SAFETY COCKPIT COMMITTEE

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ENGINEERING FOR THE TRANSPORTATION INDUSTRY

Abstract

It has been proposed that the UIM adopt a few standard designs of safety cockpit for the various classes requiring them in order to reduce the cost of the cockpits and improve the ability of technical inspectors to ensure the safety of the cockpits, It was suggested that a steel roll cage inside the safety cockpit might be a cost efficient method of achieving this goal. This report will compare the structural strength of a cockpit with and without a roll cage. The report concludes that while the roll cage does add strength to the cockpit, it is not as efficient as the current crash box design.

In the U.S. over the last year or so, there have been two serious accidents where drivers have suffered paralysis. The report discusses possible causes of these injuries and offers some recommendations regarding cockpit design and the design of seat belt anchors.

Since last year's report by Isatec showed the improvements that can be made in protection by careful design of the pickleforks, much discussion has ensued about their design. The report discusses some of the issues around the design of the pickleforks.

Roll Cages Inside Safety Cockpits

Introduction

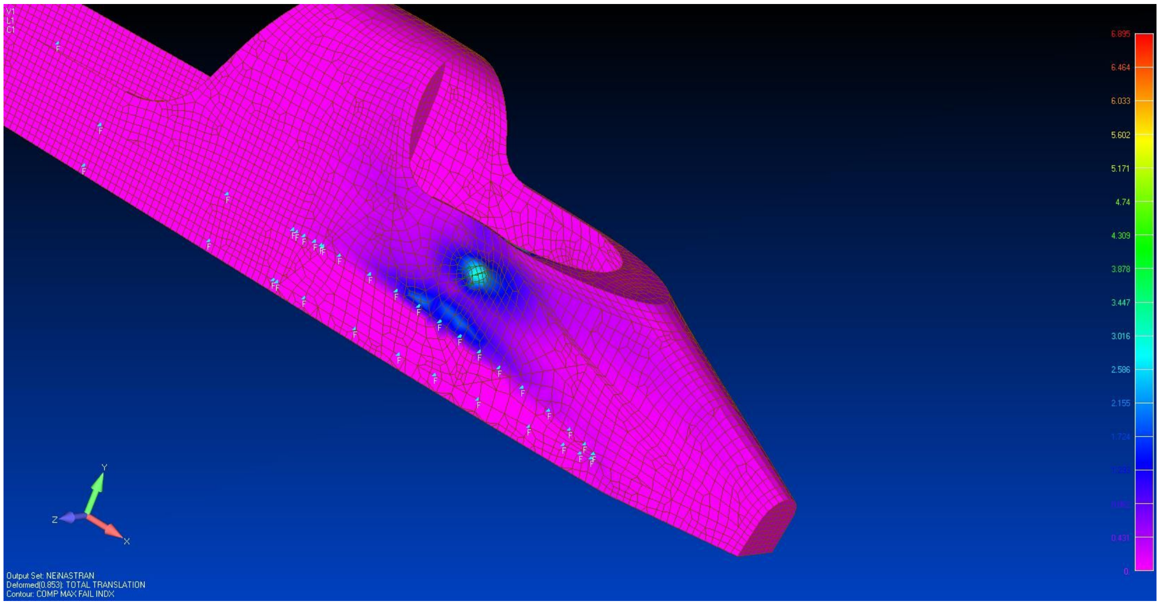
It has been proposed that the UIM adopt a few standard designs of safety cockpit for the various classes requiring them in order to reduce the cost of the cockpits and improve the ability of technical inspectors to ensure the safety of the cockpits, It was suggested that a steel roll cage inside the safety cockpit might be a cost efficient method of achieving this goal. In the U.S. the drag boat community has adopted this practice and has worked with SFI to develop standards for construction. The advantage of this method is that it is easy to confirm that the roll cage meets the desired standard of strength and durability. In addition the construction tools and methods are commonly available throughout the world so that the investment remains low. The application to drag boats has been successful.

Procedure

Two computer models of cockpits were prepared for structural analysis using the finite element method. The software used for this analysis was NEi Nastran from Noran Engineering. One model was of a cockpit with a lay-up previously submitted to the UIM and tested. Previous work verified that the analysis software predicted the performance of this lay-up with reasonable accuracy. The second model was identical in shape and material lay-up, but had the steel roll cage added to the inside. The size of the tubing for this roll cage was taken from the SFI standard for drag boat capsules. The arrangement of the tubes in the cage was patterned after that specified in the SFI standard. Both models were loaded with about 18 KN (4000 lb.), a load far less than what would be experienced in a real accident. The roll cage added about 15 kg (33 lb.) to the weight of the cockpit.

