



*Research Paper*

# ERGONOMICS OF CHINESE ARMOUR FIGHTING VEHICLE

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Noises and variations in ambient conditions experienced by the human body in the course of its employment have direct bearing on the performance efficiency of the crew. Tank crew has to wear bulky gears, and perform complex movements or assumes un-usual postures/positions. This necessitates that tank crew must be kept comfortable for safe and efficient performance during operations. Fatigue is generally caused by various sources of excitation, such as ground surface irregularities, characteristics of suspension, construction, of seat, environmental factors and anthropometry. The ergonomics study on vibrational effect and response of crew to it, noise effect and anthropometry have been carried out in detail prior to recommending the measures to reduce the fatigue effects caused. The anthropometric analysis of armored corps personnel of Pakistan army has been carried out in relation to working space available in T-series tanks of Chinese origin especially T-59 M extending it to MBT-2000.

**Keywords:** Ergonomics, Chinese armor and fighting vehicle

## INTRODUCTION

It is not the gun; it is man behind the gun, who matter. The human body is susceptible to the environments in which it is being employed. Vibrations, noise and the environmental factors in which the tank crew is working effects the performance of the crew. No consideration was given to the human engineering in the design aspects of the equipment. Human body used to be utilized as a machine operating another machine. The term environment is

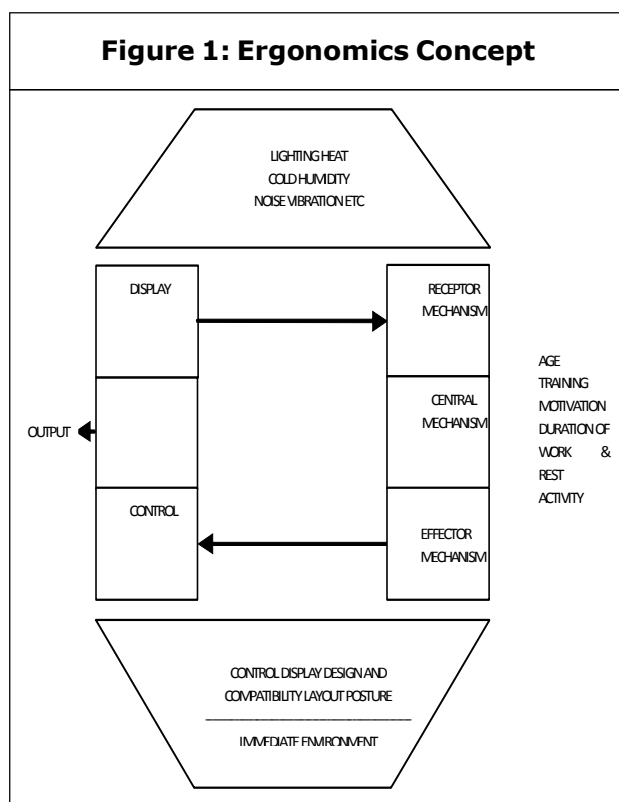
taken to cover not only the ambient environment in which he may work but also his tools and materials, his method of work and the organization of this work. All these are related to the nature of man himself and to his abilities.

## Ergonomics

Ergonomics has been defined as the scientific study of the relationship between men, equipment and his working environment, i.e.,

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to provide a fatigue free working environment to man. In this sense the term environment is taken to cover not only the ambient environment in which he may work but also his tools and materials, his method of work and the organization of this work. All these are related to the nature of man himself and to his abilities, capacities and limitations. The fundamental relationship involved between the man, equipment and the working environment is shown in the Figure 1.



## PROBLEM STATEMENT

Chinese tanks are used as main battle tanks by Pakistan army. These tanks are low Shallotte tank and incorporate many environment factors like noise, vibration, temperature and fatigue effects. Which directly affect the efficiency of tank crew? Pakistan armoured corps soldiers are comparatively have more bright and better built than Chinese

counterpart. Thus making it even worse for them. The tank crew has to operate tanks for longer duration of time during war therefore; they have to be made comfortable and possible for imparting with efficiency.

