Improving Analysis Accuracy By Modeling rivets/bolts As Solids In Sheet Metal Structure

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ABSTRACT

In general, main assembly consists of different sub-assemblies. These sub-assemblies are joined together using rivets/bolts, welds etc. Individual subassembly is often verified for performance using commercial CAE software. To save time, rivet/bolt joints are usually modeled with beam-spider arrangement. Spider represents the rivet/bolt head and a beam connecting two spiders at the centre represents the rivet/bolt diameter. Analyst's always try to perfect the verification close to practical conditions. In this article, the belt anchorage bracket in seat track assembly is considered for simulation. The performance of rivets joining the belt anchorage bracket to the upper rail of the track is studied in detail. In first simulation, these rivets are modeled with solid hexahedral elements. In the second simulation, these rivets are modeled with beam-spider arrangement. Stresses around the holes, in sheet metal belt anchorage bracket, are studied in both simulations. It has been found, that solid rivet proved to be better option over the beam-spider arrangement. The simulation is carried out as quasi static analysis in Ls-Dyna 971.

Keywords: rivet/bolt joint, solid rivets/bolts, beam-spider arrangement, seat belt anchorage bracket, average stress

1.   Introduction

Method of modeling bolts as solid elements in solid structures is well established. Commercial software included the procedure of inducing pretention in the solid bolt. A detailed study is done by Montgomery Jerome (1) and proved that solid bolts are always preferred over beam-spider arrangement.
In sheet metal, modeling rivet/bolt as solid is always a matter of concern. In reality sheet metal with rivet/bolt joint behaves differently compared to the solid structure. Rivet/bolt undergoes multi-axial loading and thus deformation pattern of sheet metal structure is different than solid structure. John D. Reid and Nicholas R. Hiser (2) studied the bolted joints with slippage. They used two modeling techniques and concluded that very good accuracy was achieved when using finely meshed deformable elements.
In this article, seat track is taken as a sub-assembly. Riveted joints are used to join belt anchorage sheet metal bracket with the upper rail of track. The rivets are modeled with hexahedral solid elements. An interference fit between heads of rivet and the plate is considered. Brendan O'Toole et.al (3) used this as one of the technique of preloading the bolted joints under impact loading. Beam-spider arrangement is used in second simulation with suitable preloading conditions. The track assembly is then taken to carry out seat belt anchorage test as per ECER 14 regulations. The simulation is run for 200ms in both cases. Finally the benefits of using solid deformable hexahedral elements in rivets are highlighted.

2.   Brief Description of Track Assembly

The track assembly consists of lower rail, upper rail, sliding assembly, latch pins, lever to operate latch pins. The lower rail is made of sheet metal section with rectangular slots at the bottom. The latch pin gets hooked into these slots to lock the track mechanism. The upper rail is made of sheet metal section with rectangular slots on the top surface. The latch pin and the handle of lever protrude through these slots. The sliding assembly is made of ball and cylindrical rods. The lower sliding assembly is located in the rectangular groove of the lower rail and the outward taper surface of the upper rail. The upper sliding assembly is located in the inward tapered surface of the lower rail and the outward tapered surface of the upper rail. Latch pins are operated by the lever. One latch pin is operated at a time. The movement of latch pin is vertically downward. The lever is operable by means of a cable. The passenger can operate the lever with the help of cable operating knob fixed to the seat lower structure. The assembly of track mechanism is shown in the figure-1. The seat lower structure is fixed to the upper track rail by means of bracket that is riveted to the upper rail. A belt anchorage point is fixed to this bracket.
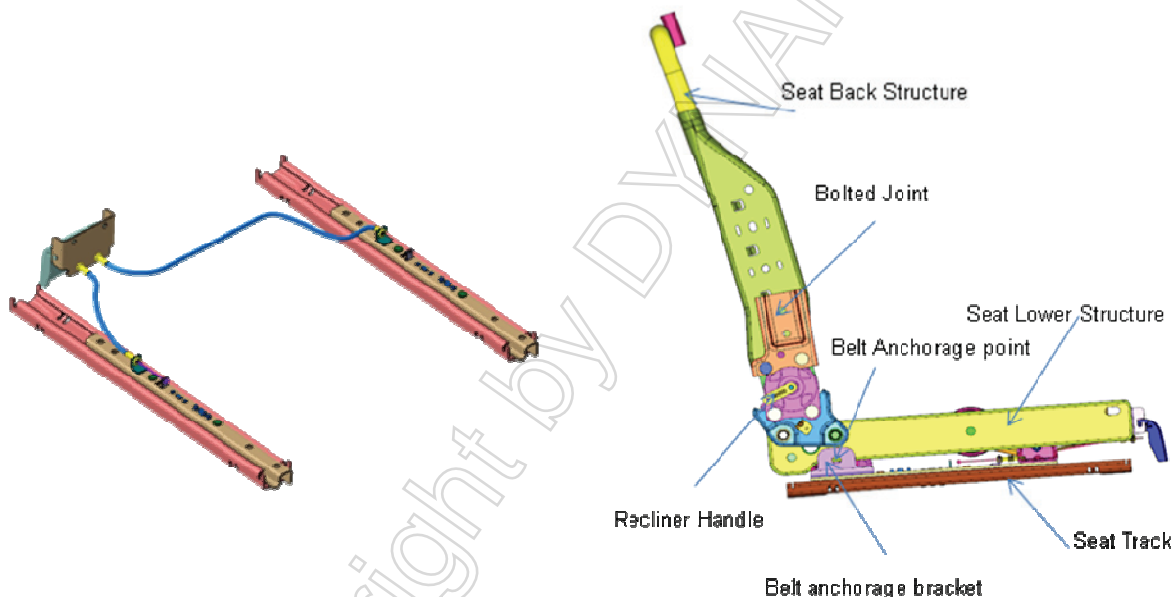

