

Stock Car Racing Driver Restraint – Development and Implementation of Seat Performance Specification

John P. Patalak

National Association for Stock Car Auto Racing, Inc.

John W. Melvin

Tandelta, Inc.

Copyright © 2008 SAE International

ABSTRACT

Over the last decade large safety improvements have been made in crash protection for stock car racing drivers. It has been well established that in side and rear impacts the driver seat provides the primary source for occupant retention and restraint. With the implementation of NASCAR®'s (National Association for Stock Car Auto Racing, Inc) newest generation of stock car, the Car of Tomorrow (COT), into the racing schedule, the opportunity to develop and implement a universal stock car driver seat performance specification was accomplished.

This paper describes the development of the Seat Performance Specification including the goals of the specification, the methodology used to develop it, a census of the existing driver seat population used in on-track competition, review of developmental dynamic specification sled tests and quasi-static tests as well as summation of the Seat Performance Specification requirements.

INTRODUCTION

Just as NASCAR's present day COT race car has evolved from prior generations of stock cars, so too have today's driver seats. As technology continually advanced, large improvements have been made in driver and spectator safety. These improvements have come in multiple forms with notable ones including chassis roll bars, SAFER® Barriers, head and neck restraint devices, helmets, fire retardant clothing and fire suppression systems.

When stock car racing began, the driver's seat was a necessity to facilitate operation of the race car. As stock cars and race tracks became more sophisticated, additions were made to the original equipment driver seats to add safety, comfort and support while competing on the racing surface. Eventually, this progression led to the implementation of purpose built racing seats. It was from these initial purpose built seats that today's aluminum and composite seats have evolved.

Currently, the two main types of seats being utilized by stock car drivers are an all aluminum construction and a composite seat. The composite seat consists of carbon fiber inner and outer shells bonded with an aluminum honeycomb interior. Both seats utilize a mounting system which attaches the seat at the base and shoulder/head area to the stock car chassis.

There are multiple aluminum seat manufacturers and fewer composite seat manufacturers.

Figure 1 shows the breakdown of NASCAR Sprint Cup Series driver seats based on their construction material. This breakdown fluctuates slightly on a weekly basis depending on which teams attempt to qualify for events.

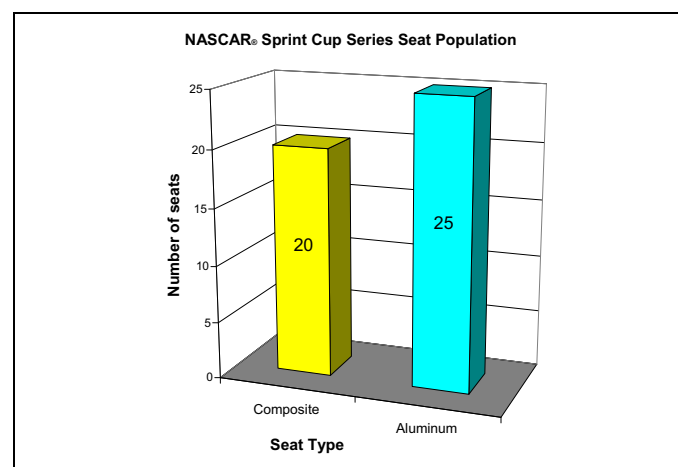


Figure 1.

BACKGROUND

In the early 2000's the need for changes in some specific areas of driver safety was realized and pursued. Among the areas identified for improvement were the driver seats. Prior to 2000, while driver seats provided support and comfort to the driver during a race event, most seats lacked the structural stiffness required to react the loads generated during dynamic impacts.

As crash data gathering capabilities were increased and improved, significant databases of on-track incidents were created and analyzed. From these databases, specific crash accelerations, time durations and principal directions of force (PDOF) were quantified. These acceleration-time profiles and PDOF's were then able to be applied to stock cars and seats with anthropomorphic test devices (ATD) in laboratories via full scale crash testing, dynamic sled testing, dynamic component testing, quasi-static component testing as well as non-linear finite element analysis studies.

DISCUSSION

It has been well documented through crash research that a seat must rigidly support the pelvis, shoulders and head to provide high levels of side impact protection (Melvin, et al. 2006). The seat also serves as the primary source for occupant restraint in rear impacts and therefore this principal is shared for rearward PDOF's as well. While both high G lateral and rear impacts are experienced in on-track incidents, the Seat Performance Specification addresses only lateral impacts. This is due to the seats being rigidly mounted to vehicle structure at shoulder level, as well as at the base, providing occupant protection and retention in high G rear impacts. This rigid mounting provides excellent support for occupants during rear impacts, necessary for maintaining head, neck and upper torso alignment.