## LITERATURE REVIEW

According to the result of recent survey 4.4 million people in United States are suffering from ergonomics related disease (Seller, 1994). According to Dr. Steve Burastero the number of cases of work related musculo-skeletal disorder has increased dramatically to near-epidemic proportions in the workforce, from about twenty percent of occupational illness nationwide in 1981 to more than sixty percent of all occupational illness today. These disorder cost the US nation over forty billion dollars per year in medical cost alone. When productivity losses and disability and retraining costs are included, the total bill may rise to eighty billion dollars per year (ergonews.com). Ergonomics is the science of man, machine and environment integration. It removes barrier to quality, productivity and human performance by fitting products, tasks and environment compatible to people ([www.uhs.berkeley.edu/Facstaff/Ergonomics](http://www.uhs.berkeley.edu/Facstaff/Ergonomics)).

## Ergonomics

A poorly designed workstation may force a worker to sit in awkward working postures, to bend and stretch unnecessarily and apply more force and repetition in work, this misfit may lead to a number of problems internal to the human body causing temporary and permanent injuries ([www.ansi.org](http://www.ansi.org)). The goal of ergonomics is to fit the task, tool, and environment to the worker. By ergonomic intervention one can reduce injury, illness and

discomfort, which in turn improves the efficiency and worker quality.

### **History of Ergonomics**

Frederick W Taylor was a pioneer of this approach and evaluated jobs to determine the "one best way" they could be performed. At Bethlehem Steel, Taylor dramatically increased worker production and wages in a shoveling task by matching the shovel with the type of material that was being moved (ashes, coal or ore).

Frank and Lillian Gilbreth made jobs more efficient and less fatiguing through time motion analysis and standardizing tools, materials and job process. By applying this approach, the number of motions in bricklaying was reduced from eighteen to 4.5 allowing bricklayers to increase their pace of laying bricks from one hundred and twenty to three hundred and fifty bricks per hour.

### **Environment**

Environment plays an important role in a man machine system. Environment can be bifurcated into two types: the external environment and internal environment. The external environment encompasses physical working conditions and the layout of workstation. It includes such influences as temperature, noise, humidity, dust, equipment, etc. Whereas the internal environment encompasses the physiological conditions within the body of the worker. These internal factors hampering efficiency arise as a result of non-ergonomically designed external environment (Morgan and Lund, 1963). Human beings can withstand moderate changes in the external environment, because their internal environments are kept reasonably constant by

regulatory mechanism, the body fails to maintain the internal environment and result is the deterioration in the performance of the sense organs, central nervous system, muscles and glands (Morgan and Lund, 1963).

At a workstation various external factors such as inappropriate lighting and temperature, size of chair & table, positioning of equipment posture and bad air quality give rise to some problems inside the body (Sellers, 1994). The physiological health problems range from minor muscle problem to permanent damage. The result of which are disabilities and dissatisfaction of the users that intern leads to decrease efficiency. It is important to control the environment so that the user can maintain his efficiency and interest for longer duration and utilize his abilities fully.

### **External Ergonomic Factors and Standards**

Following are the external factors that may become a cause of internal problems at a computer work station.

- Temperature
- Noise
- Lighting
- Driver seat
- Positioning of fire control system in turret
- Positioning of equipment
- Internal environment

### **METHODOLOGY**

Scientific research methodology has been followed in the research .

- Interior of the armored fighting vehicles has been measured for compatibility with crew.

- Practical measurement have been taken.
  - Anthropometry dimensions of individuals.
  - Noise level in tanks in different speeds and RPM.
  - Vibration.
  - Working environments.
- Tank driver seat adjustability and movably has been designed for crew comfort

Ergonomics of all these factors have been matched international standards

## ANTHROPOMETRY

The human body in structure and mechanical function occupies a vital place though often neglected in machine design. He breathes and likes to move in the confines of his place of operation while performing his job. He may have worn bulky gears and perform complex movement or assume un-usual; positions. Human being must be made comfortable, safe and efficient.