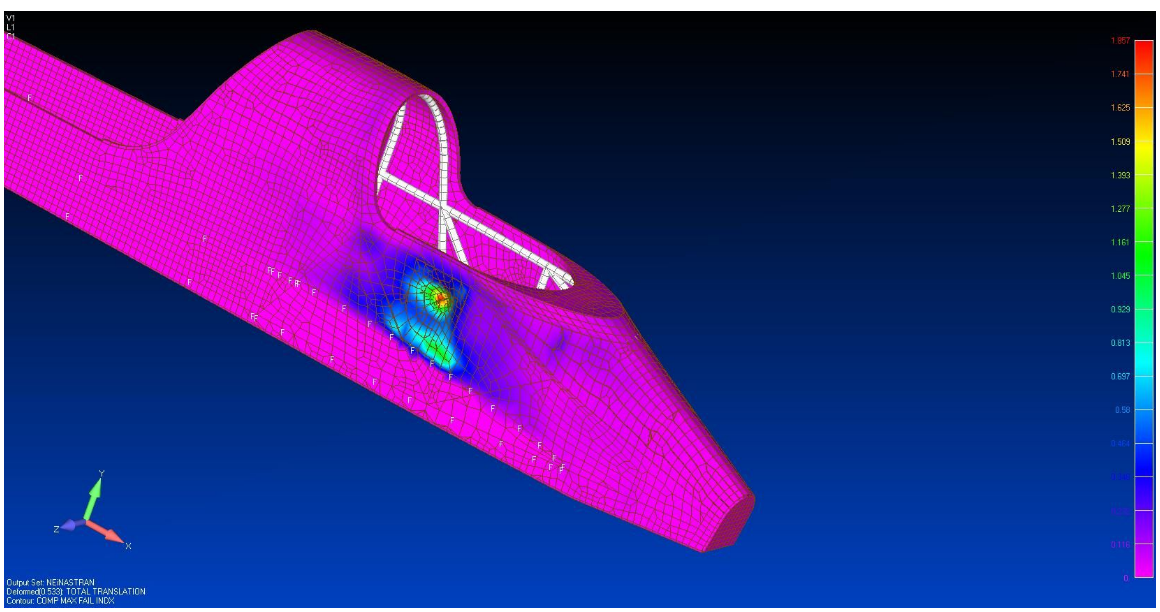
Results

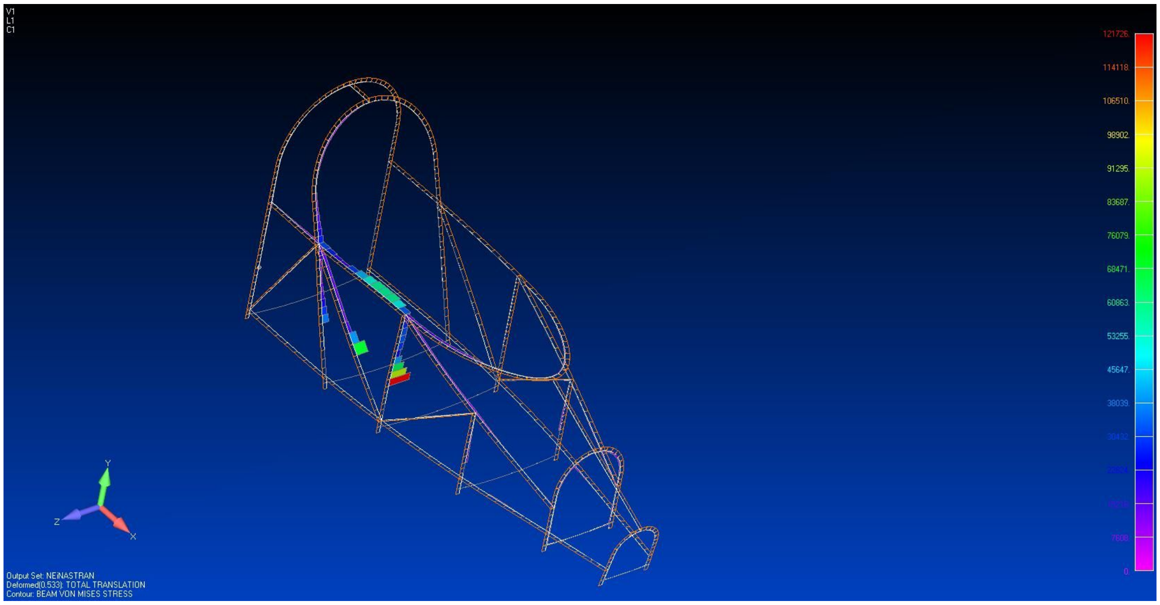
The results of the analysis of the plain cockpit are shown below:



