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Evaluation of the Residual Bagging Height using the Regression Technique and Fuzzy Theory

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Abstract
This paper deals with the evaluation of the residual bagging height using the fuzzy theory method. An experimental design was used to objectively evaluate the effect of input parameters on the residual bagging height of knitted fabrics using two different yarn structures without and within elastane filament. Our findings show that among the overall input parameters tested, two are influential. In our experimental design the fuzzy theory method was applied using five different membership functions: triangular-shaped, trapezoidal function, Gaussian, generalized-bell and Π-shaped . To prove our results, the experimental regression technique and fuzzy theory were compared. In addition, among the other membership functions tested, the triangular membership function gives a more effective evaluation and widely fits to residual bagging height behaviour.

Key words: *bagging, knitted fabric, residual height, fuzzy membership function, regression.*

Introduction

One of the advantages of knitted fabrics is the ability to produce complex structures which seem close to the form finished with a production facility. Thus their exploitation has never stopped and is constantly developing. Crumpling, bagging and contracting with the seam are the phenomena most noticed, due to repeated deformations at the time of the repetitive setting and removal of clothing. This is obvious for crumpling, whereas for bagging it appears in the elbows and knee zones. Also various research tasks are carried out to increase the lifetime of the woven article. Bagging is the residual part which remains after several multidirectional requests, such as in the knees, elbow and hand zones. In the literature, many studies attempted to determine bagging behaviour experimentally [1, 2, 6 - 15]. Some different techniques have been used, referring to the literature survey, to analyse and study bagging behaviour [1, 2, 6 - 15, 18 - 20] in order to understand this aesthetic zone on a garment. Thus many works have been conducted to evaluate the residual bagging height of woven fabrics, but not enough for knitted ones. Zhang's study [8] investigated the residual deformation of a woven fabric before and after having undergone a multidirectional or cyclic multiaxial force on the surface using an Instron tensile tester. In addition, to predict the bagging volume and bagging tendency index, Yokura et al. [14] used the KES-FB system to measure the specimen's mechanical properties. Therefore, according to a recent study of Doustar et al. [12], it may be concluded that some parameters such as fabric design and weft density seem to influence cotton woven fabric bagging behaviour. In contrast, some studies focused on knitted fabrics behaviours. Indeed, Uçar [15] used the KES-FB test to analyse the bagging behaviour height for knitted fabrics. Furthermore the bagging of a knitted garment by the image analysis method was evaluated by Yeung et al. [19]. Recently our work [1 and 2] has dealt with the bagging behaviour of knitted samples with respect to some influential inputs and their corresponding contributions using Taguchi design analysis. Evaluating the bagging phenomenon of fabric as a spherical deformation was proposed and investigated by Zhang et al. [6 and 7] to simulate bagging in the elbow and knee zones. This paper made a comparison between the experimental regression method and fuzzy theory to objectively evaluate and predict knitted fabric bagging behaviour. Moreover the study deals with a comparative analysis of the linear regression technique and fuzzy theory method to evaluate objectively residual bagging height behaviour. Because it seems very important to know the knitted sample's ability to bagging as a function of input parameters, the comparative membership functions were established. Thus it can help industry to select the best fuzzy function which can predict accurately the evolution of the bagging height behaviour of knitted fabric samples.

Fuzzy logic theory

According to Cox [4], a fuzzy logic theory system works on many types of vague data, but the originator must specify the relations between them using a rule database. The rules start in parallel to accumulate the presumptions in favour or not of such or such solution. A fuzzy set contains elements with only partial membership ranging from 0 to 1 to define uncertainty for classes that do not have clearly defined boundaries [5]. In comparison with our earlier work [3], the fuzzy model essentially consists of four parts: fuzzification, a fuzzy rule base, a fuzzy inference engine and defuzzification. Firstly, when the feature values are converted into appropriate fuzzy sets, this step is named fuzzification. Thus the fuzzified values are then inferred to provide decisions from the inference engine with the support of the fuzzy rule base [1]. The results are fuzzy sets, which are converted into a crisp value by defuzzification. The defuzzified value represents the decision made by the fuzzy building model. Five different membership functions ("triangular", "trapezoidal", "Gaussian", "G-bell shape" and "Π-shaped function") are chosen and applied as shown in ***Figure 1***.

Although there is a very wide selection for the suitable membership function, the Fuzzy Logic Toolbox allows us to create our own membership functions in case a restrictive list is found. In fact, the triangle, trapezoid and exotic membership functions are by no means required for perfectly good fuzzy inference systems. These functions offer more details and are considered as the simplest membership functions because they are formed using straight lines. Among these, the simplest is the triangular membership function, which has the function name *trimf*, being nothing more than a collection of three points forming a triangle. However, the trapezoidal membership function, *trapmf*, has a flat top and is re-

