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Ergonomics Program at Freightliner

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ABSTRACT

This paper describes the ergonomics program at Freightliner and how it is integrated in the engineering and design process. It will also describe how we use advanced technologies such as 3-D Digital Human Modeling with RAMSIS and how these are applied to the design process to ensure optimized ergonomics in our trucks.

INTRODUCTION

Sound ergonomics is an important differentiator among all vehicles but especially among trucks, because professional truck drivers spend many hours at a time on the road in their trucks. It is not unusual for a truck driver to spend up to 10 hours each day behind the wheel and to log more than 100,000 miles per year. With today's changed anthropometrics, demographics and shortage of qualified truck drivers, good ergonomics in trucks has become even more important to attract and retain drivers. Due to secular growth (younger generations are taller than older generations) and an increase in overweight people (40% of the adult populations is overweight or obese) cab and seat design has to accommodate taller and bigger drivers. In addition, during the last decade the number of female truck drivers, including those of class 8 trucks, has nearly doubled from 100,000 to 175,000 (1). This also has important implications for the design and layout of the driver cab and seats. Today this anthropometrically more versatile driver population must be accommodated by addressing the spatial and comfort needs of shorter and smaller female drivers as well as taller and heavier male drivers.

Traditionally, general ergonomic guidelines provided in textbooks, published papers and SAE procedures have been used. However, these guidelines are often not specific enough for the truck environment, are out-dated, and frequently fail to address any interactions that different items would have with each other. For example, the location of a dash-mounted shifter may be optimized for reach and reduced effort to actuate, but at the same time obscure vision to important controls. Therefore a truck OEM has to build bucks or prototypes, select appropriate test subjects that reflect their domestic and international truck buying populations and then test for ergonomic, safety and comfort concerns. This is always time consuming and expensive to develop and build the hardware, find test subjects and administer tests. Also to build bucks, you have to have the design completed to a certain point to produce parts. This becomes especially difficult early on in the truck development cycle. It is very important to incorporate good ergonomics early on in the concept phase, when changes are still easily and economically made. With today's shorter product development cycles, the use of virtual mock-ups and virtual people in a CAD environment is one solution that can provide quality information early on in the design process. In addition, the 3-D CAD environment is easily changed when new design proposals or different iterations need to be evaluated. This is much faster and less costly than modifying existing hardware or building new bucks.

ORGANIZATIONAL OVERVIEW

To address ergonomic and comfort issues Freightliner has a dedicated ergonomics and human factors group that is part of the Engineering Body Center. The Ergonomics group works closely with styling, interior and exterior body groups, chassis and safety departments to implement ergonomic design in our vehicles. We provide support to all truck platforms within Freightliner, which allows for uniform ergonomic guidelines, criteria and tool applications.

Ergonomic support is provided during all phases of the truck and feature development cycle. However, the main emphasis for us is to provide input early on in the concept phase when design concepts are developed. This allows Freightliner to implement optimized ergonomic design and changes relatively easily and economically.

In order to evaluate many ergonomic issues early on in the concept phase we employ RAMSIS, a 3-D Human Model for ergonomic evaluations. This allows us to perform necessary ergonomic investigations in the CATIA CAD environment even with little geometry defined. In addition, we use SAE and ISO guidelines and perform subject testing in either concept bucks or trucks.

3D- HUMAN ERGONOMIC MODELING

RAMSIS is a 3-D human model for ergonomic evaluations and was specifically developed for use in the automotive and trucking industry (2). We use RAMSIS to define and develop the driver and passenger workspace and to develop design criteria to meet our ergonomic objectives. Issues such as reach to dash, controls, pedals, and outside and instrument visibility are addressed. In addition we use RAMSIS to address spatial accommodation for the sleeper cab and entry and exit issues.

RAMSIS allows us to generate and simulate any truck driver population. This enables us to evaluate design issues for drivers of different sizes and proportions. Figure 1 shows a family of manikins representing a range of body heights, nationalities and body proportions. For example we can evaluate a particular design proposal and how it would impact a 5th percentile female vs. a 95th percentile male, or the impact on a driver with the same stature but different body proportions such as leg length and weight.

