# TECHNIQUES AND METHODS FOR TESTING AUTOMOTIVE INDUSTRY TEXTILES

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**Abstract:** Testing standards have become increasingly higher, due to consumers' requirements and the increased competitiveness of the automotive markets. The vehicles that are produced now must last longer than before and allow for higher prices upon consecutive re-selling. That is the reason why the inside of the vehicle must be preserved in the best of conditions in time, in spite of its being exposed to multiple physical and chemical factors. This paper tackles a selection of testing methods for textile materials that are currently in use in the automotive industry, with a view to ensuring the standards that are typical for the automotive market.

*Keywords: automotive-industry textiles, testing, control, standards, material resistance*

## 1. Introduction

The testing of automotive-industry textile materials is a rather expensive activity, but nevertheless one that is necessary for obtaining an improvement in technical performance features, as well as in the user's comfort. Most of these costs are non-productive costs and are to be added to the final product cost, an under-evaluation being not the case.

The purpose of the monitoring and control system is to allow the correction of reject/scrap parts before the finished product is accomplished, special emphasis being laid on preventing the occurrence of any defects. The strategy for a permanent improvement and for meeting the requirements that are specific for the automotive-industry textile materials aims at preventing any defects that may appear during the manufacturing process, rather than to merely detect those flaws when the product is finished; its objective is to reach a "zero-defects" quality level.

## 2. Testing activities during the manufacturing process

During the manufacturing process, there are stages when testing must be undertaken in order to improve a given product, or to prevent persisting in the production of sub-standard semi-manufactured goods. [6]

### *2.1. Raw-material delivery taking*

The manufacturing process is supposed to start with raw-material delivery taking, since raw materials that are not up to quality standards do not allow for achieving finished products that are up to specific requirements.

In the textile industry there are various procedures that are performed in different locations, in every instance the raw material being checked for its quality features, according to specifications. The material that is not up to specifications is rejected, and sometimes certain adjustments can be made in the manufacturing process. Standards that need be satisfied should be chosen in such a way as to meet the intended quality level for finished product [1]. Therefore, if quality requirements are too high for a certain batch of material, it will be rejected – although it is good enough for the final product; conversely, if the quality requirements for the raw material are too low, large quantities of bad materials will be included in the manufacturing process.

### *2.2 Production monitoring*

The successful production monitoring depends upon correct testing, accurate projections of the sampling procedures, as well as the employing statistic analysis methods able to point out the findings that are necessary for reaching conclusions. The purpose of monitoring is to maintain certain specified features of the product within acknowledged tolerance.

### *2.3 Final-product evaluation*

When the final evaluation is made, the products are checked against quality specifications, before being shipped to the customer. Checking takes place, therefore, when the fabric has already been manufactured, thus being too late to perform production adjustments. In some cases, the testing is based on prior sampling; in others, a thorough checking is made and corrections are executed. For instance, tests are made for material characteristics in areas where flaws are noticed, these being fixed due to the worker's ability; when the correction has been made; the item is marked 'first class'.

### *2.4 Investigating the flawed material*

If the flawed material has only been identified upon the final inspection, or as a result of the customer's complaint, then it is of critical importance to find the source of the flaw [2]. It becomes thus possible to attain superior-quality, faultless products in the future. The process of investigating the flaws may imply the identification of the party who is responsible for the flawed material in case of conflict between the supplier of raw material and its customer, particularly when the finishing procedures are performed off the company premises. In such cases, it may prove useful to contact independent laboratories that have the capacity to act in full objectivity.

### *2.5 The product development*

In the textile industry, production technologies are under permanent alteration, by modifying either the material or the production methods. It is necessary, prior to any product modification, to test it, in order to see whether its characteristic features have been improved, or maybe the quality has been diminished (due to faster production means). Only by doing so, the clients may be offered either products that have been improved, or products that preserve the characteristics but have been obtained at a lower cost. A big organization will have a dedicated department for the product research and development, including casual testing.

