



## Simulation of 301 lockstitch at different stitch densities for the prediction of sewing thread consumption

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Article Information	Abstract
<p><b>Article history:</b></p> <p>Received: 2025-09-06</p> <p>Accepted: 2026-02-17</p>	<p>Sewing threads are a critical component in garment manufacturing, and accurate prediction of their consumption is essential for efficiency and cost reduction. This study employs CATIA software to simulate 3D modeling of a 301 lockstitch under varying stitch densities and thread counts. The simulation determines the required sewing thread length for producing this stitch type, incorporating the physical properties of sewing threads and fabric layer thickness. Three stitch densities (3, 4, and 5 stitches per centimeter, SPC) were modeled, with fabric thickness measured using a digital thickness gauge to enhance accuracy compared to conventional computational approaches. Validation was performed by comparing simulation outputs with experimental values obtained through the unraveling technique and with results from established geometrical-based model methods. The findings demonstrated that the CATIA-based simulation achieved high accuracy (2.62 % error) in predicting sewing thread consumption, outperforming conventional geometric approaches. Furthermore, this study highlights the influence of stitch density and fabric thickness on thread usage and establishes a reliable computational framework for industrial applications. Unlike earlier studies that relied primarily on mathematical or geometrical approximations, the novelty of this research is the use of advanced CAD simulation (CATIA V5R21) combined with experimentally measured fabric thickness to predict sewing thread consumption, providing a more accurate and versatile framework for garment manufacturing.</p>
<p><b>Keywords:</b></p> <p>Sewing Thread Consumption, Simulation, 301 Lockstitch, Stitch density, CATIA Software.</p>	

### 1 INTRODUCTION

Every garment is composed of several fundamental components, including fabrics, linings, accessories, and sewing threads. Among these, sewing threads play a particularly important role. They are used not only to join the different parts of a garment but also serve a decorative purpose, such as in embroidery. Selecting a sewing thread of high quality, with the appropriate type and count, is essential for enhancing the durability and overall quality of garments. Proper thread choice also minimizes breakage and reduces common sewing issues such as stitch skipping in an industrial sewing machine, thereby lowering production time and costs. Accurately predicting the required quantity of sewing threads with the specified characteristics can significantly influence the final product cost and reduce excess inventory. Excess sewing threads in production lines can create disorder and increase the risk of errors, such as selecting the wrong color. Conversely, underestimating the required quantity of sewing thread for a specific order may cause interruptions or delays in completing the order.

Moreover, when special and costly types of sewing threads are used, accurate prediction of their required quantity

becomes even more critical. According to ASTM D-6193, Standard Practice for Stitches and Seams, stitches are classified into six main categories, each further divided into multiple subclasses. Referring to the literature, several approaches have been proposed for predicting sewing thread consumption across different stitch classes. These include statistical and mathematical methods, fuzzy logic, artificial neural networks [1-10], and geometric modeling [11-24]. Geometric modeling, a branch of applied mathematics, utilizes geometrical and actual profiles to represent and analyze stitch structures.

In the subsequent sections, procedures based on the use of actual stitch profiles will be presented to predict sewing thread consumption in stitch class 300. Ghosh et al. introduced a geometric modeling approach to estimate sewing thread consumption by analyzing the original cross-section of a 301 lockstitch in woven fabrics. Their model incorporated several critical parameters, including fabric thickness, feeding rate, thread diameter, sewing machine velocity, and the position of the cross-over point. By integrating these variables, the model provided a versatile framework capable of predicting thread consumption across different stitch