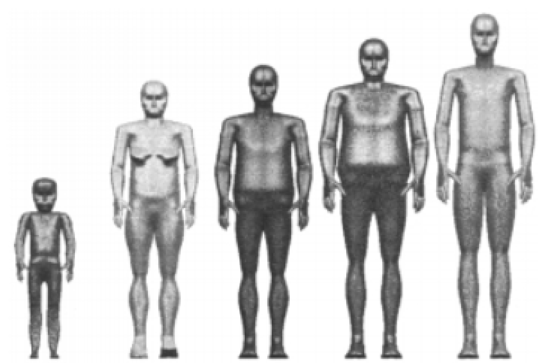

Figure 1. Family of Manikins, 4-year old Child, 5% US Female, 50% Mexican Male, 5% US Male and 95% US Male (from left to right)

One of the most important features of RAMSIS is that it allows us to consistently and repeatedly position a manikin with a realistic posture in the seat and the vehicle CAD geometry (3-4). This gives us a high degree of confidence for any subsequent analysis such as arm reach or visibility evaluations (5). Figure 2 shows overlaid seated postures for manikins representing a 5% female, 50% male and 95% male.

Besides being able to evaluate ergonomic issues with RAMSIS early in the truck development cycle, RAMSIS also is an excellent visualization tool. Ergonomic issues are presented in a context that is easily understood by non-experts, such as high level managers. We will show 5 examples of RAMSIS applications in the truck development cycle.

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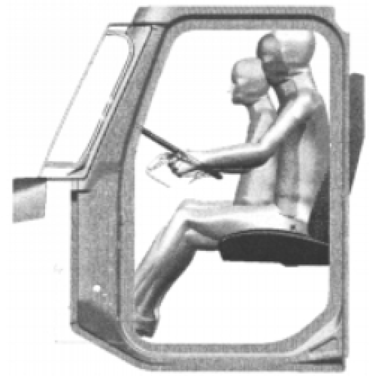

Figure 2. 5% female, 50% male and 95% male in overlaid driving position.

VISIBILITY EVALUATIONS – In trucks, one of the most critical ergonomic and safety issues is visibility to the outside of the truck. One of the methods to evaluate visibility is the horizontal planar projection provided in SAE J1750 (6). With this procedure we determine the ground area obstructed from the view of the center of the SAE eyellipse. The results of these evaluations are very abstract and the impact is often hard to understand, especially by non-experts such as managers. These procedures do not show visibility in the context of the driving environment, as a driver would see, nor do they provide what the negative or positive effect would be for drivers of different body sizes. This very often makes it difficult to understand the impact of proposed design changes or design differences. While there may be a numerical difference in ground visibility, is the difference large enough to be perceived by drivers? What is the impact for short vs. tall drivers?

Figure 3 shows a comparison of two different hood designs using the SAE J1750 horizontal planar projection method. Design 1 shows a lowered hood design and 2 a raised hood. The results of SAE J1750 clearly show hood design 1 has less ground obstruction.

With RAMSIS we get a realistic perspective from the driver's eyes. Figure 4 shows the RAMSIS street scene setup for our visibility evaluations. Child manikins of age 4 are placed around the truck at defined locations. Figures 5 – 6 show forward visibility for hood design 1 for a 5% percentile female and 95% male. Figures 7 – 8 show the effect of hood design 2 on visibility. This example shows that hood design 1 clearly provides superior visibility over hood design 2 and is presented in a clearly understood context from a driver's perspective.

