COMFORT IN DEFENSE CLOTHING

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ABSTRACT

Defense textiles have to exhibit many unique performance characteristics due to the diverse hostile conditions and wide range of threats under which it has to function. Although the functional requirements for this clothing are of major interest, comfort aspects of the same have to be considered seriously during designing of garment and selection of basic textile material, especially for hot climatic conditions. Because the ultimate success of combat troop would much depend on the comfort, mobility and protection provided by the particular garment. The clothing comfort is an extremely complex phenomenon, which may lead, inevitably, to incompatibility with the protection requirements, posing a serious challenge for the textile technologist and the garment designer. In this paper, we have discussed the important comfort properties in particular reference to the hot climate weather conditions in relation with defense protective clothing. There are various innovative techniques by which comfort properties of garment can be enhanced. These include the use of various types of new generation fibres, engineered yarn and fabric constructions as well as advance finishing techniques. This paper deals with some of the above aspects of improving the comfort in defense textiles.

KEY WORDS: CALM scale, clothing comfort, clusters, defense textiles, liquid moisture transfer, microclimate, physiological comfort, psychology comfort

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1. INTRODUCTION :

Defense and civil defense industries rely heavily on technology. Textiles perform a large number of roles for the military. Fabrics can be tailored for protection against extreme weather conditions (heat, cold, wind, and rain), against ballistic impact, and against nuclear, biological and chemical threats[1]. Defense clothing requirements are becoming more complex as the defense personnel have to perform at unprecedented levels, while threatened by array of ballistic, chemical, biological, thermal and environmental threats and hazards. Basic requirement of defense textiles can be listed as follows: Physical lightweight, durable, comfortable, low noise emission and antistatic, Windproof, water repellent, water vapour permeable, UV light resistant, air permeable and biodegradable. Camouflage from visual spectrum, detection and surveillance system like radar, UV, heat and for infrared, Flame retardency, heat-resistance, ballistic protection, and nuclear, chemical, biological protection, Minimal cost, easy maintenance, long storage life and readily available.

Apart from these basic requirements, India has hot tropical weather with variation from region to region, from the sub-freezing Himalayan winter to the tropical climate of coastal region and from the dump, rainy climate in the eastern states to the arid Great Indian Desert. The temperature ranges are wide from 15ºC to 38ºC in most of the climatic areas and in some region temperature can reach as high as 48ºC during the day in summer. Hence, the requirement of defense clothing, particularly for the hot Indian climatic condition, is very complex and also the human comfort factor should not be neglected. Because, on the battlefield under hostile conditions, it is the defense personnel who will take the ultimate decision and action that will be an important factor in deciding the final outcome of war. Because human performance is affected by clothing comfort, it will have serious implications on the ultimate result of war[2].

2. GENERAL ASPECTS OF COMFORT

Slater (1977 & 1996) defined comfort as ‘a pleasant state of physiological, Psychological and physical harmony between the human being and the environment’ and ‘Comfort or Protection: the clothing dilemma’ that ‘human beings cannot function satisfactorily[3]. There are three main viewpoints for analyzing comfort of any fabric as shown in the figure 1.The foremost notion of comfort is always ‘thermal comfort’, i.e. that is comfort or discomfort related to how a hot or cold a person feels. Thermal comfort is associated with changes in many physiological and environmental variables; the activity level of the individuals; and clothing properties, such as the fabric insulation values and water vapor permeability. Thermal comfort is mostly quantified using physiological parameters though it is a psychological concept. Second way to interpret comfort is the tactile sensations that result from the fabrics in contact with the skin. For instance, a military garment may prove smooth or rough when rubbing against skin. The buzz words in tactile comfort are stiffness, thickness, and fuzziness etc. Since mostly military clothing are worn on a daily basis in routine, non-combat situations we are forced to consider the tactile comfort or the discomfort also to the overall comfort and performance of the military clothing[4].