The loaded area shows a failure index of about 4, without the roll cage.

The results of the test with the roll cage are divided into the composite portion and the steel roll cage portion.





In this case the composite shows a failure index of just under 2, and the steel roll cage shows a stress of over 827 MPa (120,000 psi), well over the yield strength of the steel.

Discussion

The results show that adding a roll cage does significantly add to the strength of the cockpit.

However, this analysis does not take into account dynamic effects. The tests that Isatec did showed that the damage becomes localized as the application of the force becomes more dynamic. The roll cage does little to spread out the load, so that in real life accidents, the penetration of the cockpit will not be prevented by the roll cage.

On the other hand, the crash box construction does spread the load, and in actual tests has shown good ability to absorb dynamic impacts.

Regarding the ease of construction of the roll cage versus the crash box, the actual fabrication process uses the same techniques and materials that the boat builder is already using to construct the boat itself, so the only new aspect of the crash box is the knowledge of how it should be designed for maximum efficiency.

Conclusion

While the roll cage does add strength to the cockpit, the addition of the crash box adds more protection for the amount of weight added to the cockpit.

Head Clearance / Seat Belt Anchorage

Introduction

In the U.S. over the last year or so, there have been two serious accidents where drivers have suffered paralysis. An examination of the photographs of the damage to one of the boats leads me to believe that the injury in that case was caused by the lid of the cockpit pressing down on the driver's spine hard enough to break the seat. A demonstration was done at the APBA meeting last January showing how much a belted driver can shift around under his own weight. It is evident that we have a problem with vertical space in the cockpit. The belts must be installed properly to resist all vertical motion as well as forward motion, and the cockpit must have enough vertical room to take into account the stretching of the belts.

Discussion

Regarding head clearance, it is of course obvious that a lower frontal area will improve the speed of the boat. On the other hand, the recent F1 race in Shenzhen showed that other factors can outweigh this increased frontal area. The winning DAC boat in Shenzhen was a new boat fitted with crash boxes and measured 105 cm (41.3 in) vertically from the bottom of the seat to the underside of the capsule.

A review of the seat belt installations at Shenzhen and from many years of looking at race boats at the local level tells me that many boats do not have the seat belts installed according to the manufacturers recommendations. A video prepared by the Sports Car Club of America of their safety seminar in 2004 showed both how the belts should be installed, and how much the belts stretch even when properly installed. Since then, one of the presenters, Schroth, has published a manual available on the Internet that details the proper installation.
(http://www.schrothracing.com/docs/Competition_Instructions.pdf)

I have taken the liberty of extracting two pages from it. The first page shows how the belts should be located to take advantage of the strong points in the human body.

ANCHORAGE LOCATIONS AND GEOMETRIES

BELT ROUTING

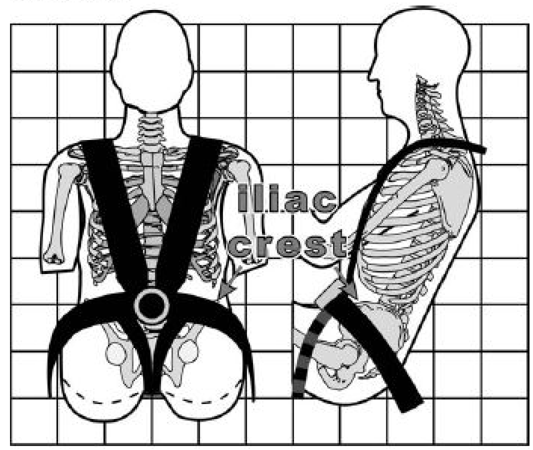
The expected restraining function of any seat belt or racing harness can only be achieved by

- optimised strap routing around and from the wearer's body
- optimised anchor point locations

An occupant can be effectively restrained ONLY by load transfer through the hard points of the occupant's body. The only accessible hard points are the following:

- pelvic
- thorax [chest]] to a limited level only
- clavicle [shoulders]

Therefore, it is essential that strap routing be optimised as described in the following graphs.



