**TITLUL TEZEI**

"RESEARCHS ON THE DURABILITY OF LEATHER SUBSTITUTES"

**Teză de doctorat – Rezumat în limba engleză**
pentru obţinerea titlului ştiinţific de doctor la
Universitatea Politehnica Timişoara
în domeniul de doctorat INGINERIE MECANICĂ
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luna Martie anul 2017

## Chapter1. IMPORTANCE AND CURRENT THEME OF RESEARCH

The research topic choosen has a strong interdisciplinary character as it addresses issues of sustainability leather substitutes used in the furniture industry and the automotive industry. Leather substitutes are generally take the form of composite materials having a textile backing is poured synthetic material, usually a polymer polyvinyl chloride (PVC) or polyurethane (PU). Composite materials are spread in all fields, be it light industry, aeronautics, civil construction, military, etc.
Fatigue or aging these materials from artificial leather has a negative impact on those who use these products with such materials.

It is therefore necessary as a thorough research of all the factors leading to this deterioration and fatigue studies on materials from the design and production of these materials and to their use in various sector.
Sustainability leather substitutes, is an area of research that is always in the market with the requirements of consumers upholstery and furniture.

Therefore studies on the factors that cause degradation of skin substitutes are of particular importance.
The studies conducted so far do not address systematically the effects of environmental degradation under the action and environmental factors in combination with the mechanical stresses that occur during the use.
The actuality of research work is supported by the fact that addresses the systematic study of damages caused by environmental factors and ambient taking into account factors structural and mechanical stresses that occur during periods of use of products mainly used for finishing, substitutes PVC and PU leather.

The use of leather substitutes currently limited primarily due to limited durability and sometimes the occurrence of premature degradation. According to the study conducted bibliographic main factors that contribute to premature degradation of leather substitutes are: low humidity, high or low temperature than normal, ultraviolet radiation and dust. The importance of the research topic appear as a direct consequence of the simulated leather scale growing for a wide range of consumer products and the requirement that they have a durability as possible by improving the mechanical properties and increase the stability of these properties time.

## Chapter 2. RESEARCH ON THE CURRENT STATE OF SUSTAINABILITY SYNTHETIC LEATHER

Synthetic leather materials are increasingly being used in many sectors due to lower production cost compared with materials of leather.

The main challenge faced by researchers is the improvement of manufacturing technologies of these composite materials, in which the support material knitting and the starting material from which it is made, on the one hand, and the composition of the matrix polymer which has certain characteristics and properties, of other side. Analysis of these materials from the design stage, technological achievement and use in various industries, the subject of many research studies over the years.

Sustainability replace materials from leather, was, is and will always be a thing of research and analysis, from all points of view. All materials manufacturers, who process these materials in making upholstery for sofas, armchairs and chairs but also consumers of these products will want products that can resist and be sustainable for a longer period of time.

Manufacturers of synthetic leather substitutes insufficiently addressing the issue of sustainability of these materials with consideration of environmental factors and the environment in combination with the mechanical properties.

Degradation problem of artificial leather material is studied both in terms of degradation under the action of ultraviolet radiation, degradation under the action of temperature differences, of all the factors involved in the use of upholstery products. The industry is doing a lot of tests that are either of the mechanical, physical or chemical-mechanical, to be seen when and how these processes material damage.

The aging of polymer composite materials under environmental factors have given rise to research for more fields. Determination of resistance of these composites is to observe the changes that occur to the physical-chemical or structural properties caused by exposure of these materials to degradation of the main factors which act environment (strong light, moisture and excessive heat). It is known that these environmental factors specified produce a number of negative effects on materials by changing the color and glossiness of material that is detrimental to the aesthetics and design of the surface material leading to shortened life of the product used by consumers .

The degradation or aging of the polymer composite materials are a result given by the reactions that occur in chemical structure and the properties of the polymers constituting the matrix of the composite material. Degradation of polymeric materials can be researched more time to come because there are new and new materials market substitutes leather, and new models of tapestries that have to be in tune with the requirements of fashion in furniture products and consumer demands furniture.

Addressing degradation and lifetime leather substitutes is a current research direction which envisages a number of properties in materials with polymeric matrix, operational factors.

The research theme is multidisciplinary and contain the domains of mechanics of materials, textiles and artificial leather, composite materials and chemical technology.

## Chapter3.EXPERIMENTAL RESEARCH ON MECHANICAL PROPERTIES AND ELASTICITY OF SYNTHETIC LEATHER

Artificial leather with polyurethane (PU) with the matrix material weft knitted fabric with the fiber composition of 65% polyester (PES) and 35% cotton, have characteristics of a

composite material, and mechanical properties depend on the direction of load and the direction of the row of knitting .
Knitted mesh row direction plays a decisive role on the mechanical properties of composite materials as a substitute for leather, polyurethane (PU).
Tensile strength, modulus of elasticity (Young's modulus) and Poisson's ratio have maximum values in the direction of the row of stitches of the fabric (sample angle 0 °), Fig. 3.16 and Fig.3.17.

