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DEFENCE RESEARCH ESTABLISHMENT OTTAWA

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Protective Sciences Division

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ABSTRACT

This paper recommends that a minimum seam strength rather than a fixed percent seam efficiency be used as a criteria for acceptable seam strength in Canadian Forces (CF) fabrics. The minimum seam strengths are calculated based on a working stress of 3500 N/m and a factor of safety of 4 for the CF lightweight combat and the twill fabrics and of 6 for the CF heavyweight combat fabric. Seam types which meet this criteria and could be used as alternatives to the double-lap seam in CF clothing made from these fabrics are given. Keywords: Combat uniforms, Seaming, Optimization, Tensile strength.

RÉSUMÉ

Les auteurs recommendent qu'un indice numérique minimal, plutôt qu'un pourcentage fixe, serve de critère d'évaluation de la solidité des coutures, à l'égard des vêtements destinés au personnel des Forces canadiennes (FC). Ainsi, l'indice minimal de résistance des coutures est calculé par rapport à une tension (en situation de travail) de 3,500 N/m; un indice de 4 s'applique aux tissus servant à la confection de la tenue légère de combat et les sergés de toile et de 6, dans le cas des tissus lourds entrant dans la fabrication des tenues de combat des FC. Les auteurs précisent en outre les types de coutures dont les caractéristiques répondent à ces critères et qui peuvent être employées en remplacement des coutures doubles, dans la confection des vêtements destinés au personnel des FC.

INTRODUCTION

In a DCGEM-sponsored task to determine if alternative seam types could replace the commonly-used double-lap seams in Canadian Forces (CF) clothing, the question was raised as to how strong seams have to be in clothing. In a 1952 study, Frederick at Natick had stated that the seam strength, for the end uses he was considering, should be 80% of the fabric strength. The recommendation arising from the DCGEM-sponsored task (1) was that the criteria of 80% seam efficiency be revalidated because of the progress made in technology since Frederick's work, resulting in stronger, more durable sewing threads, seams and fabrics.

The approach taken to this problem was: to determine where maximum stresses occur in clothing and thus in seams (2, 3); to find a reliable method to measure these maximum stresses (4); and to determine the maximum stresses which would occur in the seams of various CF garments which presently have double lap seams, namely the CF combat shirt and trousers and the CF flying coveralls (5). This has been done and the maximum stress which occurs in clothing was found to be about 3500 N/m. The maximum stresses occur in the back trouser and coverall seam when the subject squats and across the shoulders in the shirt and coverall top when the subject crosses his arms in front of him.

This paper concludes the study by answering the question of how strong seams have to be in clothing, (re-evaluating the criteria of 80% seam efficiency) and determining if alternative seam types could replace the commonly-used double-lap seam in the CF combat clothing.

Required Seam Strength

In order to arrive at a criterion for the seam strength required for the CF combat shirt and trousers, made from the lightweight fabric and for the coveralls, made from the twill fabric, we turned to the field of engineering and its factor of safety, f_s, which is defined as

$$f_s = \frac{S_m}{s_w}$$

where S_m is the strength, taken here to be the required maximum seam strength and s_w is the allowable or typical working stress, now known to be approximately 3500 N/m (5).

The value assigned to f_s, in arbitary but accepted engineering practice assumes a value between 1.5 and 4 for ductile materials which are defined as those materials with an elongation greater than 5%, i.e. textiles. In the Machinery's Handbook (6), a table of general recommendations for the values of the factors of safety is presented. This information is summarized in Table 1.

In order to select the appropriate f_s, it is necessary to categorize seams and their wearing conditions according to the descriptors given in Table I. Because of the variabilities in such things as sewing thread strength, sewing machine performance, operator skill and quality control standards, seams cannot be categorized as "reliable" but rather "ordinary" or "less tried". Loading conditions for seams would be categorized as "not severe" since there is a limit to how much a person can stress clothing which he would wear, or fit into. Further, we found the loading conditions, or the maximum stress in clothing to be 3500 N/m which is small relative to the CF fabric strengths of 15,000 to 26,000 N/m.

It is not as easy to define confidently the environmental conditions, taken here to mean the conditions which cause deterioration of the seam strength in wear. Very little is known about how fabrics actually deteriorate in wear, let alone seams made in these fabrics. Thus "difficult" would be the best descriptor here. Taking the worst possible case, i.e. "difficult" environmental conditions, a factor of safety of 4 would be appropriate for seams. Therefore S_m is calculated to be 4 times s_w which is 3500 N/m to give a value of 14,000 N/m for the minimum seam strength for the two CF fabrics we are considering here.