## 3. The testing of textile parts and components in the automotive industry

In 1994, three big American automobile manufacturers – General Motors, Ford, and Chrysler – established a set of quality-ensuring systems, QS 9000, especially for this field of industrial activity. Producers from Europe and from other continents, who then proceeded to impose that system, or an accredited equivalent, to their suppliers, supported the third edition of QS 9000, issued in March 1998.

In such a case, production control has to be accomplished for two reasons: first, in order to ensure manufacture continuity as well as satisfactory results for both the first time and for subsequent activity; second, in order to simulate real-life performance during automobile usage. Simulating real-life conditions over a few years by means of rapid testing in a laboratory is no easy task, and for that purpose there exist methods which are specific to every manufacturer. In addition, climatic conditions vary to a considerable extent across the globe, and they have to be taken into account. Testing methods that are to be applied also depend upon the particular physical conditions that are characteristic for the next stage of manufacture. Seat covers have the strictest of abrasion resistance; airbags are air-permeable and fireproof; the dashboard must have as high a light-exposure insensitivity factor as possible. Also, the checking of the colors and shades of the textile components of a vehicle must be done with the utmost care, to prevent combining two or several pieces belonging to different batches.

## *3.1 Automotive industry standards*

The methods for testing that are requested by manufacturers are protected in confidence with their suppliers. These are based on national or international standards such as BS, DIN, ASTM, SAE, JIS. Nevertheless, the testing methods may differ from one producer to another, which makes it possible that what is acceptable for one producer may be unacceptable for another. That is why test laboratories must be equipped with two, three, or even more apparatus for the testing of the same property, such as the Martindale, Schopper, and Taber machines for the testing of abrasion strength. The United Nations, as well as certain governmental and professional organizations, especially the International Automobile Producers Organization, is involved in the harmonization of test methods that are employed in Europe and in the United States.

Table 1 below presents the parameters that are likely to determine the client’s satisfaction. The figures for quality specifications in this case may seem much too severe in comparison with other textile articles, but we have nonetheless to remember that a vehicle is to be used for a long period of time, at a certain intensity, in which time it is subjected to the combined influence of factors such as high temperatures, variable humidity, or ultraviolet radiation. Cars, and this implies the textile components, must have the capacity to withstand any climatic conditions [3].

## *3.2 Testing methods and techniques*

### *3.2.1 Checking the appearance and the color shades*

General characteristics such as material width, total and residual thickness of the laminated material for seat covers, the specific weight, the material structure and ratio, the set of the cloth, the fineness of sewing thread must be checked on a regular basis, to make sure that order specifications are observed. Such checking is made according to standard procedures, which may in their turn provide solutions for other characteristics. For instance, if the thickness of the laminated material is identified as superior to specifications, that may be due to insufficient temperature or pressure during the process of laminating the material (peel bonds). Also, plush fabric has to be over-checked, to determine if the orientation, the uniformity and regularity, as well as the raising observe the specifications.

It is a matter of utmost importance that the customer and the dyer should agree on what is and what isn’t acceptable in terms of color shades. This can be established visually, by means of laboratory analysis based on color-measurement instruments. The procedure is meant to avoid making errors that are due to human subjectivity, by employing two instruments: the spectrophotometer, and the tri-chromatic colorimeter, both devices being used for quantitative determinations that are to be used in the calculation of chromaticity coordinates.

The equation CMC (2 : 1) is to be used here, as adopted by the ISO and CEN standards and issued as a standard for measuring the shade gap BS EN ISO 105-J03:1997. The determined value DE represents the color gap as perceived by the human eye.