Anthropometry deals with the measurement of the human body with which the equipment designer is concerned. Such measurements include body dimensions and ranges. The design of all equipment must be considered in relation to both the size of the individuals who are going to use it and the movements which they can make without difficulty/strain. Individuals vary greatly in their size from dwarfs to giants; on the other hand the limits imposed on movements by the joints show much less variability. It is, therefore, necessary to have some information about body measurements of the populations which is likely to use the equipment. Anthropometric mismatch with

nature of work can produce safety and health hazard.

### Anthropometry Data of Armoured Corps Soldier

Body measurements of 158 Armoured Corps Personnel have been taken. This data is based on region basis and for this purpose following regions have been made:

- Sindh Baluchistan
- Punjab
- NWFP
- Azad Kashmir

While collecting data following points have been taken care of:

- The group measured is representative of the equipment user.
- Sample is large enough, and yields reliable results.
- It pertains to all ranks, that is, officers, junior commissioned officers, no-commissioned officers and sawars.
- The data pertains to the persons of different age groups.
- The data pertains to the persons of Armor corps belonging to various parts of the country.
- The data pertains to the persons of various class compositions.

To make the data useful for ergonomics study the following procedure was adopted:

- Arithmetic mean of the data was calculated to find 50<sup>th</sup> percentile or the average value.

- Standard deviation for each human body dimension was calculated using mathematical formulae.
- To find the 5<sup>th</sup> and 95<sup>th</sup> percentiles the standard deviation was multiplied by a factor of 1.645. The value thus obtained was subtracted from arithmetic mean to get the 5<sup>th</sup> percentile and added to the arithmetic mean to get the 95<sup>th</sup> percentile.

The available working space dimensions of the tank have been co-related with the body dimensions and working postures in various positions. Then the analysis has been made and based on this, it is concluded that the height and built of the tank crew, especially the driver must be kept at lower side of recruitment and selection standard of Pakistan Army for Armoured Corps personnel. It should be between 5'-3" to 5'-6". This built of tank crew will facilitate in maintaining the proper working postures resulting into crew comfort.

## WORKING ENVIRONMENT

The environment in which a an operators work must be included as a consideration in the design of the man machine system because the environmental conditions can seriously affect their performance, equipments/ machines often have failed to fulfill their missions, not because they were poorly designed or badly constructed, but because they demanded more of the operator than was humanly possible considering the environment.

The working environment includes:

- Noise
- Temperature

- Vibration
- Working Space

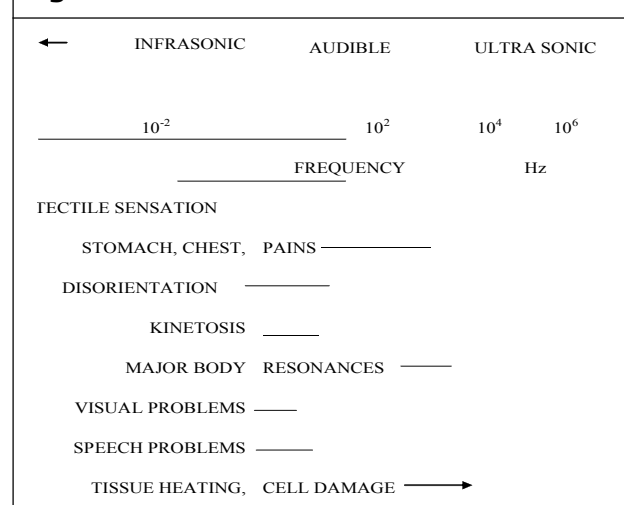
## Vibration

Human body is very susceptible to the environments and vibrations. Vibrations caused by the tank movement affects the performance of the tank crew and if not taken care of, it causes fatigue and also affects the health of the crew. The main sources of excitation of vibrations are surface irregularities, suspension characteristics and design factors. The influence of vibration in tank on crew is so significant that it needs looking into the design features for providing comfort to the crew. The sources of vibrations in tanks are caused by:

- Engine
- Propeller/Fans
- Tracks
- Road Wheels
- Suspension System

The effect of vibration on a tank crew is shown in Figure 2.