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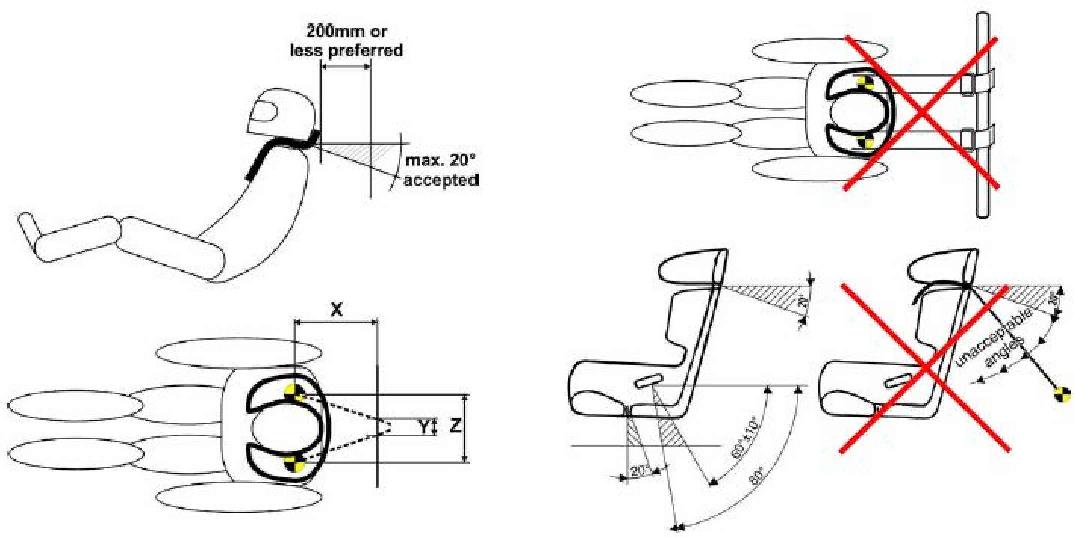
The second page shows the geometry of the belts in relation to the anchor points.



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Many of the installations I have seen do not conform to these recommendations, particularly in relation to the crotch and lap belts.

One other recommendation made at the 2004 presentation was that there should be no hardware next to the driver's neck. At the recent event at Shenzhen I noticed that many drivers had the shoulder strap eye bolts bolted through the backboard to the required aluminum bar behind the backboard. In some cases it looked as though no insert was used in the core of the backboard, allowing some crushing of the core and preventing proper torquing of the eye bolts.

Selio has proposed using threaded inserts to replace the core of the sandwich skin construction for the anchoring of the crotch belts. A possible problem with this type of installation is that the bolt going through the insert could cause delamination of the outer skin of the sandwich. As well galvanic corrosion could become a factor since carbon fiber is a good electrical conductor. On the other hand if properly bonded it would provide a clean safe installation.

Recommendations

Head clearance in the cockpit is the most difficult problem. A time limit should be specified after which all new boats must conform to a minimum head clearance standard. I recommend the 10 cm (4 in) as recommended by UIM and specified in the APBA rule book. Perhaps an absolute minimum should also be made (between seat bottom and the underside of the capsule) as a rule to ensure that average height drivers would meet the 10 cm criteria without having to modify the capsule mold. This would give boat builders guidance. A time limit should also be specified after which all existing boats must be retrofitted in such a way as to conform to the new standard. An alternative to retrofitting could be the removal of the lid and cutting back of the capsule where it covers the head. In no case though, should the headrest be completely removed. An inspection tool should be designed to allow inspectors to easily check this dimension. Above all, rules 509.03 and 509.05 need to be enforced in order to achieve our goal to ensure a safe structure for our drivers to sit in.

Rules should be clarified regarding the geometry and anchoring of seat belts so that they conform to the manufacturer's recommendations. Under no circumstances should guides be used to reroute seat belt straps to achieve the desired geometry, the belts should follow a straight line from the anchor point to the driver's body.

