IMPROVE BUILDING DATABASE ON THE OPERATION PROCESS AND PERFORMANCE TIME FOR SEWING OPERATIONS OF KNITTED GARMENT PRODUCTS

THAO, PHAN THANH* AND PHAN, DUY-NAM

Hanoi University of Science and Technology, Hanoi 10000, Viet Nam

ABSTRACT

This paper presents the findings of the study of building and completion of a standard database on the operation process and sewing time for 02 typical products from knitted fabrics, namely Polo-Shirt and T-Shirt. The study process is carried out based on applying MTM (Methods Time measurement) standard time analysis method and predetermined time system GSD (General Sewing Data). In this research, we have inherited the results from previous studies including Classifying the main parts sewing linkages, formulated sewing technology process and theoretical analysis of the process of manipulating sewing of the main parts, linkages of the 02 classical textile products including Polo-Shirt and T-Shirt by MTM standard time analysis method and GSD predetermined time system; The studies work of the group of authors on the experimental research content determines the simultaneous influence of a group of factors: distance to place the sewing element (cm), the rotation angle of the sewing element (˚), the size of the sewing element, the number of element layers involved in the sewing, the light intensity (lux) and the skills of sewing workers (grade worker) to the sewing time of knitting products and research simultaneous influences of a group of technological factors including: seam length (cm) and stitches per centimeter (stitches/cm), experiment on 4 sewing devices such as 1-needle lockstitch machine, overlock machine (1 needle and 3 threads) and (2 needles and 4 threads), coverstitch machine (2 needles and 3 threads); and with 3 kinds of single jersey fabrics, which are thin, medium, and thick fabrics to sewing time on the machine of Polo-Shirt and T-Shirt products. The above research results show that there is a big difference between the actual values and theoretically calculated values according to MTM method, GSD predetermined time system, the authors have determined a set of adjustment coefficients for the former and the latter for two values of sewing preparation operation time and sewing time on the machine. We have tested the above research results in 03 enterprises: Hanoi Star Fashion Co., Ltd., Tinh Loi Garment Company and Ha Nam Hanosimex Company Limited and received a lot of practical comments from businesses.

KEYWORDS

Motion study; Time study; GSD; MTM; Database; Knitted garment products.

INTRODUCTION

Industry 4.0 has been spreading globally, strongly affecting all social life activities, including the textile industry. The application of scientific and technological achievements to production is labor - the most effective solution to increase labor productivity, reduce production costs and increase the competitiveness of enterprises. The introduction of MTM standard time analysis method and GSD predetermined time system marked a new step in improving the time and process in manufacturing. But it is always a time difference between standard sewing operation procedure and actual production. Because the labor level is still low, mainly blue-collar workers, there are many redundant operations in the production process, leading to large processing times and low productivity. Realizing this, the author has built a database on the operation process and sewing time of typical knitted products, namely Polo-Shirt and T-Shirt. This database is a manual to help businesses come up with a reasonable sewing process and time by actual production conditions.

Currently, there have been several research works on this issue. Habibur Rahman et al. [1] has researched analyzing the movements and actions of garment workers. Phan Thanh Thao et al. [2] has studied the factors affecting productivity in garment industry enterprises. Phan Thanh Thao et al. [3] researched and proposed solutions to improve garment workers for operation and working speed. Dinh Mai Huong et al. [4] studied the influence of the sewing process on productivity. Phan Thanh Thao et

* **Corresponding author:** Thao, P.T., e-mail: thao.phanthanh@hust.edu.vn

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al. [5] have built a database on the operation process and sewing time of knitted products. Dinh Mai Huong et al. [6] studied and built the adjustment coefficient for preparation and sewing time on the machine of GSD and MTM, sewing products from knitted fabrics in Vietnamese conditions.

In this article, the authors present the research results of building a complete database on the operation process and execution time of sewing two typical knitted products: Polo-Shirt and T-Shirt with the following contents:

- Synthesize the data set on the operation process and sewing time (the preparation sewing tp and the sewing time on machine tm) from previous studies.
- Collecting actual data on the sewing technology process and time of detail assemblies, seams of two products, and conducting a comparative analysis of the operation process and sewing time of data each pair obtained from Hanoi Textile and Garment Joint Stock Corporation in Ha Nam (Hanosimex) and Tinh Loi Garment Company Limited with the results developed by the research team BKG (Bach Khoa Group).