**Figure 2: Effect of Vibration on Tank Crew**



## Human Response to Vibration

The surfaces over which tanks move are generally uneven. In consequence they give rise to vibrations which affect the crew and can seriously degrade or restrict their performance. The sensitivity of the vibrations depends in the first instance on the geometry and hardness of the surface over which tanks move and on the speed of tanks; however, it also depends on the suspension system of the tanks, which are intended to minimize the displacement and the forces experienced by them. The most difficult, from the vibrations point of view is broken ground, which can severely restrict the speed of tanks over it. Restrictions on speed on tanks are ultimately related to the reactions of their crews, they involve the human response to vibrations. Extensive attempts have been made to establish limits of human vibration tolerance. Such limits are of direct interest in relation to the speed of tanks over rough grounds because the crews efficiency he is restricted due to the degree of discomfort or risk of injury they are prepared to accept. However, there is no general agreement on what these limits are.

In the modern era of advancement, it is greatly emphasized that in the main battle tanks, crew comfort plays a pivotal role for fast and accurate mobilization and hit probability. Continuous and progressive means of providing maximum comfort to crew is being asserted so that optimum use of man power in correct and result oriented direction is achieved. Keeping in view this factor, most of the main battle tanks of the world armour armies have been equipped with modern and comfortable apparatus, so that efficiency of the

tank crew is maximized and their fatigue in minimized.

The important crew comfort factors are suspension system, power pack, Fire Control System (FCS), Night Vision Devices (NVDs), auto loader system, hydraulic assisted operating system, gun stabilization system, crew seats, etc.

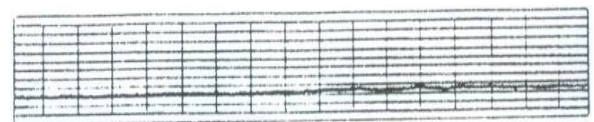
Vibrometer has been used to measure and then graphically representing the vibrational effects of tank during static running and moving of tank on Tank Test Track of H.I.T Taxila Cantt. The graphical representation of tank movement at Test Track is shown:

Vibrational effect with original driving seat is 85 cps at 20 Kmph in Figure 3 pg. 28.

Vibrational effect at gunner's seat is 83 cps at 20 Kmph in Figure 4 pg. 28.

Vibrational affect at driver seat with modification is 63 cps at 20 Kmph in Figure 5 pg. 28.

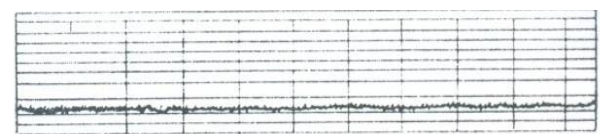
**Figure 3: Vibration of Tank at 30 Kmph  
Speed 85 cps**



**Figure 4: Vibration on Old Driver Seat  
83 cps**



**Figure 5: Vibration After Incorporating  
Dampers in Driver Seat 63 cps**



Vibrational effect at gunner's seat is 62 cps at 20 Kmph. Instrument used for this purpose is HOIKS INSTRUMENT.

### **The Effect of Noise on Efficiency**

Noise is defined as any undesirable sound even though it might be meaningful. The criterion of undesirability is based on the capacity as to disrupt communications, cause injury to hearing (hearing loss), produce annoyance or discomfort, or reduce skilled performance. The effects of noise are:

- Annoyance
- Irritation
- Hearing Loss. Temporary hearing losses resulting from noise exposures are greater the higher the noise level, the longer the duration of exposure, and within limits, the shorter the band-width within which the energy is concentrated. The effect is seen as a loss in auditory acuity, especially between 1,000 and 6,000 cps.
- Commitment of error
- Effect on efficiency

All kinds of noise which have been specified may, under circumstances, have an effect on efficiency. Continuous noise has an effect which is related to its intensity. It may cause irritation (and, indirectly, in-efficiency). Intermitted noise, if it is regular, may have effects which differ little from those of continuous noise but if it is regular and unexpected it may cause a 'startle reaction' which can be most disturbing. The influence of meaningful noise will be related to a large extent to particular circumstances and is likely to depend on the nature of the noise and what it means to the hearer.

