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Design Optimization of Electrical Connector Assembly using FEA

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Abstract

Due to the increasing number of devices and systems connected to an electric system, the need for reliable and high-quality electrical connectors has become more prevalent. This project aims to optimize the design of an electrical connector during its two most critical stages: insertion and retention of housing using FEA. A structural analysis is performed during the insertion and retention stages of housing. This process involves calculating the dimensional deformations and maximum strains developed during the steps mentioned above to determine the reliable functioning of electrical contacts. The input geometry is fed to the finite element analysis. The forces applied on the connector's latch on their respective connection are ensured to be under the limit. The analysis and simulation results are reflected to validate the safe forces in the connector assembly and a proper justification for an experimental set up in the laboratory.

Keywords: *Electrical Connector, housing latch, ANSYS Mechanical APDL.*

1.0 Introduction

A connector is a component that connects two or more electrical contacts. There are various types of these connectors, and their sizes can vary depending on the usage and environment[1-3]. A connector is composed of two parts, one of which is a plug, and the other is a receptacle. These components are commonly used to connect various features inside a house[4-5]. The electrical contacts are an essential component of a connector and make a high-conducting copper alloy.

On one side is the contact without spring properties, while on the other side is the contact with spring properties. When the plug [6-8] is inserted into the other component, the two contacts form a solid connection. Thus, allowing electric flow.

Hybrid connectors are electronic devices that allow the intermixing of different types of connectors. They can be used to interface non-electric and electrical components [9-10], such as those found in pneumatic and optical fiber lines. Due to their modular nature, they can be easily repaired or modified. Hybrid connectors [11] is also used to create different cable and connector assembly projects that reduce the time it takes to implement equipment.

Although refitting or re-seating an existing damaged or defective hybrid connector can prevent surface corrosion [12], this process can also cause the surface to scratch. High ambient temperatures can also lead to the failure of hybrid connectors. This condition [13-14] can decrease the insulation resistance of the connectors, which can cause them to fail. Although they are designed to improve the functionality of a circuit, connectors should not be used as the primary component of a system.

2.0 Materials and Methodology

The input geometry is fed to the finite element analysis so that the forces that are applied on the latch of the connector on their respective contact are ensured to be

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under the limit. Suppose the forces exceed the limit, which is further calculated using the material properties. Suppose the exceeded value is beyond the threshold limit.

In that case, the designer intimates the same so that the necessary modifications can be done in the design specifications, including material change, dimension adjustment, chamfer, edge radius, etc.

The actual work of the project includes taking the existing model of a connector with predetermined material properties and conducting a full-scale simulation analysis in the Ansys software by applying the loads and comparing the results with the permissible limits.

FE Modelling parameters are as follows :

(a) The element type used in the modelling is 187, second order tetrahedron.
(b) The number of nodes are 131910.
(c) The number of elemets are 80210.
(d) The types of contact element are 170,174,175.

The connector material properties are given in the Table 1.

Table 1: Material properties of the connector

Description	Type/Value
Material	POCAN B1305 PBT
Youngs Modulus inMPa	2706
Tensile strength inMPa	66
Elongation percentage	6.7
Poissons ratio	0.35

2.1 Housing insertion

A typical connector has two individual parts in which one has a groove known as female housing that can accommodate the other part known as male housing that slides through it till the latch gets in place. This latch is positioned so that a locking mechanism uses the tension force to hold it in place.