Figure 1: Schematic presentation of seat and track assembly

The design philosophy of the track assembly is based on the criterion of energy absorption by track assembly, recliner mechanism, seat back structure etc. When loads are applied, static or impact, on the full seat structure each component plays a critical role in transferring the same to the vehicle floor. The weakest links are brackets and rivets/bolts those have to withstand such heavy and complex loads. In the system of back frame, belt anchorage bracket and track assembly, the belt anchorage bracket and corresponding rivets connecting to the floor are important links. Hence, more focus is given on these components in the virtual verification.

3.   Finite Element Modeling

Figure-2 shows the finite element model of the track in the full seat assembly. Seat back structure and brackets are modeled with shell elements. The recliner assembly, rivets/bolts, upper and bottom rails of track assembly are modeled with solid elements. The CAD dimensions of shoulder and lap blocks are

taken as per the regulation. Lap and shoulder blocks are modeled with shell elements. These blocks are considered to be rigid. Lap and shoulder belts are modeled with shell elements and given the properties of belt material. A slip ring is placed at a suitable location. Surface to surface contacts are defined between mating components. Suitable coefficient of friction is applied to establish contacts. The track assembly is taken into the full seat structure. Full seat structure is analyzed for belt anchorage test as per ECE 14R.
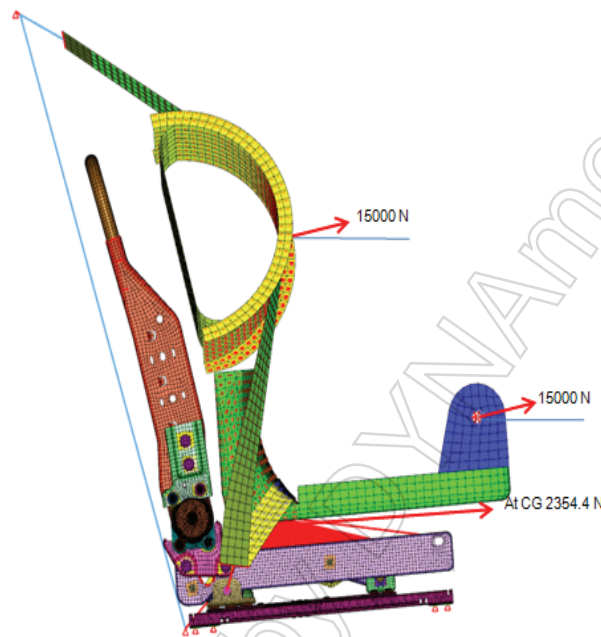

