

# Human Engineering in Tractor Design- A Review

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**Abstract -** In India agriculture is one of the important sectors which provide local employment and have significant contribution in our GDP. The large population in our country needs various types of food and other agriculture products. As the land available with the country for cultivation is limited therefore in order to increase agriculture output we should make best use our available cultivable land using farm equipment's and implements. Tractor is one of the main reasons which helped to increase productivity of farming sector reducing dependency of our farmers on animals for tillage and irrigation activities. Tractor was one of the main components which helped in making India self-sufficient in producing food items for its large population and creating green revolution in our country. Unwanted accidents involving farm equipment and machinery especially involving tractors continue to happen. One of the reasons for these accidents is driver fatigue and non-implementation of human factors while designing tractors. There are many human factors which enhance the use of tractor in farming activities without any troubles to the driver/ Operator making it easy to use.. This paper will explain the details of those human factors which need to be taken care while designing a tractor.

**Keywords-** Hand-and foot controls, cabs and protection frames, Tillage, Transportation, Comfort factors, Environmental factors.

## I. INTRODUCTION

Initially up to year 1856 all such machines which were used for traction were known as traction motors and later in the year 1906 these were designated as Tractor by deriving Half word "Trac" from traction and other half word "tor" from motor. Tractor is a self-propelled power unit having wheels or tracks for operating agricultural implements and machines such as water pump, thresher, seed drills, trailers etc. Tractor engine can also be used as a prime mover through belt pulley or power take-off shaft (PTO) for stationary farm machinery and moving tools. It has complete hydraulic system for hitching of Implements and movement of those Implements.

Because of these special features tractor is also called as a special vehicle as it is very different in construction and working from other commercial vehicles. The farm tractor is one of the most important machines of farm mechanization and it is the main unit for the utilization of other farm equipment and implements for various agricultural operations such as ploughing, ridging, harrowing, weeding, planting, harvesting etc. The operator apart from tractor operating can perform many activities such as equipment cleaning/sheltering, housekeeping, inspection, lubrication, and daily adjustments. These activities can be done without error if the operator is not over stressed due to non-adaptation of human factors while designing a tractor. Tractors are like

companions for many operators. A well-designed human-tractor interface (i.e. hand-and foot controls, cabs and protection frames) can increase operator's productivity, safety and comfort.

### Classification of Tractors

Tractors on the basis of structural-design can be classified into three categories:

**1. Walking tractor (Power tiller):** Power tiller is also known as walking type tractor. This type of tractor are generally having two wheels. The operator walks behind the tractor and controls the direction as well as its field operations.

**2. Crawler tractor:** This type of tractor is also known as chain type or track type tractor. In place of pneumatic wheels, there is endless chain or track in this type of tractors.

**3. Wheel tractor:** In this type of Tractors are fitted with three or four pneumatic wheels. Out of these two every where only four wheel tractors are popular.

### 4. Main Components of Tractor

A tractor is made of following main components:

- (1) I. C. engine
- (2) Control panel
- (3) Clutch
- (4) Transmission gears
- (5) Tractor pulley
- (6) Front wheels
- (7) Steering mechanism
- (8) Brakes
- (9) Hydraulic control and hitch system
- (10) Differential unit
- (11) Final drive
- (12) Power take-off unit and
- (13) Rear wheels

Every tractor is fitted with an I. C. engine, the engine, nowadays almost all the tractors are diesel tractors. Due to

small size of land holdings in India, it is the largest market in the world for small tractors i.e. below 37 kW. India has also attained the position as largest tractor manufacturers in world. These tractors are mainly used for primary and secondary tillage operations and for transportation of goods.

## II. IMPORTANT HUMAN FACTORS IN TRACTOR DESIGN

Human engineering or ergonomics deals with the possibilities of man-machine system which means making the products or machines to fit the operators. Ergonomics (ergo means work; nomos means laws in Greek) has become a field of importance in recent times, as it helps to get maximum operational efficiency. These two approaches has slight variations with each other , One approach mainly deals with man- machine system integration , the second approach whereas mainly concerned with welfare of concerned individual. Hence, ergonomics deals with the relationship between man and his occupation and environment, particularly the application of anatomical, physiological and psychological knowledge to the problem arising thereof. Objective of ergonomics is also to achieve a rational use of human capabilities and to an optimum adaptation of the work situation to these capabilities.

It is sometimes also known as human factors engineering or human engineering. Ergonomics is the study of designing the device and equipment according to the human body, its cognitive abilities and its movements. It deals with the tools design, technology design, job demands, and workstation design, and work environment, biomechanical and physiological effects on the body. The modern tractor design essentially considers human factors an important consideration. If the human factors are incorporated properly in tractor design then tractor operator can perform complex tasks with minimum fatigue, safety and efficiency.