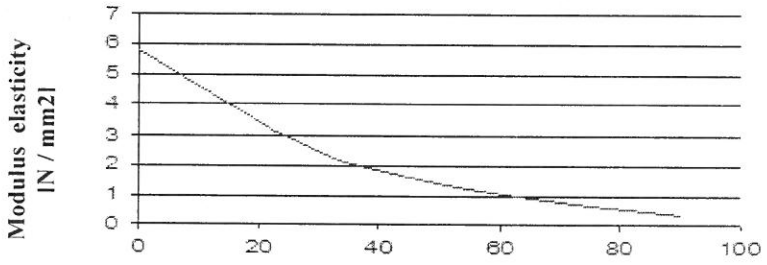


Fig.3.16: The variation of the modulus of elasticity of sample depending on the direction of the row of knitting [Lengyel, B., 2014]

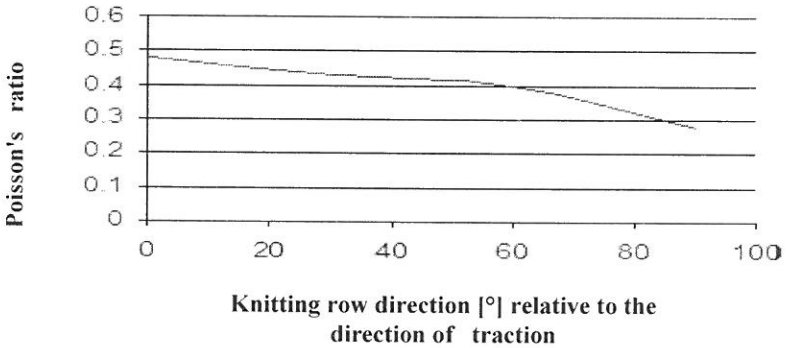


Fig.3.17: Variation of Poisson's coefficient sample depending on the direction of the row of knitting

The properties of deformation, elongation at yield and elongation at break values for the maximum angles of 30 ° between the direction of the knit meshes of the row and the direction of loading.
Analyzing the stress-strain curves drive specific behavior is observed quasi-linear elastic material to final rupture.
The higher tensile strength in the direction of the row of knitting recommends placing upholstery made of this material so as to produce maximum demands in this direction.

The specimens were kept warm in the cold were a strain with a 0.78% lower compared to the environment due to variations in temperature, which produces changes in the structure became more rigid polymer matrix and a change regarding the elasticity of synthetic leather (be it of the matrix array of PU or PVC).
The changes of the mechanical properties of the composite materials with textile and PVC or PU matrix used as artificial leather for upholstery, subject to small variations of temperature, within the limits of -2 ° C to 18 ° C, are not significant.

Mechanical and elastic properties of composites with textile and PVC or PU matrix changes with temperature. At low temperatures increases the rigidity and reduces elasticity and decreases stiffness at elevated temperatures and increases elasticity. Requests for the use of mechanical furniture upholstery with such low temperature of -2 ° C adversely affect durability of the material, Fig.3.18 and Fig.3.19.

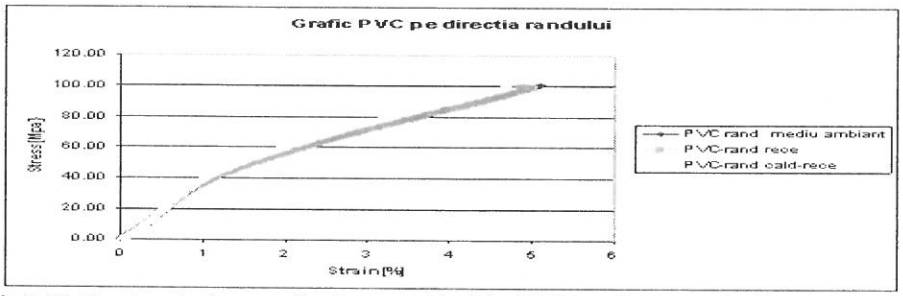


Fig.3.18. Tension-strain curve for the material of the PVC matrix composite line extracted in the direction of the support fabric

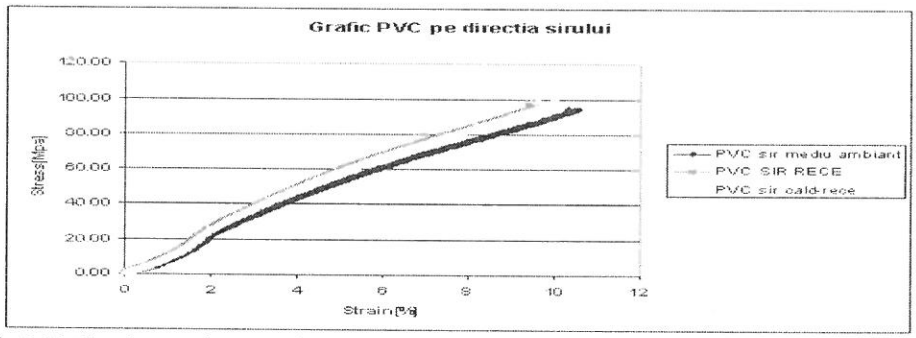


Fig.3.19. Tension-strain curve for the material of the PVC matrix composite string extracted in the direction of the support fabric

During the research of these polymeric composites were discussed in terms of micromechanical research on synthetic leather PVC elasticity.