**Annoyance:** Under such circumstances some individuals may become irritated by certain types of noise and this may, in turn, have an effect on their work. High pitched noises appear to be more annoying than lower pitched noises. Low pitched noises were also said to cause annoyance. From these results it seems that annoyance is associated with the higher or lower frequencies.

Relating a subjective feeling such as annoyance to an objective measure of performance would seem to be just as difficult as trying to relate, boredom to performance. Therefore, it is difficult to say whether or not annoyance does cause loss of output, since it will be necessary to rely on the reports of the individuals that they found certain conditions annoying, always assuming that they know what that term means.

### **Noise Reduction for Tank Crew**

Ergonomists are of the opinion that a human being working in a calm, quiet and noiseless environment gives better output than his counterpart who is subjected or is working in a noisy environment. Tank crew efficiency is also related/affected by frequency of noise to which an individual is subjected to. In the present era of technological advancement, every effort is being made to control the noise, as it is one of the most important factors which contribute a lot in overall reduction efficiency of an individual worker-operator.

Noise produced by automobiles of different categories varies in band width from one another in their intensity and effect. It well proved that in present day the restlessness, irritation, aggressiveness and many more symptoms shown by the individual in day to day contacts

are the out-come of severe noisy/polluted atmosphere present around us. All above mentioned factors are main source for causing fatigue and reduction in output/efficiency. The working conditions and ambient conditions play vital role in human efficient output. Ergonomics deals in depth about the effect of all above in detail in relation to human body.

### Noise Level Measurement

- Static Running of Tank Engine noise level is shown in Table 1 on pg. 20.
- Running Tank noise level is shown in Table 2 on pg. 20.
- Depending on the level and duration, noise may be a major irritant. Or even a threat to your hearing. Acceptable noise levels for exposure duration of workers are as given in the Table 3 pg. 20.

**Table 1: Static Running of Engine Noise Level**

Engine (RPM)	Sound Level		Outside the Hull (db)
	Fighting Compartment (db)	Driver Compartment (db)	
550	104	103	100
1000	107	108	105
1500	110	111	108
2000	117	118	111

**Table 2: Running Tank Noise Level**

Engine (RPM) Kpm	Sound Level		Outside the Hull (db)
	Fighting Compartment (db)	Driver Compartment (db)	
10	108	106	102
15	112	109	104
20	115	112	107
30	119	112	112

**Table 3: Duration of Exposure of Worker at Various Noise Level**

Duration Per Day (Hours)	Sound Level (db)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or Less	115

### Protection Against Noise

The engineering solution to the noise problem requires one or more of the following procedures to be adopted:

- Reduction of the noise output at the source. This procedure involves design and material consideration, damping by suitable mounting.
- Attenuation or deflection of the sound from the source. This procedure involve insulation at the source, use of baffles and ears protective devices.
- Noise Damping System should be incorporated.

In modern tanks, the designers and engineers are very vigilant about noise control, as noise produced by high speed tanks may lead to severe damage to hearing capacity and nervous system. Noise produced by tank T-69IIMP with 580 HP engine is also of high intensity, which along with vibration causes extra crew fatigue. Noise of tanks has been measured with sound meter. The exhaust manifolds subjected to outside atmosphere produces great noise. There is no muffling



device in the exhaust manifold and exhaust, hence it produces a thundering pressurized noise, as exhaust of the tank is expelled with high pressure higher than surrounding ambient pressure thus its intensity is increased manifolds.

To evaluate the environmental effects on crew, I got the technicians working on the engine testing dynamometers medically examined by doctor and it was found that the technicians working in test bench room have lost up to 56% hearing. Hypertension also developed severe headache thus declaring them unfit to work under noise and vibration conditions. The noise level on dynamometer is approximately 120 db.

## **Fatigue**

Since one of the main objectives of crew comfort is to reduce fatigue and to make working as easy and satisfying for the individual as possible. In this context it is desirable to examine the nature of fatigue.