The commonly used, human factors include such items as visibility, riding comfort, arrangement and location of tractor controls, ease of controls operation, sound control and thermal comfort. The designing of devices and equipment that suits the human body, its movements and cognitive abilities is studied under Ergonomics. It consider the tools, workstation design, technology design, physical work environment, job demands, biomechanical and physiological loading on the body. Hence the productivity and the efficiency of the operator can be increased by application of ergonomics without jeopardizing their health.

The primary function of a tractor seat include the position the tractor operator where he can operate the tractor safely with experiences reduced vibration levels and all around

vision . In the seat cushion material operator must also feel comfortable. Due to long and extended period field operations and seating results in problem of discomfort in buttocks due surface pressure and there is also a high risk of back problems, discomfort in feet and legs due to pressure under the thigh. Hence all the controls are designed and located in such a way to need minimum body movement and least operating efforts.

### 1. Visibility

The operator should be able to see things in front and surrounding with ease and without much physical movements to ensure proper movement and safe operation of tractor. Two functional conditions in design the workplace for a tractor operator are visibility and clearance. Primary visibility for a tractor requires provisions so that the operator can look in any direction. Near ground vision to the front and rear of the operator is important. Far vision in all directions is necessary. Secondary visibility is concerned with monitoring lights or instruments inside the workplace of operator. To maximize this aspect the operator cabin is positioned in the middle of the chassis to improve visibility. Clearance at various levels is necessary to provide access to and from the workplace. For ease in grasping and operating controls proper workplace dimensions in relation to the seat are important.

### 2. Riding Comfort

Comfort is combination of driver's feelings like relief, enjoyment, encouragement etc. Comfort is dependent on geometric parameters of driver seat and exposure to environmental factors such as thermal conditions, machine vibrations reaching up-to operator body, sound, humidity etc.

### 3. Distribution of Pressure over operator Seat

To provide comfort to the operator the pressure distribution along the human body should be uniform over the seat as is very important factor for the health of operator. Over a seat Pressure distribution is dependent on the cushioning material properties such as hardness, deflection, stiffness and design of cushion. Also it depends on nature of seat bracket design, seat loading and seat pan design. The function of seat pan contour is to distribute uniform pressure over seat which avoids stress concentration in human buttocks. Hence the design of seat pan contour should be proper.

### 4. Exposure to Environmental factors

Tractors are generally used under different geographical and climatologically conditions. The operator is directly exposed to below mentioned environmental factors

1. Temperature
2. Humidity
3. Wind
4. Thermal radiation
5. Dust and
6. Chemical

Hence in order to minimize the effect of above mentioned factors design of a suitable enclosure for the tractor operator is very essential. Table I defines levels of comfort and bearable zones for humans.

### 5. Thermal Comfort

When the state of mind expresses satisfaction with the thermal environment in surroundings it is known as thermal comfort. The ideal temperature for tractor operator cabin should be from 18 to 24 degree Celsius. This range is best for the thermodynamics process of heat exchange between man and his environment. Excess amount of heat storage in body of operator will cause the mean body temperature to rise; less amount of heat storage will cause it to fall. Most individuals will be comfortable when the External Temperature is between 23.9 and 26.7°C.

Table 1 Environmental Zones for Selected Parameters

Environmental Parameter	Bearable Zone		Comfort Zone	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Temperature, °C	-1	38	18	24
Humidity, %RH	10	90	30	70
Ventilation, m <sup>3</sup> /min	0.14	1.4	0.37	0.57

Operator enclosure design must include cab pressurization, filtration, air movement, heating, cooling and window defrosting. These factors must be considered in order to provide clean air and proper velocity, temperature and air humidity for human thermal comfort. Cab pressurization is necessary to prevent dust from entering in the operator's cabin. Design parameters to meet a wide range of climatic conditions are given in Table II below.

Table 2 Design Parameters for Maintaining Thermal Environment in a Tractor cabin

SN	Parameter	Rating or Capacity
1	Heating	8.2 KW at 66°C and water flow 11.4 h/min
2	Cooling	7.0 KW at 33°C and 60% relative humidity
3	Air movement	0.235 m <sup>3</sup> /s at 50 Pa using Three-speed blower
4	Cab pressurization	50-100 Pa above outside of cab
5	Fresh air filter	1.92 m <sup>2</sup> pleated paper, self-cleaning

### 5. Operator Exposure to noise

The continuous exposure to very loud sounds reduces the hearing capacity and can cause permanent hearing loss to the tractor operator. It has been find out by many researches that exposure to the sound level of 90 dB and above for more than 40 hours will produce permanent

hearing loss. Moreover Noise-induced hearing loss does not happen immediately unless the noise exposure is highly severe. Table III shows the presently acceptable sound levels in existence. It has been found in many tests that average noise levels for tractors tested with cabs at 75% pull averaged 88.04 dB(A) with the lowest reported being 80 dB(A). The average noise level for tractors without cabs at 75% pull averaged 96.0 dB(A), with the lowest reported being 89.5 dB(A). Acoustic noise is sound. The sound is characterized by amplitude, frequency and phase.