Mechanical properties were analyzed both experimentally and analytically based on a micromechanical model taking into account the coefficient of Krenchel. The study described emphasizes on the one hand the accuracy of analytical models for predicting mechanical properties of materials on the basis of synthetic leather and on the other hand, it shows the cumulative effect of the mechanical properties of the yarns, the fabric and polymer PVC respectively; and the mechanical properties of the material as a composite material, Fig.3.29.

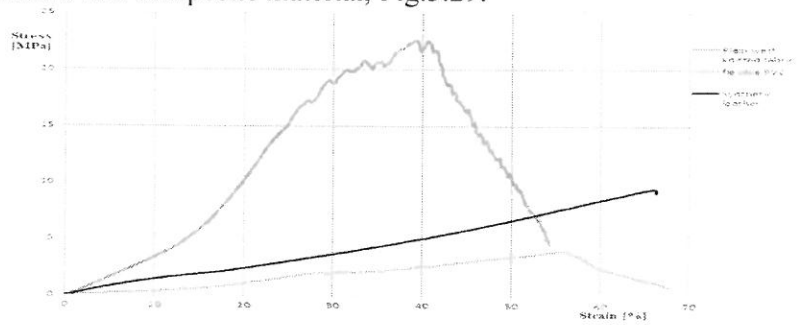


Fig. 3.29. Tension-strain curves of materials with matrix PVC and support of knit type glat [Lengyel. B.. 2015]

At the end of the tests resulted in an acceptable concordance between analytical and experimental evaluation of Young's modulus. Young's modulus to substitute leather (PU) in the direction of one of fiber orientation is greater than the Young's modulus of synthetic leather with (PVC) in the same direction, both for experimental determination and analytical deviation of 9,47 [%]. The direction of orientation of fibers 2, the Young's modulus of the material (PU) is less than that of the material (PVC).

Analyzing the values obtained by analytical and experimental research, can get new information on the behavior of materials in synthetic leather. Thus the new design can achieve a simple structure of the weft glat that gives the material better overall mechanical

characteristics.

In the third part of the research was focused on the mechanical properties of the fabric composite material with PVC matrix and support knit of glat. The deformation of the knitted fabric was observed by various analytical geometry calculation models for both the first material and the matrix of the PU to the second array of PVC. Geometric patterns analyzed in this study are: Chamberlain, Pierce, Dalidovici and Vekassy. Theoretical and experimental results obtained on the relative deformation, deformation maximum transverse and maximum deformation longitudinal fabric analyzed are essential elements in the development of theoretical and experimental studies on the initiation and propagation degradation of structural materials synthetic leather covered with polyurethane (PU) or polyvinyl chloride (PVC).

The last part of the study of this chapter was booked analytical study on the calculation of the resistance of the fabric bursting glat for these two polymeric composite materials used in the furniture industry. To develop new and ingenious design solutions that increase durability of these materials knitted structures which support composite materials, it is necessary to know all the requests that these structures have to meet.

The Vekassy model applied to the fabric, which is deformed along a spherical shape provides a better understanding of the physico-mechanical properties of the fabric when it is subjected to deformation.

All research described above presents new engineering specialist and study the decay of these textile matrix composite PVC and PU.

## Chapter.4. RESEARCH ON INFLUENCE OF RADIATION ON SUSTAINABILITY SIMULATED LEATHER

In order to study the influence of UV radiation on a leather substitute PVC-type "Capranova Ciftip" were used two different installations in the power emission of UV radiation.

The first step was to use a installation source with low radiation in ''Strength of Materials''Laboratory, UPT; and in the second stage, the aim of accelerating the phenomenon of degradation was used a system with high levels of radiation, endowment ''ISIM'' Timisoara.

The connection with low UV radiation in the Lab. Material Strength, UPT, Fig. 4.2, consists of a source of UV radiation (quartz lamp) UV-IR 220V, 280W; STAS 6048-59 and a support device placed at right angles to the direction of image that has been subjected to the simulated leather located degradation. As the intensity of UV radiation depends on the distance from the radiation source, the system allows changing the distance from the radiation exposed material. Using this facility to simulate the phenomenon of degradation under the action of UV radiation under near natural phenomena of degradation.