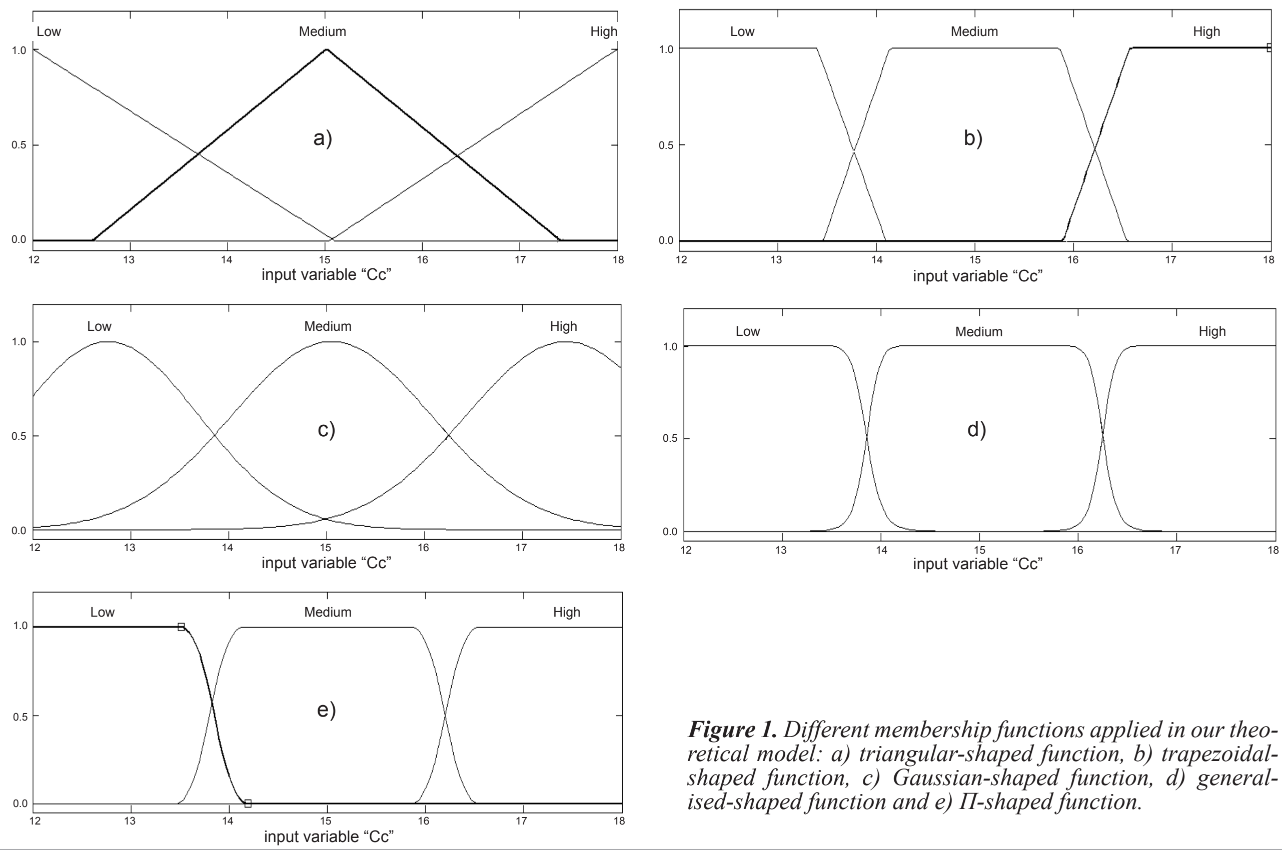

***Figure 1.** Different membership functions applied in our theoretical model: a) triangular-shaped function, b) trapezoidal-shaped function, c) Gaussian-shaped function, d) generalised-shaped function and e) Π-shaped function.*

ally just a truncated triangle curve. Furthermore it is clear that these straight line membership functions have the advantage of simplicity.

The generalised bell membership function is specified by three parameters and has the function name *gbellmf*. The bell membership function has one more parameter so it can approach a non-fuzzy set in case the free parameter is tuned. Because of their smoothness and concise notation, Gaussian and bell membership functions are popular methods for specifying fuzzy sets. These two curves have the advantage of being smooth and nonzero at all points. Two membership functions are built on the Gaussian distribution curve: a simple Gaussian curve and a two-sided composite of two different Gaussian curves. The two functions are *gaussmf* and *gauss2mf*. Although the Gaussian membership functions and bell membership functions achieve smoothness, they are unable to specify asymmetric membership functions, which are important in certain applications.

As well as the related membership functions such as Z and *S*, the *Π-shaped* curve is also considered as a polynomial function (all named according to their shapes) which is based on curve accounts for several membership functions in Toolbox of Matlab Software. The function *pimf* is an asymmetrical polynomial curve and is zero at both extremes, with a rise in the middle.

The overall rules used, shown in ***Table 1***, are fixed and developed in order to investigate the best to fit experimental values in the specific field of interest.