Figure 2: Set up for seat belt anchorage test

3.1   Joint Simulation- Belt Anchorage Bracket to Track upper rail

3.1.1   Rivet: Solid elements

The typical rivet joint simulation between the belt anchorage bracket and the upper rail is shown in figure-3. The rivets are modeled with hexahedral elements. The sheet metal bracket is modeled with shell elements. The connectivity between the shell elements of sheet metal bracket and the solid elements of the rivets is achieved using null elements. The area of the sheet metal bracket that is contacting rivet head is modeled with solid hexahedral elements. Minimum two solid elements are considered across the thickness of the sheet metal bracket. Null elements are placed between the solid elements in continuation with shell elements of the sheet metal bracket. These null elements are assigned negligible thickness. The material properties of sheet metal are assigned to these null elements. Rivet heads are modeled with solid hexahedral elements. Proper non-linear material properties are assigned to the sheet metal and rivets. A coefficient of friction specified in Ls-Dyna 971 user's manual is applied.

3.1.2   Rivet: Beam-spider arrangement

Figure-4 shows the beam-spider arrangement for rivets. In this case the rivet head is modeled as spider of beams connected to the centre of gravity of the head. Other ends of these beams are connected to the

bracket at the diameter where the head contacts the sheet metal. The rivet diameter is modeled as a beam connected between the CG's of two heads.
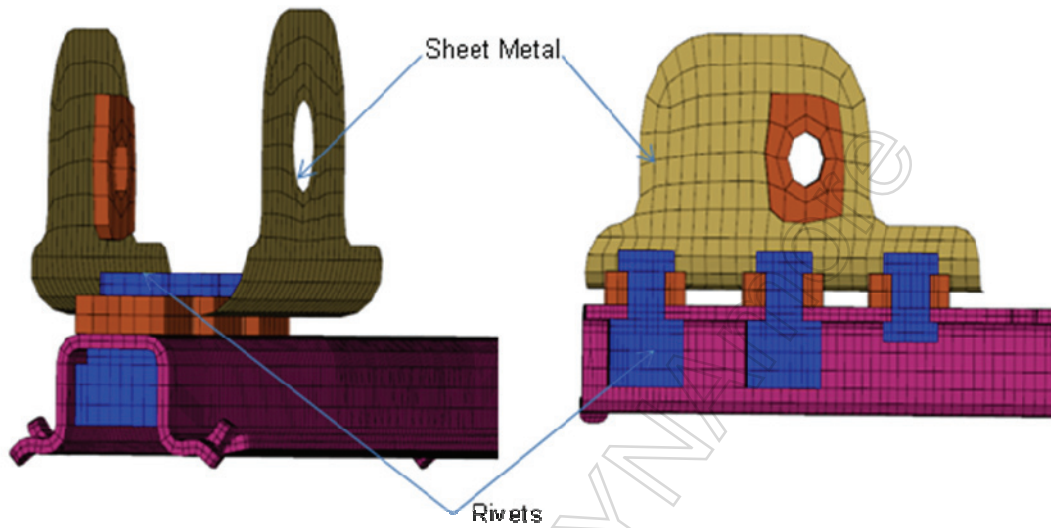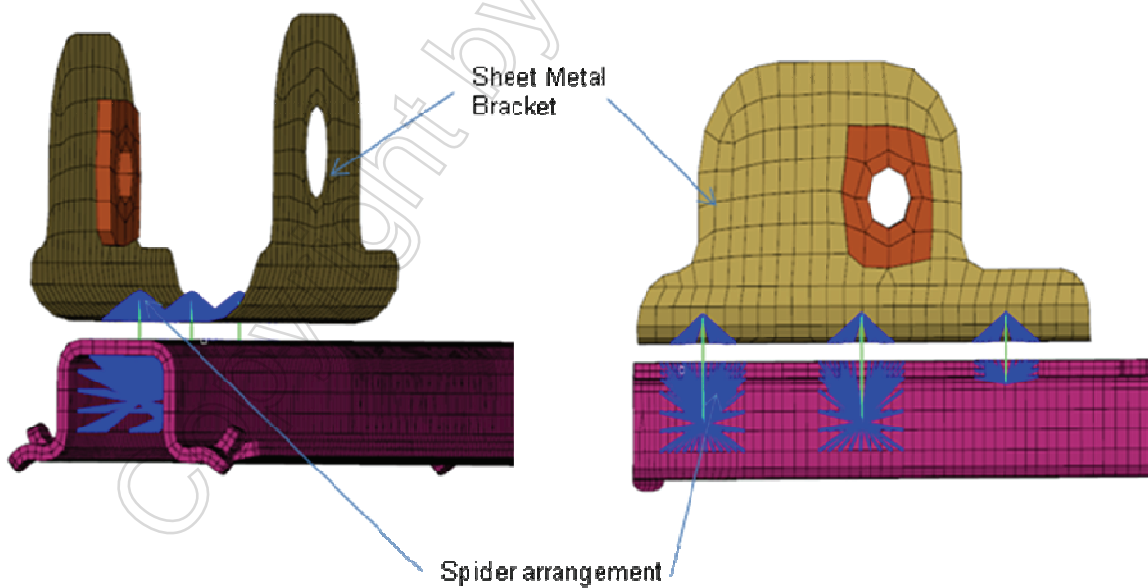
Figure 3: Riveted sheet metal assembly