Proposing a complete database on the operation procedure and the sewing time (sewing preparation time *tp* and time on machine *tm*) reasonable to detail assemblies, and seams of Polo-Shirt and T-Shirt products under different manufacturing conditions. From that, progress to complete the database for all detail clusters, seams of two product categories Polo-Shirt and T-Shirt.

EXPERIMENTAL

Research subjects

Theoretical research object

Polo-Shirt and T-Shirt products in theoretical research are inherited from previous research works of the authors [6]. These products have a structure of detailed clusters and seams that ensure the diversity, richness, and universality of all technological structural options of the Polo-Shirt and T-Shirt product categories and are suitable for actual garment enterprises as presented in Table 1.

Experimental research object

Selected subjects for the experimental survey were Polo-Shirt PE19, T-Shirt DHA19-024/OCKS0025 manufactured at Hanosimex and Polo-Shirt with code DC1963, T-Shirt with code 142N212 at Tinh Loi Garment Co., Ltd. To maintain brevity, we refer to Polo-Shirt PE19 and T-Shirt DHA19-024/OCKS0025 as P1 and T1, respectively, and Polo-Shirt DC1963 and T-Shirt 142N212 at Tinh Loi Garment Co., Ltd as P2 and T2, respectively.

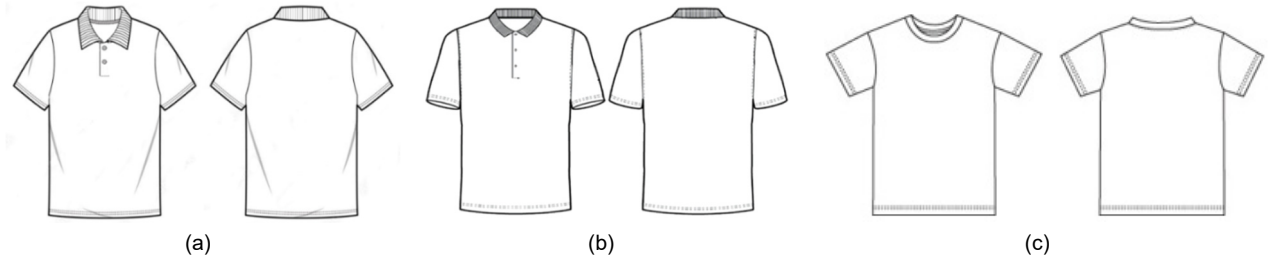
Research Polo-Shirt has the following characteristics:

- P1, Figure 1 (a): Closed collar without legs, woven neckband, body fabric neckline, skewed placket, 2-needle chains bottom hem and sleeve opening. Fabric used for sewing is Single fabric with material composition: 55% cotton mixed with 45% polyester, weight: 180 g/m^2, horizontal density: 130 (column loops/100 mm), vertical density: 210 (row loops) /100 mm), fabric thickness: 0.15 (mm), yarn count: Ne = 18 (m/g).
- P2, Figure 1 (b): Closed collar without legs, woven neckband, woven tape neckline, fold of edge placket and skewed placket, 2-needle chains bottom hem and sleeve opening. Fabric used for sewing is Single fabric with 100% polyester material composition, weight: 145 g/m^2, horizontal density: 150 (column loops/100 mm), vertical density: 210 (row loops/100 mm), fabric thickness: 0.15 (mm), yarn count: Ne = 18 (m/g).

Researched T-Shirt T1 and T2, Figure 1 (c) produced at both factories, have the following characteristics: Rib neckline folded in half, back neck binding, sew label to side seam, 2-needle chains bottom hem and sleeve opening. Fabric used for sewing is 1x1 Rib fabric with 100 % polyester material composition, weight: 149 g/m^2, horizontal density: 180 (column loops/100 mm), vertical density: 445 (row loops/100 mm), fabric thickness: 0.146 mm, yarn count: Ne = 19 m/g.

