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Developing sustainable structural design features

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Abstract
Living spaces in our day are densely furnished with very different artificial objects. Especially urban life requires that these objects should be various as well as their materials. Interior and outer spaces in cities, interior fixtures of living and working spaces accommodate all items of the material culture and thus spaces are swarmed with objects. Objects of use in living spaces, as products of design, are structures made of one or two materials. These industrially produced designs are products whose features were determined according to many factors such as their function, their place of use, their users, the competitive power of their manufacturing company, the company's expectations, and to environmental protection and recycling factors.

Also among the factors that affect the design of industrial products are material and structure. Designating the right material, production type and right structure are important in terms of the sustainability of designs and production management. This paper studies how the type of structure, amount of materials used in the structure, the number, thickness, and weights of parts that form the structure, the number of processes in the production affect the design of product and sustainability of production. For this purpose, designs are categorized under different structure types in the study. Furthermore, in the production method, the study explains a measurement technique with the strain gauge and making use of computer analyses as an auxiliary method in developing the mentioned structure types.

Keywords*: Structure design, sustainability, production, design management*

1. Introduction

Material and structure are of great importance among the criteria that affect industrial product design. It is compulsory that material and structure have to be considered together with production and with all other factors related to production. Various structure types with different structural features are developed during industrial product design. While one step in the design process is producing the design with a suitable material another step in the process is choosing a structure which is suitable for the material, function, space, production methods, etc. Structure design of the product requires team work of people that include designing engineers, constructors, marketing experts, etc. A design process is required to meet the expectations from the design in the production process in the most precise and proper manner. In this context, the relations between form-material-

structure are observed and analyzed in various industrial product samples. The study considers the effects of structure in industrial product design in the context of sustainability of future designs.

Material choice is of great importance in design, and the structure of the design is effective in such choice. This article deals with structure, which has not been studied much in the literature of product design. What's more, the place of each structure in product design is considered in terms of sustainability. The relations of each studied structure with the form and material require a comprehensive examination. Comprehensive studies on the relations of structure, form, and material will make it possible to gather different information about different products. Various structure types were analyzed in this study in order to identify the connection of structure-form-material relationship with design and its sustainability. These relations were considered along with the laboratory tests made on a design, and their connections with productivity and sustainability were established.

2. The Structural Features of Industrial Product

It is the objective of this study to direct design process towards focusing on structural works in terms of the sustainability of designs. The extent to which design may be improved by focusing on structural work and different measurement methods will be shown with an application. Today the employment of material and energy are matters of great importance in all fields. The use and quantity of material gain importance in industrial product design where millions of products are mass-produced in industrial plants. The material, its amount, its type and manner of use, the shapes and numbers of assembly parts are decisive in the structure of design. Producing an optimal solution for the design will be easier with decisions made by focusing on these details in design management. Productivity is one of the important criteria of sustainability (Bal, Ildırar, Özmen, 2001). One aspect of this multi-faceted phenomenon could be the creation of products whose structures economize on material, work force and energy. This article deals particularly with various structure types used in designs and their productivities. According to the definition by Mayall (1967) the requirements of product design fall into three groups: technical, ergonomic, and aesthetical. All three groups are closely interconnected and all factors of design could be considered within these three. Structure is in the technical group: structure, as a system of relations between elements and parts and as a concept that shapes these relations is the physical basis of product design. The structures that will be dealt with in the scope of product design could be defined as follows (Günal Ertaş, Bayazıt, 2007).

2.1. Shells

Shells are structures in which an outer shell of a certain thickness forms the structure and keep it standing. They are elements with curved surface, whose thickness is rather small compared to their other dimensions. Shells are structures with curved surface for easy removal from their molds as it is the nature of their production; they have radiuses (a segment of a circle) on

their sides and corners and they form an upper surface similar to the skin, which covers the viscera of organisms (Figure 1,2). Shells could be used in many fields in design such as furniture, household and office objects of use, sanitary materials, food containers, products whose inner volume is used such as suitcases and bags, etc.

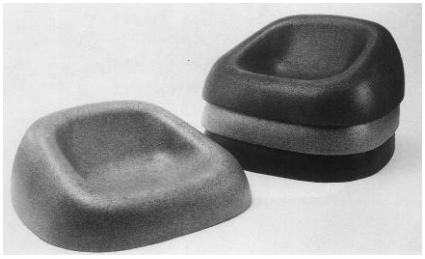

***Figure 1**: Shell design*

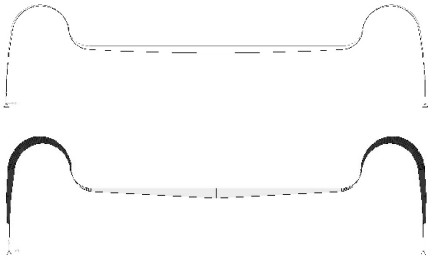

***Figure 2**: Behaviors of shell design*
top: Deformation diagram of shell design
bottom: Moment diagram of shell design

Structural features:

- Shells generally stand alone as one piece; they are continuous, curved and thin surface carriers.
- They are structures where few materials could be used and whose strength depends on the measurement, thickness, form and material.
- They generally convey load with tensile, compressive, and shearing forces (Engel, 2004: 226-257).
- Their resistance against uniform load is better than against concentrated load.

