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THE INFLUENCE OF SEWING THREAD FINENESS AND STITCH LENGTH ON SEWN JOINT STRENGTH

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ABSTRACT

The strength and, by extension, the aesthetic integrity of sewn seams in upholstered furniture covers are key determinants of overall product quality. An upholstery fabric with a sandwich structure composed of two plain-weave layers is examined in the study, and how sewn-seam performance in both warp and weft directions is affected by sewing thread fineness (linear density: 135, 90, and 70 tex) and stitch length (3, 4, 5, and 6 mm). Specimens were prepared and tested in tension in accordance with EN ISO 13935-1. The maximum force at failure (F_{max}) and failure modes were recorded. Results show that increasing thread linear density (i.e., using coarser threads) increases seam strength in both joining directions, with the highest F_{max} obtained for 135 tex. Shorter stitches (3–4 mm) provided higher seam strength than longer stitches (5–6 mm). Failure mode depended on stitch length: at shorter stitches, rupture occurred primarily in the fabric at F_{max}, whereas at longer stitches, failure was dominated by thread breakage. The findings provide actionable guidance for selecting thread and stitch parameters to enhance seam performance in upholstery applications. Optimizing these parameters can extend the service life of upholstered products, reduce material waste, and support more sustainable manufacturing practices.

Keywords: sewn joint; seam strength; stitch length; sewing thread fineness; upholstery fabric; tensile test; seam failure.

INTRODUCTION

The upholstery of functional surfaces in seating and sleeping furniture can be considered a unique type of surface finishing. In addition to its aesthetic value, upholstery significantly enhances user comfort. Upholstered constructions are typically characterized by a sandwich structure composed of materials of different natures, with textile cover fabrics playing a key role. The cover layer of the upholstery is subjected to user-induced loading during the service life of the product; therefore, upholstery fabrics are required to exhibit higher strength and performance characteristics compared to apparel textiles (Skorupińska *et al*., 2021; Joščák and Langová, 2018; Zubauskienė, 2017).

Research into the properties of textile materials used across various fields, including upholstery, provides valuable insights through evaluations of parameters such as tensile strength, elongation, abrasion resistance, air permeability, and others. The production of upholstery covers is a process in which two-dimensional fabrics are transformed into three-dimensional forms by assembling various pattern pieces. This transformation is achieved through sewing, which represents one of the critical processes determining the quality of the final upholstered product (Levent, 2016; Vilhanová, 2021; Liao *et al*., 2014; Hunter and Cawood, 1979; Hui *et al*., 2007; Al Sarhan, 2011; Khanna *et al*., 2015; Bharani and Mahendra Gowda, 2012).

The mechanical properties and structural characteristics of the joined material are fundamental determinants of seam quality; consequently, it is essential to examine and understand how specific material attributes influence sewability. Among the key factors affecting both seam strength and appearance is the fabric weave. Mukhopadhyay and Midha (2013) demonstrated that plain-weave fabrics exhibit the highest seam strength in both directions, attributed to the high number of interlacing points per unit area, which restricts yarn mobility under load. By contrast, twill constructions allow greater yarn displacement, thereby reducing seam strength. Moreover, Al Sarhan (2011) reported a positive effect of fabric density on seam performance, with higher densities enhancing seam strength across all seam types. Stitching direction also significantly influences strength, with warp-oriented seams generally stronger than weft-oriented seams. Çitoğlu *et al.* (2011) observed that the highest values of seam strength and elongation were achieved when fabrics were joined diagonally. Similarly, Oztas and Gurarda (2019) compared stitch angles and reported that seams prepared at 0°, 45°, and 90° had the greatest seam strength, whereas seams prepared at 30° and 60° had the lowest.

Mohamed (2019), in a study on the influence of weft density and yarn material origin, reported that increasing fabric density positively affects the strength of sewn joints. Yildirim (2010) further highlighted the problem of seam opening in woven fabrics, which occurs due to the relative movement of weft yarns through warp yarns (or vice versa) during use.

