

The invention relates to a method of manufacturing uncoated industrial fabrics in a close weave setting.

In the case of many industrial fabrics, air permeability is crucially important for their function. Examples of this are woven fabrics for parachute materials or sail fabrics. This applies particularly to air bags. The required low air permeability values have up till now been achieved mainly through application of a coating.

The drawback of coated, as opposed to uncoated, fabrics is above all that they are more expensive to produce. A further serious drawback, which applies above all to the use of coated fabrics to manufacture air bags, is a folded volume which is at least 10% higher than that of uncoated fabrics. The space required to accommodate the air bag, e.g. in the steering wheel, is therefore greater for coated than for uncoated fabrics. A particular drawback arises from the need to dust the coating with talcum to prevent parts of the coating, which lie adjacent to one another when the air bag is folded, from sticking together. When operation of the air bag is triggered, the talcum then discharged from the air bag is a nuisance to the vehicle passengers. Air bags made of uncoated, as opposed to coated, fabrics also lead to a substantial reduction in weight and so improve handling of the steering wheel.

For said reason, attempts have made to circumvent the coating. One possible means of achieving this is described in EP-A 314 867 for air bag fabrics. Here, the desired low air permeability is achieved by successive shrinking, thermo-fixing and calendering. Said treatment stages mean that a very elaborate and, from the point of view of cost, disadvantageous finishing process has to be accepted. Furthermore, the fabric described in EP-A 314 867 is hardly suitable for air bag manufacture since it is impossible, with the proposed asymmetrical weave setting (differing thread

numbers in warp and weft), to meet car manufacturers' requirements for identical strength values in both thread directions. This is necessary because, in the case of a radially symmetrical component like an air bag, there is no privileged direction.

A further possibility is proposed in CA-PS 974 745. Here, very closely woven asymmetrical fabrics manufactured from heat-shrinkable synthetic fibre yarns are subjected to dry heat treatment, preferably in a tentering frame. Besides the cost situation being unfavourable on account of the energy costs incurred, the fabrics described here, when used for air bags, do not meet car manufacturers' requirements for identical strength values in warp and weft owing to the selected asymmetrical weave setting.

EP-A 336 507 describes a method of manufacturing woven fabrics using extremely high-shrinking polyester fibres. Initiation of shrinkage and densification of the fabric to achieve a low air and water permeability are effected by a wet process followed by a thermo-fixing process. Said method may also be employed for industrial fabrics. However, for most articles in this field, in particular for air bag fabrics, said method is unsuitable because the high strengths required for industrial fabrics cannot be achieved with the high-shrinking polyester yarns used here. Also, the proposed thermo-fixing process leads to higher production costs and even has a negative effect upon air permeability.

The aim therefore was to develop an inexpensive method of manufacturing industrial fabrics, which fully satisfies the demands placed on said fabrics not only as regards air permeability but also as regards strength. Of primary interest here are woven fabrics for air bags.

Where the term "air bag fabrics" is used below, it is taken to mean, in particular, the fabrics for the contact part of the

two-part air bag, which are required to have a particularly low air permeability of $< 10 \text{ l/dm}^2\text{min}$ at 500 Pa test differential pressure. To allow discharge of the air which flows into the air bag when operation of the air bag is triggered, the two-part air bag has a filter part of a higher air permeability. In the case of a one-part air bag, holes are punched in the air bag to allow the air to escape. Here, the requirement for low air permeability applies to the entire fabric used for the air bag.

The above-mentioned aim is achieved in that a woven fabric of the type described initially, made of polyamide filament yarns having a hot air shrinkage of 6 - 15% (measured at 160°C, according to ASTM 19-525), with an at least substantially symmetrical, close weave setting is treated in an aqueous bath at temperatures in the range of 60 - 140°C. This initiates a shrinking process, which leads to further densification of the already close-woven fabric and hence to extensive closure of the pores of the woven fabric. In said manner, it is possible to achieve the low air permeability of $\leq 10 \text{ l/dm}^2\text{min}$ at 500 Pa test differential pressure called for in the specifications of car manufacturers.