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formation conditions, such as balanced and unbalanced stitches [12]. Rasheed et al. developed a predictive model for sewing thread consumption that utilized the fundamental geometry of the 301 lockstitch. To ensure the reliability of the model, 19 experimental samples were prepared, incorporating variations in stitch density, fabric ply thickness, and the length of interlaced parts. The validation process confirmed that the model achieved a high level of accuracy in estimating thread consumption across diverse sewing conditions [13]. Boubaker et al. examined sewing thread consumption in relation to stitch density, fabric thickness, and the number of assembly layers by comparing experimental data with regressive and geometrical modeling approaches for 310 and 401 stitch types. Their analysis revealed that fabric thickness exerted a pronounced influence on thread consumption across both stitch configurations, underscoring the importance of material properties in sewing performance. Furthermore, the regressive model exhibited a higher degree of correlation with experimental results compared to the geometrical model, suggesting that statistical regression provides a more reliable predictive framework for estimating thread usage [14]. Chavana et al. proposed a geometrical modeling approach for sewing thread consumption by incorporating the actual elliptical profile of the 301 lockstitch. To validate the model, they tested multiple fabric configurations, including woven, knit, and nonwoven fabrics, arranged in varying numbers of layers and three distinct stitch densities. The analysis demonstrated that increases in ply number and stitch density reduced the efficiency of the model, reflecting the complexity introduced by thicker and denser assemblies. Despite this limitation, comparative evaluation against other available models showed that Chavana's approach achieved higher accuracy in predicting thread consumption [17]. Sarah et al. proposed geometrical models to predict sewing thread consumption for multiple stitch types within stitch class 300, aiming to improve efficiency in garment manufacturing. Their study focused on key parameters such as the thickness of six different denim fabrics, stitch density, and the linear density of sewing threads. To strengthen the reliability of the predictions, a statistical method was also employed alongside the geometrical modeling. The comparative analysis revealed that the geometrical models provided highly accurate estimates of thread consumption, outperforming other approaches [20]. Chauhan et al. developed an equation to predict sewing thread consumption by utilizing the authentic image of a 301 lockstitch. Their approach incorporated three different geometrical modeling techniques: elliptical, racetrack, and circular to evaluate the accuracy and applicability of thread consumption calculations. Comparative analysis revealed that the racetrack model

provided superior performance, being both simpler and more versatile than the elliptical and circular models. Moreover, it achieved higher accuracy in estimating thread usage for 301 lockstitch configurations [24].

Accurate prediction of sewing thread consumption directly influences garment-manufacturing costs and profit margins. A review of the literature on sewing thread consumption prediction revealed no studies that employed mechanical design programs, such as CATIA software, for predicting and calculating sewing thread consumption. The 301 lockstitch, composed of two groups of sewing threads- needle and bobbin threads- is one of the most widely used and recognized stitch types in both home sewing and industrial garment production. This research aims to employ CATIA software to simulate the precise geometry of the 301 lockstitch under varying stitch densities (stitches per centimeter, SPC) and sewing thread counts. Through this approach, sewing thread consumption- calculated separately for both needle and bobbin threads- can be determined without the need for a complex formula. Unlike earlier studies that relied primarily on mathematical or geometrical approximations, the novelty of this research is the integration of CAD-based simulation with measured fabric thickness values, enabling more precise prediction of sewing thread consumption and reducing error compared to conventional models.

## 2 Material and Methods

### 2-1 Material

To verify the validity of the simulated model, an experimental sewing method was employed. A polyester/viscose woven fabric was selected to accomplish this objective. The properties of the woven fabric specimens were determined using testing instruments under controlled and standard conditions after performing five separate tests. Fabric ply thickness was measured with a Digital Thickness Gauge (Model M034a) in accordance with the ASTM D-1777. The average values obtained from these measurements were calculated and presented in Table 1.

An industrial brother SL-7340 sewing machine, operating with the 301 lockstitch, was used to join two fabric plies. Two types of sewing threads were employed: polyester and polyester/viscose spun threads, with counts of 40/2 and 30/2, applied as needle and bobbin threads, respectively. Six distinct seams were sewn using three stitch densities and two sewing thread counts (identical for both needle and bobbin threads), as shown in Table 2. All seams were prepared with the SSA-1 seam type, and a needle size of 90 Nm was used.