Thin shell structures makes it possible to economize on material. Despite the fact that they are thin they provide the required resistance to forces. Thanks to this feature, shell designs are productive and sustainable.

2.2 Massive Structures

They are structures that stand as a solid mass. This is a type of structure from the ancient times when, not knowing much about material processing, they processed only the outer surface of the material Massive wood structures were encountered a lot. This structure is employed when a mass weight is required and when solidity is required as with the case with light materials of today. Traditionally, massive structure is seen in chiseled and engraved wood and stone ornaments, and in contemporary forms we can see polyurethane foam, etc and some two-component material (Figure 3,4).

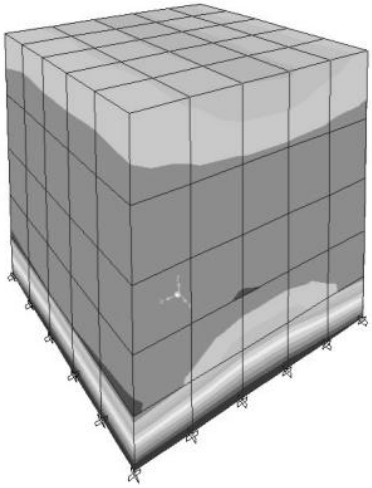

Figure 3: *Tension diagram of massive prismatic cube stool*

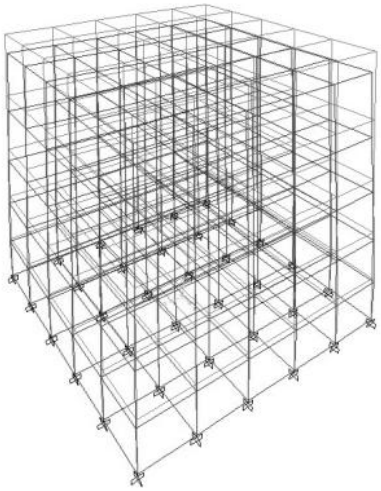

Figure 4: Deformation diagram of massive prismatic cube stool

Structural features:

- They are structures whose static and dynamic features and resistance depend on their geometrical form.
- They are massive conveyors which bear loads in all directions. Although their resistance depends on the massive structure of the material, long-term resistance may change according to dimension, form, and type of material.

Massive structures are used when design, material, or production method so requires. Massive structures do not provide productivity in terms of economizing on material. However productivity increases in some designs where massive structures make it possible to use different contemporary and regional materials and simple production techniques.

2.3. Frames

Frames are systems obtained by a rigid horizontal, vertical, or diagonal connection of hollow or solid rods. Frame structures could be grouped as pipe-section frames and massive-section frames. Generally bicycles, furniture, fitness tools, bathroom-kitchen accessories, display units, etc. may be counted among frame structures (Figure 5,6).

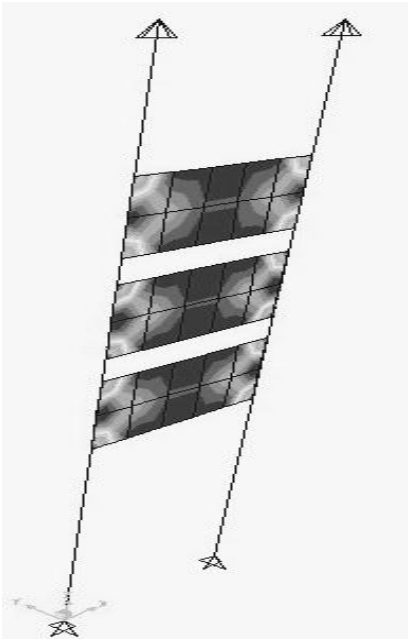

***Figure 5**: Tension diagram of frame*

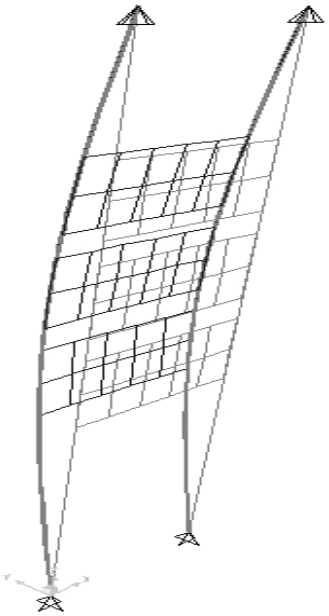

***Figure 6**: Deformation diagram of frame*

Structural features:

- Frames are systems where loads are conveyed by rods at different directions (Engel, 2004: 178-191).
- The directions of the rods in the system, section types of parts, dimensions and materials are important for the balance of the frames.
- The structural behavior of the frame differs according to uniform load and concentrated load.

Frames are ideally sustainable structures because of their productivity. They are systems with high rates of use in product design. Frames make it possible to create designs with less material and parts, to use ready-made parts and support modularity. A longer life-span is provided with their endurance. These qualities provided by frames increase productivity in product design. The experimental study in the article was based on a frame design which has high productivity and sustainability.

