

A REVIEW OF THE CURRENT SEAT TECHNOLOGIES IN AGRICULTURAL TRACTORS

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1. INTRODUCTION

In today's age of advanced technology, manufacturers have devoted a significant part of their research in finding new ways to improve the safety and comfort of the agricultural vehicle operators. These improvements target to maximize their work quality and reduce their stress during long working hours. An important part of these improvements is the cab of agricultural vehicles and especially the farmer's seat. Seats present a high research interest as they connect the driver with the whole vehicle.

This fact has two main consequences, the external and the internal. The first can be explained in terms of the vibration percentage that passes from the ground to the driver through the seat. This is a very important issue that a 'high quality' seat has to deal with. Vibration transferred from the machinery to the human body may cause discomfort and reduction in performance, and may contribute to a permanent acute back pain. The second consequence can be explained in terms of the ideal seat position and the convenience of the farmer during operation. Farmers while driving tractors often assume a rotated posture as they are watching the implement attached to the rear of the tractor. Activities such as ploughing, harvesting and spraying will require such a rotated posture. Farmers involved in these activities may spend many hours, in this rotated posture and therefore, the seat must provide the necessary adjustments to meet their needs. Both mentioned consequences can clearly explain the research directions that the manufacturers follow in order to create more efficient seats.

Up to the 90's the majority of the farmers had a negative criticism regarding their agricultural vehicle's seats. A lot of them have reported discomfort after a typical operation (Walker-Bone and Palmer 2002). Their complaints included high and low back

pain, hip and buttock pain, neck pain, and leg aches. Back pain was one of the most frequently occurring problems while operating the tractor due to the exposure to vibration (Burdorf et al. 1990). Whole-body vibration while driving tractors has been found to be a cause of low back pain in freight-container tractor drivers (Nishiyama et al. 1998) and agricultural tractors (Bovenzi and Betta 1994). Forty three percent of sprain/strain injuries in farmers have been found to be back strain injuries (Low et al. 1996).

The intensity of vibration affecting the body is under high consideration. The levels required for health effects have not been identified yet, but there are guidelines for comfort. The latest ISO standard is based on a weighting factor for each vibration frequency. Vibrations above a standard level are considered uncomfortable no matter how short or long the exposure (ISO Document: 2631).

Studies completed by Nishiyama et al. (1998) shown that modifications to tractor seats design, including changes to the suspension, may reduce the vibration in which farmers are exposed. Seat adjustments have been found to significantly reduce the symptoms of back pain in tractor operators, although the presence of a lumbar support or changes in backrest inclination did not change the incidence of symptoms (Perkiomakela and Riihimaki 1997).

2. CURRENT TRACTOR SEAT TECHNOLOGY

Practically, every modern seat is built upon the principles of ergo-mechanics, the study of how the human body works and how to keep it comfortable and productive in work environments such as tractor cabs.

Operational issues. Farmers spend long hours in close contact with tractor seats and are consequently greatly concerned with their comfort. Most cab characteristics that the farmers may perceive as unpleasant are somewhat temporary (e.g., too hot or too noisy), however, the seat is a constant concept. Generally, seat acceptance is influenced by the two following factors:

- The intrinsic seat characteristics; and
- Factors that the operator associates with the seated position

For example, a high cab temperature is a significant factor that can influence seat discomfort. This phenomenon is associated with the heat and perspiration levels which the operator might experience at the seat contact area.

Non-seat factors that the operator associates with the seated position and which are directly related to the seat acceptance include:

- Leg room,
- Knee room,
- Availability of footrest,
- Clearance from sidewall,
- Vibration levels,
- Ease of entry/exit,
- Clearance when swiveling (for seats that provide this adjustment),
- Visibility; and
- Reach-to-control distance

Leg, knee room and footrests have comfort and health implications. For example, little leg and/or knee room forces immobility. Thus, the resulting discomfort can be endured for a short time, but not for long periods typical of a farmer's operation. Also, health aspects is an issue as the lack of muscular movement during operation results to serious blood circulation problems with cramps being the most common effect.

Current solutions. Modern tractors are equipped with an air suspension seat that redefines working comfort. The seat cushion itself is usually extra wide and deep for all-day support in the important upper leg and lower back area. Most times, the cushion is covered in fabric that has a carbon layer to help the operator stay cool and relaxed during operation. This advanced, climatic seat technology absorbs moisture while the driver is on the seat and releases it when he gets up. When temperatures drop, the only action that the driver has to do is to turn on the special heater switch to keep the seat warm.