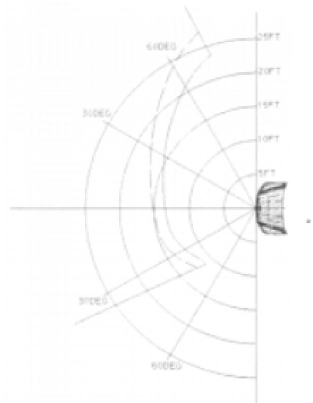

Figure 3. Horizontal Planar Projection per SAE J1750

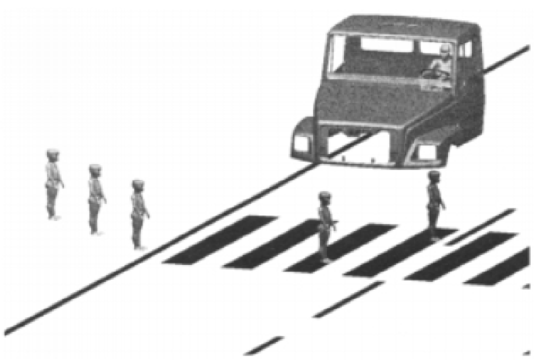

Figure 4. Visibility Evaluation SetUp with RAMSIS

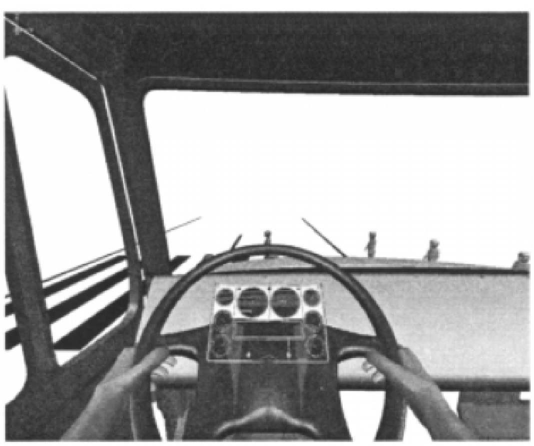

Figure 5. Visibility for a 5% US Female with Hood Design 1

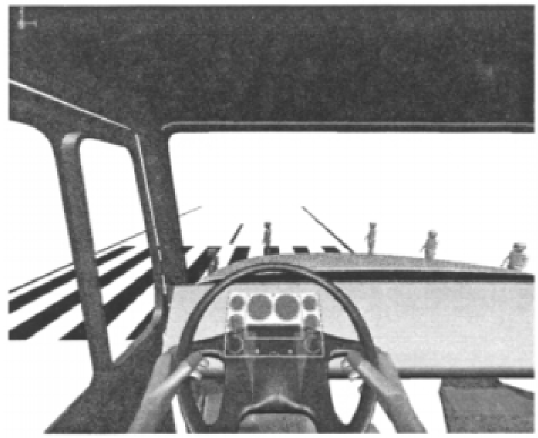

Figure 6. Visibility for a 95% US Male with Hood Design 1

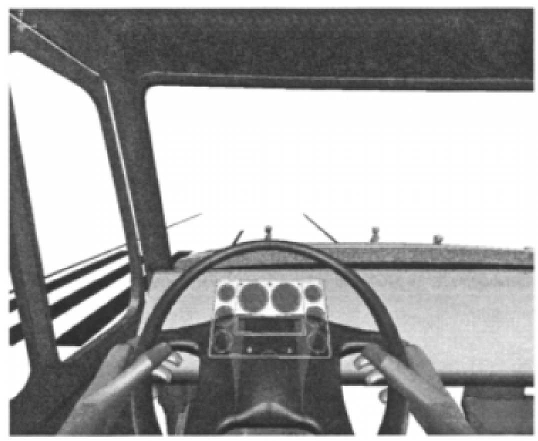

Figure 7. Visibility for a 5% US Female with Hood Design 2

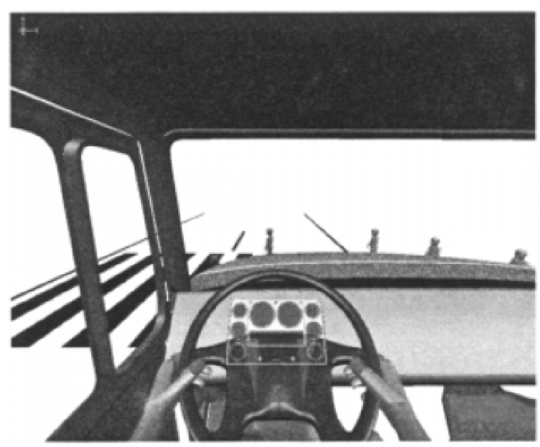

Figure 8. Visibility for a 95% US Male with Hood Design 2

MIRROR VISIBILITY – Another major ergonomic and safety factor is mirror visibility. In order to test mirror visibility, a real truck with proposed mirrors usually has to be set-up and tested with drivers. Two issues are of importance:

a. unobstructed visibility to the mirrors
b. indirect visibility as covered in the mirrors