2.4. Membranes

These are structures filled or inflated with material such as air, gas, liquid, granule, foam, waste, etc. Depending on the material they are called filled or inflated (Figure 7,8). Filled or inflated structures are generally spherical, cylindrical or curved. Products such as filled or inflated furniture, toys, rubber dinghies, sea toys, life vests, air-pressured huts, and sports tents, etc. could be counted in this group.

***Figure 7**: Inflated membrane*

***Figure 8**: Filled membrane (Fiell, 1997, pp: 473, 482)*

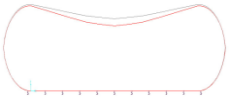

***Figure 9:** Deformation diagram of the filled membrane*

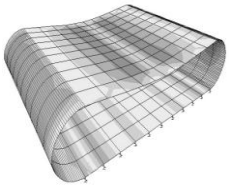

***Figure 10:** Tension diagram of the filled membrane*

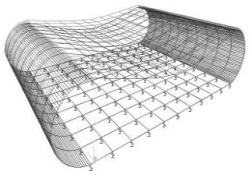

***Figure 11:** Deformation diagram of the filled membrane.*

Structural features:

- The materials used in membrane structures are generally resistant to pressure thanks to the air or fill inside. They are flexible, but with a weak tensile strength (Figure 9,10,11).
- Inflated membranes could be subject to compressive, tensile, and shearing loads. Their flexural rigidity is low (Engel, 2004: 89-103).
- The membrane is theoretically in balance when inner pressure is equal to the outer forces. The surface tensions are zero. The force affecting the surface changes according to the air, liquid, or granule inside the membrane and conveyed to certain areas. No breaking occurs during conveyance.

Since membranes are fillable or inflatable outer surfaces, they are easy to use and practical. Economical material use in membrane designs increases productivity of design. The use of right materials with proper techniques in membranes adds to the endurance and life-span of the product, thereby increasing the sustainability of design. Bio-degradable plastic could be used as material in membranes instead of harmful plastics to avoid problems in sustainability.

2.5. Sheets

Sheet structures could be of plane, ribbed, or folded type and they are structures whose thickness is quite smaller than other dimensions as their name suggests (Figure 12). Load distribution could be seen in two directions. Examples for this group are display, roof covers, advertisement panels, cupboards, tables, writing boards, etc.

Figure 12: *Sheet furniture*

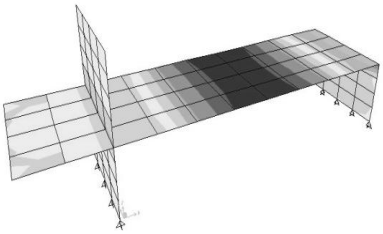

Figure 13: *Tension diagram of a sheet furniture*

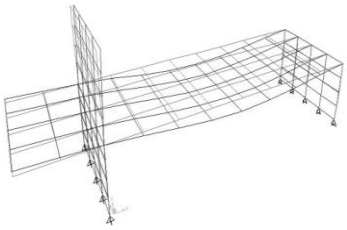

Figure 14: *Deformation diagram of a sheet furniture*

Structural features:

- Sheets are subject to tensile, compressive, shearing, and flexural forces, they convey the load best to the surface. In such case they behave according to section thickness and material (Figure 13,14).
- Their resistance against uniform load is higher than against concentrated load.
- Flexural moment is more in sheets.
- The balance of the sheet structure is proportional to the correct positioning and connection of sheets in the structure.

Sustainability of sheets differs according to design, material and production method. In some designs endurance is provided by twisting the material in proper areas. Sometimes the thickness is increased in order to increase endurance. The sustainability of sheet-structure designs are affected by processes on material such as pressing, perforating, folding, laminations, etc. Design could provide the development of optimum solution.

2.6 Space Systems

Space systems which find extensive use particularly in the field of architecture are systems where rods are joined at their ends together in web-like networks. They form quite a steady structure with very little material. Among the designs that bear the features of this structure display stands, storage, sales and advertising units, modular toys, furniture such as chairs and tripods, etc. could be counted (Figure 15).

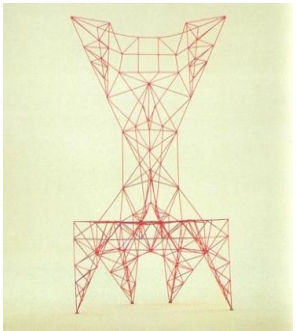

Figure 15: *Chair with a space system - Tom Dixon design, produced from steel rods (Fiell, 1997, pp: 650)*

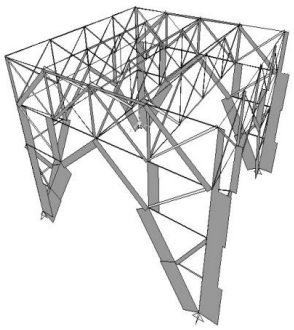

Figure 16: *Distribution of force on the product*

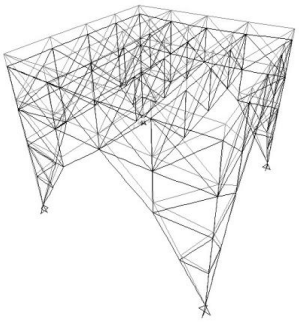

Figure 17: *Deformation diagram of the product*

Structural features:

- In load conveyance at space structures, affecting forces are distributed on many rods and on components at different directions. Since they are determined geometrically, various designs could be made with different angles (Figure 16,17).
- Generally the top surface resists to compressive force, and bottom surface to tension.
- Different joint point solutions could be used. Different solutions developed for joining the rods include bolting, welding, and sliding into one another.