Another issue regarding the current solutions in tractor seats is the presence of seat adjustments. Adjustments are very important as they allow seat to accommodate people of different sizes in an otherwise fixed workspace, suit personal preferences and permit changes of position to relieve fatigue. For example, a latest development allows

tractor seat to rotate in both directions in order to keep the driver in the ideal position. In addition, some other basic seat adjustments that the modern tractor seats provide are:

- Angle and length of seat cushion,
- Fore/aft cushion movement,
- Fore/aft overall movement,
- Left armrest height adjustment,
- Backrest angle,
- Lumbar support,
- Sliding headrest; and
- Setting for operator height & weight

At this point it must be emphasized that the presence of seat adjustments is not enough. The adjustment mechanisms must be easy to use and be reliable. It is meaningless to have a seat which has the latest adjustment technology with the operator experiencing a number of difficulties to find these adjustments, to understand their operation and finally to make the necessary adjustments properly.

3. DESCRIPTION OF EARLIER AND MODERN TRACTOR SEATS

Designers of modern tractor seats have contributed a significant effort in order for seats to offer the maximum convenience whereas being as easy as possible to operate them in terms of making the necessary adjustments. Special interest is presented in the different types of suspension which they are based on. Usually, modern seats are classified according to their type of suspension system. The type of suspension systems may include pneumatic (air), hydraulic (oil), mechanical, or a combination of any of these suspension systems. Until today, there has been no specific research regarding which is the best type of suspension system. However, many agricultural vehicles are offered with a pneumatic or a mechanical suspension in their standard equipment. At this point it must be noticed that nowadays the mechanical suspension systems continue to improve and it is expected that in the near future they will probably be more competitive.

3.1 Mechanical Suspension

The seat presented in Figure 1 is based on a mechanical suspension system. The suspension system is suitably designed to absorb the vibrations and jolts typically occurring in agricultural vehicles. Specifically, it reduces the horizontal and vertical vibrations that arise when traveling at higher speeds than usual, when working with rear attachments, or when working in rough ground. This result is achieved by a combination of low-frequency fore/aft and lateral suspension systems. Thus, the driver keeps



comfortable and stays fit longer while having the vehicle fully under control.

Some basic characteristics of modern seats which belong to the above category are presented below:

- Low profile seat back with ergonomic contoured cushions,
- Wide profile mechanical suspension,

- Suspension which incorporates up to a 6 in. stroke at max. height,
- Adjustable shock damper,
- Fore/aft isolator with lockout,
- Integral swivel that locks at 10 and 20 degrees, both left and right,
- 5 position lumbar support,
- Backrest extension and 3 in. comfort armrests; and
- Weight range: 110–290 lbs

3.2 Pneumatic Suspension

The seat illustrated in Figure 2 is based on a pneumatic suspension system. As it can be seen, the seat presented has a more complicated design than that with the mechanical suspension, in terms of the number of available adjustments. Also, it is equipped with an active seat climatization, which carries away the body perspiration. Sensors and electronics presented for active weight adjustment must be emphasized as they represent the current level of seat technology. Fully automatic adjustment to the driver's weight guarantees relaxed and healthy sitting while at work. Furthermore, the seat top with adjustable seatback angle, the mechanical lumbar support and the optional adjustable seatback extension are some representative characteristics which offer an optimum seating comfort.



Figure 2. A modern tractor seat with a pneumatic suspension system.
(courtesy: Grammer driver seats)

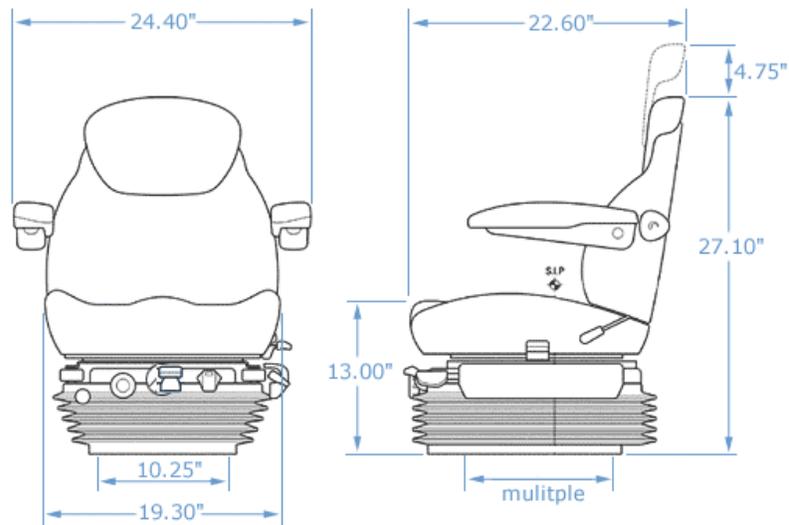


Figure 3. Representative dimensions of a modern tractor seat.
(courtesy: Grammer driver seats)