For indirect mirror visibility, RAMSIS has a mirror analysis function that lets the designer simulate mirror reflections based on specific eye point locations. Any trimmed surface in CATIA can be transformed into a mirror. RAMSIS calculates and displays a view volume. Vision rays from the manikin's active eye are projected to each segment of the mirror edge curve and reflected, thus visualizing the limits of the possible mirror view. This allows us to optimize a mirror design for specific truck applications. For example, we can evaluate the effect of mirror size, shape, radius of curvature and effects of mirror location and orientation on mirror coverage.

Figure 9 shows a top view of a mirror evaluation study. The ground intercepts for the vision rays for a 95% male and 5% female are shown. Figure 10 shows a side view with the reflected vision rays and in Figure 11 a vision ray intersecting one of the child manikins. The area below the vision ray is visible to the driver.

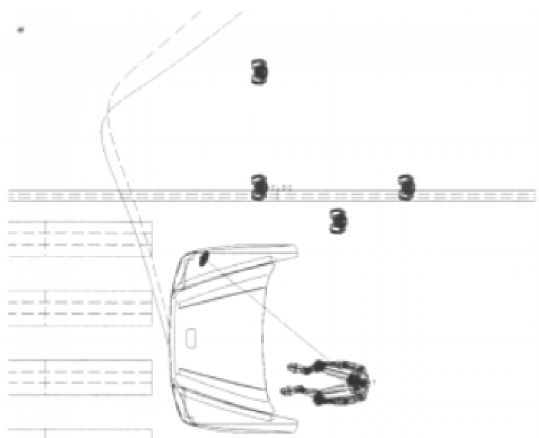

Figure 9. Top View of Mirror Reflective Ray Ground Intercepts

ARM REACH AND FORCE EVALUATION – At Freightliner we also use RAMSIS to design and evaluate the interior vehicle lay out such as dash design and control locations. Here we use RAMSIS to either evaluate proposed or existing control locations on the dash or to develop optimized locations early on in the design process. Where appropriate, we also perform maximum arm force evaluations that are posture dependent in addition to the reach evaluations.

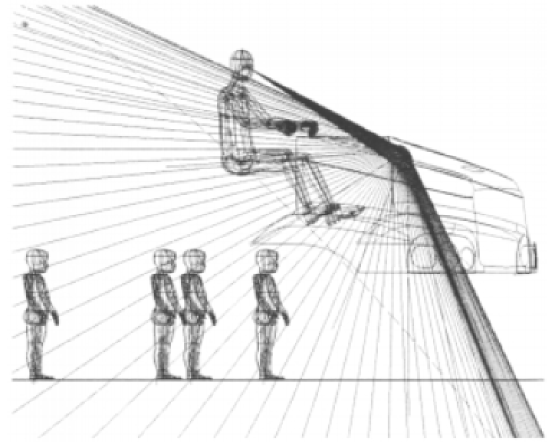

Figure 10. Side View of Mirror Reflective Rays

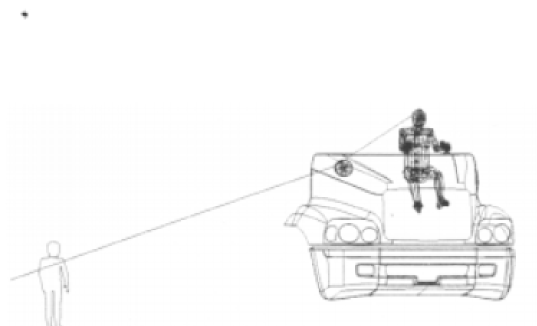

Figure 11. Front View of Mirror Reflective Ray Intersecting Child Manikin

In the arm reach and force evaluation example we show how we optimized the dash location of an automatic shifter handle.