Although we did not measure the stress in clothing made from the heavyweight combat fabric, we had recorded its load-elongation curve and carried out preliminary load versus stress calibrations with it. We found these properties to be similar to those of the lightweight combat fabric with the exception, of course, that the heavyweight combat fabric is 40 to 50% stronger than the lightweight combat fabric. Therefore, we conclude, that the maximum stresses which would occur in the clothing made from it would be similar to those measured in the other combat clothing. However, this fabric is stronger, heavier and has more abrasion resistance than the lighter version. Therefore, it would be expected to have a longer life expectancy than the lightweight combat fabric as it would be exposed to "difficult" environmental conditions for a longer length of time before it failed. Therefore, a greater factor of safety would be required for its seams. In the absence of details of wear life of the heavyweight combat fabric, prorating its strength to the factor of safety for the lightweight fabric seems reasonable. This would give it a factor of safety of 6, and thus, a minimum acceptable seam strength of 21,000 N/m.

TABLE 1

SUMMARY OF GENERAL RECOMMENDATIONS FOR VALUES OF FACTOR OF SAFETY (FROM MACHINERY'S HANDBOOK, (6))

f_s	APPLICATION		
	TYPE OF MATERIAL	LOADING CONDITIONS	ENVIRONMENTAL CONDITIONS
1.3 to 1.5	HIGHLY RELIABLE	NOT SEVERE	NOT SEVERE
1.5 TO 2	RELIABLE	NOT SEVERE	NOT SEVERE
2 TO 2.5	ORDINARY	NOT SEVERE	NOT SEVERE
2.5 TO 3	LESS TRIED	NOT SEVERE	NOT SEVERE
3 TO 4	NOT RELIABLE	NOT SEVERE	NOT SEVERE
3 TO 4	RELIABLE	DIFFICULT	DIFFICULT

Re-validation of 80% Seam Efficiency

If we calculate the percent seam efficiency using the 14,000 N/m and the 21,000 N/m values, we find the lightweight fabric requires seam efficiencies of 56 and 65, the twill 67 and 93 and the heavyweight fabric 52 and 54% for the warp and weft directions respectively. (To avoid confusion, Figure 1 shows the sense of warp and weft directions). The higher seam efficiencies are found for the weft simply because the weft is traditionally weaker than the warp in a woven fabric. Herein lies the problem of using percent seam efficiencies. The majority of seams in the CF combat clothing are in the warp direction and as we found, are stressed the most in the weft direction, i.e. across the shirt and coverall top back and arm seam and the trouser or coverall trouser centre back seam.

Therefore, stronger seams are required in the weft direction than in the warp direction. By applying a percentage rather than a fixed minimum value, one may obtain weft seams which are weak and warp seams which are very strong and over-designed.

As stated in the introduction, one of the reasons for the re-validation of the 80% seam efficiency was that fabrics which are stronger and more durable than those in use in 1952 are now available. In fact, the fabrics used in the CF combat clothing have been designed or selected mainly to withstand high levels of abrasion and to have high tear strengths. Abuse almost always takes place in areas of "fabric only". Severe abrasion occurs mainly in the knee and elbow areas where no seams exist. Tears or rips, caused by snagging, occur randomly over the clothing. Since seams take up such a small area of the total clothing area, the chances of a seam rather than the fabric being torn is small. Therefore, it would appear to be more practical to quote minimum seam strengths for combat clothing (rather than percent seam efficiencies based on the strength of the fabric) since we are designing clothing seams for the stress put on them and have included a factor of safety to ensure seam integrity despite their decline in strength during the life of the garment.

Applying the criterion of a minimum seam strength (14,000 N/m or 21,000 N/m) to the results of the seam breaking strengths, as listed in Table 2, we find the double-lap seam in all three fabrics and directions well exceeds this criterion. The only other seam which exceeds this value is the stitch-and-serge with topstitching for the lightweight fabric. No other seam type is strong enough to be used in the twill fabric, although the stitch-and-serge with topstitching comes close and could be used if one is prepared to accept a lower margin of safety. All seam types except the stitch-and-serge would be acceptable for the heavyweight combat fabric.

