

Occupant Preferred Back Angle Relative to Head Restraint Regulations

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ABSTRACT

Having, by now, introduced several new vehicles that comply with FMVSS 202a, manufacturers are reporting an increased number of complaints from consumers who find that the head restraint is too close; negatively affecting their posture. It is speculated that one of the reasons that head restraints meeting the new requirement are problematic is that the FMVSS backset measurement is performed at a back angle that is more reclined than the back angle most drivers choose and the back angle at which the seat / vehicle was designed. The objective of this paper is to confirm this hypothesis and elaborate on implications for regulatory compliance in FMVSS 202a.

INTRODUCTION

The National Highway Traffic Safety Administration [1] recently revised Federal Motor Vehicle Safety Standard (FMVSS) 202, which governs head restraints. The new standard, known as FMVSS 202a, establishes, for the first time in the U.S., a requirement for the fore-aft position of the head restraint. The head restraint position is measured using the Head Restraint Measurement Device (HRMD), shown in [Figure 1](#). The HRMD head-form is mounted on the H-Point machine (HPM-1), a weighted manikin that is widely used for measuring automotive seats. The H-Point represents the manikin's most important reference point; a joint intended to represent the pivot between the thighs and torso of a medium-sized vehicle occupant [2]. With the HPM-1 installed in a vehicle seat, the location of the H-Point and the manikin's back angle are key measures of the vehicle interior geometry. In fact, these measures are audited during assembly operations. Many industry design practices, standards, and regulations (including those related to safety) reference the H-Point [3, 4, 5].

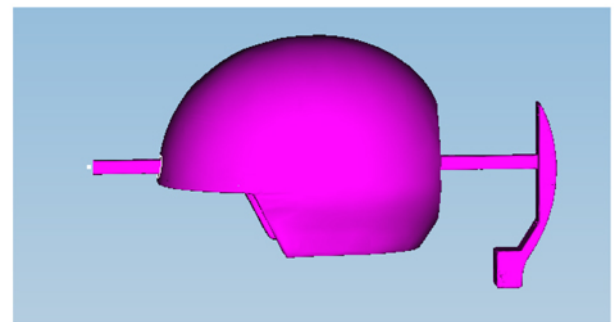


**Figure 1. Head Restraint Measurement Device (HRMD)
- CAD Representation of Physical Part**

The FMVSS 202a procedure specifies that the test seat be adjusted so that the back angle of the HPM-I is 25° aft of vertical. In this position, the HRMD is leveled and a probe is moved rearward from the head of the manikin to measure the head restraint position. The distance between the back of the HRMD head-form and the head restraint, a dimension referred to as “backset,” is required to be no more than 55 mm.

It is important, at this point, to distinguish between torso angle - an occupant based measure - and back angle - an HPM-I derived metric referred to as A40 in SAE J1100 [4]. There is no standard method for measuring torso angle. Assuming one could measure torso angle in a reliable (repeatable and reproducible) and valid way, it is likely that two people with the same demographics and anthropometry, when exposed to the same seat position (i.e. the same track position, back frame angle, etc.), would sit with a different torso angle (some people slouch, some people sit upright, etc.). This is why no standard seat tests or design practices use torso angle.

The spirit / intent of FMVSS 202a is to reduce the distance between occupants' heads and the head restraint. Simulations and epidemiological studies both suggest that decreasing backset decreases the likelihood of whiplash-associated disorders in rear-impact crashes. Eriksson [6] suggested that the "optimal" backset is zero (i.e. back of the head is in contact with the head restraint). Stemper et al. [7] has recommended a maximum backset of 60 mm. Reductions of the incidence of whiplash-associated disorders are a high priority for vehicle safety regulators because of the high societal cost associated with these injuries-including approximately 27% of all costs to insurance companies for bodily injury claims [8].

As manufacturers have begun to phase in head restraints that comply with the FMVSS 202a backset requirement, they are receiving an increasing number of complaints from occupants who find that the head restraint is so close to their heads that it interferes with their preferred head posture. Reed et al. [9], prior to the adoption of the new requirement, analyzed data from driver posture studies conducted in vehicles and in laboratory conditions in which the head restraint did not affect driver posture. They estimated, based on the distribution of driver head locations with respect to the seat, that an HMRD-measured backset of 55 mm would interfere with the preferred head positions of more than 10 percent of drivers (assuming that seat designs would remain the same except for changes in the head restraint).