Space structures are the closest to sustainability with their basic structure. The semi-product rods they contain require a minimum amount of material. Since space structures contain reusable modular prats they are ideal systems in terms of productivity and sustainability

2.7 Hung- tensile Systems

Hung tensile systems are structures with tensile strength hung with components such as rope, wire, cable, etc. They can be mounted to the ground, wall, or to other fixed elements. Display units, tents, shelf systems, etc. could be counted as examples to these systems (Figure 18).

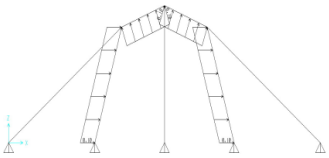

Figure 18: *Forces in hung system tent*

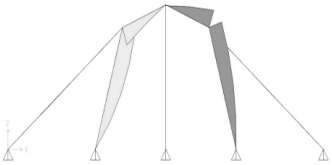

Figure 19: *Moment diagram of the hung system tent*

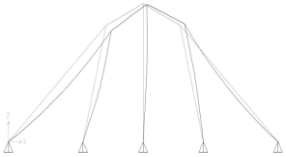

Figure 20: *Deformation diagram of the hung system tent*

Structural features:

Materials subject to tensile, compressive, and flexural forces show physical reactions such as twisting, turning upside down, and crumpling. Therefore additional safety measures should be taken (Figure 19,20).

- Materials with high resistance are more suitable for use.
- Wires or ropes installed in the system and membrane surfaces with no elasticity of flexure may convey the load if they are positioned so that they are deformed in the direction of the force and the whole system will be operable.

Hung-tensile systems are used both indoors and outdoors. Therefore, products with hung-style systems have a longer life when proper weather-proof materials are chosen and the structure is installed accurately. Productivity and sustainability of space structures could be increased with correct decisions in the design process.

2.8 Mixed Systems

They are mixed systems that bear the characteristics of different structures at the same time. Mixed structures may be tools with complicated systems, furniture, lighting fixtures, display units, roof covers, direction systems, etc.
Structural features: They carry the features of different structures they embody.

Each of the mixed structures carry different structural features. Therefore, a different solution should be developed to provide sustainability to each.

3. Sustainability and its Development

In recent decades the number of forest fires and population increased; industrialization pervaded the world, petroleum products have been used increasingly as fuel; natural sources are on the decline. Scientific studies are in progress for the protection of habitats and researches are in place for the measures that could be taken for the sustainability of such protection.

For the last 40 years, raw material and petroleum fuels have been used extensively. Accordingly, "sustainability" emerged as the outcome of increasing waste and resulting environmental pollution that put lives into peril. In 1984, World Commission on Environment and Development (WCED) convened for the first time and issued the Brundtland Report in the spring of 1987. This report defined the term "sustainable development" for the first time, and it showed that people could achieve sustainable development (www.mddep.gouv.qc.ca). In 1992, the United Nations Conference on Environment and Development-UNCED) convened in Rio de Janeiro. The conference opined that the main reason for the gradual deterioration in nature was the unsustainable models employed in production and consumption in industrialized countries. With the "White Paper" issued by the European Commission in 1994, a political infrastructure was formed with the title "Growth, competitiveness, employment: new formations and methods to follow on our way to 21st century". To state it briefly, raw materials have to be used as efficiently as possible. Mounting technologies should be improved, recycling and reproduction capabilities must be supported. Recycling of materials is possible with design measures taken during the planning of the product or the process. Experts should accompany designers and engineers who are competent in product development. For a sustainable development of the product in terms of structural features: Design process could easily perceive the integrity of respective elements.

- The integrity of elements should be judged well.
- In this integrity, design and the structure of the product are important. Sustainability starts where future lives could be intuitively guessed by gathering information from the present.
- We live in an era that is flooded with irrelevant and excessive information. So, it is important to ensure that beneficial information is chosen.
- It is essential to support designers in their efforts to find solutions to problems and ease their work at a period when design problems are both exhaustive and various, and to work in teams when necessary.