Table 1 shows the building of fuzzy rules using our input and output parameters. In our experimental design of interest, using the membership function each fuzzy input has an effect on the output parameter (R_{bh}). Regarding our experimental database, it can be concluded that the change of inputs affects considerably the R_{bh} from one fuzzy value to another. For example, the first rule (see ***Table 1***) means when the knitted fabric (B_d) is made using a 1×1 rib structure, the gauge (G_g) equals 7, the yarn type (Y_t) to realise loops is without elastane, and the tightness factor (C_c) or looseness of the plain weft knitted structure equals 12, in which case the residual bagging height of knitted elastic fabrics, $R_{bh,}$ presents a medium value. This characteristic of the medium value of R_{bh} is statistically calculated, evaluated and fuzzified within a high weight, which is equal to 1. In the fuzzy theory method,

***Table 1.** Rules used to build our fuzzy model; *indicates corresponding weights applied to each rule. In general, the specific weights should be from 0 to 1 under the weight setting.*

Rule	Rules
1	If Bd, Gg , and Yt are high and Cc is low, then Rbh is medium (1)*
2	If Bd is low, Gg high, Yt low and Cc medium, then Rbh is low (1)
3	If Bd and Gg are high, Yt low, and Cc is low, then Rbh is low (1)
4	If Bd and Gg are high, Yt is low, and Cc is high, then Rbh is low (1)
5	If Bd is low, Gg and Yt are high, and Cc is medium, then Rbh is low (1)
6	If Bd is low, Gg, Yt, and Cc are high, then Rbh is low (1)
7	If Bd is low,Gg high, Yt low, and Cc is medium, then Rbh is low (1)
8	If Bd, Gg, Yt and Cc are low, then Rbh is high (1)
9	If Bd is high, Gg and Yt are low, and Cc is medium, then Rbh is medium (1)
10	If Bd is low, Gg high, Yt low, and Cc is high, then Rbh is high (1)
11	If Bd is low, Gg and Yt are high, and Cc is medium, then Rbh is medium (1)
12	If Bd and Gg are low, and Yt and Cc are high, then Rbh is medium (1)

Table 2. Levels of input parameters; [a]Referring to twisted yarn within Spandex® end and coded in our fuzzy model as well as in the relative figures as 1. [b]Referring to twisted yarn without Spandex® end and coded in our fuzzy model as well as in the relative figures as 0. [c]No level was considered in our experimental design of interest.

Levels	Rectilinear knitting machine inputs			Yarn input parameter
	Course count - C_c, mm	Gauge - G_g, mm	Binding - B_d	Type of yarn - Y_t
I	12	5	Jersey	Within elastane [a]
II	14	7	1 × 1 rib	Without elastane[b]
III	16	-[c]	-	-
IV	18	-	-	-

the weight of rules can be ranged from 0 to 1, as a low and high value, respectively. Indeed it is notable that all these fuzzy model parameters can be identified using ***Table 2***. Referring to both ***Tables 1*** and ***2***, and based on this example, it will be easy to understand the fuzzy model interpretation because in each rule the same methodology of explanation will be adopted.

Materials and methods

Data collection and analysis

Twisted spun yarns with and without elastane filament were fed in with Acrylic fibres to spin a 66.6 tex yarn. Two kinds of spun yarns with varied knitting machine input parameters (gauge (G_g), binding (B_d) and course count (C_c)) were used in the experiment. To achieve an elastic kind of spun yarns, we assembled two twisted acrylic ends with elastane filament of the type Spandex© (***Figure 2***). The percentage value of the Spandex© filament in the twisted yarn count equals 1.9%.

The twist value and direction of both yarns mentioned above are 150 t.p.m and S-twist direction, respectively. To adjust the knitting conditions, four input parameters with their corresponding regulation points were varied. Each level of the input parameters (I, II, III and IV) for adjustment represents a regulation point, with I corresponding to the minimum, II and III referring to medium level values and IV corresponds to the maximum, as shown in ***Table 2***. When the input factor presents only two levels, then II corresponds to the maximum. These optimised parameters affect the performance of the bagging height behaviour according to our previous works [1 and 2]. The combinations of regulation points built referring to the Taguchi experimental design method represent the overall knitted fabric specimens tested.

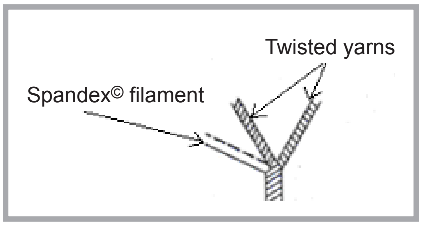

Figure 2. *Assembled yarn specimen compounded by two twisted ends and one Spandex© filament.*

The experimental design is chosen to minimise objectively and have a suitable number of tests. A rectilinear knitting machine of the Morretto type was used to prepare all samples. ***Figure 3*** shows the binding structures, jersey and rib 1×1 used, respectively.

The width value of samples was 100 mm. However, their lengths were variable and depended on the rate of extension of the specimens tested regarding both the row and column directions. Furthermore after determining the percentage or extension rate, taking into consideration the row and column directions, we deduced the length from the test-tube to be tested and the arrow to be applied [16]. The samples were conditioned for 24 hours in a standard atmosphere for textile testing, as recommended by Standard NF G00-003 (20 ± 2 °C and 65 ± 2%). Using steel ball pressure applied to the specimens, the bagging test lasted 5 hours. After 30 minutes, the relaxed samples were tested using a bagging tester, type Sodemat, to measure the residual bagging height (R_{bh}).

