Non-Linear Finite Element Analysis of Typical Wiring Harness Connector and Terminal Assembly Using ABAQUS/CAE and ABAQUS/STANDARD

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Abstract: The objective of this paper is to showcase effective usage of ABAQUS capabilities to solve for typical connector-terminal assembly to meet global design requirements. In general, connection systems must qualify for mechanical and electrical performance criterion, to meet global customer requirements. The connection system must not only conform to such mechanical performance requirements; like Tensile Strength, Engage force, Retention force, Mating force, Disengage Force & durability; but also to electrical performance requirements like low level termination resistance, Voltage Drop, Isolation Resistance, Continuity, Temperature rise, and Current Cycle. Further, compliance is also required towards environmental performance requirements, like voltage and Temperature Range, High temperature Exposure, thermal cycling, temperature/humidity cycling, Mechanical shock, vibration, salt fog immersion, & Fluid Compatibility. An attempt has been made to demonstrate use of ABAQUS to ensure compliance with the mechanical performance requirements of a typical connection system assembly. This paper will also be addressed the FE Modeling of the Connection systems, Non-Linearity’s (Geometric and Material) and Contact issues.

The FE Modeling has been carried out using ABAQUS/CAE and analysis Using ABAQUS/STANDARD. With the above modeling approach adopted, in general ABAQUS Results have been observed to correlate with Standard Design Requirements and therefore substantially save on physical testing. ABAQUS results not only help to know the mechanical parameters but also provide insight to the physics of the problem that help to provide meaningful conclusions and design direction.

Keywords: Connector, Flex locks, Terminal, Primary Lock Reinforcement, Engage Force, Mating force and Retention Force
1. Background:

Delphi Packard Electric Systems is a leading Supplier of electrical and electronic connection systems, building on its reputation as the world leader in the Design, development and manufacture of power and signal distribution systems. Over the past 100 years, Delphi continually developed innovative connection systems which continue to exceed the most strenuous performance requirements, and which provide solid value for our customers. In partnership with our customers, Delphi has been able to anticipate their needs for reliable and cost effective connection systems. That kind of customer focus helps to make us more than the World’s Best Wiring Supplier.

A vehicle’s wiring harness system keeps everything else going, powering every component, every switch, and every device. It’s the vehicle’s central nervous system. It must work, every time and all the time. Without connection system, no system will work; it will play vital role any industry whether in automotive or aerospace. The main function of the connection system is to distribute the power supply from one system to another system. In automotive cars, it requires lot of connection systems to distribute the power from one system to another. Definitely any connectors, it should have sufficient strength to withstand any abrupt situations without affecting the performance of the total system. Figure.1 shows the typical wiring harness system of the front portion of the car.

Figure 1. Typical wiring harness system of the front portion of the car.
In general, connection systems must qualify for mechanical and electrical performance criterion, to meet global customer requirements. The connection system must not only conform to such mechanical performance requirements; like Tensile Strength, engage force, Retention force, mating force, Disengage Force & durability; but also to electrical performance requirements like low level termination resistance, Voltage Drop, Isolation Resistance, Continuity, Temperature rise, and Current Cycle. Further, compliance is also required towards environmental performance requirements, like voltage and Temperature Range, High temperature Exposure, thermal cycling, temperature /humidity cycling, Mechanical shock, vibration, salt fog immersion, & Fluid Compatibility.

The design requirements for typical Connector systems: Mechanical Performance Requirements
Retention Force (Terminal in Cavity) --- Minimum Pullout Force required is 67 N without PLR
Retention Force (Terminal in Cavity) --- Minimum Pullout Force required is above 100 N with PLR.
Retention Force (Connector to Connector)--The connector retention force, with Lock features, shall be greater than 110 N when disengaged an axis parallel to the centre line of the terminal.

1.2 General Description of the Connection System Components

Figure 2. Shows the Cross-Sectional view of the typical connector Assembly. Any typical connection system consists of Female Connector assembly and Male Connector assembly. The Female connector assembly consists of Female Connector, Female terminal, Connector position assurance (CPA), Primary lock reinforcement (PLR), Connector Seal and Cable seal. The male connector assembly consists of Male Connector, Male terminal, Primary Lock Reinforcement and Cable seal.

The Female Terminals will be inserted into the Female Connector cavity of the Flex lock. They will travel over the flex lock, the flex lock will move up and, then flex lock will sit into cavity of the terminal. The flex will not allow the terminal come out from the assembly. When PLR was included, the retention force of the flex lock will be increased. Figure 2. Shows that PLR is already in the second stage position. As the PLR is initially seated the side of the PLR will deflect and ride over the bump on the green connector and initially stop at the first stage position. At this point the terminals are plugged and the flex locks do not hit the PLR. Once all terminals are plugged the PLR is fully seated to the second stage position. The PLR backs up the flex locks to increase the retention. Similarly for the Male connector assembly, The Male terminal will be inserted into the cavity of the Male Connector. To increase the retention of the flex lock, the PLR will also be included. Finally, The Female connector assembly and Male connector Assembly will be assembled.
In generally, the following analysis has been carried out to evaluate the feature of the connection system. First, the Female connection assembly has been analyzed to determine the strain/stiffness analysis of the flex lock to verify whether flex lock is within the strain limits or limit and then, determine the engage and disengage force of the Female terminal with and without PLR. When PLR was included, the retention force of the flex lock will be increased. Similarly, Male connection assembly has been analyzed to determine the engage and disengage force of the Female terminal with and without PLR. When PLR was included, the retention force of the flex lock will be increased. Next, to evaluate the female connector PLR for both the first and second stage engage and retention and then to evaluate the male connector PLR for both the first and second stage engage and retention.