Due to space limitations, the shifter had to be dash mounted with the shift action moving from right to left. First we determined the maximum 3-D reach envelopes for our driver population sample. These reach curves represent maximum reach zones on the dash in which the shifter handle should be located. Next, we optimized the shifter location within the dash reach zone based on maximum force analysis with 5% females. The criterion was to find the location that requires the least effort to engage the shifter handle. The study also provided us with design information on maximum allowable efforts for a new shifter design. Figure 12 shows an overlaid 5% female and 95% male reaching for the shifter. The figure includes 3-D reach curves for three sample manikins: 5% female, 5% male and 95% male in stature.

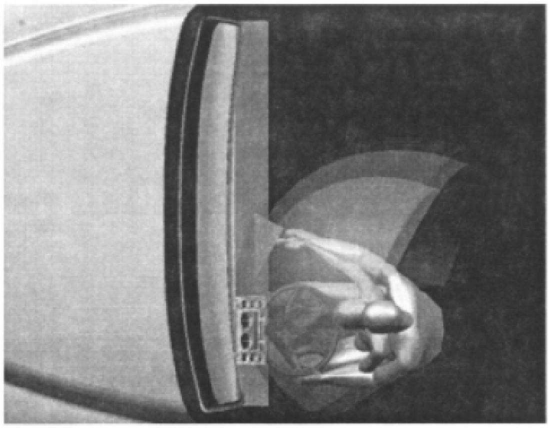

Figure 12. Overlaid 5% Female and 95% Male Reaching for Dash Mounted Automatic Shifter

ENTRY EVALUATION WITH RAMSIS – Cab Over Engine (COE) trucks are very difficult to enter and exit. Drivers have to pull themselves up into the cabin with handles. The steps are offset from the door opening due to tire space needs. After the driver climbs up the steps he/she has to move sideways to transfer from the steps into the cabin interior (Figure 13).

Figure 13. Driver Entering the Argosy Cab with Traditional Steps

With our Argosy COE we introduced swing out steps. This allows drivers to enter or exit a cab similarly to walking up and down stairs. With this design the stairs swing out from below the cabin, resulting in a reduced swing out angle for the door.

There was a concern that a large truck driver would not be able to fit through the door opening, but in a very short time we were able to demonstrate that a very large male has ample room. We created a US male of 95% stature with a weight of 270 lbs. We used this manikin to visually show how much space is available to such a large driver while entering the Argosy cabin. Figure 14 depicts a heavy set and an average weight manikin. Both manikins are of the same stature and proportions (leg to torso length) but differ in weight. Figure 15 shows the heavyset manikin entering the Argosy cab.

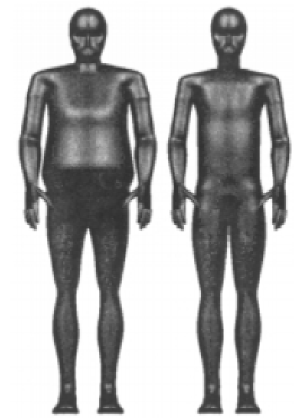

Figure 14. Heavy Set (270lb) and Average Weight Male Manikins of 95% Stature

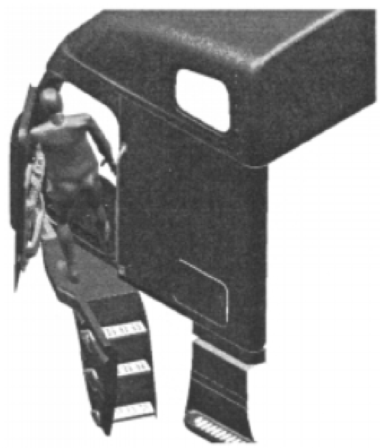

Figure 15. 95% Male of 270 lbs. Entering Argosy Cabin with Swing-Out steps

SLEEPER CAB EVALUATION – The sleeper cab is an important area for the driver to rest during breaks on long-haul trips. Often husband and wife teams are on the road and it is important to provide easy and safe access to the beds.