The boundary conditions for housing insertion while doing analysis are essential. The backside face nodes of the female housing are constrained in Z & Y direction. The displacement of 7 mm is applied in the -Z (negative Z) direction as shown in the figure, and the Y direction is constrained on face node in the male housing. This allows the forces applied on the locking mechanism is measured accurately. Another practical approach is that the complete model is not considered for the analysis. Instead, only the half model is taken for analysis by cutting the model along the z-axis since the model is symmetric along the z-axis. This

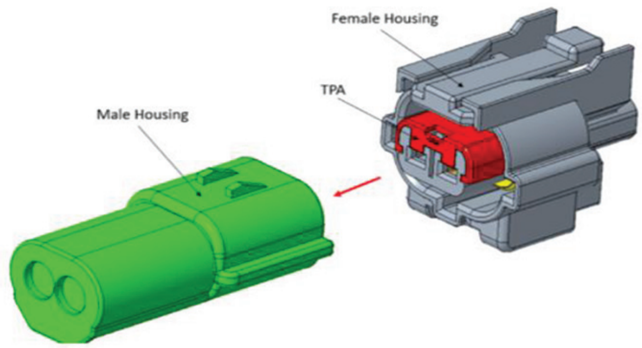

Figure 1: Geometry Model representing housing insertion

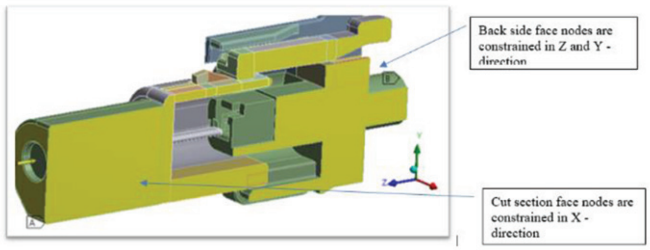

Figure 2: Boundary Conditions for both cases (half-model)

approach can ease the complication process and thus reduce the run time of pre-processing and post-processing in the software. Contact friction between the mating parts is considered to be 0.2 in both the cases.

2.2 Housing retention

Like the above scenario, the retention of the male housing from the female housing is nothing but the consideration of forces while it is being removed.

The boundary conditions for housing retention are similar to insertion (case 1). The only difference, in this case, is that the male housing is displaced by 7 mm

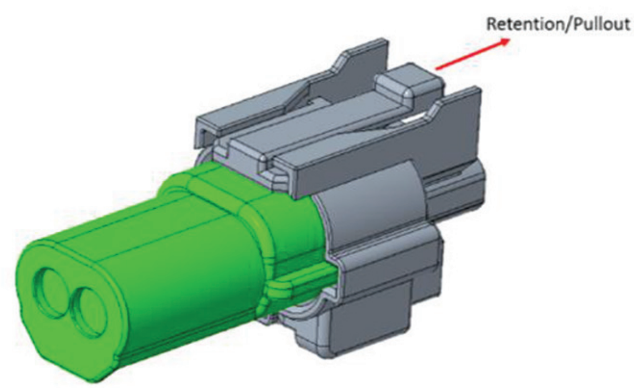

Figure 3: Geometry Model representing housing retention

towards the Z (positive Z) direction since the male housing is pulled out during retention. The resulting forces, Z-reaction forces, Y-displacement, and Von-Moises distribution are calculated during the pullout.

3.0 Result and Discussion

3.1: Housing insertion

This method allows the forces applied to the locking mechanism to be measured accurately. Another advantage of this method is that it only takes a half model to analyze, since the model is not considered for the complete analysis. This method can also reduce the time needed to perform post-processing and pre-processing in the software. For instance, it can eliminate the need for manual calculations. The analysis of the connector housing insertion is done where the loads are being applied. As discussed above there are two parts in which one has a group known as the female housing that can accommodate the mail housing which slide through it till the locking mechanism gets in place.