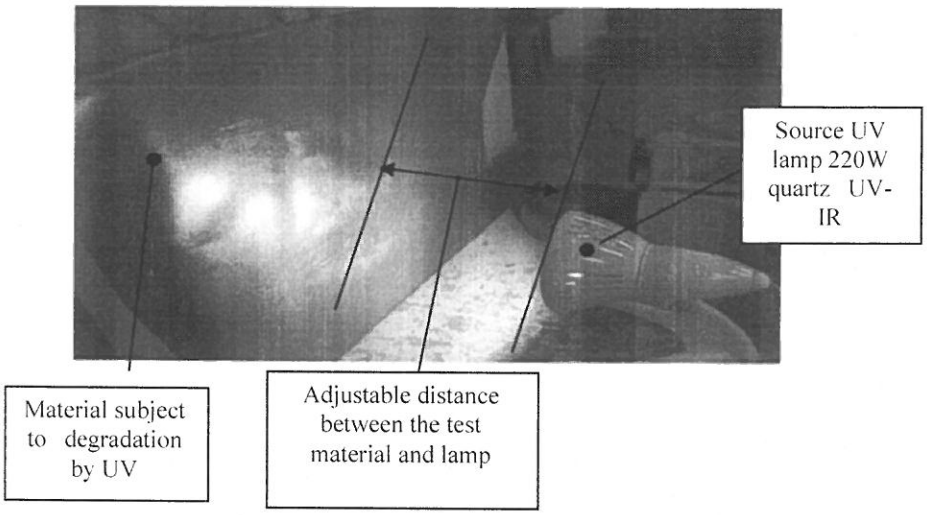


Fig. 4.2. Image degradation by UV radiation during low radiation for material with PVC matrix and support knit from type glat

It is noted that at a distance of 40 to 35 cm, the temperature is similar to that value, and a significant increase is in the area where the distance is 15 cm of the material to the lamp UV with a value of 120 °, after a period of time for 120 minutes.
When decreases the distance between the UV lamp increase and UVR radiometer measuring device 365, the power output of the lamp tends to reaching the final value of 2.76 nW / cm2, when we have minimum distance of 10 cm.

The study of the variations in the intensity of the emission power of the UV lamp according to the distance from the material, it is important to determine when the starting degradation material of PVC composite fabric with matrix, according to the UV radiation.

The installation degradation with high levels of UV radiation (accelerated degradation) of equipping the National Institute for Research and Development in Welding and Material Testing ,''ISIM ,, Timisoara, Fig.4.12, 4.13. Installation is with large halogen lamps power enabling acceleration of the phenomenon of degradation, with a significant reduction in exposure times. In this way the cycle tests performed to study the influence of UV radiation on leather substitutes shortens durability. It tested the same type of material.

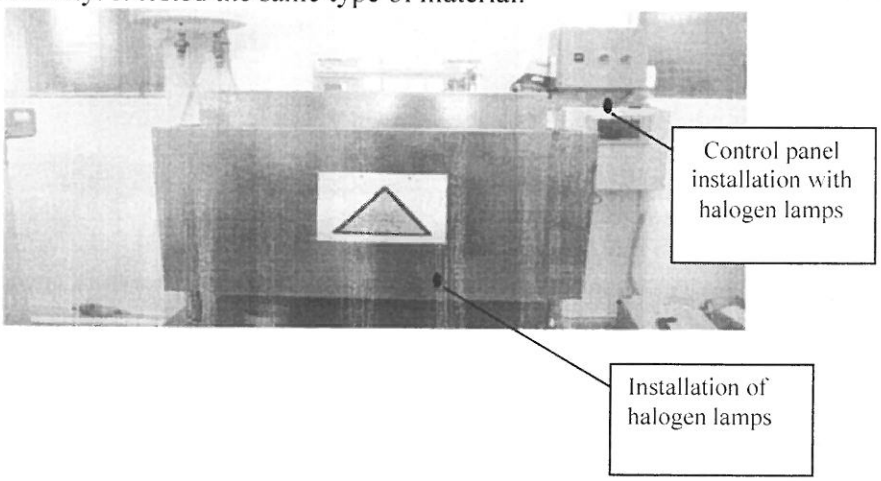


Fig.4.12. UV degradation installation of high intensity (with halogen lamps from "ISIM".Timişoara)

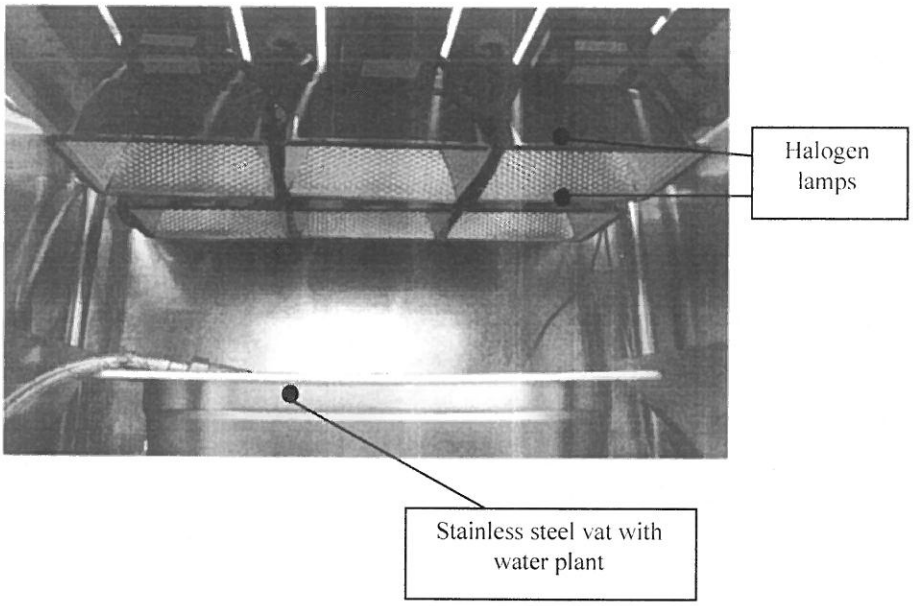


Fig.4.13. Overview inside installation with halogen lamps

The material was tested in two stages:

1. The first step the samples were subjected to degradation for a period of 4 hours;

2. In the second stage the specimens were subjected to degradation for a period of 14 hours.

Matrix composite material degradation of PVC using installation 6 halogen lamps, it is given in a relatively short time (4 hours). The sample is subjected to degradation for 14 hours is no gloss, full of bubbles , or swelling occurred on the surface of the PVC matrix due to exposure to UV radiation. Both samples are degraded at least 85% of the processing capacity of the composite material. The sample subjected to accelerated degradation presents the entire surface evenly distributed degradation except margins fixing system.

Fatigue tests were limited to a total of $10^6$ cycles. At the end of the test matrix composite material of PVC and textile was analyzed visually and microscopically to identify the damages incurred, Fig.4.21.

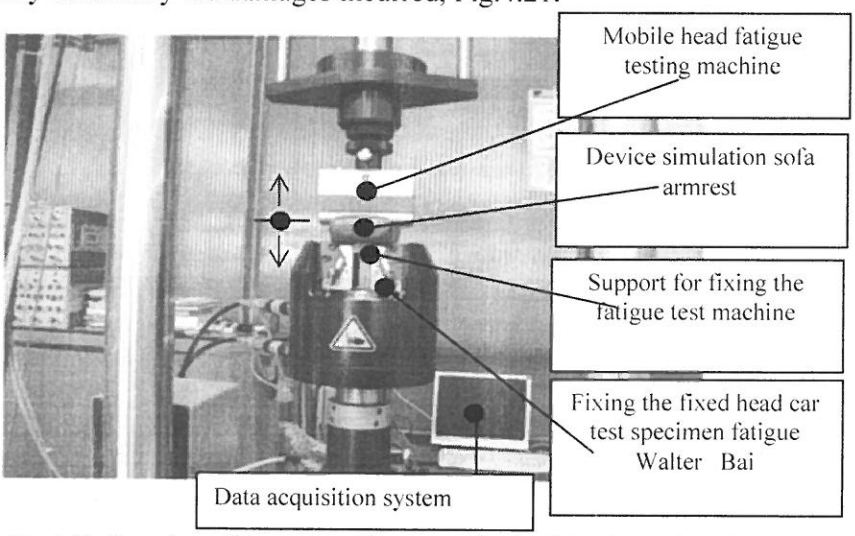


Fig.4.21. Overview of the test machine at varying loads Walter Bai 10 [kN]

After analyzing the following conclusions were drawn on the composite virgin (not subject to aging under the influence of environmental factors):

1. No cracks or splits at the macroscopic level.
2. Residual deformations appeared in the folds, with imports of samples mounted armrests with pretensioners.
3. In areas without pleats were not altered macroscopically visible.
4. The fatigue tests with a total of $10^6$ cycles have a duration of 150 hours, which is a very short time in comparison with duration of use of the consumer goods category of upholstered materials tested.
5. Cracks in upholstery with imitation leather in this category not only requests occur because the mechanical variables. Causes irreversible degradation of these must be analyzed taking into account the phenomenon of degradation while under the influence of environmental factors in combination with the mechanical action during the duration of use.

After analyzing the results appear following observations:

- The simulation support sofa springs because of the flexibility offered during compressive load variable in time, has highlighted the irreversible degradation Leatherette material PVC matrix and support knitted glat after $10^6$ cycles.
- Highlighted degradations are mechanical in nature, of PVC polymer matrix microfracture after row knit direction. Microfractures has a rectilinear configuration.
- After a number of cycles $10^6$ glat type support knitted no visible degradation.
- The test material was taken from a recent batch production date, without having borne aging under ambient environmental factors.

If we analyze the curves stress-strain, is observed with a sample taken in the direction of the row of stitches knitted degradation moderate based UV for 550 hours and is similar result with the degraded 1.700 hours on the resistance force during movement compared with specimen taken in the direction of the row of stitches knitted degraded, Fig. 4.37.

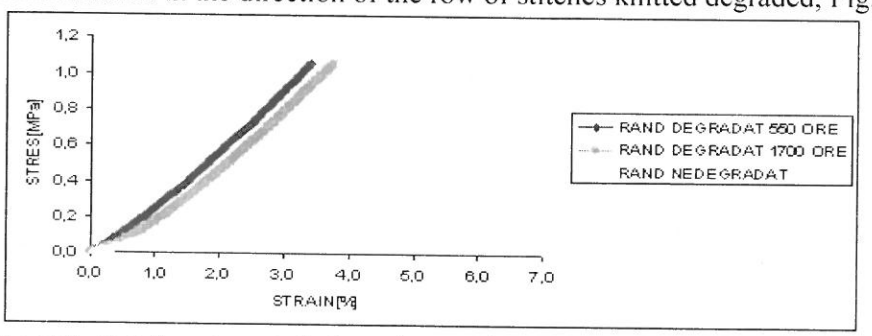


Fig.4.37. Variation stress-strain in testing specimens Taken from the direction of the row knit degraded by the action of UV radiation for moderately degraded for 550 hours and 1700 hours

Specimen taken in the direction of the row of stitches knitted and moderately degraded based UV for 550 hours and subjected to the UV radiation for 1.700 hours have similar values. If we compare the results of tensile tests to those in which the specimen is not degraded, there is a large difference in the resistance force depending on the displacement Fig.4.38.