Research methods

To complete the construction of a database on the operation process and sewing time of Polo-Shirt and T-Shirt products, the team used the following research methods [7]:



(a) (b) (c)

Figure 1. Product description of (a) Polo-Shirt code PE19 – P1, (b) Polo-Shirt code DC1963 – P2, (c) T-Shirt produced at both enterprises T1 and T2.

Table 1. Detailed assembly, seams classification table of 2 Polo-Shirt and T-Shirt products.

Collar assembly	T-Shirt: - Rib neckline folded in half, back neck binding - Neck facing (leg opening) - Neck facing (leg folded) - Collar uses edge tape - Collar uses blind	Polo-Shirt: - Closed collar without legs, woven neckband, woven tape neckline - Closed collar without legs, woven neckband, body fabric neckline - Closed neck with legs, woven neckband - Closed neck with legs, body fabric neckband	
Placket assembly	- Symmetrical placket and fold edge - Symmetrical placket and open edge - Skewed placket and open edge - Skewed placket and fold edge - Placket has zipper	Slit assembly	- Open edge slit - Close edge slit - Slit facing
Pocket	- Pocket with no flap - Double welt pocket	Bottom	- Coverstich bottom
Sleeve opening	- 2-needle cover stitch sleeve opening - Sleeve has cuff facing fold in - Sleeve has cuff facing - Sleeve cuff	Seams	- Shoulder seam - Armhole seam - Side seam, Sleeve seam

To complete the construction of a database on the operation process and sewing time of Polo-Shirt and T-Shirt products, the team used the following research methods [7]:

- Method of building technological process of sewing products.
- Method of document research: inheriting the research results on building a database of the authors sewing technology processes for 27 detailed assemblies, the seams of two the product and determining the set of adjustment coefficients for the actual sewing time value compared to the theoretical calculation time for two values of sewing preparation operation time *tp* and sewing time on the machine *tm*.
- Experimental survey method: recording and taking pictures to record sewing operations performed by workers. After that, analyze, evaluate, compare and collect data on the operation process and reasonable sewing time.
- Using the interpolation method to get a complete data set for all detailed assemblies, seams that have not been implemented experimentally.

The authors conduct data analysis, processing and comparing the operation process and sewing time of the detail assemblies and seams obtained from Hanosimex and Tinh Loi Garment Co., Ltd. to build the research results. From there, a reasonable database on the operation process and sewing time are proposed for four experimental research products, namely P1, P2, T1, and T2.

Due to a large amount of processed data, the article represents the research results analysis of the process theory and the time to perform the armhole seam operation of Polo-Shirt and T-Shirt by MTM and GSD method, applying a set of adjustment coefficients on time values, empirically surveying workers at Hanosimex and Tinh Loi Garment Co., Ltd., compare the theoretical and experimental analysis to propose a complete data set on the operation process and sewing time to perform a reasonable armhole seam of Polo-Shirt and T–Shirt for traditional and modern companies.

RESULTS AND DISCUSSION

The results of theoretical analysis of armhole seam using time value adjustment coefficients of 2 products Polo-Shirt and T-Shirt

Table 2 presents the theoretical analysis result of the operating procedure of armhole seam according to MTM and GSD combined with the application of a set of adjustment coefficients on the time value researched by our team.

Analysis results of the operation process and sewing time to sew Polo-Shirt products at Tinh Loi Garment Co., Ltd and Hanosimex

Table 3 and 4 present the empirical analysis results of the operation process and sewing time of armhole seam following MTM and GSD methods at Hanosimex and Tinh Loi Garment Co., Ltd.

Sum comparing the time value to perform the operations of sewing polo-shirt and t-shirt products at tinh loi garment co., ltd and hanosimex with the research team results

Based on the motion analysis process, companies can be easily divided into two groups:

- Group 1: Traditional company (Hanosimex): using traditional sewing methods, heavily dependent on human factors.
- Group 2: modern company (Tinh Loi Garment Co., Ltd.): using modern equipment, and templates to support production to minimize the dependence of motion on humans.