The frequency range of the human ear varies from 16 Hz to 20,000 Hz. But only few adults can perceive sound above 11,000 Hz. The magnitude is most commonly expressed as the RMS (root mean square). Hence care should be taken while designing the cabin of the tractor all the high dB sounds are restricted outside the cabin itself so that discomfort due to high sound can be controlled and the operator can also be saved from permanent hearing loss over a long period of time.

Table 3 Occupational Safety and Health Noise Criteria

Duration/day h	Sound level dB (A)	Duration/day h	Sound level dB (A)
8	90	1½	102
6	92	1	105
4	95	½	110
3	97	¼ or less	115
2	100		

Reduced noise levels have in part can be achieved by incorporating sound control measures in the operator enclosures. This design approach includes isolation mounts for the cab and suitable insulating materials for ceiling, walls, and floor. The sound reaching the tractor operator is airborne, structure-borne or may be a combination of both types.

Structure-borne sound results from vibrations transmitted from the vehicle through the cab attaching points. Air-borne sound is transmitted through air and enters the operator area through holes or through the enclosure walls. The floor of the cab is treated with a barrier material, normally polyvinyl chloride (PVC). Surface areas above the floor are treated with noise absorption materials that are effective for the 125 to 2000 Hz range. The predominant noise frequency ranges from 125 to 500 Hz. Originated from tractor and other off-highway equipments. But Through design and development efforts, the sound levels should be reduced to 80 dBA inside operator enclosures.

## 6. Operator exposure to vibration

Continuous exposure of the human body to vibrations can produce mechanical, biological, psychological and physiological effects. Studies has find out that more than 75% of the tractor drivers had stomach complaints in tractors which were operated at higher speeds and in result vibrations were produced and reached up to the body of operators. Care should, therefore, be taken while designing the seat of tractors to reduce shocks and vibration to minimum by providing suitable suspension and shock absorption system and to position the controls of tractor in such a way which will ensure tractor operator's comfortable posture and minimum effort to operate these controls.

The vibrations having frequency up to 20 Hz are called low frequency vibrations and Most of the troubles are caused by these low frequency vertical vibrations. This low-frequency vibration results in whole body excitation. During many studies it has been find out that vibration range from 4 to 8 Hz are critical for humans as resonance occurs in parts of the human body which produce discomfort. Low frequency vertical vibrations are present during normal field operations. The Amplitude of vibration is dependent on roughness of the field. The undamped natural frequencies of tractors commonly lie in the 3 to 10 Hz range. Further Higher frequency vibration (30 Hz and up) results in part-body vibration, it is the source of foot and hand-arm excitation. The higher frequency vibrations can be present at the gear shift levers, steering wheel, floor panels and control levers. Vibration levels are expressed in decibels. The vibration reference level which is convenient for humans is 1 m/s<sup>2</sup> RMS.

## 7. The Operator – Machine Interface

Whenever an operator operates a tractor, the sensing, decision making and muscular powers of the operator are joined to operate an engineering system. To interface with the control-instrumentation components the operator uses sound, sight and fuel to interpret inputs and to achieve the desired output of the tractor. All the acceptable ranges for environmental factors i.e. noise and vibration must be take care in while designing the location and construction of tractor operator's workplace to ensure operator comfort and safety. The operator's work place location on the tractor should be such that visibility in the driving position is good without requiring the operator to work in an awkward, tiring position. Work place should fit both short and tall operations, pedal, levers and instruments should be conveniently located. The operator should be able to easily change his working position and the work area should be free from obstructions such as transmission cases.

## III. CONCLUSION

A large number of studies were surveyed to list out the type of problems faced by the tractor operators during the tractor operation in fields. The environment was also studied to which they are subjected and its effect on their health, comfort, physical and mental conditions was also studied. The objective of this paper is to explain the techniques which can be used to overcome the difficult environmental conditions faced by the tractor operator. They are subjected to dust, chemicals, high volume sounds, mechanical vibrations, high temperature, High/low humidity, physical and mental fatigue, acute weather conditions, which makes this profession un-attractive. Moreover Fatigue which is also be referred as physical impairment that leads to decreased attention which leads to unwanted accidents. Hence designing the tractor according to the needs of operator providing them comfortable, healthy and safe working space will ensure enhanced output and great contribution in the economy of our country.

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