Virgin fuzzy parameters

To evaluate the R_{bh} accurately in our experimental field of interest, five different fuzzy membership functions were investigated. Indeed, triangular, trapezoidal Gaussian, generalized bell-shaped and Π-shaped memberships were compared to find the one that best fits the experimental R_{bh} result. As concluded in our earlier and Majumdar's results [1, 3 - 5], it has been proved that the triangular-shaped membership function for each input gives a wide prediction and accurate evaluation of the R_{bh} of knitted fabric samples. Thanks to its simplicity and because it is formed with straight lines, the triangular membership function fits the R_{bh} well regarding all functions considered, mentioned above. In this paper, for fuzzy modelling, we used the Fuzzy Logic Toolbox of MATLAB software, version 7.0.1. The overall fuzzy rules of R_{bh} (see ***Table 2***) were obtained by using our previous experimental data [1 and 2] and trained for the fuzzy model constructed. In addition, our fuzzy modelling method is based on the following steps:

1) ***Defining input and output parameters:*** The overall input parameters are observed. Besides this, the R_{bh} for elastic and non elastic knitted fabric specimens are both tested.
2) ***Defining fuzzy conditions of parameters:*** According to the actual situation to determine the universe of discourse of every input parameter, this step deals with the determination of input and output parameters as well as the scope of the operation. Moreover we assign linguistic expressions and their corresponding membership functions.
3) ***Designing fuzzy rules and fuzzy inference:*** The linguistic fuzzy rules shown in ***Table 1*** are established according to the database developed during our earlier experiments [1 and 2]. Mamdani's min–max fuzzy inference approach [7] is adopted to satisfy the requirements of the present study.

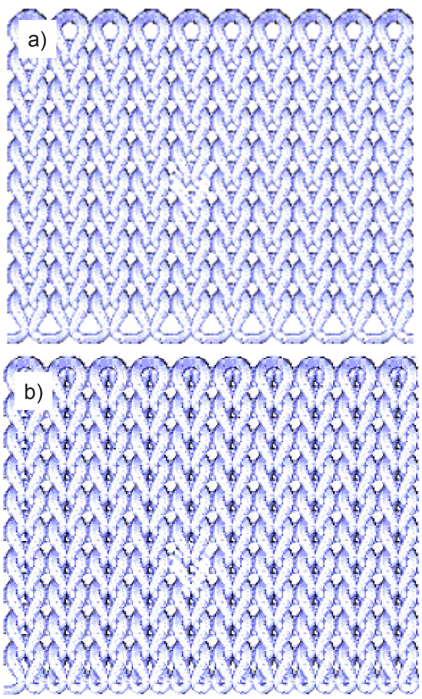

Figure 3. *Plain-knitted structures: a) jersey binding, b) rib1×1 binding.*

4) ***Selecting the fuzzying technique:*** The fuzzy output conferred is converted into clear values and the centroid calculation method (returns to the centre of the area under the curve of each output) is used to defuzzify [1, 6 and 7]. There are five built-in methods supported: centroid, bisector, medium-maximum (the average of the maximum value of the output set), high-maximum and low-maximum.

Results and discussion

Figures 4 and ***5*** show the evolution of R_{bh} as a function of the input parameters. Considering the behaviour of the knitted samples, we may conclude that the bagging height remains the function of each input factor, especially the course count (C_c) and gauge (G_g). The type of yarn (Y_t) and plain-knitted structure (B_d) can also be considered as influential input parameters but classified in second place. In fact, ***Figure 4.a*** shows that the R_{bh} evolution is a function of the binding structure and course count. It is clearly shown that knitted specimens using 1×1 rib (represented by B_d = 1) structures present the minimal R_{bh} compared to the jersey ones (expressed by B_d = 0). According to Derimoz and Dias's study [17], plain-knitted fabrics have complex structures. Many yarns and knitting variables affect the corresponding properties and relative dimensions. Internal stresses and forces during and especially after the bagging test can also affect the R_{bh} behaviour [6 - 11].

Nevertheless, as shown in ***Figures 4.b*** and ***4.e***, the R_{bh} of samples decreases considerably when the yarn contains elastane filament - Spandex©. This finding is in agreement with our earlier work [1], that is to say, by increasing the percentage of elastane inside the fabric, permanent bagging decreases after the test, whereas elastic bagging increases during the experiment. As knitted elastic fabrics can stretch far more than those without elastane, the residual bagging height decreases because they are preferred as an attempt to increase comfort and fit-