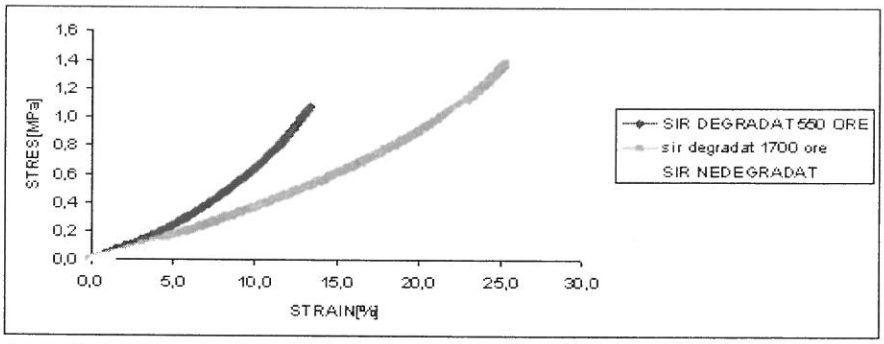


Fig.4.38. Variation stress-strain in testing specimens taken from the direction of the string knit degraded by the action of moderate UV radiation for 550 hours and 1.700 hours while the degraded

Comparing the values for tensile strength degradation caused by different levels of exposure in accordance with the above, that UV radiation levels have influence in the degradation of leather substitutes with textile and PVC matrix. In the cases analyzed by increasing the level of UV radiation; was a decrease in tensile strength as follows: the direction of the row knit fabric with matrix PVC and support knit type glat Δmed = 10.65% and the direction of the line of knit fabric with matrix PVC and support knit type glat, Δmed 5.19%.

Factors favoring the degradation of PVC flexible under the action of UV radiation (photodegradation): the intensity of the radiant energy, the presence of plasticizers, water, humidity, pollution agents. As a result of the action of UV radiation, there are a number of changes to support flexible PVC exposed to UV source. Among these changes, the color change, perceptible to the eye and damage to the mechanical properties are most significant and easily detected (highlighted).

Exposure to UV degradation with high intensity for 14 hours, lead to changes in the structure by changing gloss, roughness, color PVC matrix.

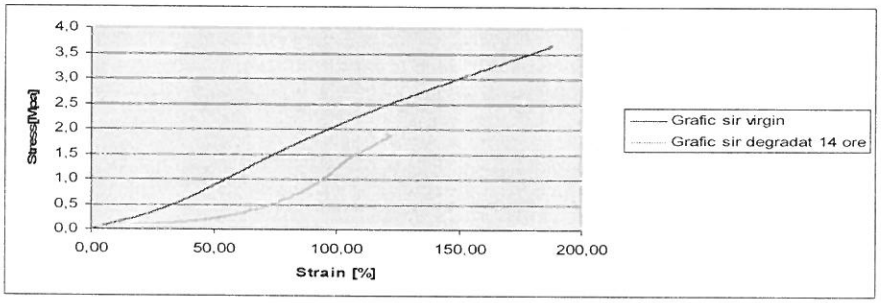


Fig.4.44. Variation stress-starin specimens extracted string direction of material with PVC matrix degraded and material matrix PVC virgin from row

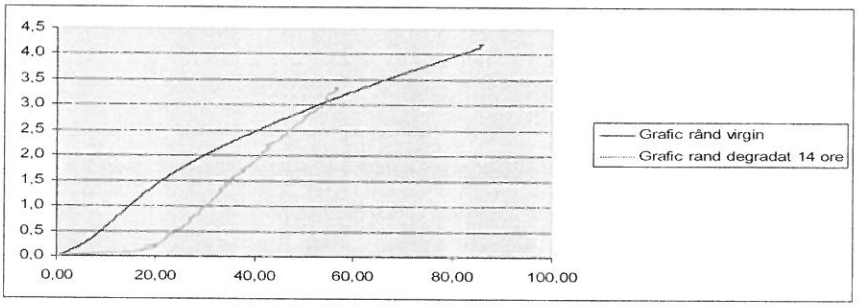


Fig.4.45. Variation stress-starin specimens extracted row direction of material with PVC matrix degraded and material PVC matrix virgin

The specimens were fixed in fatigue testing machine Walter Bai 10 [kN], from the laboratory of Resistance of Materials „Stefan Nădăşan "UPT Fig.4.48.