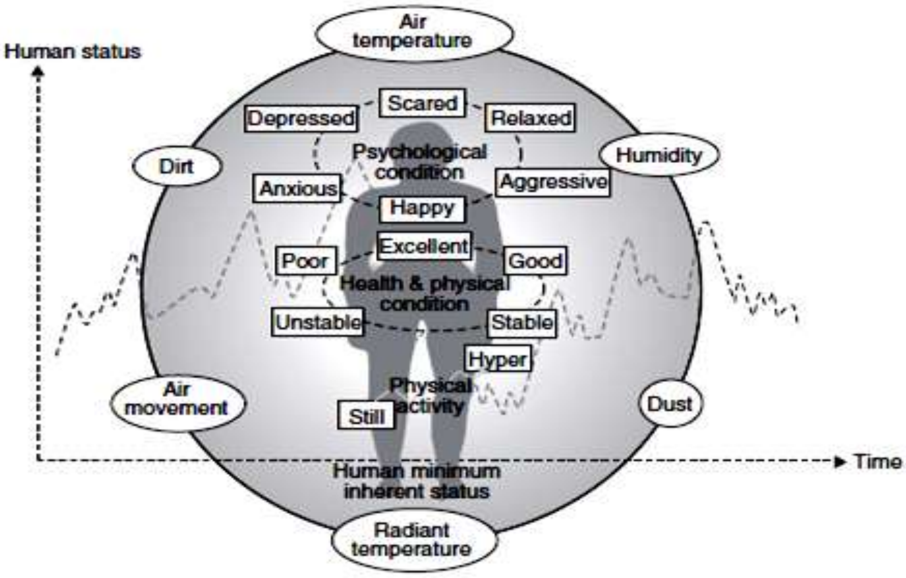


Figure 1 – Primary factors influencing human comfort

A third component of comfort arises from the fit of the garment. A poorly fitting garment, especially too small or too large can impede mobility and performance, although impact on comfort may not be as great, but it influences the psychological perceptions of the wearer through personal or cultural preferences regarding fit and fashion size trends. We know that fashion play fewer roles in the case of military clothing. When it comes to psychological comfort, even the protective element of military clothing plays a significant role. Whether we are considering thermal comfort, sensory skin-feel comfort, comfort due to fit, or the psychological comfort of clothing, each of these can have considerable impact on the individual' physical and cognitive performance and, in turn, on mission performance. For this reason 'Comfort' must be seen as an essential element in all areas of military clothing[5].

In the context of protective clothing systems, comfort may be defined in many different ways:

- A state of satisfaction with the protective clothing system in terms of human body interaction with the system.
- The presence of a friendly environment provided by the protective clothing system in terms of heat and moisture transfer from and to the body
- A state of unawareness of the protective clothing system by the user.

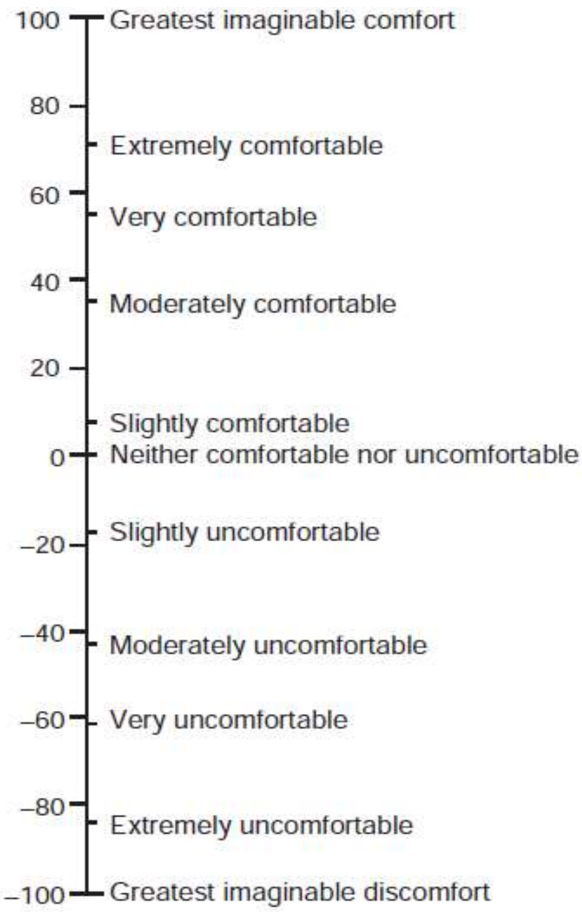
The above definitions define the physical effects, thermal effects and the psychological effects. Psychologically comfort being a natural state makes it easier for the wearer to describe the discomfort using common terms as 'too prickly', 'too hot', or 'too cold'. Among all the aspects associated with the human feelings and desires, comfort represents a central concern. The comfort level of a human is driven by a host of factors, which may be divided into three main categories: Environmental, Physical and Psychological which is depicted in the figure 2. We should also note that human hardly ever experiences a still environment or body conditions[6]. In other words, there is a continuous change over time that leads to transitional effects. Comfort analysis can be divided into three main categories:

Objective analysis – Tactile and thermal parameters

Subjective analysis – Psychological evaluation

Correspondence analysis – Combining the above two to develop quantitative measures

CALM scale



US Army Natick Soldier RD&E (NSRDEC) using contemporary psychophysical scaling techniques developed a scale for measuring comfort. This **Comfort Affective Labeled Magnitude (CALM)** scale was modeled after earlier labeled magnitude scales. The scale[7] was developed by having consumers rate the semantic meaning of 43 different word and phrases that can be used to describe comfort or discomfort. There are 5 main phrases which define comfort and discomfort, which also have other sub levels. As said earlier, the scale was modeled using two different works; one is Cardello et al, and the second from Gagge et al.

Figure 2 – The Comfort Affective Labelled Magnitude (CALM) scale

This comfort scale employs a line with the end-points labeled 'greatest imaginable discomfort' and 'greatest imaginable comfort' and with neither 'comfortable nor uncomfortable' located in the middle. The CALM scale shown in the figure 3 has several advantages over other comfort scales.

- The scale is simple to use, merely requiring individuals to place a slash mark somewhere on the vertical line.
- The labels are located along the scale at points that represents the magnitude of labels are located along the scale at points that represent the magnitude of their semantic meaning as determined by a ratio scaling procedure (magnitude estimation), the measured distances along the scale can be treated as ratio-level data. This property of the CALM scale makes it possible to describe a fabric as one-third, 2 times as comfortable or uncomfortable as another fabric.
- The CALM scale labels of 'greatest imaginable liking/disliking' enable extreme ratings than 'extremely comfortable or uncomfortable', allowing greater sensitivity to differences among very comfortable or uncomfortable fabrics/garments.
- This can be used in both laboratory and wear trial evaluations to assess either skin contact or overall contact.

2.1. PHYSIOLOGICAL AND PSYCHOLOGICAL ASPECTS OF COMFORT

This is one of the important factors in military clothing. The physiological effects of climatic variables, e.g. Temperature, Relative Humidity and Air movement on a body situated in the particular conditions are studied. The other factors studied are the effect of clothing factors, particularly fabric geometry, pore volume and enclosed air content on physiological as well as physical parameters[8].

It is considered that a study can be made by framing a suitable questionnaire for the users particularly in Defense sector for their reaction of comfort factors like weight, breathability, fit etc based on field trials or practical performance tests on garments suitable for various and uses (like protective clothing's for extreme climatic, conditions, for jungle and desert conditions, for industrial apparels etc.)