**Table 1 Properties of the woven fabric specimen**

Weave type	Weight g/m <sup>2</sup>	Thickness(mm)	Warp density (ends/cm)	Weft density (picks/cm)	Warp count(N <sub>e</sub> )
Twill	190±2	0.28	36	26	18

**Table 2 Details of samples coding**

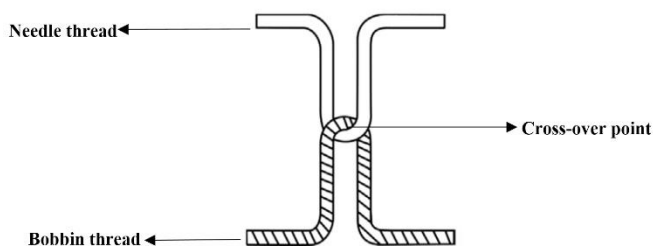
No.	Sample code	Stitch density	Sewing thread count
1	1-5-40/2	5	40/2
2	2-4-40/2	4	40/2
3	3-3-40/2	3	40/2
4	4-5-30/2	5	30/2
5	5-4-30/2	4	30/2
6	6-3-30/2	3	30/2

## 2-2 Simulation of the 301 lockstitch with seam and measurement of sewing thread consumption using CATIA software

In this study, a 3D model based on the actual profile of the 301 lockstitch with seam was designed and developed. To achieve this, the design and simulation capabilities of CATIA V5R21 software were utilized. The term seam refers to the assembly of two fabric plies joined together by the 301 lockstitch and created SSA-1 seam type. The simulation therefore included both the stitch geometry and the sewn fabric layers, providing a realistic representation of the seam structure. Several assumptions were considered in the design of the simulated model, including:

- All sewing threads were considered circular in their cross-section.
- The fabric thickness was assessed in accordance with the result of the fabric thickness gauge.
- Plies of sewn fabric were considered to be a continuous shell.
- The deformation of sewing threads and fabrics during the sewing process and after it is neglected.
- The stitches were formed balanced, meaning equal tension between the needle and bobbin threads was assumed.

Yarn tension is an important factor influencing stitch length; it was not explicitly modelled in this study. This simplification allowed us to focus on stitch density and fabric thickness while minimizing tension-related variability. As shown in Fig.1, each unit of the 301 lockstitch consists of two threads- needle and bobbin- and a cross-over point where the two threads entwine together.



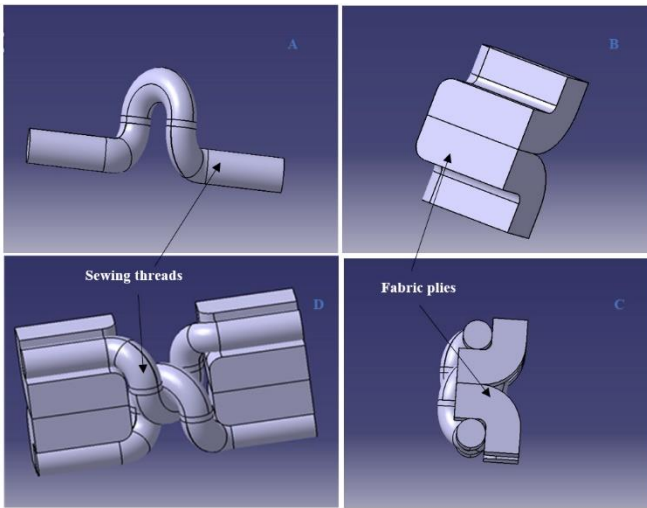
**Figure 1 The Schematic of 301 lockstitch geometry [25]**

The components of the 301 lockstitch, along with two fabric plies sewn together in six distinct configurations-three stitch densities and two sewing threads count- were meticulously designed step by step in CATIA software and subsequently assembled. The first step involved simulating the shape of the fabric plies. In the simulation, the fabric plies were modeled as continuous shells with a measured thickness. In the second step, the diameters of the sewing threads and the stitch lengths required for the simulation were calculated using Equations (1) and (2), based on the characteristics of the sewing threads and the stitch densities presented in Tables 1 and 2.

$$\text{Diameter of sewing thread : } d(\text{inch}) = \frac{1}{28 \times \sqrt{N_e}} \quad (1)$$

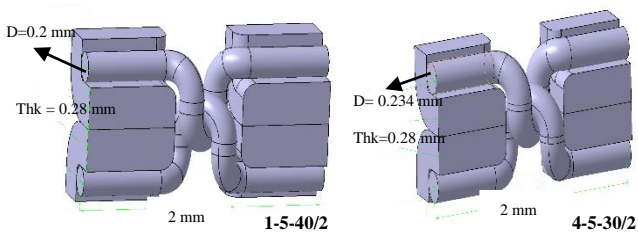
$$\text{Stitch length (mm)} = 10 / \text{SPC} \quad (2)$$