A temperature range of 90 - 100°C is particularly preferred for the treatment in the aqueous bath because said temperature range has proved particularly advantageous in terms of the sought-after low air permeability. Said temperature range offers the advantage that the choice of machine for the wet pass is less limited than at temperatures above 100°C.

The tests carried out have demonstrated that, even at temperatures as low as 60° and below, treatment in the aqueous bath leads to a marked initiation of shrinkage and hence to densification of the woven fabric, which results in a reduction in air permeability. By selecting the treatment temperature, it is even possible to effect purposeful control of the air permeability. This is particularly important

because, in many applications of industrial fabrics, e.g. for the filter part of air bags, higher air permeability values, e.g. in the region of 40 - 80 l/dm²·min at 500 Pa test differential pressure, are desired. The air permeability of woven fabrics may therefore be purposefully adjusted by means of the treatment temperature in the aqueous bath, together with the selected weave setting.

The treatment in the aqueous bath may, for example, be effected at all machines made available in textile finishing for open-width washing. Open-width washing machines have proved advantageous. However, jiggers too are suitable for such treatments.

At operating temperatures above 100°C, the machine used for said purpose may be an HT jigger. This allows treatment temperatures of up to 140°C.

Said wet treatment simultaneously has the effect of removing any size applied prior to weaving. This is advantageous to avoid bacterial attack of the fabric during the, at times, prolonged storage of industrial fabrics, e.g. of air bags in the steering wheel of a motor vehicle.

Even in the case of use in the warp of twisted yarns, which are normally used unsized, the treatment in the aqueous bath simultaneously has the effect of removing any preparation on the yarn resulting from manufacture of the fibres.

The treatment time to be selected for the wet pass, as well as any admixtures to the bath depend on the size or preparation to be removed and are known to the person skilled in the art.

The method here described therefore offers the advantage that woven fabrics having low air permeability values may be manufactured in a very simple and inexpensive manner.

Drying of the fabrics is effected at 130 - 170°C at the machines commonly used for said purpose. A drying temperature of 150°C is preferred. The residual moisture after drying is approximately 5%.

Care should be taken during drying to ensure that the residual moisture does not drop below a value of approximately 5%. At operating temperatures higher than 150°C, there is a risk of excessive drying and, in the case of longer dwell times, of thermo-fixing already setting in. The air permeability values of the woven fabrics then increase. At operating temperatures higher than 150°C, it is therefore necessary to shorten the dwell time during drying.

Although, at lower drying temperatures, there is no risk of an increase in air permeability, problems may arise with ageing resistance.

The influence of the temperature during wet treatment upon shrinkage and the influence of the drying temperature upon air permeability are illustrated in Figures 1 - 3.

Fig.1 is a graph illustrating the residual shrinkage of a polyamide 6.6 yarn treated at various temperatures using the method according to the invention. The residual shrinkage was measured as hot air shrinkage at a treatment temperature of 160°C. The wet treatment temperatures are plotted in temperature units of 20°C along the X-axis. The residual shrinkage is plotted along the Y-axis. The graph shows that the high initial shrinkage of 8.3% (left column of graph) is already sharply reduced at a treatment temperature of 60°C and continues to reduce as the wet treatment temperature rises.

Fig.2 illustrates the initiation of shrinkage achieved during wet treatment. The treatment temperatures are plotted in units of 20°C along the X-axis and the initiation of shrinkage achieved is plotted along the Y-axis. The percentages

indicated here refer, in each case, to the initial length.