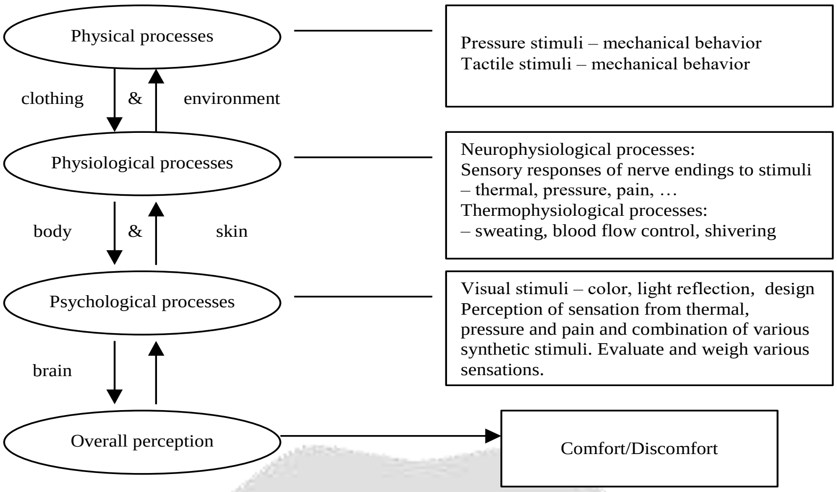


Figure 3: The processes involved in sensations and attitudes on comfort

The figure: 3 illustrate[11] the processes of how the subjective perception of overall comfort is formulated. The physical process provide the signals or stimuli to the sensory organs of the solders body, which will receive them, produce neurophysilogical impulses, send these to the brain, and take action to adjust sweating rate, blood flow and sometimes heat production by shivering in cold environmental[9]. The psychology of comfort is the study of how the brains receives individual sensory sensations, and evaluates and weights the sensations to formulate subjective perception of overall comfort and performance which become our wear experience. In military textiles twenty six descriptors are important in winters wear that can be classifies in to four clusters[10],

Cluster -1: Tactile sensations:-
Prickly, Tickling, Rough, Raggy, Scratchy, Itchy, Picky, Staticky
Cluster – 2: Moisture sensations:-
Clammy, Damp, Wet Sticky, Non Absorbent, Clingy
Cluster – 3: Pressure (body fit) sensations:-
Snug, Loose, Light Weight, Heavy, Soft, Stiff
Cluster- 4: Thermal sensations:-
Cold, Chill, Cool, Warm, Hot

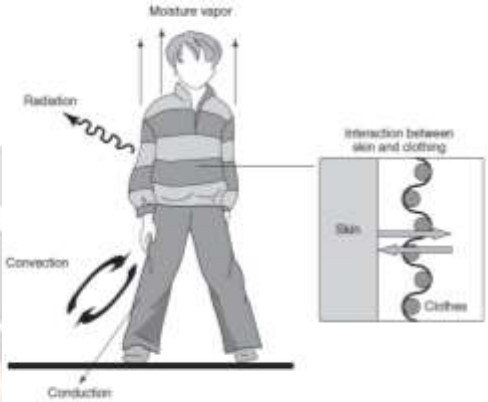
3. PHYSICAL ASPECTS OF COMFORT

In studying the physical factors determining the comfort performance of textiles, it is concluded that heat transfer between man and his environment, together with the movement of moisture for insensible heat transfer, constitutes the major comfort maintaining mechanism. Depending on the particular functional requirements of garments, the parameters which can be evaluated for physical aspects of comfort are conductivity, water-vapour resistance, air-permeability, moisture-holding ability, wind resistance, abrasion resistance etc.

It is obvious that comfort involves a complex combination of properties, both subjective and physical. There is general agreement that the movements of heat, moisture and air through a fabric are the major factors governing comfort, but some of the subjective factors such as size, fit and aesthetic behavior like softness, handle and drape are obviously very important in the textile field[3].