In Equation (1), 'd' represents the diameter of the yarn or thread in inches, and 'Ne' denotes the yarn count in the English system. Based on this equation, the diameters of sewing threads with counts of 40/2 and 30/2 were calculated as 0.202 mm and 0.234 mm, respectively. Furthermore, the stitch lengths corresponding to three, four, and five stitches per centimeter were 3.3 mm, 2.5 mm, and 2.0 mm, respectively. In the next step, and based on Fig. 1, Table 2, and the values obtained previously, the bobbin and needle threads were simulated. To ensure accuracy, both threads were modeled with their calculated diameters and stitch lengths, then interlaced at the midpoint of the fabric to form a balanced 301 lockstitch. Balance was achieved by assuming equal tension between the needle and bobbin threads, so that the cross-over point remained centered within the fabric thickness. This assumption, as mentioned before, reflects the standard lockstitch mechanism, where uniform thread tension prevents seam distortion and ensures structural ability. In the simulation, to accurately represent this area, the curve of the entwined section was divided into seven distinct segments (Fig. 2-A). This segmentation was determined to be the optimal and minimum number of divisions required to achieve the most precise intersection between the two threads, ensuring that the lockstitch geometry was faithfully reproduced in the model. Ultimately, the fabric plies together with the entwined bobbin and needle threads were assembled to construct the final 301 lockstitch seam simulation model (Fig. 2A-B). The fully prepared three-dimensional model, along with the sequential steps of its development, is illustrated in Fig.2.

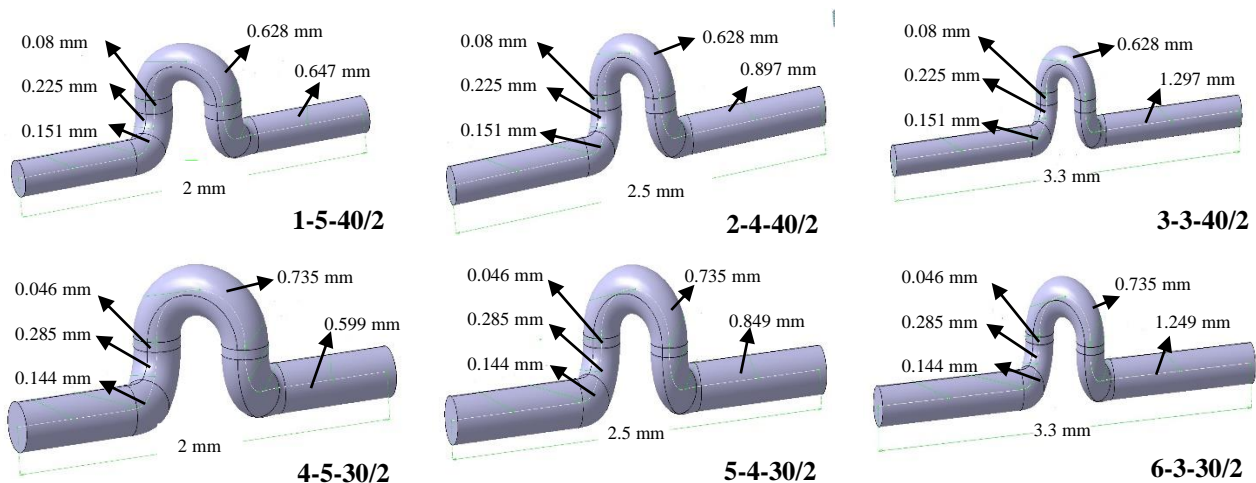


**Figure 2** Steps of the simulation and the final of 301 lockstitch seam model, A- simulation of sewing thread, B- simulation of fabric plies, C- assembly of fabric plies and threads, and D- entwining of needle and bobbin threads

Based on the properties listed in Tables 1 and 2, six different models of the simulated 301 lockstitch were developed, each characterized by its specific parameters. (The models incorporated combinations of three, four, and five stitches per centimeter, together with sewing threads of different count (30/2 and 40/2), to reflect the range of practical conditions encountered in woven fabric seams. By systematically varying these parameters, the simulation provided a comprehensive set of seam models that enabled the evaluation of sewing thread consumption under diverse structural conditions.) Figure 3 presents two of the simulated models with a stitch density of 5, constructed using sewing threads of 40/2 and 30/2 Ne counts.