The seat adjustments provided in Figure 2 are presented below:

- Adjustable backrest recline (5 positions),
- Adjustable mechanical lumbar support,
- Pneumatic low–frequency suspension with 12–volt compressor,
- Active seat climate system and seat heating,
- Suspension travel: up to 100 mm,
- Lateral isolator with lockout,
- Fore/aft isolator with lockout,
- Ride firmness adjustment,
- Heavy duty sliderails,
- 3 in. adjustable armrests; and
- Weight range: 110–330 lbs

An interesting feature which the above seat provides is the Active seat climate system. This system is capable of maintaining the normal temperature through an internal fan where the operator’s body contacts the seat. The whole concept is illustrated in the Figure below.

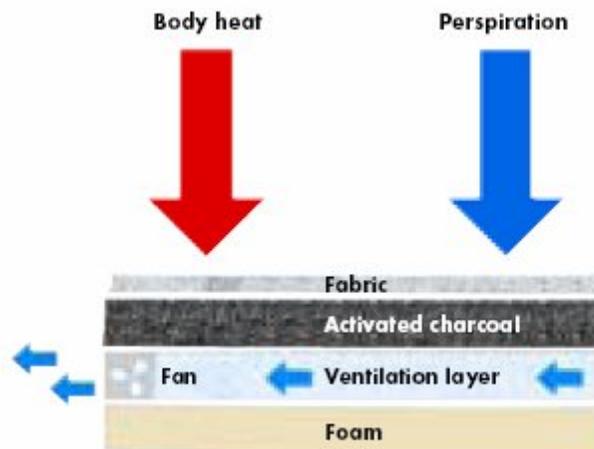


Figure 4. The Active seat climate system.
(courtesy: Grammer driver seats)

Early tractor seats. Early tractor seats are still in use at some early agricultural vehicles. A representative seat which belongs in this category is presented in Figure 5. Early seats do not have such adjustments that the new seats are equipped with. In terms of design, for example, there is a lack of right and left armrest and also a lack of backrest. In addition, the mechanical suspension is based on an old technology which has a moderate rate of vibration absorption. As a result, the driver can experience a significant amount of vibration transfer and discomfort while in operation. Finally, the seatback angle is not adjustable and also there is no existence in any climate system to control the seat temperature.



Figure 5. An earlier tractor seat.

Some general design characteristics of the above seat are presented below:

- ✚ Vibration absorption: 25–45%,
- ✚ Suspension stroke: 4" [100mm],
- ✚ Height adjustment: 2.4" [60mm],
- ✚ Suspension weight adjustment range: 110 lbs. to 265 lbs; and
- ✚ Fore and aft adjustment: 5.9" in increments of 0.6" [150mm of 15mm]

3.3 The Addition of Seat Cushion

Studies comparing the intensity of vibration between simple and more complex seats, completed by Ozkaya et al. (1996), found that some simple seating designs transmitted less vibration than more complex designs.

A simple modification which can be made to a tractor seat and is followed by many farmers due to its low cost is the addition of an air polymer-based gel seat cushion (Figure 6). Using this kind of air cushion, farmers experienced less low back pain and neck pain while driving the tractor and less back pain after tractor driving (Scutter et al. 1999). The vibration transfer and discomfort that comes from riding on the tractor is significantly reduced because of the gel seat cushion's ability to dampen cyclic chair vibrations and relieve bony prominence pressure points.



Figure 6. An air polymer-based gel seat cushion.
(courtesy: Gel Tec products)

The following are a few examples of cushions that have been widely used in the tractor seats for a better pressure management:

- ✚ *Flotation cushions* have individual air cells to allow air circulation. Although a flotation cushion is excellent in allowing for changes in seat pressure, the seating stability is reduced (Cook and Hussey 1995). This limitation can be a concern when operating the tractor over rough ground. Seat stability is important in order to maintain seat balance and safe control of the tractor. Therefore, with this type of cushion, additional support may be needed to maintain stability.
- ✚ *Combination cushions* are made of a combination of either:
 - Foam and an air-holding membrane
 - Foam and a viscous fluid

This kind of cushion achieves a significant stability while effectively distributing pressure (Trefler et al. 1993). These specialized seat

cushions also have dampening characteristics that allow the shock and vibration absorption.