Fig.3 reproduces the influence of the drying temperature upon air permeability. The drying temperatures are plotted along the X-axis, the determined air permeability values in $l/dm^2 \cdot min$ (at 500 Pa test differential pressure) are plotted along the Y-axis. The treatment times were, for curve 1, 15 seconds, for curve 2, 20 seconds, for curve 3, 45 seconds and, for curve 4, 60 seconds. Fig.3 clearly shows that with a short treatment time, irrespective of the drying temperature, low air permeability values are achieved. On the other hand, with longer treatment times, particularly at higher temperatures, thermo-fixing already sets in and leads to a marked increase in air permeability. Thus, it is also proved that the thermo-fixing recommended in prior art for industrial fabrics is a detrimental process stage in fields of application where a low air permeability is required.

By means of the described treatment in the aqueous bath, the requirement for a low air permeability of

$$\leq 10 \frac{1}{dm^2 \cdot min}$$

may be fully met. Testing of the air permeability was effected according to DIN 53 887. Only, in a departure from said DIN standard, the test differential pressure was raised to 500 Pa in order to obtain, for the woven fabrics manufactured according to the invention, an additional positive test result.

The measurements carried out on various fabric samples, treated in the manner described, produced values between 3 and 9 $l/dm^2 \cdot min$ at 500 Pa test differential pressure, which are therefore clearly below the maximum limit allowed by car manufacturers for air bags of 10 $l/dm^2 \cdot min$ at 500 Pa test differential pressure.

Any polyamide fibre, with which the required strengths may be achieved, is suitable as a fibre material for manufacture of the woven fabric here described. The polyamide fibres are used in the form of filament yarns. Polyamide 6.6 has proved particularly advantageous. However, other synthetic fibres with a shrinkage behaviour similar to polyamides may alternatively be used. Bicomponent fibres are also suitable for this field of application.

For industrial fabrics, yarn titres of 230 - 940 dtex have proved particularly suitable. Titres of 235, 350 or 470 dtex are particularly suitable for air bags. The number of monofilaments may be, for example, 36 for titre 235 dtex and 72 for titre 350 or 470 dtex.

The yarn used to manufacture the fabric moreover preferably has a strength of at least 60 cN/tex and an elongation of 15 - 30%, with a hot air shrinkage of 6 - 15% (measured at 160°C).

As already stated, in the interests of a low air permeability a high fabric density has to be achieved during weaving. The following thread numbers have proved advantageous for a linen texture:

<u>Yarn titre</u>	<u>Thread number/cm</u>
235 f 36	26 - 30
350 f 72	18 - 28
470 f 72	18 - 25

The fabrics are preferably manufactured in a linen texture with a symmetrical setting. For finer titres it is possible, in the interests of an attractive feel to the product, alternatively to select a panama texture 2/2 with a symmetrical setting. Here, thread numbers of 25 - 36/cm are then used for a titre of 350 f 72 and thread numbers of 32 - 40/cm for a titre of 235 f 36.

A symmetrical setting for the woven fabric means that warp and weft have at least substantially identical thread numbers, with the warp threads and the weft threads possessing at least approximately identical textile properties such as titre, strength, elongation at break and hot air shrinkage. The symmetrical setting of the fabric allows the requirement regarding identical strengths in warp and weft to be met in a simple manner. Said requirement is particularly imposed by car manufacturers on air bags because an air bag is a radially symmetrical component with no privileged direction.

Using the described procedure, the required air permeability values may be achieved without difficulty, as the following table clearly demonstrates:

Test No.	1	2	3	4
Yarn titre	350 f 72	470 f 72	470 f 72	350 f 72
Texture	linen	linen	linen	panama 2/2
Grey fabric:				
thread number/cm				
- warp	24.0	20.5	19.5	27.0
- weft	22.0	19.5	19.2	30.0
fabric width cm	163	147	156	159
Finished fabric:				
thread number/cm				
- warp	27.5	23.0	21.0	32.0
- weft	24.8	22.0	20.4	33.0
fabric width cm	151	136	144	142.5
Air permeability				
l/dm ² ·min at 500 Pa	3	3	8	7.5

The tests reproduced in the table were carried out using fabrics woven from polyamide 6.6 filament yarns. The treatment in the aqueous bath was effected at a jigger. The treatment temperature in each case was 95°C.