3.1. THERMAL PROPERTIES AND COMFORT

Heat is gained by the body from the sun (directly or indirectly), by internal metabolism, by physical exercise, or by involuntary contractions of skeletal muscles in shivering. Heat loss of solders by conduction, convection or radiation, depends partly on the temperature gradient between skin and the environment, and varying the skin temperature modifies this gradient, which is explained[10] in figure 4. Body flow near the body surface and evaporation from it control the skin temperature, and one function of clothing is the support of these processes. Excessive heat may be dissipated rapidly by vaporization of body water, the body being used, as a source of latent heat for the purpose and clothing systems that hinder free evaporation to any appreciable extent will thus be uncomfortable[11]. On the other hand, undesirable heat loss can be prevented by increasing the thermal resistance of the barrier between the body and its environment, and a fabric will again result in discomfort for the wearer. The ambient air temperature is the dominant influence in determining the skin temperature and that at low temperature, clothing is essential for the regulatory process because the body does not have the ability to continue compensating for heat loss under these conditions. In addition to prevent undue heat loss, the winter clothing must also allow the escape of surplus heat or moisture when this is necessary. Figure: 4 Mechanism of heat loss from human body



3.2. HEAT TRANSFER

The resistance that a fabric offers to the movement of beat through it is of critical importance to its thermal comfort. In studying the thermal insulating properties of garments during wear, it is reported that the total thermal resistance to transfer of heat from the body to the surrounding air is the sum of three parameters[12], which is explained figure 5:

1. The thermal resistance to transfer of heat from the surface of the material,
2. The thermal resistance of the clothing material, and
3. The thermal resistance of the air interlayer.

It is obvious that heat transfer through a fabric is a complex phenomenon affected by many factors. The three major factors in normal fabrics appear to be thickness, enclosed still air and external air movement. It is also reported by many authors that entrapped air is the most significant factor in determining thermal insulation. There are "micro layers" (those between contacting surfaces of the materials) and "macro layers" (between non-contacting surfaces) of air enclosed within an assembly, and an increase of either of these can increase thermal insulation.

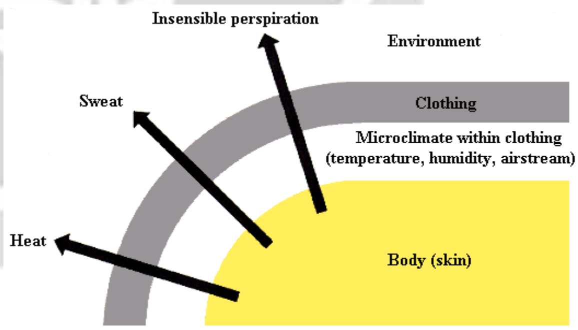


Figure: 5 Mechanism of heat transfer from body to atmosphere air

The above concepts are significant from the point of view of Thermal Protection, since one of the major functions of clothing is to protect the solders to against extremes of environmental temperature, i.e. from excessive ambient heat as well as cold and it produce comfortable to them.

3.3. THERMAL COMFORT

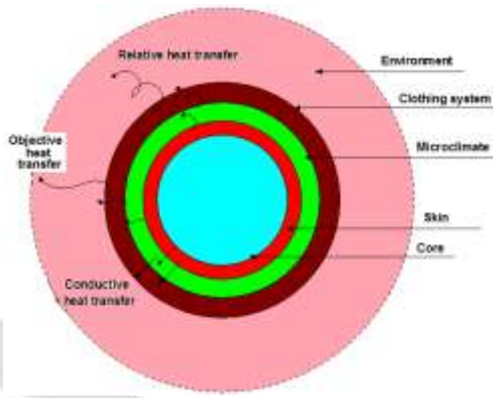
One of the fundamental factors of clothing is to keep the human body in an appropriate thermal environment in which it can maintain its thermal balance and thermal comfort. Therefore miltery textiles are needed to protect the solders from climatic influence and to assist its own thermal control functions under various conditions and physical activity.