**Figure 3** Schematic modeling of 301 lockstitches using sewing thread of 40/2 and 30/2 Ne counts at 5 SPC



**Figure 4** Nine sequential steps to determine the length of a single bobbin thread in each stitched sample

The Measure Toolbox of CATIA software was employed to obtain simulation results for sewing thread consumption in the 301 lockstitch seam. This tool enabled the measurement of the length of all components of a single stitch in millimeters, providing detailed quantitative data for subsequent analysis. In this simulation, each sewing thread (needle or bobbin) of the modeled stitch was divided into nine distinct segments, as shown in Fig. 2. Four of these segments were symmetrical, reflecting the balanced structure of the stitch and ensuring that the interlacing of the needle and bobbin threads was modeled consistently. By capturing both the unique and symmetrical components of each thread, the simulation achieved a precise representation of the stitch geometry, which was essential for accurate measurement of thread consumption. Figure 4 presents the segmentation and corresponding lengths of the bobbin thread across six different forms of stitched samples.

### 2-3 Experimental measurement of sewing thread consumption

For validation of the model, six forms of the 3D simulation of the 301 lockstitch seam were compared with experimental measurements of sewing thread consumption. The experimental outcomes were obtained using the unraveled-stitches technique, which allowed the actual thread length in each seam sample to be measured and contrasted with the simulated results. In the unraveled-stitches technique, the bobbin and needle threads of a given gauge were carefully unraveled and straightened separately to eliminate waviness before measuring their lengths. This step was critical because residual crimp or curl in the threads could artificially increase their apparent length, leading to overestimation of consumption. The accuracy of this procedure was essential for validating the simulation results, as even a small deviation in measured length could significantly affect the comparison between experimental and modeled values. For this purpose, ten lines of 301 lockstitches were sewn for each of the six sample forms, with each line measuring 20 cm in length. Sewing multiple lines under controlled conditions ensured reproducibility of the results and minimized random error in thread consumption measurements.

After 24 hours of relaxation in a standard environment, five stitch lines were marked to be unraveled over a 10 cm section in order to eliminate starting and ending effects. This controlled relaxation period ensured that the threads reached equilibrium in terms of tension and dimensional stability before measurements. By focusing on the central portion of the stitch line, the influence of thread handling at the beginning and end of sewing was excluded, thereby improving the accuracy of the experimental results. This procedure provided a consistent basis for comparing the measured thread lengths with the simulated values, strengthening the reliability of the validation process. In five stitch lines, the needle threads were unraveled, while the bobbin threads were straightened to remove crimp before their lengths were measured. In the remaining five lines, the procedure was reversed: the bobbin threads were unraveled, and the needle threads were straightened to eliminate crimp before measurement. This dual approach ensured that both thread types were evaluated independently under identical conditions, thereby eliminating bias in the measurement process.

#### 2-4 Prediction of sewing thread consumption based on other models

Another approach to evaluate the validity of the simulation using CATIA software is to calculate the error percentage of sewing thread consumption prediction based on three other models presented by different researchers, and then compare these values with the error percentage of the simulated model. The three models consisted of mathematical, elliptical, and geometrical models, all of which utilized the actual stitch geometry for their modeling approach. Jaouadi et al., based on a mathematical model, presented Eq. (3) for predicting sewing thread consumption in 301 lockstitches[26]:

$$Q_{301} = 2 \times L \times (1 + 2 \times n \times e + n \times d \times (\pi - 1)) \quad (3)$$

Where  $Q_{301}$  is sewing thread consumption,  $L$  is the sewing length,  $n$  is the stitch density,  $e$  is the fabric thickness, and  $d$  is the sewing thread diameter. Chavan et al., using an elliptical model, proposed Eq. (4) for predicting of sewing thread consumption in a 301 lockstitch[17]:

$$T_{301} = \pi \times \left[ 3 \times (a + b) - \sqrt{10 \times a \times b + 3 \times (a^2 + b^2)} \right] + 0.0111 \sqrt{N_t} \quad (4)$$

$$a = 0.5 \times \left[ \frac{1}{S} - 0.000512 \times \sqrt{N_t} \right], \quad b = \frac{(n \times t + 0.00398 \times \sqrt{N_t})}{2}$$