Fatigue may be defined as decrease in work capacity caused by work itself. It is important to state that fatigue is not only caused by work, work capacity may also be lowered by other causes, i.e., by drugs, illness or lack of incentive. In every case there is a sensation of fatigue, although no work may have been done.

The term fatigue has various meanings, depending upon the point of view that is taken in considering the subject. Fatigue in industry refers to three related phenomena:

- A feeling of tiredness.
- A physiological change in the body (the nerves and muscles fail to function as well

or as fast as is normal because of chemical in the body resulting from the work).

- A diminished capacity for doing work.

Fatigue is often divided into two types, mental and physical. The first type implies a state of fatigue which results from mental work. This is often due to boredom because of lack of interest and is a problem for the psychologist, the psychiatrist, and the sociologist, as much as for the physiologist. Physical fatigue is caused by physical or muscular work and should be of great interest to be physiologist. It is true that the physiologist has all too frequently emphasize the effects of fatigue on the working muscles, but ordinarily recognizes a two fold nature of fatigue. Thus, when speaks of neuromuscular fatigue which indicates the respective share of muscular and nervous elements. It is difficult if not impossible, to separate wholly these two types of fatigue. Mental concentration and emotions are factors in much of the fatigue associated with work. It is generally recognized that excessive mental work may also cause muscular weariness.

Many factors affect the amount of work that an individual will do in a day and the extent of the physical fatigue that will result from this work. With a given set of working conditions and equipment the amount of work done in a day will depend upon the ability of the worker and the speed at which he works. These factors depend directly upon the individual's inclination or his will to work, which itself is affected by many things. The fatigue resulting from given level of activity will depend upon such factors as:

- Hours of work, that is, the duration of the working day and the weekly working hours.

- The number, locations, and the length of rest periods during working hours.
- Working conditions, such as lighting, heating, ventilation, vibration and noise level.
- The work itself.
- Mental and physical concentration required in work.

## RECOMMENDATIONS

After carrying out detailed analysis for crew comfort criterion in T-series tanks of China origin as discussed earlier the recommendations are summarized as follows:

### Recruitment Policy

The analysis carried by correlating the body dimensions and working space available, it is concluded that height and built of tank crews especially the driver must be kept at lower standard of recruitment in Pakistan Army.

### Vibrating Damping

It is recommended that special attention be given to dump the vibration in tank by improving its suspension systems and transmission system for comfortable movement of crew.

### Noise Reduction

It is recommended that noise must be reduced by incorporation the following improvements in design of exhaust system of tank:

- Reduction of noise output at source.
- Alteration or deflection of sound from the source.
- Noise damping system incorporation.

## Temperature Control

It is recommended that following measures maybe adopted for control of temperature erosion:

- Circulation of air form compressor being used for air starting system of tank engine.
- Body conditioning by designing special dress and closed circuit Air-conditioning.

## CONCLUSION

A comprehensive study of application of ergonomics criteria developed by author has yielded:

- The height and built of armoured Corps personnel should be at the lower side of the requirement criteria of Pakistan army, i.e., 5' 3" to 5' 6".
- To reduce the noise effect three different noise reduction exhaust systems have been suggested for which a practical demonstration has been arranged. With this system approx 30% noise have been reduced through exhaust.
- In addition to reduce the vibrational effects, vibration damper has been suggested to be incorporated in the seat with which approx 25-30% improvement can be achieved. Through this arrangement the author has succeeded in reducing fatigue effect on the crew by approx 30%.
- Due to the Environmental and vibrational effects on the crew the driver was taken as a test sample as he is the worst effected out of the crew because of these effects.

In the modern era of advancement, it is greatly emphasize that in the main battle

tanks, crew comfort plays an pivotal role for fast and accurate mobilization, hit probability continuous and progressive mean of providing maximum comfort to crew is being invented so that optimum use of manpower in correct and result oriented direction is achieved. Keeping in view this factor most of the main battle tanks of the world armoured armies have been equipped with modern and comfortable apparatus, so that efficiency of the tank crew is maximized and their fatigue is minimum. ♣

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