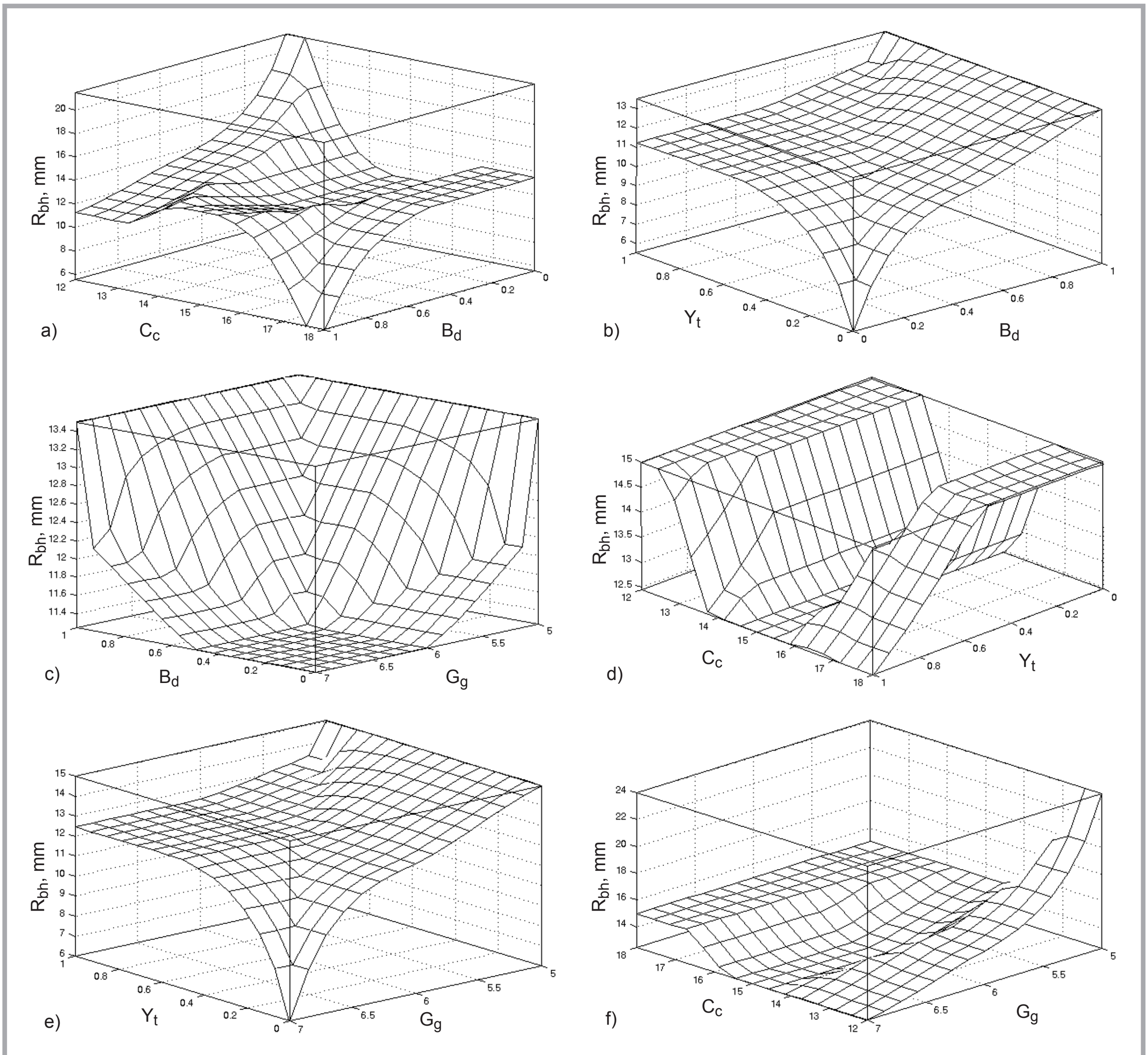

Figure 4. *Residual bagging height evolution as a function of parameters: a) C_c and B_d, b) Y_t and B_d, c) B_d and G_g, d) C_c and Y_t, e) Y_t and G_g, f) C_c and G_g.*