In solving complex design problems, team work is ideal in relieving the burden of designers and developing proposals for sustainable solutions. However, we are in dire need of design managers who will perceive the design problems of the future in advance. Meier's (1978:246) schematic

definition made by making use of Andersen's (1971) studies show the comprehensive scope of the design management that would address this need. Design management covers all issues related with the following concepts:

● Design purpose system,
● Design information (Informatics),
● Design planning,
● Design organization

For a conscious development of structure in design all these concepts should be considered together. The relations between the concepts and information flow will lead to development in design. Design process should most efficiently deal with the production methods of the manufacturer firm and cost-efficiency of the material. This takes into account not only the sustainability of the company, but also of the future habitats. It may be necessary to plan again the whole organization and design; obtaining information will be more sensitive and comprehensive with concepts such as green design and production. Although the purpose of design is to create income for the enterprise, design management should accept that income system will collapse if sustainability is ignored. Accordingly, while the products differentiate for the market, design management has to find a balance between innovative design and rational and economic behaviors. It should be among the tasks of the design management to improve the corporate identity and relevant product identity for sustainability. Sustainable production requires environment-conscious enterprises and designing sustainable products. Sustainable design could be grouped in the following manner:

- Products which could be collected and reused, such as glass, stainless steel, etc.
- Products whose modularity and worn parts could be changed and renewed such as household and office objects, cars, etc.
- Products which could be recycled to obtain new raw materials, such as paper, metal, plastic etc.
- Products whose structures are retouched with economic measures to save energy, time, etc.

"Productive design of structures" will be considered in this study with a model work. This model study employs frame structures which are widely used especially in design sector. Other structure types were analyzed in terms of the productivity of sustainability.

4. Improvement of Structural Features in Terms of Sustainability of Design

In the scope of the sustainability of design products, strain gauge technology and stress analysis methods were employed in the study of product structure. The applicability of these techniques in industrial product design was interrogated. Methods were applied on a seating unit which was manufactured with pipes in a frame, or skeleton structure. According to measurement and analysis results seating unit was redesigned. Design should be made taking into consideration the strength of the product, material selection, and material balance. It should be noted that not only

designers but also administrators of the design process should attach importance to structural measurements. Each structure type has its own measurement and analysis type. The objective for the frame structure here is to provide resistance for the seating unit, while decreasing the number of parts and materials. For these objectives, deformation measurements and strain analyses were carried out on the structure. Strain measurement technique, applied with the “Strain gauge” will be briefly mentioned below.

4.1 Measurement Technique with the Strain gauge

Experimental strain analyses in engineering applications could be made possible only by measurement of deforming units and establishing relations between these figures and strains. The most reliable method for the measurement of stretching is by measurement with strain gauge. The strain gauge technique has become a popular tool for the measurement of many physical magnitudes.

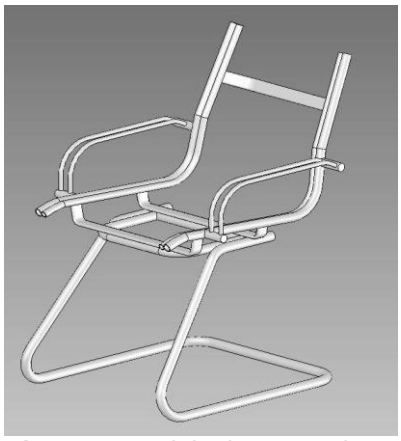

Figure 21: *Original perspective of frame chair*

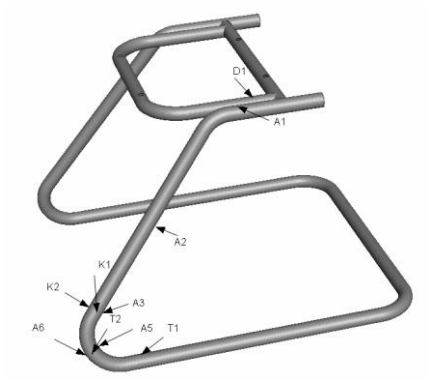

Figure 22: *Points of measurement in the frame*

Figure 23: *Tension diagram of the frame chair*

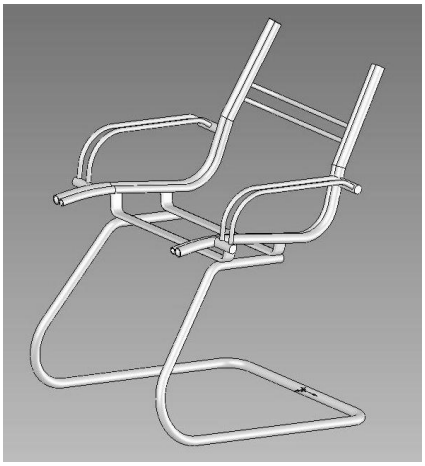

Figure 24: *Perspective of suggested structure*

In this study, the change in resistance resulting from deformation could be tracked by applying tensile force on a metal wire with electrical resistance

strain gauges. The relation between change in resistance and unit stretching could be established by approximations. Deformation component could be known by measurement of change in resistance making use of material coefficient and “gauge” factor. Elasticity and sliding module is used in the measurement of values such as fatigue strength (Toprak, 1997).
In this study, the change in resistance resulting from deformation could be tracked by applying tensile force on a metal wire with electrical resistance strain gauges. The relation between change in resistance and unit stretching could be established by approximations. Deformation component could be known by measurement of change in resistance making use of material coefficient and “gauge” factor. Elasticity and sliding module is used in the measurement of values such as fatigue strength (Toprak, 1997).

Steel frame is the dominant component of the structure and sight of the design (Figure 21). Strain gauge was applied on certain points on the frame (Figure 22). Various loads (120-180 kg) were applied on the structure, resulting deformations were measured and tensions were calculated (Figure 23). The values obtained by measurements and by finite element analysis on computer were considered together to suggest changes in the design to meet the established objectives for the structure. Whether resistance was obtained in the suggested design was studied with computer analyses (Figure 24). The tensions in the considered structure may be found too much for a standard chair, deformations, yields and breaks may occur. However spring steel, a material with a high yield stress, was employed in this design to prevent various structural problems.