RAMSIS manikins are used to evaluate the ease with which short and tall persons are able to get into and out of the beds and to optimize grab handle locations (Figure 16).

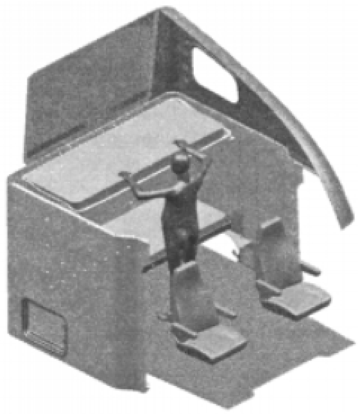

Figure 16. A 95% Male Getting into a Bunk Bed.

As these examples show, many of the ergonomics issues can be evaluated and solutions found with a 3-D human model. This can be done quickly and cost-effectively. Changes to a design in a CAD environment are faster and less expensive than when a change to an existing buck has to be performed or to an already designed structure. Another helpful feature of 3-D human modeling software is that the results can be put into the correct context and visually presented, which is easily understood by non-ergonomic experts (Figure 17). Thus it can effectively aids the decision-makers.

Figure 17. Presentation in the Ergonomic Visualization Room

BUCK AND FIELD TESTING

Once a concept has been developed with RAMSIS in the CAD environment we verify and optimize the design with test subjects in either bucks or modified drive able trucks, if needed. For this we must ensure our subject pool is representative of the truck driving population. In order to achieve this, we have established an internal anthropometric database that allows us to draw on a subject pool that represents 5% females to 95% males of varying body proportions and weights. This subject pool includes engineers, managers and senior managers in addition to test fleet drivers. Figure 18 shows data collection during a buck study. The inclusion of senior management in our buck and drive evaluations is important in that they can experience disadvantages and advantages of certain design proposals, thus aiding in the decision making process.

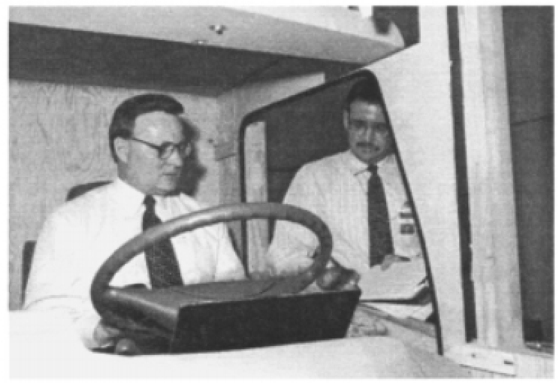

Figure 18. Data Collection during Buck Study

EXAMPLES OF ERGONOMIC INNOVATIONS AT FREIGHTLINER

Recently Freightliner has introduced three ergonomic innovations to improve driver ergonomics, safety and comfort.

SMARTSHIFT – The SmartShift allows drivers to shift with fingertips while keeping their hands on the steering wheel (Figure 19). It is mounted to the steering column and provides a convenient interface with shift-by-wire transmissions such as the Meritor SureShift and the Eaton AutoShift. RAMSIS was used to ensure an optimized location and orientation to meet the following criteria:

- Minimize distance to steering wheel for easy finger tip reach for small hands
- Maximize distance to steering wheel to provide hand clearance for large hands when turning the wheel
- Ensure an unobstructed view to the SmartShift for drivers ranging from 5% females to 95% males.

Figure 19. SmartShift

FREIGHTLINER PROPRIETARY SEAT PROGRAM: EZYRIDER – Since heavy-duty truck drivers spend up to 10 hours each day behind the wheel and the majority drives over 100,000 miles a year, it is essential to maximize seating comfort. The advantage of developing a seat in-house is that this allows us to optimize the seat and seat suspension to our truck chassis to optimize driver comfort and minimize vibration discomfort.