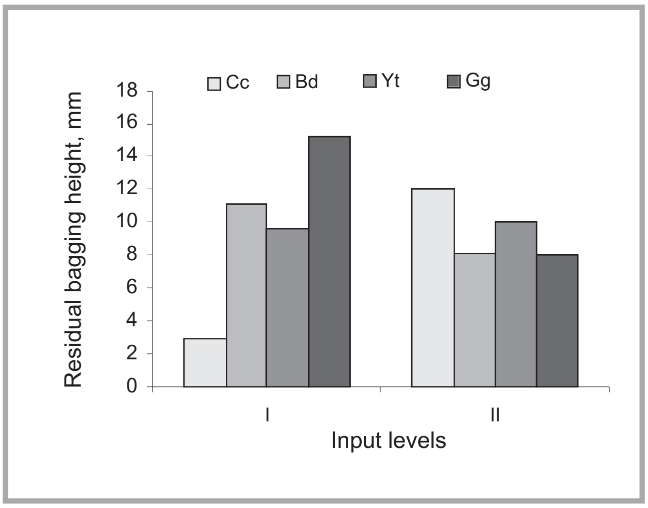

***Figure 5.** R_{bh} evolution using the lowest (I) and highest (II) levels of inputs studied.*

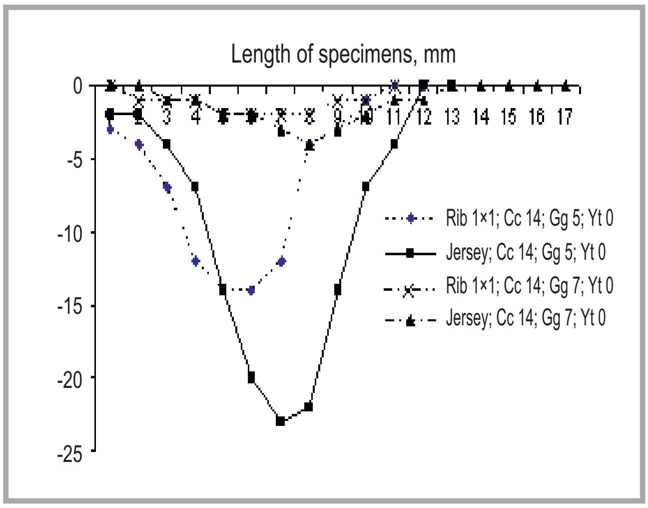

***Figure 6.** Evolutions of R_{bh} as a function of specimen lengths for different adjustment levels (case of non-elastic yarn, Y_t0).*

ting properties. Our findings are in good agreement with Özdil's study [23 and 24], which determines that woven fabric bagging decreases when the elastane content in the fabric increases, whereas elastic bagging increases. Moreover using elastic yarn to produce knitted fabrics encourages the bending rigidity of specimens, which was proved by Özdil's study [23] in the case of denim fabric bagging. According to the same study, the bending rigidity in the case of denim fabrics becomes higher with an increase in the elastane percentage. Therefore it can be stated that the knitted fabric handle becomes stiffer as the elastane ratio in the structure of the knitted fabric increases.

In reality, the elastic yarn has a higher capacity to return to the initial state after the extension test than non-elastic yarn. In our experimental field, the use of elastic yarn to produce jersey plain-knitted fabric helps to slightly decrease the R_{bh}. Based on elastic theory; Araujo et al. [21] showed that the yarn type within its mechanical properties (friction, elastic stucture, binding, compression, etc.) can also encourage high bagging height bending, besides which it becomes more pronounced when the rib 1×1 structure is used within the same yarn (***Figures 4.b*** and ***4.c***). According to David's work [22], rib is a knitted structure which cannot be unroved from the end knitted first because the sinker loops are securely anchored by the cross-meshing between face and reverse loop wales. This characteristic, together with its elasticity, makes rib particularly suitable for the extremities of articles such as the tops of socks, the cuffs of sleeves, rib borders of garments, and stolling and trapping for cardigans. Rib structures are elastic, form-fitting, and retain warmth better than plain structures. The same remark is noticed when the gauge value is increased, as shown in ***Figures 4.d*** and ***4.e***. This property helps the R_{bh} to keep minimal bend values during the relaxation test.

Figure 4.f shows an important decrease in R_{bh} when the gauge value increases and course count value variation is not considered. Knowing the minimal values of the course count ranging from 12 to 15 mm, the R_{bh} of samples remains unchanged when the gauge value is high. It may be concluded that it is convenient to decrease the R_{bh} using the minimal course count values when increasing the gauge values. To improve our findings and understand the contribution of input parameters when their level values change from the lowest to the highest, we determine the R_{bh} evolutions as shown in ***Figure 5***.

By classifying the contribution values of our input database on the R_{bh} it is noticeable that the course count and gauge have the most impact (***Figure 5***). Moreover, as proved by Derimoz and Dias [17], the complexity of knitted fabrics expressed by the binding parameter does not help the residual bagging height to acquire minimal values even if elastic yarn is used. However, the R_{bh} seems lower for elastic knitted fabrics than when the yarn used is without Spandex© filament. Compared to the rib 1×1 structure, jersey fabric presents more R_{bh}, which may be due to internal stresses during stitching and the complexity of the plain-knitted structure [17]. ***Figures 6*** and ***7*** show the shape of the R_{bh} variation from non-elastic and elastic yarns as a function of the length of samples when some input parameters are fixed.

It seems that changing the plain-knitted structure as well as other input factors for the same yarn type explains why the R_{bh} remains dependent on non-equal residual stresses and deformations. Although the plain-knitted stucture affects the bagging behaviour, yarn type can also encourage the bagging height bend. Indeed, in contrast to the study of Araujo et al. [21], which suggests that yarn friction, extension and compression effects are relatively small and can be ignored, the residual bagging shape can be affected by these yarn properties, especially during loading application inside knitted fabrics.