4.2 Analysis of Suggested Structure

No problems occurred in the suggested structure since the tensions at various points remained below yield stress. It was seen following both the experimental work and computer analysis of suggested structure that the suggested design could be manufactured with the objective to decrease the number of parts, to lighten the structure, to reduce cost and to shorten production process. The design suggested here could provide sufficient resistance although the dimensions were reduced and some parts were removed. The differences between the current seating unit and the one developed after long structural measurements are so striking as to attract the attention of designers and experts who administer design.
The superiorities of suggested structure over the current frame structure are expressed below:

- The weight of current chair’s frame structure is 13 kg. Suggested frame structure is 9 kg. A redundant 4 kg was removed by reducing the length of pipe, decreasing the number of parts and changing the steel employed. The product became more portable.
- 2 parts were reduced from the frame structure of the chair, namely a U-shape part and a rod part.
- The reduction in the number of parts in the structure made welding unnecessary at four points, thus decreasing the number of processes and shortening production time.

The benefits of structural developments in design include cost-effectiveness, lightweight design, ease of use, longer life, removal of physical faults, ideal dimensioning, sophisticated details, and reduction in workmanship as well as new functions, and a different look. It is essential that workers in product design and development are experts of their field and diligent in their work. What is more, it is important that the designer should have know-how about endurance. Heskett, keynote speaker in D2B Shanghai 2006 1st International Design Management Symposium, in his presentation titled 'Ten Steps to Heaven: Managing Design for Innovation' determined the roles of designer in the formation of a new and strategic product in the fifth step called "different levels of design practice":

- Designer as Differentiator,
- Designer as Planner,
- Designer as Interpreter,
- Designer as System Creator.

In the same organization the role of design management is 'Original Strategy Management' among "strategic and organizational emphases" next to the designer's "planner" role. On the other hand, again in the same system, the management has the role of "Original Brand Management" between "organizational emphasis" and "existing products" besides designer's role of "System Creator". In the light of this information, design management will undertake important tasks in the original strategies and brands of our time and of the future. The sustainable products that they will manage will be studied in detail in terms of structure, and these products will be measured with various methods similar to the 'strain gauge'. It must be expected that design management should have a closer understanding and knowledge about these matters rather than mere familiarity.

5. Conclusion: Principles For an Accurate Conduct of Sustainable Design

Realizing an ideal sustainable product is team work. This team work was shown by Heskett (2006) in the 21st section of his presentation, "Different Levels of Corporate Activity". The integrality of the team work is shown there with an upside-down triangle. The role of "Original Strategy Management" is the most comprehensive top of this triangle. The increase in values and risks lie at the sharp bottom tip. It shows that products are developed towards this direction. It denotes that if 'original strategy management' is achieved completely, the value of the product will increase and the risk will be reduced. Thus strategically, the future lives should be predicted in the sustainable designs. Measures should be taken to decrease sale risks and to increase productivity and value of the product. One such measure is to improve the designs structurally. In this context, this paper investigated the sustainability of structure types mentioned here in the scope of productivity. The originality of this study in terms of product design lies in the fact that it took as model one of the analyzed structure types. What's more, laboratory tests were made on the product with a new method and obtained results. Accordingly; a design development which takes into consideration the structural features in sustainable products should:

- Master the purpose system of design,
- Ensure that multi-sided information and acquired contemporary information about design are taken into consideration,
- Have grasped the meaning of its top role in the planning of design, and master every detail in its subject,

- Be a decision maker who knows about all levels from the decisions of the institution to the end of production cycle and to recycling levels, and warns and make interventions when necessary,
- Establish all links between all equipment from design to final production and master the chain of values, a popular concept of our time,
- Be aware of and evaluate all added values in the integrality of the organization besides mastering all these features.

Sustainable production and design have no place for negligence. Besides large enterprises, SMEs, which have a large share in world industry, should employ design management with the help of SME support organizations. The design management with the above features must have well perceived the importance of sustainable structures of products in their future life.

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Tasarımı etkileyen strüktürel özelliklerin sürdürülebilirlik yönünden geliştirilmesi

Günümüz yaşam ortamları oldukça farklı ve yoğun yapay objelerle donatılmıştır. Çağdaş yaşamın gerekleri bu objelerin yalnız türlerinin yoğunluğunu değil, malzemelerinin yoğunluğunu da içine almak

durumundadır. Dış ve iç mekanlar, çalışma ve yaşama alanlarının iç donanımları maddi kültürün bütün verilerini içinde barındırmakta ve mekanlar madde yığını haline gelebilmektedir. Yaşam ortamlarının tasarım ürünü olan tüm kullanım objeleri bir ya da birkaç malzeme ile meydana getirilmiş strüktürlerdir.