- ✚ The most common type of seat cushion is made of *multi-layered honeycomb*. This type of cushion provides an internal contouring for uniform load distribution, proper leg positioning, excellent shock absorption and stability over rough ground. The use of perforated honeycomb provides excellent ventilation and allows moisture to evaporate.

At this point it must be noticed that regardless of what cushion is selected for pressure management, the overall height of the operator positioned in the tractor seat must be considered. To prevent hitting the ceiling of the cab, the tractor seat should be lowered to allow for sufficient head clearance but not too low as to cause the operator's seat to bottom out when traveling over rough ground. A clearance of approximately 15 cm (6 in.) between the operator's head and the cab ceiling is recommended (Hansson 1991).

4. REVIEW OF THE LATEST SEAT DEVELOPMENTS IN TRACTORS

This chapter intends to introduce the reader to the latest seat technologies which the tractor manufacturers use in order to improve farmer's comfort and to increase their productivity. The review takes into consideration the seat developments from the following tractor manufacturers:

- ✚ John Deere,
- ✚ Fendt,
- ✚ Massey Ferguson,
- ✚ New Holland; and
- ✚ Valtra

JOHN DEERE

Active seat technology. The Active seat technology helps deliver an extremely smooth ride. This seat technology uses a combination of electro-hydraulic air seat design to provide comfort in all field conditions. The Active Seat (Figure 7) receives sensor

inputs at 200 times per second and adjusts to reduce excessive vertical movement of the seat. The result is a more comfortable, productive ride since the operator can travel faster in some field conditions. Active Seat is fully adjustable, with nine adjustment points.



Figure 7. A John Deere seat with Active Seat technology.
(courtesy: John Deere tractors)

FENDT

Pneumatic cab suspension. The Fendt cab is equipped with a front axle mechanical suspension with a shock load stabilizer. A new technology is introduced, which Fendt engineers have developed to further increase the level of comfort in the driver's seat. The air spring shock absorber module (Figure 8) has integrated leveling, which automatically adjusts the suspension to different loads and therefore makes switching to different suspension levels (suspension stiffness) unnecessary.



Figure 8. The air spring shock absorber.
(courtesy: Fendt tractors)

MASSEY FERGUSON

Massey Ferguson has introduced a swiveling seat (Figure 9) which is fully adjustable and includes double pneumatic lumbar support, pneumatic height adjustment, plus height, fore and aft adjustment of the right-hand armrest so that the armrest mounted controls can be perfectly positioned. The seat covering has a heat absorbing, active carbon layer suitable for hot conditions, and also seat heating for the winter.

Dual stage suspended cab. The design of the cab suspension system features a 'dual stage' air suspension system (Figure 10), which can be adjusted at the flick of a switch between two ride firmness settings. This unique, operator-controlled system stabilizes cab movement more effectively and further enhances the ride characteristics of the well-balanced chassis.



Figure 9. A Massey Ferguson swiveling seat.
(courtesy: Massey Ferguson tractors)

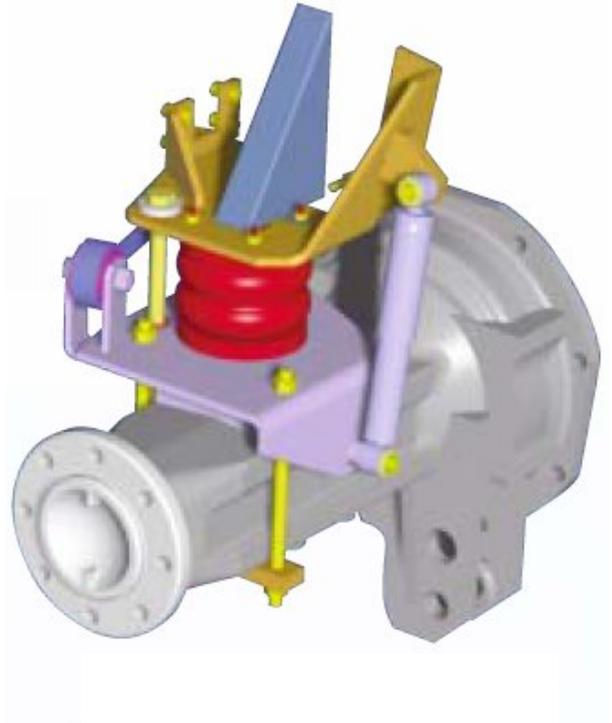


Figure 10. The 'dual stage' cab suspension system.
(courtesy: Massey Ferguson tractors)

NEW HOLLAND

Air-ride seat. New Holland has introduced an air-ride seat (Figure 11), which is fully adjustable and includes lumbar support and an armrest control console connected to it, which swivels 20 degrees to the right, 13 degrees to the left and glides eight inches forward or back. This ergonomic console puts the throttle and hydraulic remotes within easy reach. Also, the new Auto Comfort seat suspension is introduced. The specific suspension significantly dampens vertical shocks and swaying movements. The innovation behind this kind of suspension is the ability to adjust it to each driver's weight.