Updated anthropometric data and seat design practices were applied to develop seat dimensions that accommodate today's varied and changed driver population. It was critical to make the seat highly adjustable to meet the wide range of body types and the increasingly diverse driver population. The EzyRider's high back cushion is 38 mm taller than that of our standard seat, for better head and neck support, 75 mm wider in the shoulders, for better upper back support, and 38 mm wider in the lower seat cushion, to accommodate larger drivers. The lower seat cushion can be extended for drivers with longer legs.

The seat design was evaluated and optimized based on feed back from test drives. During these test drives, each driver team drove several thousand miles non-stop with each seat to evaluate long term seating comfort.

In addition we tested and developed easy to see, reach and use seat controls that are intuitive. Seat height and lumbar support are adjusted by a control with the shape and motion of the seat itself. For team drivers, the seat features easy to see fore/aft and back rest seat position numbers printed on the controls. To return the seat to the desired configuration, the driver needs only adjust the seat to the numbers that mark his or her preferred seat position (see Figure 20).

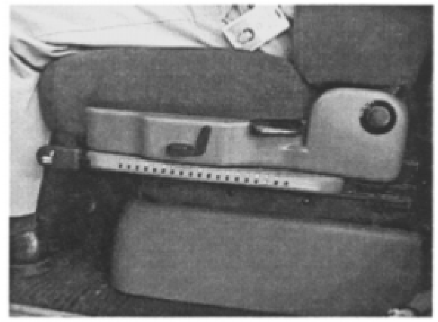

Figure 20. Seat with Seat Controls

FREIGHTLINER ADJUSTABLE PEDALS – To increase driver comfort and accommodate varying body sizes, Freightliner is the first truck manufacturer to offer adjustable pedals in heavy-duty trucks. The adjustable throttle, brake and clutch pedals move 75-mm rearward from the standard position, toward the driver and are controlled by a switch on the dash (Figures 21 – 22). Drivers of shorter stature or those with shorter legs are able to more comfortably reach the foot pedals. This is especially important for women truck drivers, who tend to be shorter than men. The adjustable pedals also benefit heavier drivers since these individuals can move the seat back to increase belly room and at the same time adjust the foot pedals rearward for easier reach.

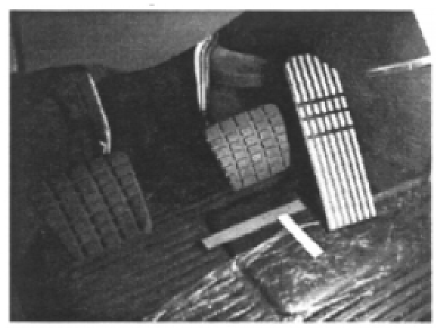

Figure 21. Adjustable Pedals in Full Forward Position

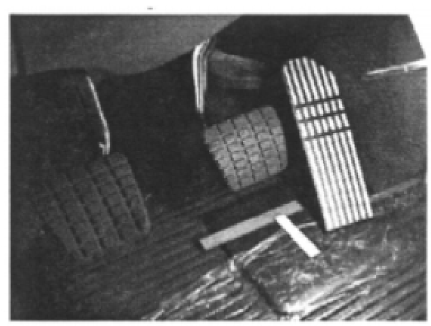

Figure 22. Adjustable Pedals in Full Rearward Position

CONCLUSION

To optimize driver comfort, trucks have to be designed and tested with a view to ergonomic issues. This is especially important since truck drivers spend long days in their trucks, often driving 100,000+ miles a year. To achieve this Freightliner has a dedicated Ergonomics group to test, develop and implement optimized ergonomic designs in its trucks. The use of the 3-D CAD Human Model RAMSIS for ergonomic design allows us to provide high quality information early on in the truck development cycle without expensive subject testing and physical mock-ups. Not only can we provide this information faster, but we are also able to investigate many different design iterations quickly and cost-effectively. In addition, we can generate RAMSIS ergonomic information as powerful images with correct driving environments that are easily understood. This can aid in review and decision making during the design and engineering process.

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