Table 1. Main parameters and testing standards for automotive-industry textiles [4], [5]

| | Material Features | Specifications |
|---|---|---|
| 1. | Thickness<br>The sett of the cloth | BS2544, SAE J882, DIN 53352, 53855/ DIN EN ISO 5084<br>JIS L 1096 |
| 2. | Specific weight. Mass | SAE J860, DIN 53353, TLS2100G4.1, BS2471, ASTM -D 3776-85<br>DIN 53854/EN 12127, ISO 3801, JIS L 1096 |
| 3. | Appearance – shades | SAE J361 |
| 4. | Dye resistance to various agents | BS1006: 1990 (1996), ATCC Test Method 16 |
| 5. | Fastness to light | BS1006: 1990 (1996), SAE J2212 Nov 93 air-cooled xenon-arc, SAE J2230 Feb 93 outdoor under glass sun tracking, DIN 75202 |
| 6. | Abrasion resistance | SAE J365 Aug 1994 Scuff Resistance (Taber)<br>ASTM D3884-92 (Taber rotating platform)<br>ASTM D3885 Flexing Abrasion (Stoll)<br>DIN 53 863/2 (Schopper)<br>DIN 53 528 (Frank Hauser)<br>BS5690: 1991 (Martindale)<br>DIN 53 754 (Taber) |
| 7. | Snag resistance | SAE J948 Aug 94 (also abrasion of vinyl/leather)<br>ASTM D5362-93 (bean bag)<br>ASTM D3939-93 (mace test) |
| 8. | Color fastness to rubbing | AATCC Method 119 (screen wire), AATCC Method 120 (emery) |
| 9. | The pilling effect | BS5811: 1996 pill box, ASTM D3511-82 (Brush), ASTM D3512-82 (Tumble), ASTM D3514-81 (Elastomeric pad),<br>DIN 53865 (modified Martindale) |
| 10. | Tear force resistance | BS4303: 1968 (1995) wing tear<br>ASTM D2261: 96 (tongue tear – single rip CRE)<br>BS3242 pt5: 1982 (for coated fabrics)<br>ASTM D1117/95 (trapezoidal tear)<br>ASTM D5587/96, DIN 53 356 (tear progagation)<br>TLS 2100G 4.12.2 |
| 11. | Breaking strength and breaking elongation. | BS1932, ISO 2062 for yarns and threads<br>ASTM D-751 (Test for coated fabrics)<br>BS3424: 1982 Method 6 (coated fabrics)<br>BS4443 pt6 Method 15 cellular foam (laminates)<br>ASTM D2261-96 for woven fabrics – single rip<br>ASTM D5034-95 (Grab method)<br>DIN 53857 (non wovens)<br>DIN 53571, TLS 2100G 4.7.1, TLS 2100G 4.16, TLS 2100G 4.9 (tensile and elongation), JIS-L 1096 |
| 12. | Bursting resistance | BS4768: 1972 (1997), DIN 53861,<br>ASTM D3787-89 ball method for knits – CRT |
| 13. | Laminated material strength | BS3424 pt7 1982 Method 9 (coating ASTM D751<br>adhesion) ASTM D902, DIN 53357, TSL 2100G 4.39.1 |
| 14. | Dimensional stability | BS4736: 1996 (cold water), SAE J883 Jan 94 Cold Water<br>SAE J315A, DIN 53894 |
| 15. | Antistatic characteristics | BS6524: 1984 (surface resistivity), DIN 54345, DIN 53282 (surface resistivity), ASTM F365-73 Charge Decay |
| 16. | Fastness to dirt | BS4948: 1994 soiling by body contact |

| | | |
|---|---|---|
| 17. | Flammability | BS AU 170 1979: 1987, DIN 75200, SAE J369, TSM 0500G |
| 18. | Accelerated ageing test | BS3424: 1996 pt 12 for coated fabrics, BS4443 pt 4 Method 11 for cellular materials, DIN 53378, BS4443 pt6 Method 12 (heat ageing) |
| 19. | Air permeability of silicone-coated materials | DIN EN ISO 9237 |
| 20. | Flexural resistance | ASTM D 4032 |
| 21. | Crease Flex Tester | 7780Z-S5A-N900 |
| 22. | Seam resistance | TLS 2100G 4.16 |

*3.2.2 Dyeing resistance*

Dyeing resistance is a term that is meant to quantify the degree to which textile materials are likely to change their colors when subjected to various phenomena. The tests to be performed are as follows: washing resistance, water resistance, and perspiration resistance, dry or wet rubbing resistance; also, the resistance to certain chemical agents, e.g. perborate (an ingredient of detergents), chloride, various aerosols; as well as the resistance of print materials.

