevertheless being able to offer exemplary sitting positions.

The newly developed organic forms of these chairs announce the era of modernity, they are born from the postwar vision of simple, middle-class oriented mass-produced objects, far from the exclusive line of concepts specific for example to Art Déco. The development of the use of innovative materials made available after WW II, like molded plywood, glass fiber reinforced polyester resin and wire mesh was necessary for the industrial production of modern, attractive yet accessible furniture. It was the moment of the complete integration of the designer in the engineering process, as it had been assumed by the Bauhaus ideology.

The results of the five chairs' synoptic comparative analysis that follow the stages of the proposed methodology are presented in Fig. 2, 3, 4, 5, 6 and 7, as well as in Table 1. These figures and the table have to be taken as both an instrument and a contribution at the inside knowledge of the *modern classics* chair design process. This process is rarely made available and requires attentive screening and careful investigation to be made public and transformed into a useful reference in the benefit of the art and science of furniture design. The methodology may be successfully used whenever such analysis is required.

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