It is speculated that head restraints meeting the new requirement are problematic for some occupants because the backset measurement is performed at a back angle that is more reclined than the back angle most occupants choose. As the seatback is moved more upright, a fixed head restraint that moves with the seatback tends to move closer to the occupant's head; potentially interfering with the occupant's preferred head location. Said another way, the hypothesis investigated as part of this research was that occupants, in a broad range of different vehicles, adjust their seats to achieve preferred driving positions that produce HPM-I back angles that are significantly less than 25°.

METHOD

Three alternative methods were considered. As part of the first method, the occupant would arrive, sit in the vehicle, adjust the driver seat to his/her preferred position, and then exit the vehicle. The HPM-I would then be installed and the H-Point and associated back angle would be measured. While this is perhaps the most valid method (because it is the most direct), it is also, unfortunately, the most time consuming (requiring one H-Point drop per test subject). Given the premium Original Equipment Manufacturers (OEMs) are placing on keeping operating costs down, this calls for a

different, more efficient method (i.e. less time consuming and less resource intensive).

The second method would begin just like the first method except, after the occupant adjusted the seat to his/her preferred position, he/she would remain in the vehicle and a determination would be made concerning the preferred body posture. The determination would be made using markers pre-positioned onto key anatomical landmarks and then captured using a video system, coordinate measuring machine (CMM), or simple angle measurement tools and scales. While this method may be slightly more efficient, it is based on the unjustifiable assumption that a torso angle measurement derived from an occupant correlates to the HPM-I's back angle. One would also need to question the gage R & R results associated with these types of measurements.

The third and final method would start with the seat set to "design position". That is the position at which the seat system (including adjustment mechanisms, foam, and trim) was designed to deliver the H-Point. In this position, selected seat reference points would be digitized using a CMM. Next, the HPM-I would be installed and the H-Point and back angle (at a minimum) would be measured. Having established the baseline, the method would then require an occupant to arrive, sit in the vehicle, adjust the seat to his/her preferred position, and then exit the vehicle (just as with the first two methods). At this point, instead of installing the manikin, the seat reference points would be re-digitized. Assuming a linear relationship, the change in seat reference points would be used to predict the HPM-I position. This method has the advantage of being slightly more efficient.

The third method, appearing to be the most robust, was, ultimately, selected for the pilot study, which was performed using a front driver seat from a 2002 model year sedan. The leather seat was equipped with a 6-way power track, a power recliner, a 2-way power lumbar, and a 2-way head restraint (not designed to meet FMVSS 202a). It was installed into an adjustable buck configured to represent the actual vehicle environment / package (e.g. head room, leg room, shoulder room, hip room, etc.). The baseline condition was represented graphically in [Figure 2](#).

The pilot study was also used to provide surrogate data concerning the standard deviation to expect when measuring occupant preferred back angles. This would provide insight into sample size requirements for the main study. In this context, the pilot study included a large, representative sample of volunteer subjects / occupants obtained from the general population at Ford Motor Company in Dearborn, MI, U.S.A.

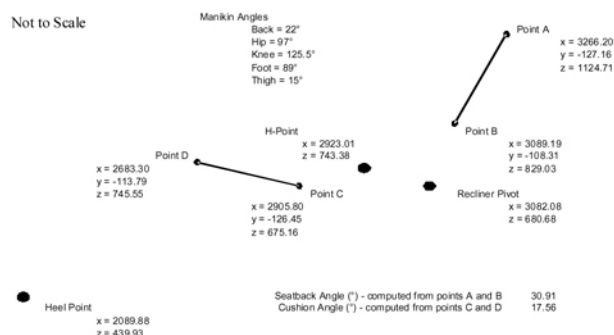


Figure 2. Graphical Representation of Baseline Data - from Pilot Study with Sedan Seat