The low value obtained for the air permeability alters, even in the ageing test recommended by car manufacturers for air bag fabrics, only to an insignificant extent. In said test, the fabric is stored for 100 hours at 105°C and then its air

permeability is tested.

Additional thermo-fixing is not necessary. The tests carried out have even demonstrated that thermo-fixing does not achieve any further reduction in the air permeability and even leads to an increase in the values. The thermo-fixing recommended in prior art for industrial fabrics is therefore a detrimental process stage in the case of fabrics in which a low air permeability is required.

The advantages of the fabric according to the invention, when used in the contact part of the air bag, result in a more reliable air bag system which, in important aspects, is an improvement on previous systems, meets the specifications of car manufacturers and is therefore marketable. An air bag system is taken to be the air bag itself, the accommodation of the air bag in the motor vehicle and the control system for triggering operation of the air bag.

Example 1

Polyamide 6.6 filament yarns with a titre of 350 f 72 were processed in a linen texture into a woven fabric. The yarn used had a hot air shrinkage (measured at 160°C) of 8.2%. The thread number was 24/cm in the warp and 23/cm in the weft.

The fabric was wet treated at a jigger at 90°C and then dried at 150°C. The drying time was 30 seconds. The residual moisture of the fabric after drying was 4.8%.

The fabric thus manufactured presented an air permeability of 7.5 l/dm²·min at 500 Pa test differential pressure.

Example 2

The fabric manufactured according to Example 1 was wet treated close to boiling temperature (97°C) at a jigger. The fabrics

thus treated were dried each for 30 seconds at 130°C, 150°C, 170°C and 190°C respectively. In the fabrics thereby obtained, the following air permeability values were measured:

Drier temperature °C	Air permeability l/dm ² ·min at 500 Pa test differential pressure
130	6
150	6.5
170	8
190	21

A further portion of fabric from said test was dried with differing dwell times at 170°C. The following air permeability values were thereby obtained:

Dwell time at 170°C seconds	Air permeability l/dm ² ·min at 500 Pa test differential pressure
15	5.5
30	8
45	15
60	19

The test results reproduced here clearly demonstrate that at a higher drying temperature there is not a reduction but an increase in air permeability. At higher temperatures, thermo-fixing already sets in. The same applies to longer dwell times when operating at relatively high drying temperatures.

This provides verification of the fact that the thermo-fixing recommended in prior art for industrial fabrics in which a low air permeability is required is an unnecessary, and even detrimental process stage.

Example 3

A fabric according to Example 1 was wet treated at an HT jigger. The treatment temperature was 138°C. The drying conditions corresponded to those indicated in Example 1.

In the fabric thus obtained, an air permeability of 4.5 l/dm²·min at 500 Pa test differential pressure was measured.

Patent claims:

1. Method of manufacturing uncoated industrial fabrics with a close weave setting, characterized in that a woven fabric, made of polyamide filament yarns with a hot air shrinkage of 6 - 15% (measured at 160°C), with an at least substantially symmetrical weave setting is treated in an aqueous bath at a temperature in the range of 60 - 140°C.
2. Method according to claim 1, characterized in that the treatment in the aqueous bath is carried out at a temperature in the range of 90 - 140°C.
3. Method according to claim 1, characterized in that the treatment in the aqueous bath is carried out at a temperature in the range of 90 - 100°C.
4. Use of a woven fabric, manufactured according to one of claims 1 to 3, for articles in which a low air permeability is required.
5. Use of a woven fabric, manufactured according to one of claims 1 to 3, to manufacture an air bag.
6. Use of a woven fabric, manufactured according to one of claims 1 to 3, as a parachute fabric.
7. Use of a woven fabric, manufactured according to one of claims 1 to 3, as a sail fabric.
8. Air bag system, characterized by a woven fabric manufactured according to one of claims 1 to 3.