Endüstrinin ürettiği bu tasarımlar, işlevine, kullanıldığı yere, kullanıcı kitlesine, üretici işletmenin pazardaki rekabet gücüne, maddi beklentilerine, çevre koruma ve geri dönüşüm gibi birçok etkene göre özellikleri belirlenmiş ürünlerdir. Endüstri ürünü tasarımını etkileyen bu farklı faktörler arasında malzeme ve strüktür de önemli bir yer almaktadır. Malzeme, üretim yöntemi ve strüktürün doğru belirlenmesi tasarımların sürdürülebilirliği ve üretim yönetimi bakımlarından önemlidir.

Endüstriyel ürün tasarımlarında farklı strüktürel özellikleri taşıyan çeşitli strüktür tipleri geliştirilmektedir. Tasarım sürecinin bir adımı tasarımın uygun bir malzemeyle ya da üreticinin sürekli kullandığı malzemeyle üretilmesiyken, sürecin başka bir adımı da malzemeye, işleve, kullanım konumlarına, mekâna, üretim yöntemine vb. uygun olan bir strüktürün seçilmesidir. Malzeme ve strüktürün, ürünün tüm biçimini meydana getirecek şekilde tasarlanması, tasarımcı mühendis, konstrüktör, pazarlama uzmanı gibi tasarım sürecine katılan ekipte yer alan farklı kişilerce yapılacak ortak çalışmalarla sağlanabilir. Üretim süreci içinde üründen beklenen farklı özellikleri en iyi şekilde sağlayacak tasarımın meydana getirilmesi, tasarım ürününün en iyi şekilde yönlendirilmesi ve geliştirilmesi ile mümkün olmaktadır. Bunun başarılması ise ürünün strüktürel özelliğinin sürdürülebilirlik bağlamında ele alınması ve tasarım süreci kapsamında sonlu elemanlar ve gerinim ölçme tekniğinden faydalanılmasıyla sağlanabilir.

Bu çalışmada tasarımı ayağa kaldıran strüktürün türü, bu strüktürde kullanılan malzeme miktarı, strüktürü oluşturan parçaların sayısı, parçaların et kalınlıkları, ağırlıkları, üretimdeki işlem sayısı gibi bazı değişkenlerin ürünün tasarımına ve üretimin sürdürülebilirliğine nasıl etki ettiği incelenmektedir. Bu amaçla da çalışmada tasarımlar farklı strüktür tipleri altında sınıflandırılmaktadır. Ayrıca üretime hazırlama sürecinde bahsedilen farklı strüktür türlerini geliştirmeye ve sürdürülebilirliğe yardımcı bir yöntem olarak, gerinim ölçer ile ölçüm tekniğinden ve bilgisayar analizlerinden faydalanılması anlatılmaktadır. Bu bağlamda biçim-malzeme-strüktür ilişkileri çeşitli endüstriyel ürün örnekleri üzerinden gözlenmekte ve analiz edilmektedir. Çalışmada endüstriyel ürün tasarımında strüktürün etkileri geleceğin tasarımlarının sürdürülebilirliği bağlamında ele alınmaktadır.

Mayall (1967)'ın tanımına göre ürün tasarımının gereklilikleri teknik, ergonomik, estetik olmak üzere üç grupta ele alınır. Her üç grubun birbirleri ile sıkı bağı vardır ve tasarımın tüm etkenleri bu üç grup içinde ele alınabilir. Strüktür, teknik grup içinde yerini alır. Elemanlar ve parçalar arasında bir ilişkiler düzeni ve bu ilişkiler arasındaki taşıyıcı dokuyu biçimlendiren bir kavram olarak strüktür ürün tasarımının fiziksel temelidir.

Ürün tasarımı kapsamında ele alınacak strüktürler arasında kabuklar, dolu strüktürler, çerçeveler, membranlar, levhalar, uzay kafesler, asma gergi sistemler, karma sistemler yer almaktadır. "Strüktürlerin verimli tasarlanması" konusu bu bildiri kapsamında bir örnek çalışma ile ele alınmaktadır.

Kısaca tanımlamak gerekirse, hammaddelerin olabildiğince verimli kullanılması gereklidir. Montaj teknolojileri geliştirilmeli, geri dönüşüm ve yeniden imalat kabiliyetleri desteklenmelidir. Malzemelerin geri kazanımı, yeniden kullanımı vb. özellikler ürünün ya da sürecin planlanması sırasında alınacak tasarım önlemleri ile sağlanabilir. Bu tasarım önlemlerinden çok önemli bir tanesi ürünün strüktürel özelliğini en doğru ve en verimli şekilde geliştirmektir. Burada tasarımcıların ve mühendislerin işbirliği içinde çalışmalarının, tasarımın ve üretimin sürdürülebilirliği adına, ürün geliştirme sürecinde zaman, emek, ve malzeme kaybına son verecek ölçüm yöntemlerini kullanarak ürünün geliştirilmesini sağlamaları çok önem taşmaktadır. Ayni zamanda tasarımcı da bu ölçüm yöntemlerini öğrenebilir ve daha tasarım aşamasında sözü edilen yöntemlerle tasarımını doğrulayabilir.