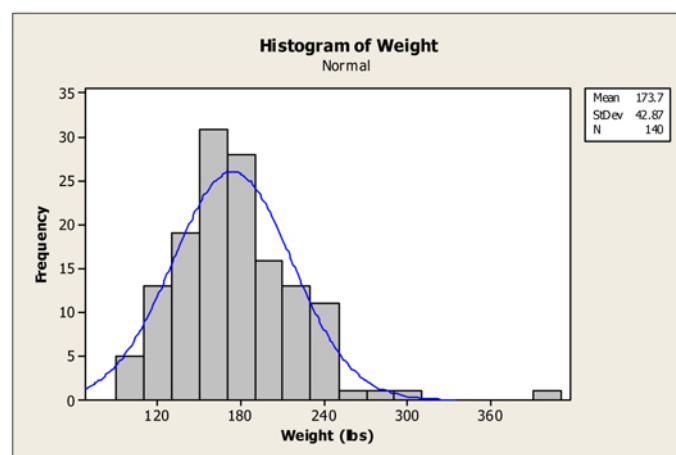


Figure 4. Weight Distribution for Pilot Study

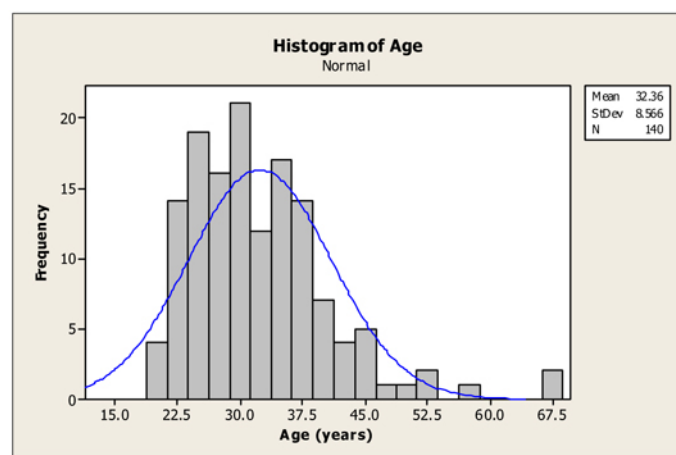


Figure 5. Age Distribution for Pilot Study

The mean occupant preferred back angle was 21.0° (Figure 6). Ninety-five percent of occupants (133 / 140) sat with a back angle less than the FMVSS 202a test position (i.e. 25°).

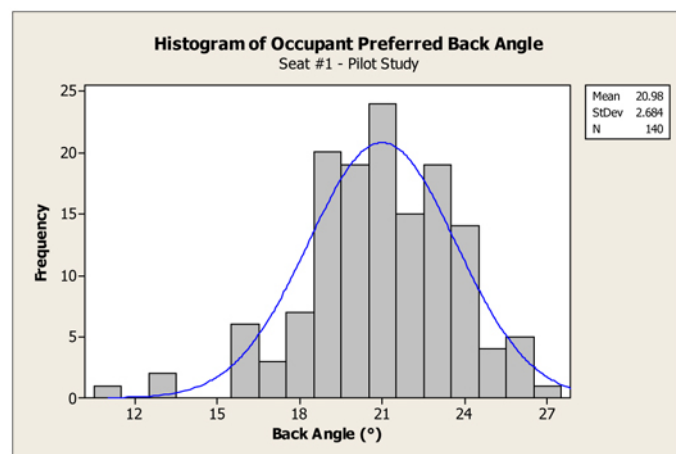


Figure 6. Back Angle Distribution from Pilot Study

RESULTS AND DISCUSSION

PILOT STUDY - In terms of sample, 140 people volunteered to participate in the study. Forty-five were female and 95 were male. The distribution of stature, body mass, and age can be found in Figure 3, 4, and 5, respectively.

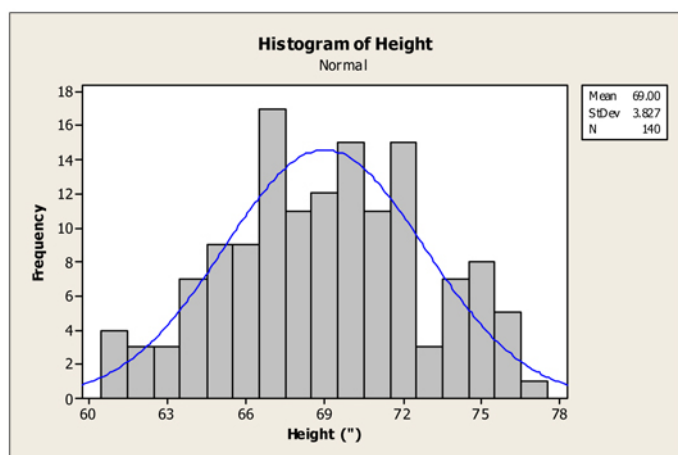


Figure 3. Height Distribution for Pilot Study