A material sample is cut to fit the dimensions required by the respective test and is then exposed to a certain environment (or to a simulation – such as to substances resembling human perspiration).

In the case of seat covers, these are fastened to the seats, therefore a high degree of resistance to washing won't be an issue. Instead, checking the textile material resistance to perspiration, to sunlight, to cold water and to rubbing is what should be taken into account.

Using the crockmeter, respectively, assesses dyeing resistance to wet and to dry rubbing. Fastness to light should be measured because of the general characteristic of all textiles to lose color when exposed to light. Any manufacturer will tend to consider the fading of colors as an unacceptable process, and that is why the testing methods should make it attainable that the alteration reaches acceptable levels. The highest standards for fastness to light are the highest in the case of automobile covers .

The test for textile fastness to light is both the most important and the most difficult to simulate, for a variety of reasons: sunlight intensity varies according to latitude and the time of the day; weather conditions and clouds have an influence on the intensity of the ultraviolet radiation. The more and more extensive use of glass for the building of modern vehicles allows the massive inflow of sunlight, which can heat up the inside of the vehicle to an astounding 130°C in some desert areas. Testing procedures, which are part of the American SAE J1885 standards attempt to replicate such temperature conditions, as daily cycles of heating and cooling are highly relevant in the process of textile material fading and degradation.

Ultraviolet radiation has the shortest of all wavelengths and, as it also carries the highest amount of energy, is the most destructive for textile materials. Although the windows of the vehicle filter part of the radiation, longer-wavelength radiation will still be able to get through. Still, the thicker the glass, the less ultraviolet radiation reaches the inside of the vehicle. Colored glass is also an efficient remedy against excessive ultraviolet radiation.

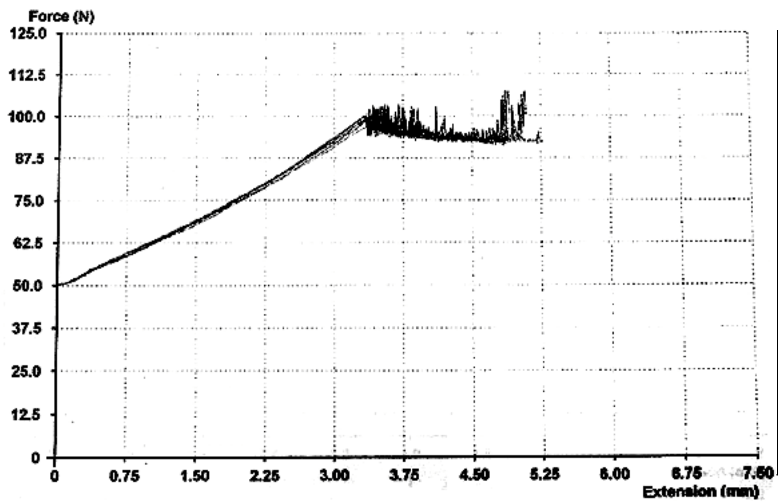
The samples are exposed to artificial light which is emitted by sources that share the same specter composition as the sun, only in a much higher intensity, which is meant to speed up degradation.

The evaluation criteria are based on shade and color intensity measurements.

*3.2.3 Tensile strength and material elongation*

Sampling is a critical operation; here, the areas that are situated at a distance from the margin which measures less than 10% of the total batch width are to be avoided because of the difference between central areas and the sides which results from finishing operations. In addition, the samples must be drawn in such a way as not to include the same warp and filling threads twice.