Which are in terms of fabric thickness 't' (cm), number of plies 'n', stitch density 's', thread linear density 'Nt' (Tex), and  $T_{301}$  is the sewing thread consumption. Finally, Rasheed et al. and Sarah et al. presented a similar equation, Eq. (5), by employing a geometrical model of 301 lockstitches for predicting sewing thread consumption [13, 20]:

$$Q_{301} = SPC \left( 2 \times \left[ \left( \frac{1}{SPC} \right) - \left( 3 \times \left( \frac{0.375}{100} \right) \times \sqrt{Y} \right) + e \right] + (3.53 \times 10^{-2} \times \sqrt{Y}) \right) \quad (5)$$

Where  $Q_{301}$  is sewing thread consumption,  $e$  is the thickness of fabric plies,  $SPC$  is stitch density, and  $Y$  is yarn linear density in Tex. Ultimately, the average of these six error percentages is considered the precision criterion for each model. It should be noted that, for all models and corresponding calculations based on the properties of the samples, the fabric thickness is expressed as the measurement obtained from the fabric thickness instrument.

### 3 Results and discussion

As explained above, the experimental values were obtained by measuring the length of either the bobbin or needle threads for six different forms of 301 lockstitch seams. Subsequently, the average of five measurements for both the bobbin and needle threads was calculated, and ultimately, the sum of these two average values was considered the thread consumption for 301 lockstitches in 10 cm of the stitch line. Table 3 presents the results of these measurements.

**Table 3 Experimental measurements of sewing thread consumption for 10 cm stitch line**

Sample code	Average of measured needle thread length(cm)	Average of measured bobbin thread length(cm)	SUM
1-5-40/2	14.6	13.1	27.7
2-4-40/2	14.4	12.5	26.9
3-3-40/2	13.8	12.3	26.1
4-5-30/2	15.2	14.4	29.6
5-4-30/2	13.9	13.5	27.4
6-3-30/2	13.1	13	26.1

The total lengths of the needle or bobbin threads derived from the models shown in Figure 4 are presented in Table 4.

**Table 4 Simulation results for Needle/Bobbin threads length for unit stitch**

Sample code	The sum of parts length of Needle or Bobbin threads(mm) in a single unit of 301 lockstitch, based on CATIA simulation
1-5-40/2	2.834
2-4-40/2	3.334
3-3-40/2	4.134
4-5-30/2	2.883
5-4-30/2	3.383
6-3-30/2	4.183

Finally, the thread consumption for a 10 cm length of the stitch line for each stitch and seam type, calculated according to Eq.(6), is presented in Table 5. As postulated, the stitches were balanced, and thread consumption estimated from the simulation results for one unit stitch was considered the sum of both the needle and bobbin threads.

Length of sewing threads (cm) for 10 cm stitch line =

Number of sewing threads  $3SPC3$ stitch line length $3$ Sum of parts length of Needle or Bobbin threads(mm) in single unit 301 lockstitch. (6)

The error percentages of the simulated model and the other models described above for predicting of sewing thread consumption are presented in Table 6. To calculate the error percentage, Eq.(7), was applied.

$$\%Error = \frac{\text{experimental values} - \text{simulation results}}{\text{experimental values}} \times 100 \quad (7)$$

The results of the simulated modeling indicate an average error of 2.62% in predicting sewing thread consumption. Although the geometrical model (Eq. 5) showed a slightly lower average error percentage (2.125%) compared to the CATIA simulation (2.62%), this outcome is specific to the tested fabric and stitch densities. The geometrical model is

based on simplified assumptions, whereas the CATIA simulation integrates measured fabric thickness and detailed 3D geometry, making it more versatile and adaptable to diverse sewing conditions. As reported in previous studies, the thickness of fabric plies is one of the key parameters in calculating sewing thread consumption. Traditionally, this has been determined using theoretical formulas; however, the observed error demonstrates that employing a fabric thickness gauge tester for modeling provides a more accurate approach.