The thermal comfort of solders is depending on combination of clothing, climatic and physical activity. The scale of effective temperature was determined by the temperature of still, saturated air which was felt as warm as the given conditions. Rohles derived[13] an equation using multiple regression to predict thermal sensations after a exposure of three hours.

$$Y = 0.1509\, T_{ab} + 0.01\, H_a - 8.3719$$

Where Y is Thermal sensation of the scale of 1= cold, 2-cool, 3- Slightly cool, 4- Comfortable, 5- Slightly warm, 6- warm, 7-Hot; Tab is the dry bulb temperature in F and Ha is R.H in Percent.

Apart from the incorporation of flame-resistant fibers or finishes, the main approach in providing heat protection appears to make use of energy reflecting surfaces as a part of the garment[14]. Most types of heat-protective clothing are impervious to water, which makes them uncomfortable to wear. To overcome the problem, the use of various organic coatings is reported. Another optimum solution is by aluminizing an open-mesh structure[15]. The concept has assured great significance in military clothing applications all over the world. The mechanism of human and clothing environment is explained in the figure 6. Figure: 6 Mechanism of human and clothing environment



4. AIR PERMEABILITY

The air permeability of a fabric can influence its comfort behavior in several ways[16]. In the first case, a material that is permeable to air is also, in general, likely to be permeable to water, in either the vapour or the liquid phase[18]. Thus, the moisture-vapour permeability and the liquid-moisture transmission are normally closely related to air permeability. In the second case, the thermal resistance of a fabric is strongly dependent on the enclosed still air, and this factor is in turn influenced by the fabric structure, as also is the air permeability. A very open cloth can inflict serious wind chill problems on the solders in cold climates with a breeze blowing and may thus affect survival chances in extreme cases. Finally, a highly air-permeable fabric may be sheer or have as very open structure, so that aesthetic factors such as modesty, dimensional stability, drape, handle etc may result in discomfort of a psychological or physical nature in the wearer. Although air permeability in itself is merely another effect, rather than a cause, associated with such manifestations of discomfort, it can nevertheless provide a convenient and readily measured way of quantifying the likely behavior of a fabric in these other areas.

Air permeability is normally measured on apparatus designed to force air through the test specimen in a reproducible manner, usually classified into two types. In one system, the pressure difference between the opposite faces of a test specimen is fixed, and measurement is made of the resulting air-flow thro' the material. In the other type, the rate of movement of air thro' the fabric is adjusted to a fixed value and the pressure[16] difference that must be developed across the fabric in order to maintain this air-flow is then measured.

5. MOISTURE-VAPOUR TRANSMISSION

5.1. MOISTURE PERMEABILITY

Another important property of a fabric, from the comfort standpoint, is the way in which it allows water to pass through it. This process can take place in both the liquid and vapour phases of water and the difference is an important one. This property is known as 'permeability of a fabric to moisture vapour'. Generally the primary cooling mechanism of the human body is evaporation of perspiration, with water vapor carrying heat away from the body as it evaporates out of the skin's pores. In the garment–skin microclimate environment, the absorption of sweat by garment and its transportation through and across the fabric is evaporated [17].

Moisture-vapour permeability in fabrics is achieved or lost at either the manufacturing or the finishing stage of the production process. Although heat transmission may be critical to survival in cold weather, it is incontestable that moisture-vapour transmission is crucial to comfort in both cold and hot weather[17]. Free movement of water to the fabric surface is essential if perspiration discomfort, causing fabric wetness with resulting freezing in winter or clamminess in summer, is to be prevented.

5.2. FACTORS AFFECTING MOISTURE- VAPOUR PERMEABILITY

The movement of water vapour through a fabric depends considerably on the micro porous nature of the material, and this movement can therefore be modified by any operation that brings about a change in this structure. The factors affecting moisture vapour permeability are enumerated by different authors, some of which are the effect of fabric structure and properties, finishing treatments, texturising, different yarn twists, blending and mechanical treatments[18].