If Selio's proposal for the insert for anchoring the crotch belt is adopted as an alternative to 509.03, it should be for new boats only. It would be difficult to achieve good bonding otherwise and impossible to inspect. The threaded hole should not be allowed to go completely through the insert so as to prevent delamination. The minimum amount of thread engagement should be at least equal to the diameter of the thread.

Pickleforks

Introduction

Since last year's report by Isatec showed the improvements that can be made in protection by careful design of the pickleforks, much discussion has ensued about their design. Several people have proposed longer crushable pickleforks to absorb more energy. Most were impressed by the energy absorbed by the pickleforks designed by Isatec and felt that this was an area that should be explored for further improvements.

Discussion

The sled testing done by Isatec using their design of picklefork against a boat with a crash box and against a boat with a bare cockpit was revealing. The system of crash box and pickle worked very well to prevent damage to the cockpit itself. Without the crash box there was still damage to the cockpit. The "system" works very well. One question remains that hopefully will be answered by Dr. Krieger is how the picklefork reacts to an impact at an angle. The existing pickleforks react to an angular load by simply breaking away as opposed to absorbing energy.

An analysis was done by myself to see if a trigger in the boat lay-up further back from the crushable zone would have an effect on the side loading. A ring area around the picklefork about 2 cm (1 in) long was put into the lay-up of the computer model. This lay-up area had double the core thickness of the lay-up on either side of it. When the front of the picklefork (minus the crushable pickle) was loaded at an angle to the centerline of the boat, this trigger area showed up as a high stress area. This indicates that with a large enough force, the pickle could be made to break off just ahead of where it joins the main part of the boat. Careful design must be done to ensure that it doesn't break prematurely. A non-destructive inspection method would have to be developed if this were put into the rules.

The existing length of the crushable pickles seems to have been developed with some driver experience. Study of numerous photos taken during turns shows that drivers often bury the front of the sponson to just the point where the crushable pickle joins the sponson, during a turn. This again puts a side load on the crushable pickle. If longer crushable lengths are to be used, careful design must take place. If a picklefork were to break off during a turn, it is likely for the turning boat to jump sideways a bit from the intended path, possibly into the path of another boat.

Conclusions

The picklefork shows great promise in improving the safety of our drivers. However, careful design must be undertaken to ensure that we reach that goal without compromising the strength of the boat in its other performance requirements. I recommend that recordings be made of the lateral G forces be made of the boat during a race so that an estimate of the forces imposed on the inner wall of the sponson during a turn. Another method would be to put a strain gauge on the inside of the sponson in the critical area, and recordings taken during a race. If the strains are known, along with the lay-up in the area, an estimate of the forces could be made. Once the forces are known, then calculations can determine whether the length of the crushable picklefork can safely be extended. As well, it could be determined whether a trigger section could safely be put into the sponson.

General Conclusions

Good progress is being made in improving the safety of our drivers, with some exceptions. We need to accumulate data on the forces (and energy) involved in our accidents so that we can make informed decisions on how much energy needs to be absorbed by our picklefork/cockpit system. It will be difficult to formulate a rule that stands the test of time for crash boxes or pickleforks if we do not have this information, whether the rule specifies construction materials and thicknesses or energy absorbing performance. The overall cost to the participants will be reduced if we invest in finding out this information so that we can formulate rules that the boat builders can be confident with lasting several years. The information, once accumulated needs to be made readily available to all the national authorities of the countries of the UIM so that improvements can be made throughout the sport.

As well, methods have to be developed for initial testing and enforcement of the rules that are less expensive than is currently the case. I believe this was the goal of Sonny Hawkins proposal of last year regarding standardized cockpits. While I don't believe in the effectiveness of a roll cage for boat to boat collisions, I believe that his proposal has a lot of merit because of its reduction of the costs to the participant. If standardized cockpits are used, the testing component of the costs drops dramatically.

Finally, I would like to comment on canopies. It is well known that the existing canopies that have a single forward hinge flop around as much as ninety degreed to the axis of the hinge during an accident. They are contributing to the injuries of the drivers. So far, there seems to be a reluctance to use the F16 canopy in the smaller (but still fast) classes. Even with this canopy, the hinging and latching system are critical to good performance. Cantando has an interesting an innovative concept for canopy latching that should avoid the flopping around of the canopy in an accident. It is not hinged at all, but slides back into a channel where it is then latched. Further work needs to be done for the drivers on canopies.