There are several tests that can be applied to textile materials, especially to woven fabrics and non-woven. The ASTM D 5034 Breaking Force and Elongation of Textile Fabrics Test (Grab Text) includes a method of testing which gives a description of the actual breaking force for a given material. It can be applied to fabrics that are woven or non-woven, but it is not recommended for the testing of knitwear because of their elasticity. For this test, the sample is wider than the material-fastening clamps of the tensile-elongation test machine, the areas which are adjacent to the area being tested having a contribution to the strength total of the material – which renders extra accuracy to the findings of the test, especially in what satisfying the customer's maintenance requirements are concerned. The breaking force which is characteristic for a given material is thus measured, along with other information such as tensile elongation, and static and permanent elongation.




| Test | Initial displace ment [mm] | Final displace ment [mm] |
|---|---|---|
| 1. | 3.500 | 5.000 |
| 2. | 3.412 | 5.090 |
| 3. | 3.368 | 5.030 |
| 4. | 3.352 | 5.090 |
| 5. | 3.592 | 5.280 |
| 6. | 3.450 | 4.980 |
| 7. | 3.330 | 4.883 |
| 8. | 3.322 | 4.912 |
| 9. | 3.352 | 4.845 |
| 10. | 3.390 | 4.912 |

Figure 1. Extension at load with load range 800 N, extension range 500 mm and speed 200 mm/min

The ASTM D 5035 Breaking Force and Elongation of Textile Fabrics Test (Strip Test) includes the method of testing samples of a given width, in order to determine the force which is necessary to break a specific width of the material. The test results describe the actual resistance parameters for the threads in the material.

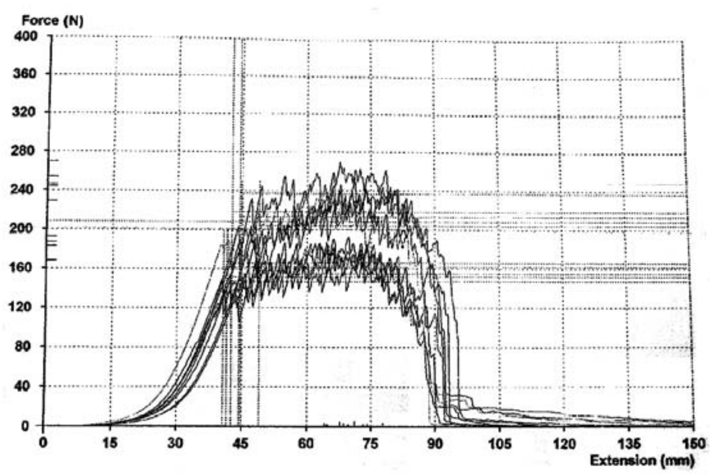
Using a sample, which is obtained by sewing two pieces of material together, and a tester, which is endowed with a dynamometer, tests the breaking resistance for seams. There are manufacturers who designed special devices for this objective. Generally speaking, using a good-quality sewing thread will lead to an improvement of the seam resistance, but that make it necessary to check the holes in the material resulted from the stitches. The phenomenon is also known as the weakening of the seams. The reinforcement on the back of the fabric, which is used for automobile seats, may well improve the resistance, but its presence will prove critical in the case of materials with low specific weight.

*3.2.4 Tear resistance*

A good tear resistance of textile materials is extremely important in the case of a vehicle seat, as we expect from it to last for as long as the vehicle will last. The individual resistance of the threads influences this characteristic, by their smoothness and fineness. The very nature of the threads is to have some influence on material resistance.

If the cloth isn't flexible but stiff, or in the case of a backing treatment, the tear resistance will be reduced. In the case when the threads can shift under the influence of the external force, they will re-arrange and that leads to a higher tear resistance. Certain lubricants, such as silicone, may produce this effect, but they are not acceptable, as they tend to affect the adherence and to contaminate other surfaces they come in touch with.