Indeed, the rib 1×1 plain-knitted structure presents a minimal R_{bh} even when the yarn used is non-elastic (***Figure 6***). This is due to the structure of loops, which is more extensible when jersey plain-knitted is used. In addition, to detect the contribution of elastane in the bend and variation of the R_{bh} shape, changing the yarn type is recommended. The elastic yarn structure enables the knitted fabric to possibly return to its first state after the bagging test. It may be concluded that although the pressure stress applied by the steel ball during the bagging test is constant, the R_{bh} of samples presents variable behaviour in each sub-length of fabric. In agreement with the results obtained by Derimoz [17], the conditions of both the production and stitch stresses as well as the experimentation of samples affect R_{bh} behaviour enormously.

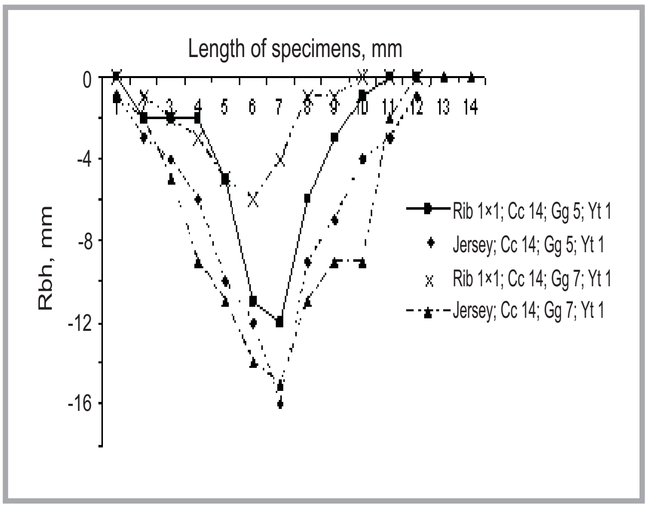

__Figure 7.__ Evolutions of R_{bh} as a function of specimen lengths (case of elastic yarns, Y_t1).

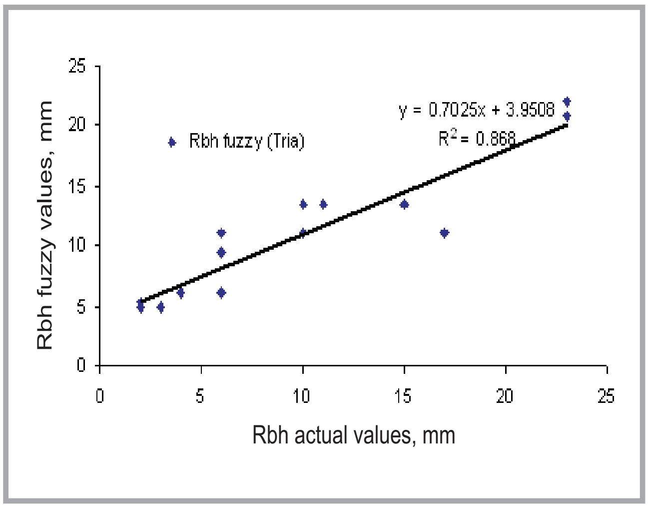

__Figure 8.__ Regression model using fuzzy theory.

The regression model (***Figure 8***) presents a good coefficient value, which improves the fuzzy analysis. Moreover, considering the coefficient regression value 0,868, we can deduce that the R_{bh} seems predictable in our experimental design of interest. Besides this, compared to the experimental results, our theoretical ones give an accurate evaluation of the R_{bh}.

Moreover, ***Table 3*** shows the mean error, difference, values between the theoretical and experimental methods. However, by knowing these error values, it may be easy to classify and analyse the effectiveness of the fuzzy membership functions. Regarding these results, only the triangular function presents a small mean error value (-1.03 mm). To improve our findings, the overall differences between theoretical and experimental residual bagging height values were analysed. Eighteen additional tests which corresponded to input parameter variations according to ***Table 2*** were investigated to validate our fuzzy theory models. Using the five different membership functions, a comparison between theoretical residual bagging height and experimental values and the mean errors in each combination (input levels or values studied) was made and analysed. ***Table 3*** shows that when the triangular membership function is used in our fuzzy model, the mean error between the experimental residual bagging height and theoretical values is low. Regarding the theoretical R_{bh} values using the triangular membership function compared to experimental R_{bh} values, there is no doubt that using the 1×1 rib knitted structure (Level II) with non elastic yarn can lead to a small residual height value. Indeed, in the case of the best membership function, our theoretical results show that the 1×1 rib structure is compact elastic, form-fitting, and retains warmth better than plain structures [15 and 22]. Besides this, when yarn without elastane is used it allows a slightly bagging formation of loop shape and plain knitted fabric deformation [24], which can be explained by the resistance to extension of these knitted fabrics, depending mainly on the bending and torsional properties of the yarn, according to some studies [21 and 24]. Indeed

*__Table 3.__ Comparison between the theoretical and experimental results; *ErrorTri: Error between theoretical and experimental value using "Triangular-shaped" membership function; a) ErrTrap: Error between theoretical and experimental value using "Trapezoidal-shaped" membership function; b) ErrGauss2: Error between theoretical and experimental value using "Gaussian" membership function; c) ErrGbell: Error between theoretical and experimental value using "Generalized bell-shaped" membership function and d) ErrΠ: Error between theoretical and experimental value using "Pi-shaped" membership function..*