Scientific studies have demonstrated that the seam quality of a given textile fabric depends on the interactions among the fabric, sewing thread, stitch type, seam type, and sewing conditions, including needle size, needle geometry and surface, stitch density, sewing speed, and appropriate machine handling and maintenance. Among the parameters influencing seam quality, the fineness (linear density) of the sewing thread plays a particularly important role. In general, researchers have reported that increasing thread thickness increases seam strength (Mukhopadhyay *et al*., 2006; Gribaa *et al*., 2006; Gurarda, 2008; Bharani *et al*., 2012; Hayes and McLoughlin, 2013; Datta *et al*., 2017; Bhavesh *et al*., 2018). On the other hand, Gribaa et al. (2006) noted that thicker threads necessitate the use of larger needles, which may damage the material being joined.

In addition to fineness, the material origin and structural design of the sewing thread play a crucial role in determining its properties (Hayes and McLoughlin, 2013). Behera *et al.* (1997) compared polyester, cotton, and core-spun polyester threads for joining denim fabrics. Their results showed that core-spun threads exhibited the highest breaking strength and elongation, followed by polyester and cotton threads. The increased strength of core-spun and polyester threads was attributed to the presence of stronger filaments in the core and the higher tenacity of polyester fibers. These findings are consistent with those of Ünal (2012) and Sular *et al.* (2015). Meric and Durmaz (2005) compared multifilament and staple sewing threads, finding that seams produced with multifilament threads had higher seam strength, whereas those made with staple threads had the lowest strength.

Many studies have examined the effect of stitch density on the tensile properties of seams. It has been consistently observed that both seam strength and seam efficiency increase with higher stitch density (Hunter and Cawood, 1979; Mukhopadhyay *et al*., 2004; Gurarda, 2008; Ünal, 2012; Nassif, 2013; Datta *et al*., 2017; Bhavesh *et al*., 2018). This behavior can be explained by the increased number of contact points between the sewing thread and the fabric yarns, which produces a firmer interlocking along the seam line and a more uniform distribution of tensile stress across multiple points.

The influence of individual factors in the sewing process on seam performance can be expressed as seam efficiency, defined as the ratio of seam strength to the unseamed fabric strength. In the context of apparel textiles, this value generally ranges between 85% and 90% (Gurarda, 2008). High overall seam quality is essential for the long-term durability of a product and, together with consumer satisfaction, influences its marketability (Bharani and Mahendra Gowda, 2012).

Research on sewn joints in upholstery fabrics remains limited, with many upholstery material types and seam variants yet to be explored. To improve seam quality in upholstery, laboratory testing of selected seam variants is necessary. The objective of this study was to determine the effect of sewing thread fineness and construction on the strength of seams in a selected upholstery fabric.

MATERIALS AND METHODS

The test specimens were prepared from an upholstery fabric with a two-layer sandwich construction comprising two plain-weave fabrics. In the face (outer) fabric, the warp system is composed of multifilament yarns. In contrast, the weft system includes a combination of multifilament and chenille yarns (Fig. 1a). In the bottom (back) fabric, both the warp and weft systems are made of multifilament yarns (Fig. 1b). The properties of the tested material are summarized in Table 1.

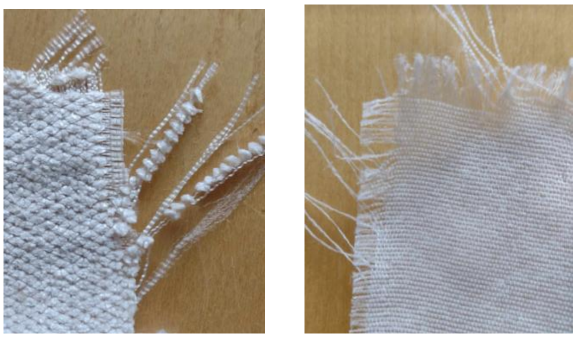


Fig. 1 Structure of upholstery fabric *LONDON*: (a) face side, (b) back side.

Tab.1 Properties of the upholstery fabric *LONDON*.

Material composition	Density (g/m^2)	Fabric breaking strength (N)		Face fabric density (thread/cm)		Back fabric density (thread/cm)	
97 % PES 3 % nylon	300	Warp	Weft	Warp	Weft	Warp	Weft
		898	801	36	21	26	14

The joining materials were sewing threads marketed under the trade names *SYNTON* and *BELFIL*. The properties of the sewing threads are listed in Table 2.

Tab. 2 Properties of *SYNTON* and *BELFIL* sewing threads.