Table 2. Results of theoretical analysis of armhole seam.

No.	Description	CODE	Freq.	GSD	BKG
1	*Match & get two parts separately*	*MG2S*	2	107	128
2	*Put to foot*	*FOOT*	2	38	46
3	*Align & reposition assembly under foot*	*ARPN*	2	75	150
4	*Sewing 20cm-curved-non visible seam*	*S20MA*	2	79	104.3
5	*Adjust*	*AJPT*	2	43	86
6	*Sewing 5cm-curved-non visible seam*	*S5MA*	2	32.5	53.4
7	*Adjust*	*AJPT*	2	43	86
8	*Sewing 20cm-curved-non visible seam*	*S20MA*	2	79	104.3
9	*Adjust parts by pushing*	*APSH*	2	24	48
10	*Sewing 13cm-curved-non visible seam*	*S13MA*	2	57.5	80.5
11	*Cut thread automatic*	*F*	2	9	9
12	*Aside part with one hand*	*AS1H*	2	23	28
13	*Get part with two hands*	*GP2H*	2	33	35
14	*Put to foot*	*FOOT*	2	38	46
15	*Align & reposition assembly under foot*	*ARPN*	2	75	150
16	*Sewing 20cm-curved- visible seam*	*S20HA*	2	112	97.3
17	*Adjust parts by pushing*	*APSH*	2	24	48
18	*Sewing 5cm-curved- visible seam*	*S5HA*	2	40.5	41.5
19	*Adjust parts by pushing*	*APSH*	2	24	48
20	*Sewing 20cm-curved- visible seam*	*S20HA*	2	112	97.3
21	*Sewing 13cm-curved- visible seam*	*S13HA*	2	78.5	71.2
22	*Cut thread automatic*	*F*	2	9	9
23	*Aside part with two hands*	*AS2H*	2	42	50
	Sum (TMU)			**2396**	**3233.6**

Unit: TMU (Time Measuring Unit)

Table 3. Analysis results of the operation process and sewing time to armhole seam at Hanosimex.

No.	Description	CODE	Freq.	GSD	BKG
1	*Get part with two hands*	*GP2H*	2	33	35
2	*Put to foot*	*FOOT*	2	38	46
3	*Get part with two hands*	*GP2H*	2	33	35
4	*Put to foot*	*FOOT*	2	38	46
5	*Align & reposition assembly under foot*	*ARPN*	2	75	150
6	*Sewing 20cm-curved-non visible seam*	*S20MA*	2	79.72	104.32
7	*Adjust*	*AJPT*	2	43	86
8	*Sewing 5cm-curved-non visible seam*	*S5MA*	2	32.68	53.42
9	*Adjust*	*AJPT*	2	43	86
10	*Sewing 20cm-curved-non visible seam*	*S20MA*	2	79.72	104.32
11	*Adjust parts by pushing*	*APSH*	2	24	48
12	*Sewing 13cm-curved-non visible seam*	*S13MA*	2	57.77	80.56
13	*Cut thread automatic*	*F*	2	9	9
14	*Aside part with two hands*	*AS2H*	2	42	50
	Sum (TMU)			**1255.8**	**1867.2**

Unit: TMU

Table 4. Analysis results of the operation process and sewing time to armhole seam at Tinh Loi Garment Co.,Ltd

No.	Description	CODE	Freq.	GSD	BKG
1	*Get part with two hands*	*GP2H*	2	33	35
2	*Put part to work table*	*PPAL*	2	10	10
3	*Adjust one part (top)*	*AJPT*	2	43	86
4	*Put to foot*	*FOOT*	2	38	46
5	*Sewing 20cm-curved-non visible seam*	*S20MA*	2	87	104.32
6	*Align two parts*	*AM2P*	2	61	122
7	*Sewing 12cm-curved-non visible seam*	*S12MA*	2	60.71	77.17
8	*Adjust parts by pushing*	*APSH*	2	24	48
9	*Sewing 33cm-curved-non visible seam*	*S33MA*	2	129.71	148.43
10	*Aside-Push away*	*APSH*	2	24	29
11	*Trim-Cut with scissors*	*TCUT*	2	50	50
12	*Put part to work table*	*PPAL*	1	10	10
	Sum (TMU)			**1130.8**	**1521.8**

Unit: TMU

Table 5. Comparison of Polo-Shirt sewing time following GSD with BKG and SAM (Standard Allowed Minute) at Hanosimex company.