Input parameters					Theoretical R_{bh} values, mm					Errors between experimental and theoretical values, mm				
C_c	G_g	Y_t	B_d	R_{bhexp}, mm	Triangular	Trapezoidal	Gaussian2	Gbell	Π-shaped	ErrTri*	ErrTrap a)	ErrGauss2 b)	ErrGbell c)	Err Π d)
II	II	I	I	2	5.38	5.51	6.01	5.38	5.23	-3.38	-3.51	-4.01	-3.38	-3.23
I	II	I	II	3	4.99	5.08	5.95	5.25	5.20	-1.99	-2.08	-2.95	-2.25	-2.20
III	II	II	II	4	6.17	15.00	14.60	14.70	15.00	-2.17	-11.00	-10.6	-10.70	-11.00
III	II	I	II	6	6.17	6.44	7.56	5.80	5.57	-0.17	-0.44	-1.56	0.20	0.43
II	II	II	I	6	11.10	12.10	11.20	10.90	10.80	-5.10	-6.10	-5.20	-4.90	-4.80
IV	II	II	I	2	4.99	5.08	5.95	5.25	5.20	-2.99	-3.08	-3.95	-3.25	-3.20
III	II	I	I	6	9.54	8.27	6.02	10.80	7.49	-3.54	-2.27	-0.02	-4.80	-1.49
II	II	I	II	4	6.17	6.44	7.56	5.74	5.53	-2.17	-2.44	-3.56	-1.74	-1.53
II	I	I	I	23	20.80	23.6	22.50	22.00	22.60	2.20	-0.60	0.50	1.00	0.40
II	II	II	II	15	13.50	15.00	15.00	13.90	13.90	1.50	0.00	0.00	1.10	1.10
III	I	I	II	10	13.50	15.00	15.00	13.90	13.90	-3.50	-5.00	-5.00	-3.90	-3.90
IV	II	I	I	23	22.00	24.90	24.10	23.20	23.50	1.00	-1.90	-1.10	-0.20	-0.50
III	I	II	I	17	11.10	15.00	15.00	13.90	13.90	5.90	2.00	2.00	3.10	3.10
II	II	II	II	15	13.50	15.00	15.00	13.90	13.90	1.50	0.00	0.00	1.10	1.10
III	II	II	I	10	11.10	12.10	11.20	10.90	10.80	-1.10	-2.10	-1.20	-0.90	-0.80
IV	I	II	I	11	13.50	15.00	15.00	13.90	13.90	-2.50	-4.00	-4.00	-2.90	-2.90
									Mean error. mm	-1.03	-2.65	-2.54	-2.02	-1.83

the mean residual bagging height equals 9.14 mm when jersey binding is used, as opposed to 10.62 mm when yarn without elastane is used. Compared to other samples (mean value of R_{bh} is 14.72 mm for the largest gauge), it seems that with the lower gauge value we obtained the lowest theoretical mean values of the residual bagging height (R_{bh}= 9.55 mm). The same decrease in the residual bagging bend was noted when elastic yarn was used to prepare knitted fabrics (mean value of R_{bh} was equal to 11.06 mm). However, the decrease in the tightness factor (C_c) level leads to enormous residual bagging height values of knitted fabrics. As a result, it may be concluded that a low ratio of the area covered by the yarn in one loop to that occupied by that loop helps to obtain a good appearance of knitted fabric in the bagging zone. When this input level increased from I (equals to 12) to IV (equals to 18), the mean theoretical value of R_{bh} increases and, consequently, the appearance of knitted fabrics decreases as well. These findings are an improvement on those obtained previously in experimental results with respect to error values (see ***Table 3***), which seem low; a good fit of experimental results is noted in the triangular membership case. In addition, the regression coefficients of all the fuzzy models were analysed, and as a result the best model for fitting experimental results is the triangular membership function (R^2 = 86.8% against R^2 = 81.55% for trapezoidal function, R^2 = 81.74% for Gaussian shape, R^2 = 78.53% for Gbell-shaped and R^2 = 78.9% for Π function). It may be concluded that the theoretical model using fuzzy theory and the triangular membership function seems to be the best model to widely predict the residual bagging height for knitted fabric specimens in our experimental design of interest. Therefore the triangular function offers more details and is considered as the simplest membership function because it is formed using straight lines [1, 3 - 5].

Conclusion

In this study, the residual bagging height behaviour of knitted fabrics was investigated using some influential input parameters in a specific experimental design of interest. A comparison between experimental and theoretical results shows that the fuzzy modelling method is still better to evaluate and predict the residual bagging height. According to our results, the theoretical coefficient of determination proves that among the overall membership functions, the triangular-shaped function predicts well the residual bagging height in the experimental design of interest. Different reasons can explain why the residual bagging height inside knitted fabrics remains important after the bagging test, such as residual frictional stresses and elongations, the yarn structure behaviour, structure composition and the conditions of experiments. Further detailed works will follow to investigate the contribution of some frictional stresses on the residual bagging height of knitted fabrics.

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