As previously stated, for lateral impacts the seat also serves as the primary means of occupant restraint. However, due to seat geometry and its mounting configuration, lateral occupant loading applies a cantilevered load through the seat side supports. Specifically, these lateral supports include the supports for the upper leg, pelvis, ribs, shoulder and head. In lateral impacts the pelvis, shoulder and head seat supports compose the primary load reaction paths for the occupant. It has been noted in previous research that the chest is highly deformable and therefore chest protection is provided via pelvis and shoulder restraint (Melvin, et al. 2004). Consequently, lateral rib supports should be limited to provide driver comfort, not impact protection. As a result, a minimum stiffness for rib supports is not included in the Seat Performance Specification.

The goal of the Seat Performance Specification is to establish and implement uniform test procedures and minimum standards for evaluating and determining seat performance capabilities. The specification is not intended to replace dynamic seat sled testing or crash testing. The test procedure consists of a quasi-static load application to specific areas of the inboard seat head surround, shoulder support and pelvis support. Load and deflection are measured for comparison to minimum load values and maximum deflection values.

The Seat Performance Specification specifically addresses seat structure lateral stiffness. This is accomplished through the minimum load and maximum

deflection criteria. The objective for the stiffness of the lateral seat supports is to provide occupant retention during lateral impacts. The supports must therefore be stiff enough to react occupant induced loading during impact events. In addition to providing the primary means of occupant retention the lateral supports also serve as a back stop for energy absorbing foam. This foam serves three primary purposes for the occupant. Firstly, the foam couples the occupant to the seat, providing a large, uniform surface area between the seat structure and occupant. Secondly, through deformation under impact loading, the foam distributes loads on the body and, in the case of the head, lowers occupant accelerations and loads. Lastly, during normal service the foam provides a conforming and snug, yet comfortable, fit to support the driver during a race event.

As was stated in the background section, prior research had resulted in initial recommendations for static loads and deflections for lateral seat supports. These initial recommendations were based on calculations from seat performance during side impact sled tests. In an effort to continue this research additional lateral sled testing was conducted. Specifically, seven sled tests were conducted on four different stock car driver seats. The test seats represented the majority of seat types being used in current on-track competition. Two separate acceleration-time pulses were used for all of the testing. These pulses are shown in Figure 2.

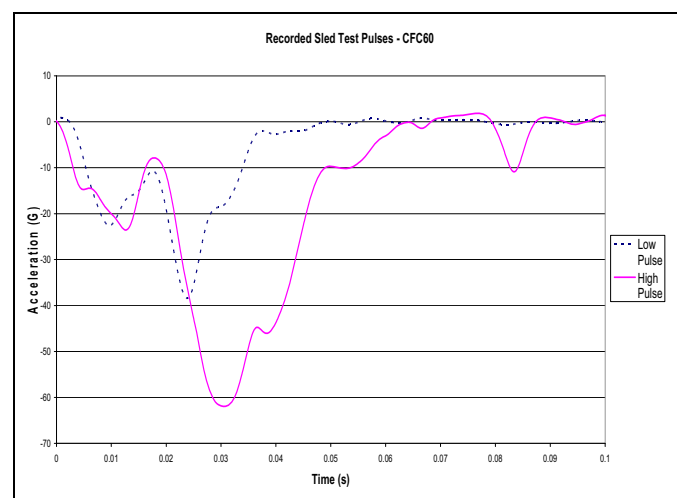


Figure 2.

Two aluminum constructed seats and two composite constructed seats were tested. Both aluminum seats and one composite seat were tested with both pulses. The remaining composite seat was only tested at the low pulse. The sled test pulses were developed from on-track incidents as well as dynamic full scale lateral crash testing.

An instrumented Hybrid III 50th percentile male ATD was used for all testing. This ATD provided a worst case loading of the seat shoulder supports due to its stiff shoulder structure. Pretest and post-test lateral measurements were taken of specific seat components. High speed video analysis was also conducted to

quantify maximum seat component deflections and performance. From this test data permanent set and maximum deflections were calculated for each test. Table one shows a composite seat with pretest and maximum deflections during acceleration.

	
Pretest (no deflection)	Maximum Deflection

Table 1.

The composite seat and the aluminum seat styles were then quasi-statically loaded in the same lateral direction. Loads were applied at 0.1 inches per second, horizontally to the head, shoulder and pelvic supports independently, until 0.5 inches of specific seat structure deflection was recorded. The loads achieved at 0.5 inch deflection were recorded. Loads were applied to the lateral support portions of the seats as shown in Figure 3.