Tear resistance testing is also made after exposure to ultraviolet light, and is based on the measurement of the force which is applied to a sample with standard dimensions, which is torn along a certain direction and for a certain material length. In such a case, a cut is made on the sample and then a perpendicular force is applied on the threads, which is going to continue the tearing. The direction of the tearing force differs from that which is applied in the case of the traction resistance test, when the direction is parallel to the orientation of the threads. The force that is necessary here is measured, and the mean figure that is reached at by means of certain formulae represents the tear resistance of the material.




| Warp | Avg. peak load [N] | Max. load [N] |
|---|---|---|
| 1 | 237.4 | 270.0 |
| 2 | 213.0 | 244.5 |
| 3 | 208.5 | 247.0 |
| 4 | 218.6 | 254.0 |
| 5 | 203.8 | 229.3 |
| Weft | | |
| 1 | 161.6 | 187.2 |
| 2 | 165.8 | 192.8 |
| 3 | 147.0 | 168.2 |
| 4 | 154.9 | 183.2 |
| 5 | 151.6 | 182.4 |

Figure 2. Tear tensile with load range 500 N, extension range 1000 mm and speed 200 mm/min

There are several tests, such as the trapezoidal method (ASTM D 5587), the Single Rip method (ASTM D 2261), or the Elmendorf method, using constant clamp speed (CRE) dynamometers, using the second clamp for the tearing (CRT), or the constant increase in the force that is applied to the material (CRL).

*3.2.5 Bursting and perforation strength*

The bursting and perforation strength is the force or pressure that determines the breaking of a textile material, applied at a 90° angle upon the material plane. As the force increases, the material is deformed as a hemisphere at the time of breaking. The maximum force to be applied during this process is measured and will constitute a resistance characteristic.

The test is applied to knitwear and non-woven fabric. In this case, the forces acting upon the material are multi-directional and simultaneous. The textile material sample is fastened between the two clamps, covered by a rubber sheet, on which a pressure will be exerted by means of a flow of water or other fluid; the rubber sheet will be deformed (ASTM D 3786). A force is thus applied onto the textile sample until it breaks. The exact procedure and the sample size will vary according to customers' requirements.

Another method is mentioned in the ASTM D 3787 for knitwear; it implies using a steel ball that is attached to a dynamometer. The test sample is either a square or a 12-centimetre diameter circle, and is to be fastened under a ring. A given force against the material pushes the ball, and the size of the force that will push the ball through the material is recorded.

*3.2.6 Abrasion and pilling resistance*

It is the characteristic feature of a material to resist to the erosion resulting from the rubbing against a surface or another material. The breaking is a result of the abrasion phenomenon that is present in the case of the threads placed under a tension in the material under observation.

The abrasion process is implied both by the wearing and by the washing of the material. The testing equipment includes a device for the fastening of the material being tested, on top of which another fastening device is applied by means of a weight, to keep the abrasion material in its place. The devices carrying the material under testing is then applied a constant motion, in a determined number of cycles that take place along the specified directions. The material is examined, and when two threads may be observed, the process is considered finished and the number of cycles is quantified.

In the case of textile materials for the automotive industry, it is most likely that pilling becomes apparent due to the passengers' clothes rather than the material itself. The pilling effect can be minimized by way of chemical processing, by using thicker threads, as well as by using threads of greater torsion force, or by brushing the material.

Pilling resistance can be determined by several methods: by comparison with photographed samples, which are attributed values from 1 to 5, or by using a Martindale tester, which subjects the material to an amount of rubbing and whose result is measured by the number of resulted accumulations of threads.

*3.2.7 Resistance to bending (stiffness)*

The resistance to bending is the capacity of the material (especially in the case of an airbag) to resist deformation when subjected to an external force. One method that may be used is the circular bending method, by using the Circular Bending Stiffness Tester, and it means identifying the stiffness of the material as the maximum force that is necessary in order to make it pass through a circular orifice [4]. The stiffness resulted after using the circular bending procedure is the mean value of the stiffness in all directions.

*3.2.8 The adherence of textile draft*

The testing of draft adherence is performed for such combinations as textile material – foam, and foam – enforcement, in order to make sure that the chipping of the coating will not take place during the utilization of the vehicle or during the manufacturing process. To simulate real-life conditions of utilization, the test is performed both upon the reception of the goods, and after a process of aging by heating, whether in a wet state or after a solvent treatment. The samples for the test are drawn for the two perpendicular directions of the warp and filling threads.