No.	Assembly	Class	GSD	BKG	SAM	k = $\frac{BKG}{GSD}$	k' = $\frac{SAM}{GSD}$
1	Collar	*Closed collar without legs, woven neckband, body fabric neckline*	48.32	71.35	70.80	1.48	1.47
2	Placket	*Skewed placket and open edge*	62.50	86.50	85.40	1.38	1.37
3	Sleeve opening	*2-needle cover stitch*	24.80	37.70	37.50	1.52	1.51
4	Bottom	*2-needle cover stitch*	18.35	36.50	37.00	1.99	2.02
5	Seams	*Shoulder seam*	26.10	38.00	37.40	1.46	1.43
		Armhole seam	37.70	56.00	55.80	1.49	1.48
		Side seam and sleeve seam	50.60	76.40	76.20	1.51	1.51
	$\overline{k_{TB}}$, $\overline{k'_{TB}}$					**1.55**	**1.54**

Unit: seconds (s)

Table 6. Comparison of Polo-Shirt sewing time following GSD with BKG and SAM at Tinh Loi Garment Co., Ltd.

No.	Assembly	Class	GSD	BKG	SAM	k = $\frac{BKG}{GSD}$	k' = $\frac{SAM}{GSD}$
1	Collar	*Closed collar without legs, woven neckband, woven tape neckline*	76.5	113.1	99.0	1.48	1.29
		Closed collar without legs, woven neckband, body fabric neckline	80.2	110.3	100.8	1.38	1.26
2	Placket	*Skewed placket and fold edge*	129.3	164.1	150.2	1.27	1.16
		Skewed placket and fold edge, have buttonhole placket	141.6	192.0	181.5	1.36	1.28
3	Sleeve opening	*2-needle cover stitch sleeve opening*	27.4	37.9	36.0	1.38	1.31
		Sleeve cuff	50.0	63.3	61.2	1.27	1.22
4	Bottom	*2-needle cover stitch bottom*	26.9	39.1	28.8	1.45	1.07
		1-needle cover stitch bottom	40.3	63.2	44.4	1.57	1.10
5	Slit	*Close edge slit*	68.8	87.6	85.8	1.27	1.25
6	Seams	*Shoulder seam*	22.7	29.4	21.0	1.30	0.93
		Armhole seam	33.9	45.7	36.0	1.35	1.06
		Side seam and sleeve seam	37.5	48.9	45.0	1.30	1.20
	$\overline{k_{TB}}$, $\overline{k'_{TB}}$					**1.36**	**1.18**

Unit: seconds (s)

$$\bar{k} = \frac{1}{m}\sum_{j=1}^{m} k_j. \quad (1)$$

In our study, we calculated the *k* and *k'* values, which are the ratios of SAM and GSD, and of BKH and GSD, respectively. After that, the $\overline{k_{TB}}$ and $\overline{k'_{TB}}$ values were determined, the values are the average of *k* and *k'*. From Table 5, comparing the values $\overline{k_{TB}}$ and $\overline{k'_{TB}}$, we see that these two values are approximately equal. The set of adjustment coefficients between the experimental value and the theoretically calculated value of sewing and preparation time is correct for traditional companies.

From Table 6, it can be seen that *k'* of Tinh Loi Garment Co., Ltd. is lower than k of the research group. Therefore, with modern production conditions (modern equipment, application of templates, highly skilled workers), the sewing stages time is shortened. This means that labor productivity is increased, product quality is uniform because the dependence on subjective factors of workers are reduced.