Ticket number (Tkt)*	Material of threads	Fineness (tex)	Construction of threads	Thread breaking strength (N)
Synton 20	100 % PES	135	multifilament	50.80
Synton 30	100 % PES	90	multifilament	34.30
Belfil S 30	100 % PES	90	staple	35.17
Synton 40	100 % PES	70	multifilament	28.87

* The ticket number (Tkt) is a commercial numbering system used to indicate the linear density of sewing threads. It is an inverse system, threads with higher ticket numbers are finer, while those with lower numbers are coarser. Although not an SI unit, the ticket number provides a convenient reference for comparing thread sizes among different manufacturers and is roughly related to the linear density expressed in tex.

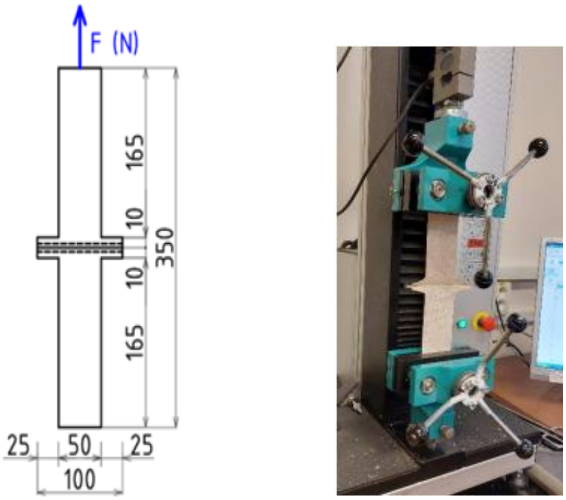


Fig. 2 The testing sample dimension and loading scheme.

Test specimens of sewn seams were produced using a Groz-Beckert 100/16 sewing needle with an R-type point, which is recommended for joining woven fabrics, on an industrial Juki 185 sewing machine operating at a constant sewing speed of 4,000 stitches per minute. The study focused on the parameters of seam type 1.01.01 with stitch type 301 in accordance with ISO 4915:1991, at stitch lengths of 3 mm, 4 mm, 5 mm, and 6 mm.

The mechanical properties of the sewn seams were evaluated following the methodology specified in ISO 13935-1. During the tensile test, the gauge length was set to 200 ± 1 mm and the loading rate to 100 mm/min. The seams were tested in both the warp and weft directions of the fabric, with eight specimens prepared for each direction. The loading scheme of the specimen and the test procedure are presented in Figure 2. Throughout testing, the maximum force acting on the seam was recorded, and the type of specimen failure was identified.

The influence of selected factors, namely stitch length, sewing thread fineness, and thread construction type on seam quality was evaluated in terms of seam efficiency. Seam efficiency is defined as the ability of the fabric material to support the seam and is expressed according to Equation (1):

$$P_s = \frac{F_{Smax}}{F_{FLmax}} \cdot 100[\%] \tag{1}$$

Where: F_{Smax} – seamed fabric strength (N);
F_{FLmax} – unseamed fabric strength (N).

RESULTS AND DISCUSSION

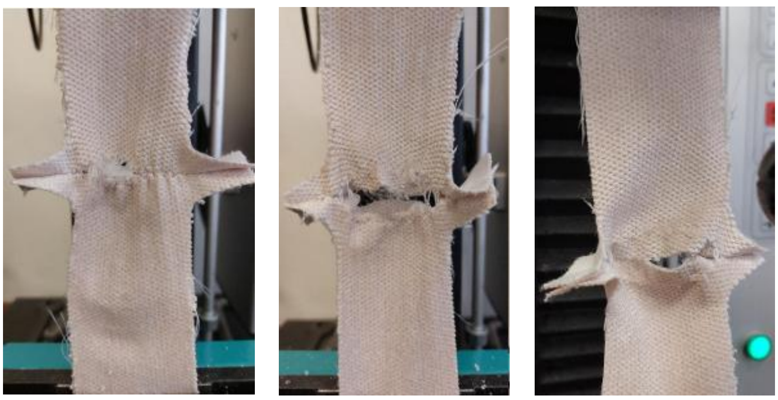
The experimental part of the study investigated the influence of sewing thread fineness and stitch length on the mechanical properties of sewn joints in the selected upholstery fabric. The experimentally determined mechanical properties of the sewn joints, in which the tensile load was applied in the weft direction of the fabric, are presented in Table 3.

Tab. 3 The average tested mechanical properties of the seam's upholstery fabric in direction weft.