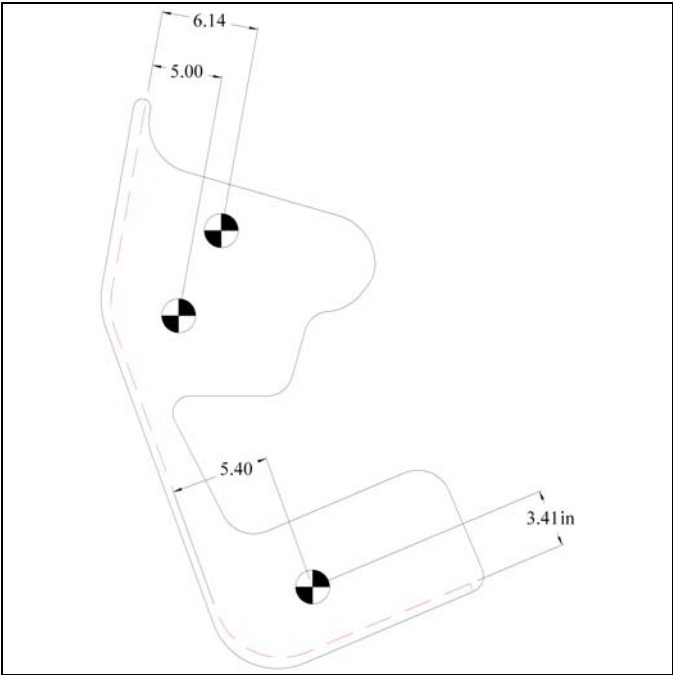


Figure 3.

The three load application points were identified with the interior seat foam in place at the dimensions shown in Figure 3. The head and shoulder load application points were centered vertically on the head support and shoulder support respectively. Each quasi-static load was applied to its specific location via a unique rigid load shape. The loads were applied with all applicable interior seat foam in place. The head surround load shape consisted of a ten inch diameter hemisphere.

The shoulder support load shape was a four inch diameter hemisphere combined with a four inch diameter cylinder. The pelvic support load shape was a six inch diameter disc which had a fifty inch diameter hemisphere on the load application side. Both the shoulder and pelvic load shapes were constrained through a ball joint to the hydraulic ram, while the head load shape was not.

These loads were applied to the interior right side of the seat, representative of occupant loading during a right side lateral impact. Two separate seat deflection measurements were captured for each load application point. Deflection of the load shape was measured via the hydraulic ram travel. This deflection measurement included interior seat foam compliance as well as seat structure deflection. A separate transducer was used to measure seat structure deflection. This transducer was placed on the exterior of the seat structure, coaxially with the hydraulic ram. The 0.5 inch deflection target was assessed using this secondary displacement transducer.

Figure 4 shows a frontal view and side view of the head, shoulder and pelvic load shapes respectively (top to bottom).

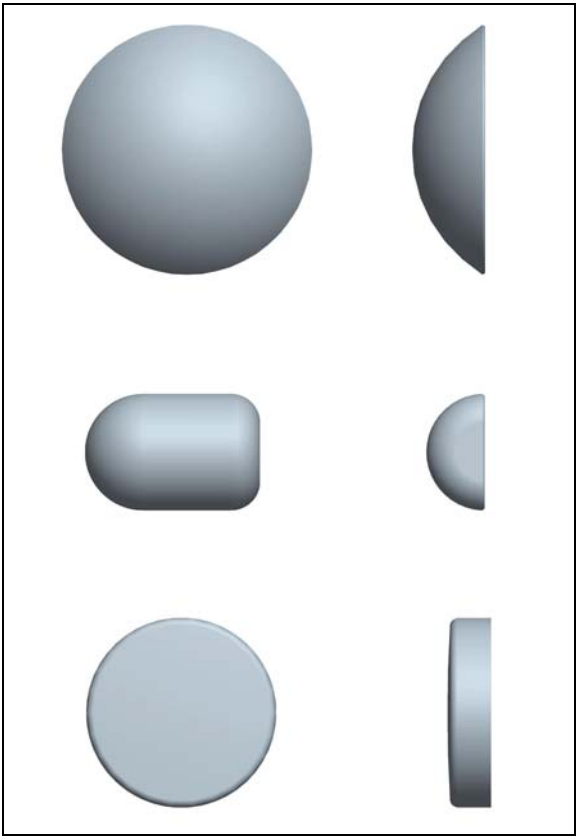


Figure 4.

The load shapes were attached to a rigidly mounted hydraulic ram. The hydraulic ram was fitted with a servo-proportional valve controlled via a closed loop motion controller. All quasi-static tests were defined by test programs and executed via closed loop feedback by the motion controller. Motion control feedback consisted