Final: In modern companies, the time value adjustment coefficient set from the study results is not suitable. When applied to this group, we have a new adjustment coefficient which is $\overline{k'_{TB}}$ (Table 6), called K_m:

$$K_m = \overline{k'_{TB}} = 1.18, \quad (2)$$

$$SAM = 1.18 \sum Y_{GSD} \frac{60}{2000} \quad [s], \quad (3)$$

where: 1 minute = 2000 TMU, 1 minute = 60s , 1s ≈ 33.33 TMU, $\sum Y_{GSD}\,(TMU)$ **:** Time to perform one workstation (including sewing and preparation time) calculated according to MTM and GSD. SAM_m [s]: Standard production time in K_m factor.

Proposing the operation process and sewing time on armhole seam for the two groups of companies

In experimental research, we have built a reasonable operation process and sewing time to detail assemblies, seams of P1, P2, T1, and T2. These are four representative products including detailed assemblies, typical seams. To build a complete database for all theoretical research products of the research team, we use the interpolation method to

Table 7. Table of the operation process and sewing time on armhole seam of traditional companies.

No.	Description	CODE	Freq.	GSD	BKG
1	*Pick up parts to table*	*AS2H*	1	42	50
2	*Unfold parts*	*FUNF*	1	23	44
3	*Position large panel to machine foot, add additional panel*	*MAP2*	2	69	83
4	*Grasp next panel*	*MAP2*	2	69	83
5	*Slide previous panel*	*APSH*	2	24	48
6	*Put to foot*	*FOOT*	2	38	46
7	*Sew to hold*	*MS1A*	2	17	17
8	*Align two parts*	*AM2P*	2	61	122
9	*Sewing 15cm – curved – non visible seam*	*S15MA*	2	52.1	87.35
10	*Align two parts*	*AM2P*	2	61	122
11	*Sewing 10cm – curved – non visible seam*	*S10MA*	2	40.4	70.38
12	*Turn shoulder seam*	*FUNF*	2	23	44
13	*Align two parts*	*AM2P*	2	61	122
14	*Sewing 5cm – curved – non visible seam*	*S5MA*	2	28.7	53.42
15	*Push assembly onto table*	*APSH*	2	24	29
16	*Align two parts*	*AM2P*	2	61	122
17	*Sewing 10cm – curved – non visible seam*	*S10MA*	2	40.4	70.38
18	*Align two parts*	*AM2P*	2	61	122
19	*Sewing 15cm – curved – non visible seam*	*S15MA*	2	52.1	87.35
20	*Aside-Push away*	*APSH*	2	24	29
21	*Trim – Cut with scissors*	*TCUT*	2	50	50
22	*Aside part with one hand*	*AS1H*	2	23	28
23	*Trim – Cut with scissors (additional)*	*TCAT*	2	25	25
24	*Obtain & pick up the sewn part*	*AS2H*	1	42	50
25	*Inspect the sewn part*	*E*	2	7	7
26	*Place sewn part back onto work table*	*PPAL*	1	10	10
Sum (TMU)				**1940.4**	**3089.76**
Actual production time according to BKG (s)					**92.69**

Unit: TMU

Table 8. Table of the operation process and sewing time on armhole seam of modern companies.

No.	Description	CODE	Freq.	GSD
1	*Pick up parts to table*	*AS2H*	1	42
2	*Unfold parts*	*FUNF*	1	23
3	*Position large panel to machine foot, add additional panel*	*MAP2*	2	69
4	*Grasp next panel*	*MAP2*	2	69
5	*Slide previous panel*	*APSH*	2	24
6	*Put to foot*	*FOOT*	2	38
7	*Sew to hold*	*MS1A*	2	17
8	*Align two parts*	*AM2P*	2	61
9	*Sewing 15cm – curved – non visible seam*	*S15MA*	2	52.1
10	*Align two parts*	*AM2P*	2	61
11	*Sewing 10cm – curved – non visible seam*	*S10MA*	2	40.4
12	*Turn shoulder seam*	*FUNF*	2	23
13	*Align two parts*	*AM2P*	2	61
14	*Sewing 5cm – curved – non visible seam*	*S5MA*	2	28.7
15	*Push assembly onto table*	*APSH*	2	24
16	*Align two parts*	*AM2P*	2	61
17	*Sewing 10cm – curved – non visible seam*	*S10MA*	2	40.4
18	*Align two parts*	*AM2P*	2	61
19	*Sewing 15cm – curved – non visible seam*	*S15MA*	2	52.1
20	*Aside-Push away*	*APSH*	2	24
21	*Trim – Cut with scissors*	*TCUT*	2	50
22	*Aside part with one hand*	*AS1H*	2	23
23	*Trim – Cut with scissors (additional)*	*TCAT*	2	25
24	*Obtain & pick up the sewn part*	*AS2H*	1	42
25	*Inspect the sewn part*	*E*	2	7
26	*Place sewn part back onto work table*	*PPAL*	1	10
ΣY_{GSD} (TMU)				1940.4
SAM_m (s)				68.69