Figure 4: Beam-Spider sheet metal assembly

3.2   Boundary and loading conditions

The seat track assembly is a structure with complicated sheet metal shape. Lower rail is either directly fixed to the vehicle floor or through risers and feet. In the present case lower rail is considered to be

directly fixed to the floor. As shown in the figure-2, all degrees of freedom of the holes on the bottom surface of the lower rail are constrained. Upper rail is fixed to the seat lower structure with the help of belt anchorage sheet metal bracket at the right rear end. In the front "L" shaped bracket is used to fix seat lower structure to the track upper rail. A load of 15.0 KN is applied to the shoulder block and to the lap block at an angle of 10 degree to the horizontal position of the track bottom rail. The seat weight is calculated as per the standard and considered at the centre of gravity of the seat. The total testing time is considered as 200ms.

3.3 Material properties for track assembly components

The material properties are shown in the table below. These are standard engineering properties. The Poisson's Ratio is 0.3 and Density is 7.86E-09 Ton/mm3

Sr. No.	Material Name	Component	Young's Modulas(Mpa)	Yield Strength (Mpa)	Ultimate Strength (Mpa)	Elongation at Break(%)
1	4130H	Latch Pin	205000	919	1009	17
2	HSLA	Rails, Brackets	205000	550	676	22
3	HSLA	C-Bracket	205000	340	483	31
4	SAE 1010	Rivets	205000	305	365	20
5	SAE 52100	Sliding balls	200000	608	725	18

4.0 Results and discussion

Figure – 5 shows stress in the bracket where the belt anchorage point is provided. Maximum stress is observed in this bracket, therefore it is considered for presentation. The average effective stress obtained around the hole is calculated. In general, the failure of the joint is considered when the sheet metal sees plastic strain beyond the ultimate value around holes. In the present case the plastic strain is much less and no failure is seen in both configurations. The accuracy in calculating average stress is highlighted. This is important in designing the sheet metal parts because of the weight constraints in the vehicle. Also it helps to calculate fatigue life of the sheet metal at the joint.

In the solid rivet configuration, it is observed that, the rivet absorbs energy and simulates the bending and torsion behavior. The sheet metal shows high non-linear behavior in the area around the holes. Under complex load and due to the elongation of rivets, the gap is created between the sheet metals. Sheet metal bracket experiences severe deformation around the hole at the centre. In practice many failures initiate from the similar locations. Therefore simulating proper joint strength is a must to get accurate results. The effective Von-Mises stress is averaged around the hole. The average stress around the first hole in the belt anchorage bracket, in solid rivet arrangement, is 1.6% less than in the beam-spider arrangement. The average stress around the second hole is 5.6% less than in the beam-spider arrangement. The average stress around the third hole is 7.6% less than in the beam-spider arrangement. This is due to the fact that in solid rivet arrangement solid rivet is the medium of transfer of load to the track rail. The load from the belt anchorage point transfers to the bracket. From the bracket it finds the path through rivets to the lower rail and ultimately to the fixing points. Rivet heads get deform and absorb energy. The energy is distributed among top rivet head, rivet diameter, sheet metal in contact and the rivet bottom head.