Geleceğin tasarım problemlerini bu günden algılayabilecek tasarım ve ürün geliştirme uzmanlarına şimdiden çok ihtiyaç vardır. Bu ihtiyaca cevap verecek tasarım tanımının ve gelişiminin Andressen(1971)'ın araştırmalarından yararlanarak Meier (1978:246)'in ortaya koyduğu şematik tanımı kapsamın ne kadar büyük olduğunu anlatır: "Tasarım amaç sistemi, tasarım bilgilenme, tasarım planlama, tasarım organizasyon" dahilindeki tüm konuları kapsamaktadır. Her biri oldukça kapsamlı kavramlar, tanımın genelini kapsayan bu maddeler yalnız küçük bir alan gibi duran strüktürel yapının bilinçle geliştirilmesi için, tasarım geliştirme nezdinde, iletişim içinde olacaklar ve birinden ötekine bilgi akışı sürerken aksamaya neden olmayan bir gelişim gerçekleşmiş olacaktır.

Bütün bir tasarım sürecinin içerdiği bu kavramların her biri süreç içindeki strüktür geliştirme çalışmalarının en iyi şekilde yürütülmesini sağlamaya yarayacaklardır. Burada konu sürdürülebilir bir tasarım geliştirme çerçevesinde, üretici işletmenin imalat yöntemlerini ve kullanılan malzemenin ekonomisini en verimli şekilde değerlendirmeyi kapsamaktadır. Ayrıca işletmenin gelecekteki ürünlerin ve yaşam ortamlarının sürdürülebilirliği de hesaba katılmaktadır.

Strüktürel özelliklerin sürdürülebilirlik bağlamında ele alındığı bir tasarım geliştirme, organizasyonun ve tasarımın yeniden planlanmasını, yeşil tasarım ve üretim, minimum malzeme ve enerji, maksimum verim, tasarlama süreci içinde tüm ölçümlerin yapılarak zaman, emek ve para ekonomisi vb. kavramlara daha çok önem verilmesini gerektirecektir.

Tasarım amaç sisteminin, temelde işletmenin kazanç sistemine yönelik olduğu dikkate alındığında sürdürülebilirliğe gereken önemin verilmesiyle, strüktürel gelişimleri önceden ölçülen bir tasarım sürecinin başarısı daha kalıcı olacaktır. Ölçüm güvenliği kazanmış, sürdürülebilir bir tasarım ile ürünlerin pazar farklılaşması sağlanmasının yanı sıra yaratıcı tasarımlar, ekonomik ve akılcı çözümler geliştirilebilecektir.

İşletmenin kurum kimliğinin ve ürün kimliklerinin sürdürülebilirlik bilinci ile geliştirilmesinde faydalı sonuçlar doğacaktır. İşletme kültürüne, işletmenin

tasarım geliştirme süreçlerine hakim olacak çevrecilik ve sürdürülebilirlik anlayışı, sürdürülebilir üretimi ve aynı zamanda sürdürülebilir ürünlerin tasarlanmasını da beraberinde getirecektir.

Sürdürülebilir tasarımlar a) Toplanıp dezenfekte edilerek yeniden kullanılabilecek cam, paslanmaz çelik vb. ürünleri, b) Geri dönüştürülerek yeni hammadde kazanımı sağlanan kağıt, metal, plastik vb. ürünleri, c) Modülerlikleri ile eskiyen parçaları değiştirilerek yenilenebilecek ev, iş araçları, otomobil vb. ürünleri, d) Strüktürlerinde ekonomik önlemler alınarak hammadde, enerji, zaman vb. verimlilik sağlanan ürünleri içermektedir. Bu bildiri kapsamında strüktürlerin verimli olması konusu uygulamalı bir örnekle ele alınacaktır.

Sürdürülebilir, başarılı bir tasarım geliştirmenin, tasarım ve üretim sürecinin iyi bilinmesini, süreçte yer alan evreler arasındaki ilişkilerin doğru kurulmasını, beklentileri karşılayacak tasarımın yapılmasını, ideal çözümlerin üretilmesini sağlaması gereklidir. Tüm bu işlerin ve aralarındaki ilişkilerin iyi organize edilmesi, sürdürülebilir, mukavemet ölçümlü-strüktürel tasarım çözümlerinin gerçekleştirilmesi ile sağlanabilir.

Strüktürel özelliklerin sürdürülebilir tasarımlar elde etmek için değerlendirildiği bir tasarım geliştirme: Tasarımın amaçlarını doğru belirlemelidir. Tasarımda çok yönlü bilgilenmeyi ve bilgilerin iyi değerlendirilmesini sağlamalıdır. Tasarımın planlanmasında yapılacakları doğru tanımlamalı ve her ayrıntıya hâkim olmalıdır. Seri üretimin tüm aşamalarına ve ürünün geri dönüşümüne kadar ürünle ilgili tüm aşamaları çok iyi tanımlamalı ve yönlendirmelidir. Tasarım sürecindeki tüm bileşenler arasındaki bağlantıları kurabilmeli ve tasarıma artı değer katabilmelidir. Sürdürülebilir bir tasarım geliştirme, bütün bu özelliklere sahip olmasının yanı sıra avantajların ve dezavantajların doğru değerlendirilmesini, artı değerlerin farkına varılmasını, organizasyonun bütününün iyi planlanmasını sağlamalıdır.