Type of sewing thread	Stitch length (mm)	Seam strength $\overline{F_{max}}$ (N)	Coefficient of variation CV (%)	Seam efficiency (%)	Slip modulus (N/mm)
SYNTON 20	3	704.43	2.66	87.9	20.65
	4	682.43	2.56	85.2	20.42
	5	675.88	2.39	84.4	19.65
	6	609.54	5.05	76.1	17.67
SYNTON 30	3	650.36	5.46	81.2	21.08
	4	540.98	3.27	67.5	22.01
	5	451.57	6.08	56.4	20.01
	6	398.28	4.98	49.7	13.24
BELFIL 30	3	706.57	3.54	88.2	21.08
	4	531.56	5.66	66.4	19.09
	5	412.80	5.14	51.0	19.70
	6	386.17	6.10	48,2	16.09
SYNTON 40	3	573.60	2.58	71.6	20.75
	4	451.80	8.83	56.4	20.01
	5	403.92	1.88	50.4	19.27
	6	338.58	5.11	42.3	17.89

Based on the results presented in Table 3, a clear and statistically significant effect of sewing thread fineness on the maximum load capacity (*Fmax*) of the sewn seams was observed. The highest *Fmax* value (704.43 N) was recorded for the seam sewn with SYNTON 20 thread at a stitch length of 3 mm. For all examined thread types, increasing stitch length led to a gradual decrease in both *Fmax* values and seam stiffness. The seam efficiency of the joints loaded in the weft direction ranged from 87.9% to 42.3%. The lowest efficiency (42.3%) was observed for the seam made with SYNTON 40 thread at a stitch length of 6 mm.

Mechanical failure of the seams occurred under the maximum applied force (*Fmax*). When loaded in the weft direction, seams sewn with SYNTON 20 thread at stitch lengths of 3 mm and 4 mm exhibited rupture of the base fabric yarns (Fig. 3a). At a stitch length of 5 mm, a combination of slight fabric damage and complete thread breakage was observed (Fig. 3b). For all remaining seam variants tested in the weft direction, seam failure occurred due to thread breakage (Fig. 3c).



a) b) c)

Fig. 3 Damage to joints loaded in the weft direction
Synton 20.3 and 4 mm; b) Synton 20.5 mm; c) Syntom 30.5 mm.

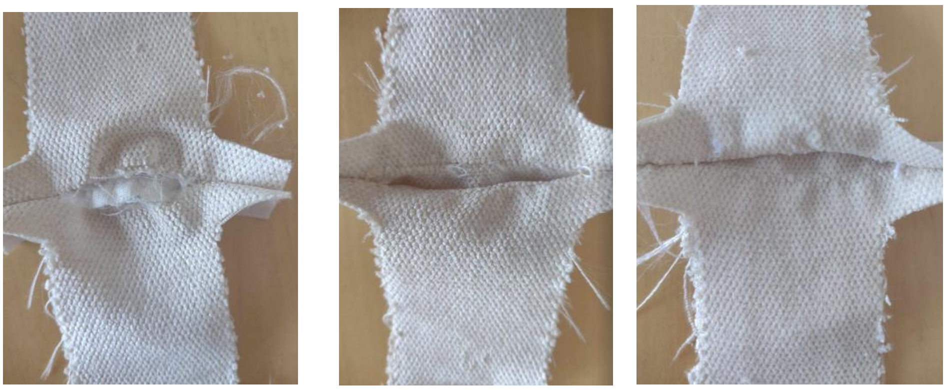
The experimentally determined mechanical properties of sewn joints in which the loading force acted in the warp direction of the fabric are shown in Table 4.

Tab. 4 The average tested mechanical properties of the seam's upholstery fabric in direction warp.