5.3. WATER REPELLENCE AND WATER ABSORPTION

In considering the movement of liquid, water through a fabric, two comfort aspects may be identified. Water from an external source, e.g rain, should be prevented from reaching the body, an aim that is achieved by using a water-resistant barrier. On the other hand, water generated at the body surface as perspiration should be removed as quickly and as efficiently as possible if comfort is desired[19], a process that is encouraged by absorption within a body-covering. Both mechanisms are generally needed simultaneously although two requirements are diametrically opposite. In defense clothing in particular, attempts have been made to find a satisfactory compromise between the two, but with no outstanding success so far.

For waterproof and water-repellent finishes on textiles various treatments with chemical compounds are used[118]. For achieving increased absorbency, three methods may be suggested. They are (i) physical modification of the structure (ii) chemical treatment or modification and (iii) coating techniques. Test methods for evaluating both repellence and absorbency are available[18].

6. SIZE AND FIT

Another important aspect of comfort, which is not strictly a textile problem but clothing one, is that of size and fit. No matter how well a fabric is engineered to have optimum values of heat, water or air transmission, any garment made from it cannot be regarded as comfortable if it does not fit properly. The garments need to be cut neatly and to be able to maintain reserve of comfort for the solders dynamic movements. There are two distinct factors in determination of whether the fit of a garment is good. The first one is a subjective one, which depends on whether the wearer achieves psychological satisfaction from the garment. The other factor is a physical one and is concerned with the conditions of contact between fabric and body. A badly fitting garment can restrict cardio-vascular flow, cause skin abrasion, create unpleasant thermal or moisture conditions or induce irritation that manifest to the wearer in the form of discomfort[20].

The relationship between fabric extensibility and anthropometric requirements of garments were reported[21]. In analyzing the anthropometric kinematics, the authors identified that there are three essential components to meet the skin strain requirements: garment fit, garment slip and fabric stretch[22]. Garment fit provides space allowances for skin strain, which is affected by the ratio of garment size to body size and nature of garment design. Garment slip, which is determined mainly by the coefficient of friction between skin and fabric and between different layers of garments, is another mechanism for garment to accommodate skin strain.

In order to establish criteria for good or bad fit, it is necessary to define the size of the body area at which the fit must be made. As a result of obvious non-uniformity of the human population, such a definition cannot be established exactly and some reliance on statistical variability must be assured. Even where a garment has been selected for optimum fit of has been made to measure; the imperfections of the tailoring process and of human body make it perfectly possible that the wearer may experience some degree of discomfort as a result of faulty fit[22]. In addition, the original size may change because of dimensional instability during use or after washing.

7. AESTHETIC COMFORT

In examining the comfort behavior of clothing, it is necessary to include some consideration of factors that are not readily measured by obvious physical tests and may be subjective in that two people may disagree about the level of comfort of the same garment[20]. These aesthetic factors include such aspects as softness, handle, drape and similar properties. It may also include properties such as color, luster, style, fashion compatibility and other similar characteristics. The aesthetic properties are normally judged by the way in which it feels or looks, but some of them are in pressed in quantitative terms in the textile technology. The aesthetic behavior may be modified in fabrics by either chemical or mechanical treatment. Imparting softness, crease resistant finishes, modifications causing a change in its appearance, wrinkling, pilling and luster of fabrics are some of the properties investigated in the recent literature[23].

8. CONCLUSION:

Clothing is an integral part of human life and has a number of functions; adornment, Status, modesty and protection. Especially in military textiles protection is very important functions, and it will fulfill the number of functions, such as maintaining the right thermal environment to the body that is essential for its survival; and preventing the body from abrasion, radiation, wind, electricity, chemical, microbiological, nuclear, and toxic substances. The comfort of military clothing is composed of a complex mix of sensory, cognitive, and affective variables. We can understand from different literatures and test results that when we apply judiciously the advanced sensory, psychophysical, and cognitive methods to the problem of military clothing comfort can lead to a better understanding of the factors that control the comfort of the military forces.

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