1.3 FE Modeling of the Connection Systems

The more challenges will come into the picture, the modeling aspects of the connection system. Instead of modeling the whole assembly of the connection systems, it is simplified the molding by considering the symmetry model. The FE Modeling has been carried out using ABAQUS/CAE and analysis carried out using ABAQUS/STANDARAD.

The terminal was modeled with Analytical rigid surface instead of considering the deformable body as it is made of brass compared to the connector, which is made of Plastic material. Because of complexities of modeling of the terminal, it will raise contact problem when solving the problem, which will end up big problem. It is easy to one can understand to consider Terminal as Analytical rigid surface which will help faster the run and also without any contact problems. The connector flex lock was modeled with C3D10M elements.
The following analyses have been carried out for the Connection Systems:

**a) Retention Analysis of Female connector and Female Terminal without PLR:**

![Figure 3. Cross sectional view of the female connector and female terminal.](image)

The main objective of the analysis to find out the retention force of the flex lock when disengage from the connector without PLR (Primary Lock Reinforcement). The female connector was modeled with C3D10M elements, where as Terminal was modeled with Analytical rigid surface. The contact definition was used with surface-to-surface treating Analytical rigid surface as Master Surface and flex lock surface as Slave Surface.

**The loading and Boundary Conditions:**

The displacement is applied in the Y-direction at Reference Point, RP (-2 mm) to pullout the terminal. Fixed all the dof’s at the cut portion of the connector. Symmetry BC’S is applied at the symmetry portion (Ux=0, URy=0, URz=0). The figure 4 and Figure 5 will show the Boundary conditions and FE Model.

The material properties are used for the connector flex lock is Elasto-Plastic materials.
Figure 4. Geometric model of the female connector and female terminal.

Figure 5. FE model of the female connector and female terminal.
Results and Discussion:

The retention force vs. history plots shows that the maximum retention force for the entire flex lock is 73 N, which is meeting as per the design requirements and it is also observed from the stress contour plots that the flex lock is failing due to the shear when terminal was pull-out.

Figure 6. The Von-Mises stress plots of flex lock without PLR

Figure 7. The Retention Force Vs displacement history Plot
b) Retention Analysis of Female connector and Female Terminal with PLR:

The main objective of this analysis is to determine the retention force of the Female Connector flex lock when disengage the Female terminal with the inclusion of the PLR (Primary Lock Reinforcement). The FE modeling of the Female connector, Female terminal and PLR have been done using ABAQUS/CAE and analysis carried out using ABAQUS/STANDARED. The Connector was modeled with C3D10M elements, whereas the terminal and PLR were modeled as Analytical rigid Surface. The contact definition was used with surface-to-surface treating Analytical rigid surface as Master Surface and flex lock surface as Slave Surface.

The loading and Boundary Conditions:

The displacement is applied in the Y-direction at RP1 (-2 mm) to pullout the terminal form the connector flex lock. The Terminal is allowed to rotate in x-direction and Translate in Z-direction by using 0-D grounded spring elements. The PLR is fixed at RP2. Fixed all the dof’s at cut portion of the connector. Symmetry BC’s is applied at the symmetry portion (Ux=0, URy=0, URz=0) of the Connector.
Results and Discussion:

The retention force vs. history plots shows that the maximum retention force for the entire flex lock when PLR included is 120 N, which is meeting as per the design requirements and it is also observed from the stress contour plots that the flex lock is failing due to the shear when terminal was pull-out.

Figure 10. FE model of female connector and female terminal.

Figure 11. The Von-Mises stress plots with PLR
C) Retention analysis of Connector Primary Lock (Connector –to– Connector)

The main objective of this analysis is to determine the retention of the Connector Primary Lock when retract the CPL from the connector system. The mating connectors are assumed to remain centered and do not rotate or translate up or down.

Figure 12. The Retention Force Vs displacement history Plot

Figure 13. Cross-sectional view of the Connector Primary Lock
The Connector Primary lock and Bump are modeled with C3D10M using ABAQUS/CAE. Both are treated as deformable bodies. The symmetry model has taken for the analysis.

The Loading and boundary Conditions:

The displacement is applied in the Y-direction at the female connector end. Fixed all the dof’s at bottom of the cut portion. Symmetry BC’s is applied at the symmetry portion. The material properties are used for the connector flex lock is Elasto-Plastic materials.

Figure 14. The geometric model of the Connector Primary lock

Figure 15. The FE model of the Connector Primary lock
Results and Discussion:

The following graph shows the retention force vs displacement history with the maximum retention force for the entire CPL is 259N, which is well below the Design standards.

Figure 16. Von-Mises stress plots for CPL when Disengage

Figure 17. The Retention Force Vs displacement history Plot
Conclusions:

From the FE analysis results, it indicates that the results are well within the Design standards. By adopting FE analysis using ABAQUS, it not only saves time, money & Physical Testing but also guides the Product Engineer for further improvement and modification of the connection system. The biggest challenges of such analyses are: FE modeling of the Connector terminals with analytical rigid surfaces and dealing with Convergence issues due to large deformation of the elements.

References


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