Adherence tests are usually performed on computer-assisted traction testers, with specified speeds of the mobile clamp. Testing procedures vary from manufacturer to manufacturer, and so do the specifications that are expressed in N/cm of width. Assembling the combination cover – foam – pads requires a superior resistance of the textile draft, as only a limited number of seams are allowed.

*3.2.9 Flammability*

The test that is most usually employed by the American manufacturers observes the FMVSS 302 and the TL 1010, respectively, which makes use of a method of horizontal burning. To improve the product quality, the material is covered with silicone, with a fireproof substance, or with fireproof foam.

Flammability is measured as per burning speed, which is the distance expressed in millimeters of material that are burned in one minute. The tests are made in burning rooms, the textile materials being placed on the combination where they belong. The flammability test is of vital importance for car airbags, as well as for materials that are to be used in the building of public transportation vehicles, or of airplanes and ships, where the standards are quite severe.

*3.2.10 The Crease Flex Testing method*
The method is employed for repeated bending and it determines the stage of dryness and adherence reached by a material covered with silicone and used for airbags [4].

## *3.3 Recording the findings; the statistical control of the process*

All findings have to be recorded within a definite period of time, in order to allow the investigation of the source of an event. These values are represented graphically in the statistic control of the process and are a reflection of the correctness of the manufacturing process. If the results are within the specified margins, that means the process is under control. In case the results are sensibly different from the mean value, that is to be taken as an indicator of problems that make corrections absolutely necessary. For instance, if the control margins are situated around the mean value $\pm 2\sigma$, the margins for corrective action are to be set at $\pm 3\sigma$ around the mean value. This technique allows for the correction of the defect upon its coming, at the right time, and not after the assemblage of the semi-manufactured pieces in the finished product – which is too late.

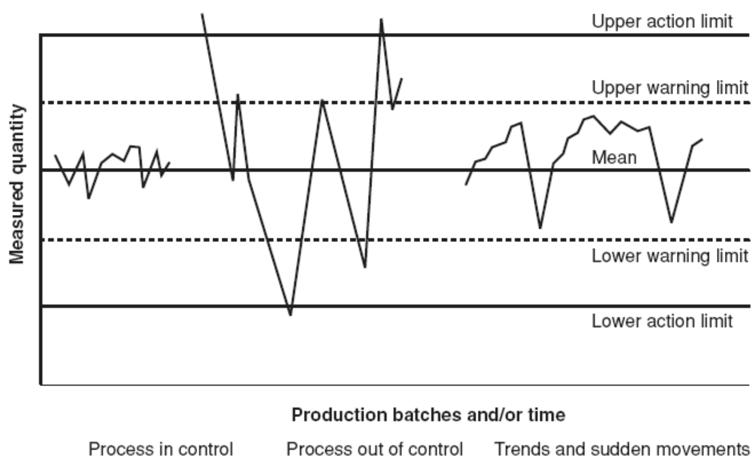



Figure 3. Statistical process control chart provides a method of detecting faults during production, as a way of continuous improvements with the objective of achieving zero defects [6]

## 4. Conclusions

Manufacturing techniques are permanently under change, and so are testing methods, since they aim at spontaneously integrating the latest research finds, and at allowing for a rapid harmonization with the existent methods. That is the reason why manufacturers of automotive textiles, in particular manufacturers of seats, airbags, door panels, rugs and headrests have developed and implemented their own standards and tests.

The defects and the mediocre quality must be detected as early as possible in the manufacturing process. After each and every operation that is performed, an amount of surplus value is added to the product and, if that value is poor, then the losses are going to be a burden.

Certain characteristics, such as thickness and specific weight, can be monitored automatically, which will decrease the control effort, on the one hand, and allow for spontaneous feedback, on the other. Nevertheless, the final inspection is a complex process, as it is done manually, it takes a relatively long time, and it implies high costs; still, since the present trend is to reach for "zero defects" in the final product, the respective costs are accounted for.

The final aim of testing textile materials for the automotive industry is also to be found in connection with the protection, security, and safety, along with the convenience and aesthetics that passengers must enjoy when using the vehicles.

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