Unit: TMU

Table 9. The sewing time results of sleeve opening by the interpolation method.

No.	Assembly	Traditional company (BKG)	Modern company (GSD) K_m=1.18
1	*Sleeve have cuff facing fold in*	76.2 s	58.8 s
2	*Sleeve have cuff facing*	109.2 s	79.9 s
3	*Sleeve cuff*	70.2 s	51 s

calculate the *Km* coefficient for two groups of companies, performed for all assemblies, the seams are shown in Table 1. Due to the limited scope of the article, we only present the results of the operation process and sewing time to the armhole seam and sleeve opening. They give in Tables 7, 8, 9.

CONCLUSION

The results have built a reasonable data set on the operation process, the time to perform the sewing operation of Polo-Shirt and T-Shirt products, contributing to a more standardized process of applying GSD predetermined time system to the reality of production in enterprises, minimizing errors that may be caused by influencing factors. The database has been built systematically and standardized to ensure the diversity, abundance, and universality of all product technology structure options in line with reality in garment enterprises. The database is applied in sewing operation analysis software built by the research team - this is an application-oriented research product that will transfer technology to garment enterprises producing knitwear, supporting the improvement and rationalization of labor methods, building standard processes and optimal technological processes, maximizing existing production conditions in order to improve labor productivity and economic efficiency, creating a premise to apply digital technology to create a breakthrough in Vietnam's garment industry. The authors have built a systematized and standardized database on the operation process and sewing time to perform the reasonable operation of two knitted products. In the future, the team will continue to research and expand with other items to diversify the database on the operation process and the sewing operation time.

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REFERENCES

1. Rahman, H., Roy, P K., Karim, R. et al.: Effective way to estimate the standard minute value (SMV) of a t-shirt by work study, European Scientific Journal 10(30), 2014, pp. 196-203.
2. Thao, P.T., Long, T.V., Huong, D.M., et al.: Apply genetic algorithm to solve assembly line balancing problem, In: Proceedings the 2st National Scientific Conference on Textile, Apparel and Leather Engineering. Hanoi University of Science and Technology Publisher, 2021, pp. 254-260.
3. Thao, P.T., Anh, L.T.M., Phan, D.N., et al.: Researching the optimal method of balancing the sewing line with T-shirt product in the garment industry in Vietnam, ECS Transactions 107(1), 2022, pp. 7869-7887. https://doi.org/10.1149/10701.7869ecst
4. Dinh, M.H., Nguyen, V.D., Truong, V.L., et al.: Cycle time enhancement by simulated annealing for a practical assembly line balancing problem, Informatica, 44(2), 2020, pp. 127–138. https://doi.org/10.31449/inf.v44i2.3083
5. Thao, P.T. and Huong, D.M.: Research on apply of polo-shirt assembly line balancing methods in Vietnam garment industry, In: Proceedings the 2st National Scientific Conference on Textile, Apparel and Leather Engineering. Hanoi University of Science and Technology Publisher, 2021, pp. 307-318.
6. Huong, D.M., Long, T.V., Thuan, D.P., et al.: Application of exhaustive search for optimization Assembly Line Balancing in Garment Industry, Journal of Science & Technology Technical Universities 141, 2020, pp. 34-41.
7. Alam, F.B. and Hasan, M.M.: Analysis on SMV to increase productivity in sewing section: a case study on T-shirt manufacturing in Bangladesh, International Journal of Research in Engineering and Science, 6(8), 2018, pp. 18-24.