In the beam-spider arrangement, the load gets transferred through the spider beams which are connected to the sheet metal bracket. There is no bending or twisting of the beam representing rivet. The arrangement becomes too stiff and transmits the load to the track rails without absorbing much energy. Therefore most of the energy is absorbed by the sheet metals in contact. Hence, the stress level is always higher compared to the solid rivet arrangement.
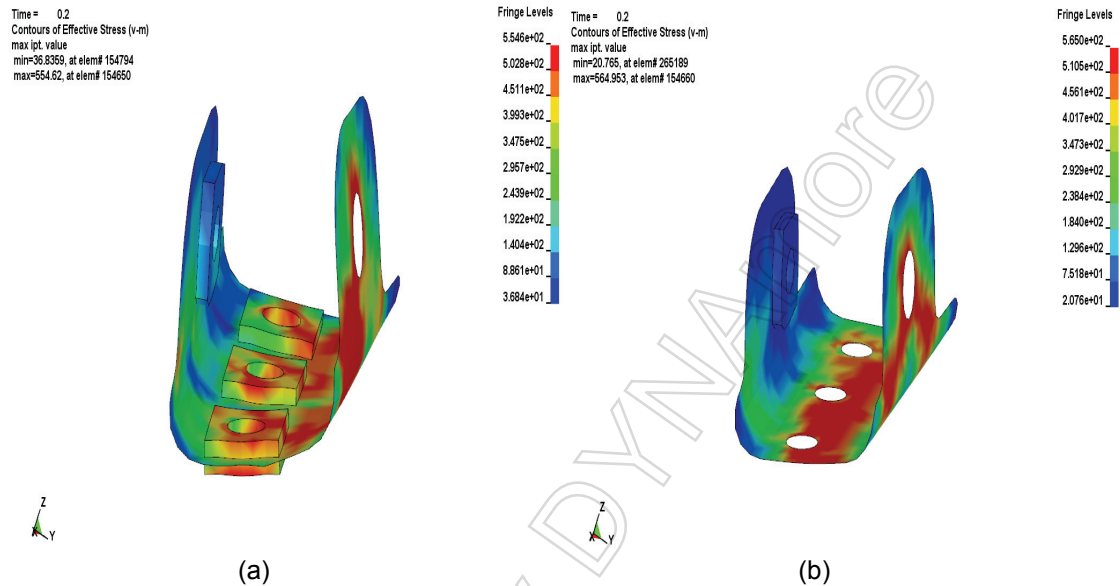

(a)   (b)

Figure 5: Stress in belt anchorage bracket a) solid rivet b) beam-spider

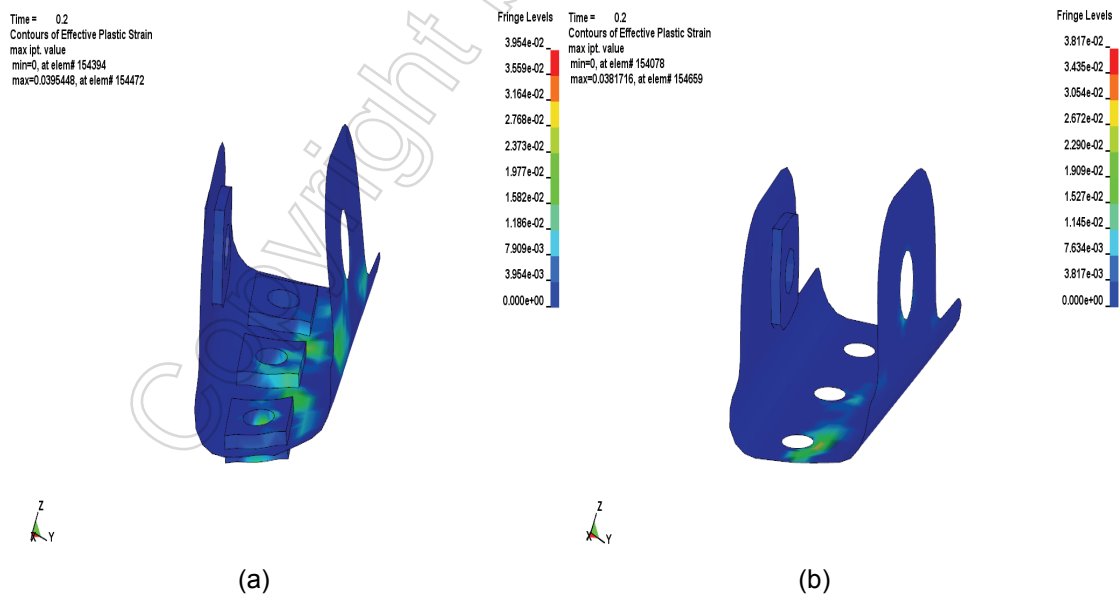(a)   (b)

Figure 6: Plastic strain in belt anchorage bracket a) solid rivet b) beam-spider

Figure-6 shows the plastic strain in the bracket. The plastic strain in the both cases does not exceed beyond the ultimate value. This makes sure that there is no failure of sheet metal bracket at the joint.