Figure 11. A New Holland Air-Ride Seat.
(courtesy: New Holland tractors)

VALTRA

Positive response air suspension system. Positive response air suspension system puts the driver in total control while providing a smoother ride. The sensor and controller system mounted inside the seat suspension (Figure 12), senses shock loads up to 500 times per second and sends electronic signals to a patented magnetic fluid shock absorber. The shock absorber adjusts to provide proper dampening based on ground conditions.



Figure 12. A Valtra seat with Positive Response air suspension system.
(courtesy: Valtra tractors)

5. FUTURE SEAT DEVELOPMENTS

Smart seat technology. The smart seat technology (DaVinci Institute, Louisville) is based on the use of an expanding polymeric gel technology. This gel has the capability to expand 1000 times its original size. As a result, future seats that will be made of this kind of gel will have the potential of sensing and meeting driver body's needs. Thousands of gel cells will line the seat's contact surfaces.

Also, a number of pressure sensors will initially distribute weight evenly to alleviate circulation problems. Temperature sensors will cause both a rhythmic pulsing of gel cells and manage a consistent air circulation provided through squeeze-pump capillary tubes. Airflow will dry perspiration, while it will cool the body at the same time.

Counter balanced motion seat. The Counter Balanced Motion (CBM) seat dynamics (American Ergonomics Corporation, CA) is a new concept which takes into consideration the Dynamic Seating in relation to driver's body posture. The CBM seat design principle of Dynamic Seating is to center the seat motion proximate and relative to

the body's centers of mass and motion, to obtain dynamic equilibrium during the pulse and stability during normal driving.

During normal driving, the CBM seat remains stationary with the occupant by gravity. The seat and lumbar adjust in response to occupant movements to accommodate the body. The general characteristics of the CBM seat performance are that the seat cushion maintains seat contact with the buttocks and remains in place as long as the body mass has forward momentum. In summary, the CBM seat increases comfort. It automatically balances the seat and lumbar support to the correct thigh, lumbar and pelvic angles. It conveniently allows and supports posture change without hand activated adjustment.

A progressive new seat design. Merford's Ergoseat (Merford, Holland) invented a new concept aiming at reducing the loads on the back and neck muscles and at the same time improving the outside view of the cab. The operator's bent forward posture is made easier by giving a new way of support. Within this concept, the support of the upper body is provided by the installation of two armrests with integrated controls, one on each side of the driver. These armrests are fully adjustable, which means that they can be adjusted in height, in a fore-aft direction, in slope and they can pivot towards each other. Thus, the driver is able to bend over with his body while leaning on his forearms.

Flexible polyurethane foam (FPF). Polyurethane foam (Polyurethane Foam Association) is a new invention which can be formulated to dampen the vibration that causes discomfort for the operator while driving. Flexible polyurethane foam can be produced in an almost unlimited variety of shapes to meet requirements of the agricultural industry. Polyurethane foam can be characterized by its durability, comfort and design versatility. The use of polyurethane foam allows manufacturers to achieve aesthetic and ergonomic objectives while practicing cost-effective production methods.

CONCLUSIONS

In most farm operations, the operator must remain seated for extended periods of time. Sitting, changes the weight-bearing surfaces, restricts spinal movement, flattens the normal curves, and immobilizes the pelvis. Seats must consider these changes. Weight has to be spread evenly to avoid pressure points and the muscular and skeletal interactions of the spine have to be addressed to avoid stresses. A modern seat must permit the worker to perform tasks from the suitable position, so its relationship to the rest of the workplace is important.

Seats also have social status implications. The size, design, and materials have an important role in terms of the status which affects the perception of the seat and its user. A seat should meet or exceed a person's perception of what is appropriate for the specific situation. A seat that appears to be poorly designed conveys a sense that the person occupying it or the job being performed is not important.

Concluding, it is important to consider that there is no perfect seat or universal definition of seat comfort. Thus, no matter how good a seat design may be, there will always be chances for improvement and criticism. Aspects like cushion softness are hard to measure meaningfully and are subject to personal preference rather than the objective standards.

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