Type of sewing thread	Stitch length (mm)	Seam strength $\overline{F_{max}}$ (N)	Coefficient of variation CV (%)	Seam efficiency (%)	Slip modulus (N/mm)
SYNTON 20	3	778.09	1.95	86.6	22.54
	4	766.66	3.11	85.4	20.19
	5	758.20	4.23	84.4	20.72
	6	623.64	4.87	69.4	19.64
SYNTON 30	3	700.93	4.07	78.1	20.87
	4	581.65	4.37	64.8	20.70
	5	448.86	4.42	50.0	19.44
	6	370.42	5.96	41.2	13.93
BELFIL 30	3	691.69	4.03	77.0	22.08
	4	518.14	2.07	57.7	21.09
	5	452.01	5.34	50.3	20.00
	6	399.29	2.03	44.5	16.08
SYNTON 40	3	607.45	3.01	67.6	19.96
	4	468.13	5.72	52.1	20.01
	5	375.35	3.42	41.8	18.90
	6	316.43	5.58	35.2	17.02

For seams loaded in the warp direction, higher maximum strength values (F_{max}) were observed compared with seams loaded in the weft direction, which is consistent with the inherently greater tensile strength of the fabric in the warp direction. The highest F_{max} value (778.09 N) was recorded for the seam sewn with SYNTON 20 at a stitch length of 3 mm. As in the weft direction, seam strength decreased with increasing stitch length across all thread types, and seam stiffness (slip modulus) generally tended to decline as stitch length increased. The seam efficiency in the warp direction ranged from 86.6% (SYNTON 20, 3 mm) to 35.2% (SYNTON 40, 6 mm), with the lowest efficiency (35.2%) measured for the seam sewn with SYNTON 40 at 6 mm. Coefficients of variation were low overall (≈ 2–6%), indicating good repeatability of the measurements.

The failure modes observed at F_{max} were comparable to those identified in the weft direction. Specifically, rupture of the base fabric yarns occurred for seams sewn with SYNTON 20 at stitch lengths of 3 mm and 4 mm (Fig. 4a). At a stitch length of 5 mm, failure was characterized by thread rupture accompanied by limited damage to the fabric (Fig. 4b). For all remaining seam variants tested in the warp direction, failure occurred exclusively through thread rupture (Fig. 4c).



a) b) c)

Fig. 4 Damage to joints loaded in the warp direction
Synton 20.3 and 4 mm, b) Synton 20.5 mm, c) Syntom 30.4 mm.

The significance of the effects of the studied factors on seam strength was assessed using univariate ANOVA followed by Duncan's multiple range test (Table 5). The independent (main) effects of loading direction, stitch length, and sewing thread fineness were all statistically significant at the 5% level (Load Direction: $F = 23.35$, $p < 0.001$; Stitch length: $F = 714.99$, $p < 0.001$; Thread fineness: $F = 1065.36$, $p < 0.001$). Two- and three-way interactions were likewise significant, with the exception of the stitch length × loading direction interaction, which was only marginally significant ($F = 2.90$, $p = 0.036$). According to the F-test, thread fineness exerted the strongest effect on F_{max} ($F = 1065.36$).

Tab. 5 Table of three-factor analysis of variance.

Effect	Univariate Results Significance for FSmax Sigma-restricted parameterization Effective hypothesis decomposition			
	SS	DOF	F	p
Intercept	65365010	1	88462.39	0.000000
Load Direction	17251	1	23.35	0.000003
Stitch length (mm)	1584917	3	714.9	0.000000
Sewing thread fineness	2361583	3	1065.36	0.000000
Stitch length (mm)*Load Direction	6423	3	2.9	0.036347
Stitch length (mm)*Sewing thread fineness	329694	9	49.58	0.000000
Load Direction*Stitch length (mm)	47711	3	21.52	0.000000
Sewing thread fineness*Stitch length (mm)*Load Direction	52341	9	7.87	0.000000

Graphically, the influence of the watched factors, i.e. the fineness of the sewing thread and the stitch length, on the F_{max} of sewn joints loaded in the warp and weft directions is shown in Figure 4.