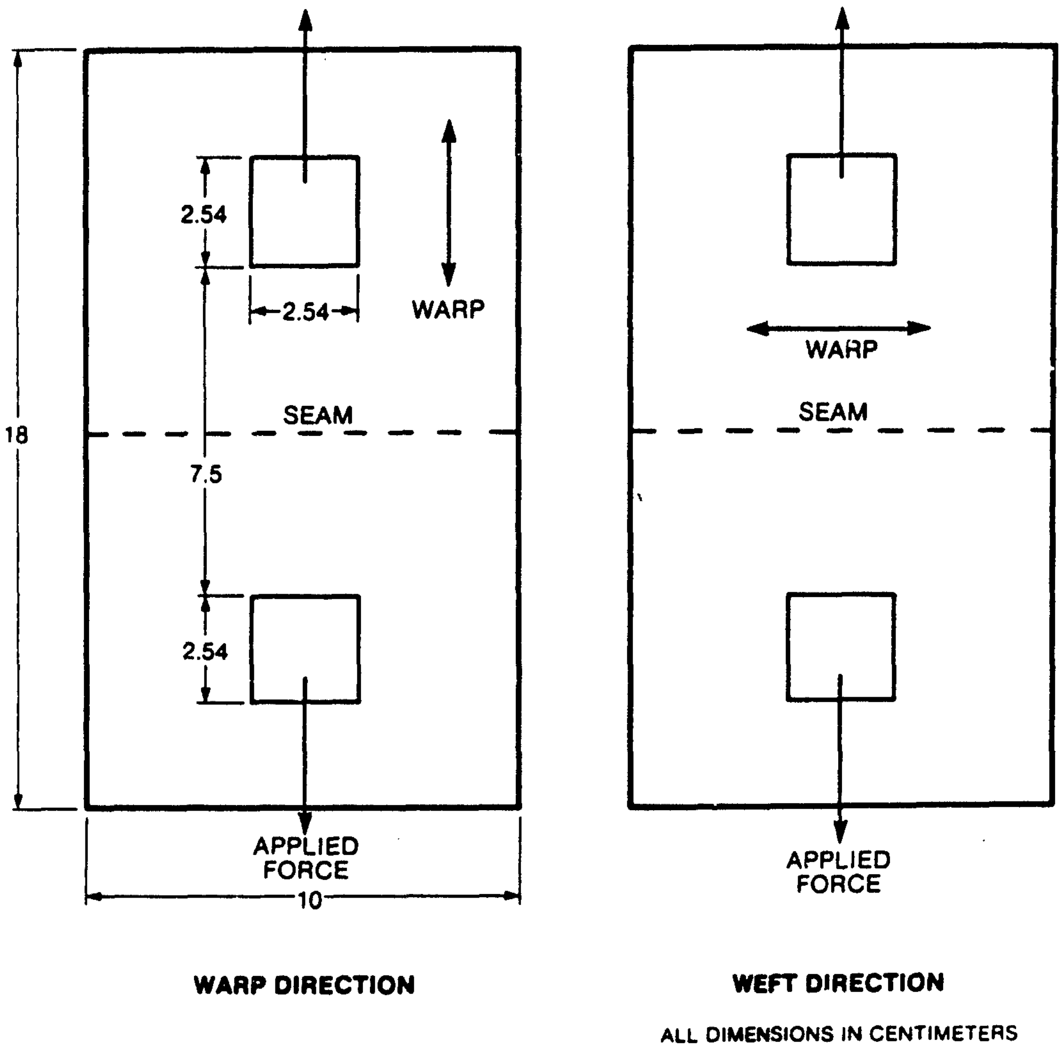

Figure 1: Illustration of the Warp and Weft Directions of Seam.

TABLE 2

SEAM AND FABRIC PARAMETERS

SEAM TYPE	BREAKING STRENGTH[1]					
	LIGHTWEIGHT FABRIC		TWILL FABRIC		HEAVYWEIGHT FABRIC	
	WARP	WEFT	WARP	WEFT	WARP	WEFT
DOUBLE-LAP	21,570	18,780	21,810	15,940	32,990	31,180
SAFETY	NO SAMPLE	14,490	5,670	11,380	28,460	25,710
SAFETY AND TOPSTITCH	16,610	10,830	1,690	NO SAMPLE	32,090	33,460
STITCH-AND-SERGE	7,870	7,520	8,110	8,150	12,800	12,560
STITCH-AND-SERGE WITH TOPSTITCH	16,020	14,760	12,800	15,670	23,350	23,190
FABRIC ALONE	25,040	21,500	20,870	15,080	40,510	39,020
MINIMUM SEAM STRENGTH	14,000	14,000	14,000	14,000	21,000	21,000
PERCENT MINIMUM SEAM EFFICIENCY	56	65	67	93	52	54

1. Measured in accordance to ASTM D 1683-81 "Standard Test Method for Failure in Sewn Seams of Woven Fabrics" and ASTM D 1682-64 (Reapproved 1975) "Standard Methods of Test for Breaking Load and Elongation of Textile Fabrics" (Grab test using 2.54 cm wide jaws)

CONCLUSIONS

Based on a minimum seam strength, the alternative seam which could be used instead of the double-lap seam in the lightweight combat fabric is the stitch-and-serge with topstitching. In the heavyweight combat fabric, the safety stitch, with or without topstitching and the stitch-and- serge with topstitching are suitable alternatives to the double-lap seam. No other seam type is strong enough for the twill fabric, although the stitch-and-serge with topstitching is almost sufficient. It is recommended that garments be made using these alternative seam types and that they be tested to see if, in fact, minimum seam strengths of 14,000 and 21,000 N/m rather than a minimum seam efficiency of 80% is adequate.

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