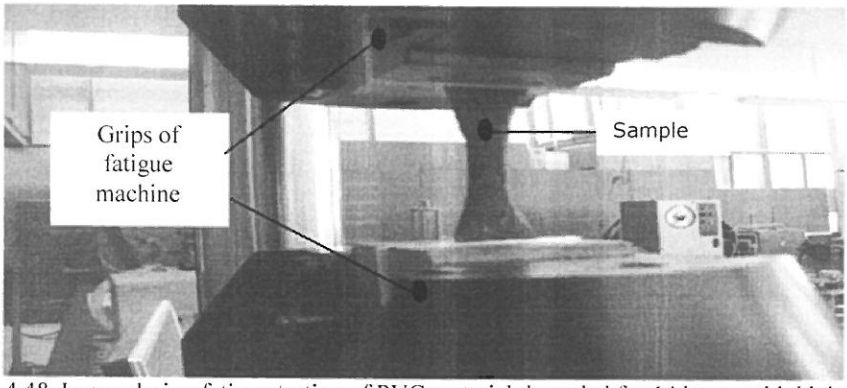


Fig. 4.48. Image during fatigue testing of PVC material degraded for 14 hours with high UV radiation intensity

Analyzing tactile easily observed loss of elasticity of the material through the phenomenon of hardening of the matrix PVC significant effects of reduction.
The application of alternating positive oscillating drive was carried out by the movement control as specified in the previous paragraph as a result of operation of the machine limits Walter Bai 10 [kN] to forces less than 100 [N] in the case of power control. In Fig.4.54. is the semi-logarithmic curve fatigue coordinates obtained from fatigue tests under the conditions shown.

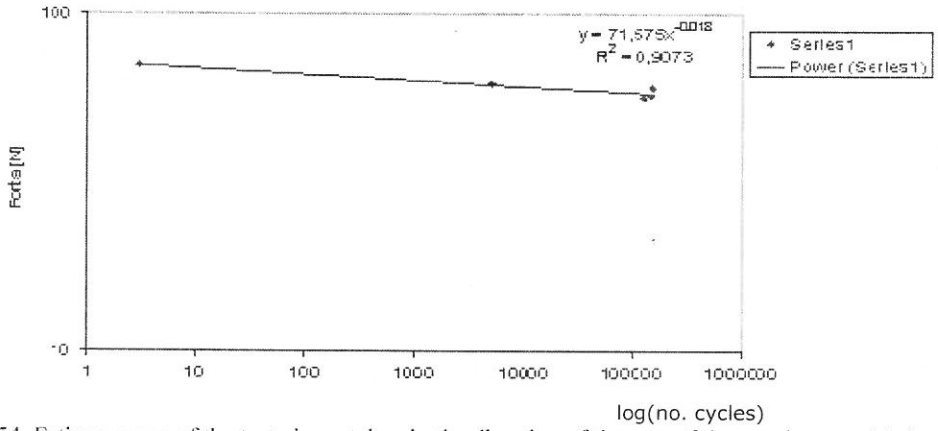


Fig.4.54. Fatigue curve of the test pieces taken in the direction of the row of the matrix material degraded PVC for 14 hours to UV radiation with high intensity

To generalize the results obtained from fatigue test was plotted coordinated sustainability σmax, log (no.cycles) of the damaged object for 14 hours with intense level UV Fig.4.55.

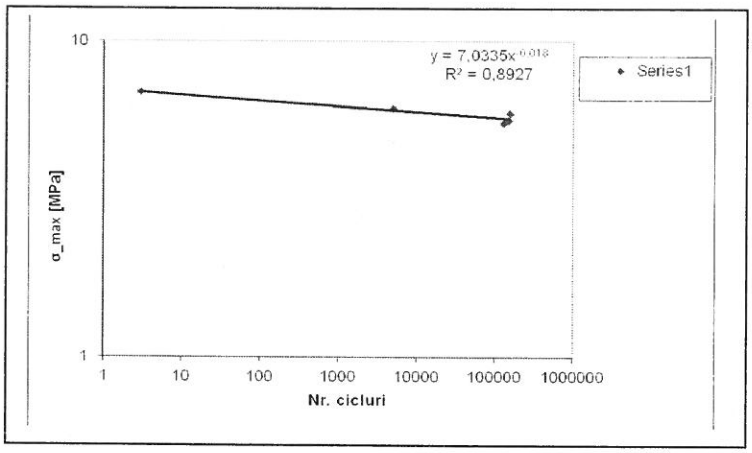


Fig.4.55. Sustainability of the damaged curve for 14 hours with high UV radiation intensity

Material degradation, simulated leather and PVC matrix and support knit glat by exposure to high intensity UV radiation for 14 hours, and is pronounced negative effect on the integrity of the material under stress variable.

Requests for time varying, materials composites and PVC backing knit type glat subject to degradation by UV high intensity, producing a mechanical degradation very quickly rolling by destroying the integrity of a small number of load cycles.

Degradation with high intensity UV radiation has negative effects on matrix composite material PVC type WG and support knitted in terms of duration of use upholstery.