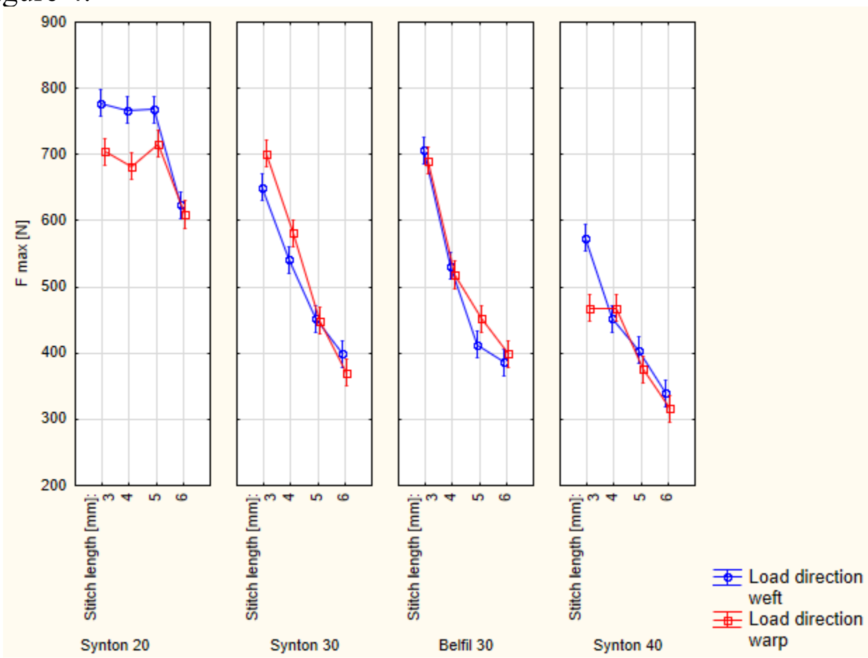


Fig. 5 The effect of the sewing thread fineness and stitch length on the strength stitched joint.

Based on the evaluation of all experiments, sewing thread fineness (thickness) is a significant determinant of seam strength. Coarser threads produced higher *Fmax*, with the highest values recorded in the warp direction (778.09 N, SYNTON 20) and, for the weft direction, 706.57 N (BELFIL 30). This is consistent with the ANOVA, in which thread fineness exerted the strongest effect on *Fmax* (F = 1065.36, p < 0.001). Increasing stitch length from 3 to 6 mm generally reduced both seam strength and stiffness (slip modulus) across all thread types; seam efficiency ranged from 87.9% to 42.3% in the weft and from 86.6% to 35.2% in the warp direction. Coefficients of variation were low (2–6%), indicating good repeatability. These findings are in agreement with the results reported by Gurarda (2008), Bhavesh *et al.* (2018), and Mukhopadhyay *et al.* (2004), who also found that increased thread fineness (coarser yarns) and shorter stitch lengths contribute to higher seam strength in woven fabrics.

Regarding failure modes, fabric rupture (yarn breakage in the base fabric) was observed at shorter stitch lengths (3–4 mm) with the coarser SYNTON 20 thread, whereas at longer stitches (5–6 mm) failure was predominantly by thread breakage; at 5 mm, a mixed mode (minor fabric damage plus complete thread rupture) occurred occasionally. These observations indicate that needle-induced damage was not the controlling factor in strength reduction: fabric rupture arose mainly from higher local stresses at shorter stitches and larger thread diameter, while at longer stitches the thread itself became the limiting element. A similar pattern of failure behavior was reported by Al Sarhan (2011) and Oztas and Gurarda (2019), who observed a transition from fabric rupture to thread breakage with increasing stitch length, attributed to load redistribution and reduced stitch density.

Interaction effects among stitch length, load direction, and thread fineness were broadly significant (including the three-way interaction, p < 0.001), underscoring that optimal seam parameters must be selected in combination rather than in isolation. These statistical relationships align with findings by Wang *et al.* (2001), who also demonstrated significant interaction effects among sewing parameters, indicating that the mechanical response of seams results from the combined influence of multiple variables rather than any single factor.

CONCLUSION

The production of three-dimensional upholstery covers is a process in which two-dimensional upholstery fabrics are transformed into three-dimensional forms by assembling individual components. This transformation is achieved through sewn joints, which are a critical quality factor in an upholstered product. Based on the experimental results, the following conclusions can be drawn:

- The strength of the seam in the tested upholstery fabric depends on the loading direction, fineness of the sewing thread, and stitch density (stitch length);
- Higher *Fmax* values were recorded for seams loaded in the warp direction compared to those loaded in the weft direction, corresponding to the higher tensile strength of the fabric in the warp direction;
- Among the investigated parameters, sewing thread fineness was identified as the most influential factor affecting seam strength (confirmed by ANOVA; F = 1065.36, p < 0.001);
- As sewing thread fineness increased (thinner thread), seam strength (*Fmax*) decreased.
- Seam strength and stiffness (N/mm) decreased with increasing stitch length (3–6 mm) across all tested thread types and load directions;
- These results confirm that both stitch length and thread fineness must be optimized jointly to ensure higher seam performance and durability of upholstery fabrics.

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