Even though overall deformation is same in both arrangements, the main concern is the effective Von-Mises stress value. Many times in sheet metal assemblies, the fatigue life of the sheet metal at the circular hole is important. It is the weakest area from where the crack can start. Therefore the stress is very important. Here we are not calculating fatigue life, but this aspect is important to note.
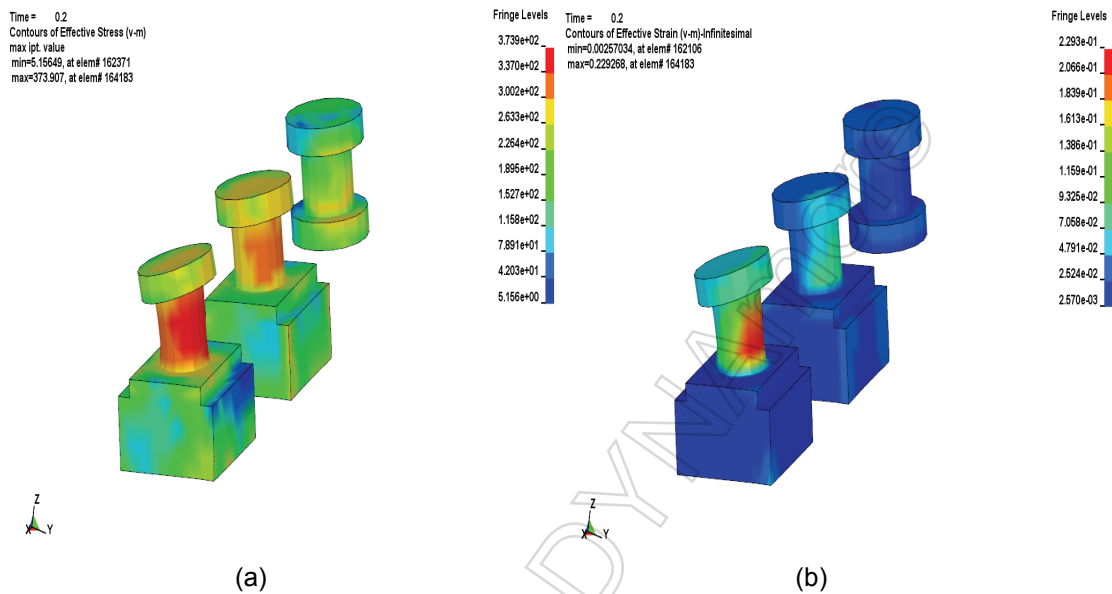

Figure 7: a) Effective Von-Mises stress in solid rivet b) Effective strain in solid rivet

Figure-7 shows the effective Von-Mises stress and effective strain in the rivets. The stress is distributed along the full length of the rivets. The effective strain is more localized. This shows that excessive bending and twisting occurred in the bracket. The solid rivets could absorb sufficient energy. The behavior of the bracket in beam-spider arrangement is different. As beam representing rivet does not undergo twisting or bending, the full load is absorbed by the sheet metal bracket. This causes the stress around the hole to exceed than in solid rivet arrangement.

5.0   Conclusion

It is observed that at the time of designing subassemblies, simulation of the joints with solid rivets/bolts transfer load precisely in sheet metal components. Thus plastic strains are distributed uniformly around the hole. One can predict fatigue life of the joint more precisely. In beam-spider arrangement the average effective stress around the hole is always higher. Therefore design becomes heavier. Many times it is not possible to use solid rivets/bolts due to time constraint or expensive run time. But in sub-assemblies, due to small size problem, one can afford to use solid rivets/bolts to increase the accuracy of the results. In this paper authors have suggested the novel method to model the rivets/bolts joints in sheet metal components. A macro can be written to generate such joints automatically. Through this exercise, it is shown that solid rivets/bolts give better accuracy in the results as compared to the beam-spider arrangement.

6.0   References

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