## Chapter5. Conclusions. Personal contributions

**Conclusions:**

1. Research on the deterioration of materials in artificial leather, PVC and PU matrix are of great current interest to environmental and engineering as well as manufacturers of mobile world.
2. The challenges facing manufacturers, designers and researchers of such materials is to improve technology manufacturing leather substitutes. The research directions refer to knitting material support and raw material composition of the polymer matrix.
3. Manufacturers of synthetic leather substitutes insufficiently addressing the issue of sustainability of these materials with consideration of environmental factors in combination with environmental and mechanical stresses over time.
4. A purpose of both the beneficiaries and manufacturers of consumer goods are made up of artificial leather upholstery, is to get the best possible quality products to stand and be sustainable as a long time.
5. The degradation of the polymer composite material is produced as a result of reactions that occur in chemical structure and properties of the polymeric materials constituting the composite material.
6. The phenomenon of mechanical degradation under stress conditions ambient is accompanied by a series of negative effects manifested on the color and gloss material. These changes are often important reasons to discontinue the use of the products, even if their mechanical integrity was not affected.
7. Experiments have been directed at the initial stage in order to determine the mechanical characteristics of the simulated leather and elastic support made of knitting glat, PVC and PU matrix.
8. Mechanical and elastic properties of the composite made of knitting type glat support

matrix PVC or PU; depends on the direction of application in relation to the string knitting material and material direction of knitting row.
9. In order to quantify the tensile stress on the individual behavior of the material support, were conducted experimental research and analytical research on determining mechanical properties and elastic string mesh direction and the row of stitches.
10. UV radiation is the environmental factors influencing sustainability while supporting artificial leather material of glat and knit type in PVC matrix.
11. UV radiation affects both the aesthetic qualities of the upholstery and simultaneously influences the mechanical and elastic properties of the degrading effects of mechanical integrity of materials to requests usual during the period of use.
12. The artificial skin material degradation knitting type support glat and PVC matrix, under the action of UV rays is dependent on both the exposure time to the UV radiation, and their intensity level.
13. The phenomenon of degradation under the action of UV radiation is uneven and is always accompanied by increasing temperature exposed material. The temperature distribution on the exposed area radiation is closely in line with the distribution of UV radiation on the same surface (Fig.4.5, Fig.4.6).
14. The mechanical degradation of the skin substitute material with the fabric support matrix type glat PVC occurs at a much smaller mechanical stress cycles where there is exposure to UV radiation (aging under UV radiation) .
15. The results of scientific research were used by publishing a number of 5 scientific paper.
16. The degradation of the material, imitation leather and PVC matrix type glat knit support by exposure to high intensity UV radiation for 14 hours, is pronounced and negative effects regarding the integrity of the material under stress variable.
17. The degradation of high intensity UV radiation has negative effects on matrix composite material PVC type glat and support knitted in terms of duration of use upholstery.
18. Requests variable in time, materials and composites, PVC backing knit type glat subject to degradation by UV radiation and high intensity produced a very rapid degradation of the mechanical integrity of the material by destroying a small number of cycles request (tens of thousands), according curve in Fig.4.55 durability. In this situation it makes a pronounced degradation and early removal from use of leather upholstery using substitutes.

**Personal contributions:**
1. Develop a bibliographic synthesis based on the latest research in the field with regard to durability artificial leather material, ie factors influencing degradation imitation leather with fabric backing and PVC matrix used for upholstery.
2. Presentation of a classification of general properties of knitted material support of composite material composition as imitation leather PVC matrix.
3 were performed both analytical and experimental research in order to determine the elastic characteristics and mechanical properties of the support material of the fabric, resulting in a good agreement between the results obtained.
4. Analytical calculation was performed for the resistance to bursting of the fabric material of the support matrix for the replacement of the leather of the PVC and PU.
5. Were determinated experimental mechanical and elastic properties of the composite imitation leather with fabric backing and PVC matrix depending on the direction of orientation of the array and row knit.
6. In order to determine the fatigue strength of the material imitation leather with fabric backing and matrix of PVC, used in furniture were designed and conducted two types of simulation upholstery with polyurethane foam backing and support of coil springs .
7. Virgin material fatigue test, simulation devices as the upholstery with foam support and

coil springs with support from a number of survived $10^6$ cycles without causing visible degradation.
8. The tests were carried out on the material fatigue „ aged "under the action of UV radiation, simulation devices fitted to upholstery with polyurethane foam-supported by support springs and eliciodale. The number of cycles that occurred degradation of the mechanical integrity of the simulated leather was extremely low, limited to tens of load cycles.
9. It has highlighted the effect determinant of aging „ "Leather material supporting knitted type glat PVC matrix on its degradation compared to the mechanical fatigue imprealabilă single without degradation under the action of environmental factors.
10. Tests to mechanical fatigue variables reveal areas appearing as crack initiation in areas with folds of skin replacement material supporting knitted type glat matrix of polyvinyl chloride in upholstery.
11. Was plotted for tensile fatigue alternating positive matrix composite PVC material and support knitted type glat subject to degradation by UV radiation.
12. The sustainability plotted for tensile alternating positive matrix composite PVC material and support knitted type glat subject to degradation by UV radiation.

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