This finding highlights that incorporating fabric thickness values measured directly with a gauge tester significantly reduces prediction error, thereby strengthening the accuracy and reliability of the simulated modeling results. Furthermore, sewing thread tension can alter the cross-section of the sewing threads. These variations primarily influence the length of the interlacing area; however, their overall effect on the final results is minimal. By conducting a comparative study of mathematical, elliptical, and geometrical modeling alongside 3D simulation modeling, it was found that the latter demonstrates a higher level of accuracy in predicting sewing thread consumption. The CAD-based simulation results can serve as a foundation for deriving simplified mathematical formulas, enabling faster prediction of sewing thread consumption while retaining the accuracy of the 3D modeling approach.

**Table 5 Sewing thread consumption prediction by CATIA simulation**

Sample code	Prediction length of Needle and Bobbin threads(cm) for 10 cm seams
	According to Eq.6
1-5-40/2	23531030.2834=28.34
2-4-40/2	23431030.3334=26.672
3-3-40/2	23331030.4134=24.804
4-5-30/2	23531030.2883=28.83
5-4-30/2	23431030.3383=27.064
6-3-30/2	23331030.4183=25.098

**Table 6 Comparison of the presented simulation model with other models**

Sample code	Calculation of sewing thread consumption by different techniques (cm)				
	Simulation model- %error	mathematical model .Eq.(3)-%error	elliptical model .Eq.(4)-%error	geometrical model .Eq.(5)-%error	Experimental results
1-5-40/2	28.34-%2.31	29.88- %7.87	28.56-%3.10	29.08-%4.98	27.7
2-4-40/2	26.672-%0.8	27.904-%3.73	25.82-%4.01	27.264-%1.35	26.9
3-3-40/2	24.804-%4.96	25.928- %0.65	23.24-%10.95	25.248-%3.26	26.1
4-5-30/2	28.83-%2.6	30.6076-%3.4	27.24-%7.97	29.62-%0.06	29.6
5-4-30/2	27.064-%1.22	28.486-%3.96	25.08-%8.46	27.696-%1.08	27.4
6-3-30/2	25.098-%3.83	26.364-%1.01	24.08-%7.42	25.572-%2.02	26.1
<b>Average of %Error</b>	%2.62	%3.33	%6.985	%2.125	

## 4 Conclusion

Accurate prediction of sewing thread consumption is a critical issue for apparel manufacturers and an important subject of investigation for many researchers. In this research, the applicability of the mechanical design software CATIA V5R21 for modeling stitches and seams was examined. The approach enables quick and accurate prediction of sewing thread consumption without the need for complicated mathematical formulas. The obtained results revealed that the simulated models of the 301 lockstitch were capable of predicting sewing thread consumption with high precision and acceptable accuracy when compared to other modeling techniques. It should be noted that the prediction of sewing thread consumption by all of the presented techniques differs from the actual amount due to waste, thread breakage, and other factors that occur during industrial production. In this research, the actual measured fabric thickness was utilized for modeling, demonstrating that this factor enhanced the predictive power and accuracy of the results. This approach has the potential to be extended to all types of stitches and seams, thereby assisting manufacturers in accurately predicting sewing thread consumption. This study demonstrates that integrating 3D simulation modeling with measured fabric parameters provides a reliable and efficient method for predicting sewing thread consumption, offering both scientific advancement and practical value for the apparel industry. While certain geometrical models may yield lower error percentages under specific conditions, the CATIA-based simulation offers broader applicability by incorporating measured fabric parameters and realistic stitch geometry. This versatility ensures higher reliability when extended to different stitch types, seam structures, and industrial applications. Beyond sewing thread consumption, this modeling framework may also be adapted to other textile engineering challenges that require precise prediction, such as seam strength analysis or fabric deformation studies. The improvement in predictive accuracy can support manufacturers in minimizing material waste, optimizing production efficiency, and advancing sustainable practices. Future work will extend the CATIA-based simulation to incorporate variable yarn tension, which is a critical factor in stitch formation and may further improve the accuracy of sewing thread consumption prediction. Although CAD-based simulation provides high accuracy, it can be time-consuming for routine industrial use. Therefore, future work will focus on deriving simplified mathematical formulas from CAD-based results, enabling faster prediction of sewing thread consumption while retaining the accuracy of the simulation framework.

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