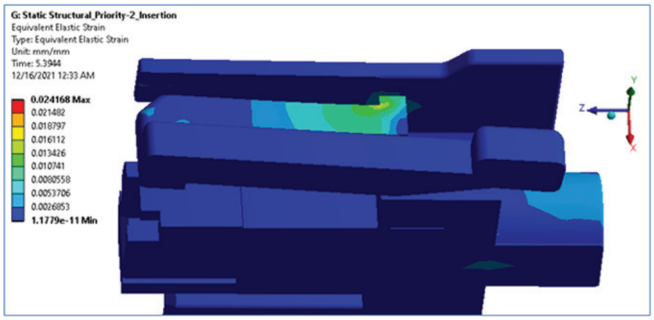

Figure 4: Housing insertion simulation

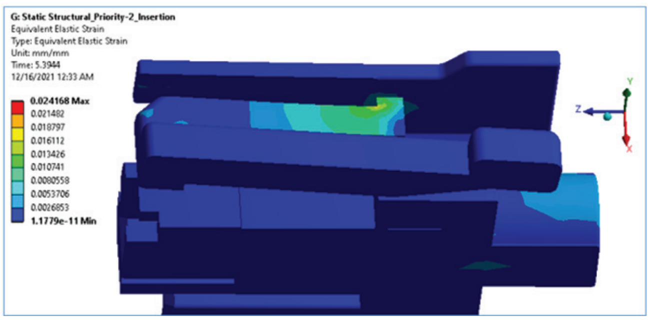

Figure 5: Half model simulation representation

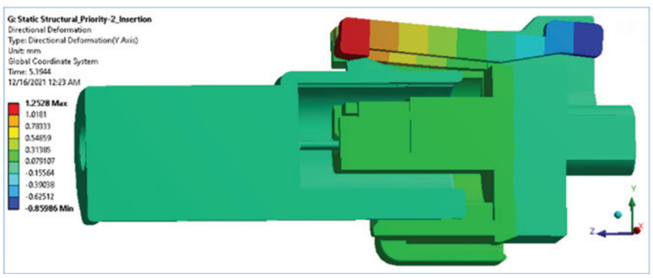

Figure 6: Housing insertion simulation

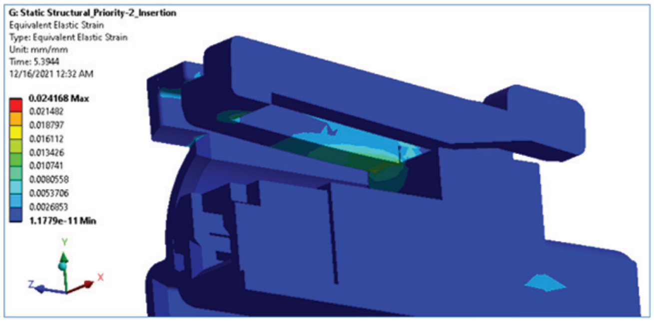

Figure 7: Von Mises Strain distribution at maximum deflection of locking latch

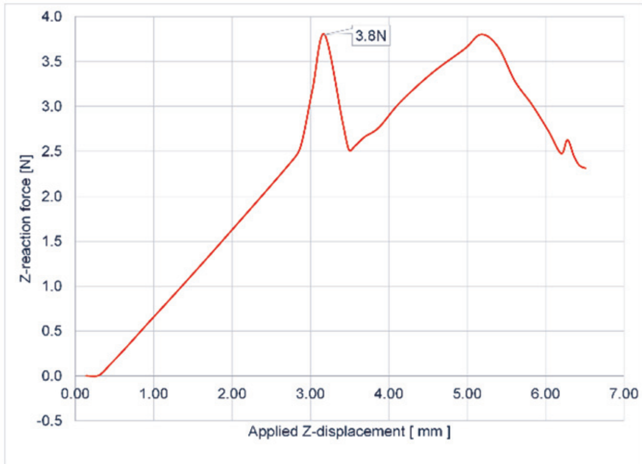

Figure 8: Z-Reaction force [N] Vs Z-displacement [mm]

While performing analysis, it is important to consider the boundary conditions of the housing. For instance, the displacement of 7mm is applied in the negative Z direction to the face nodes of the female housing. Similarly, the displacement of 7mm is applied in the positive Y direction to the face nodes of the male housing. The stress strain graph for the material is given. The following figures show the simulation of housing insertion while the female housing is accommodated with the male housing through the groove that is provided, and the respective loads will be applied on the contacts and those contact parts will be deflecting due to the application of external force considering the contact section to be 0.2. Instead of considering the entire model, we have taken half the model cut symmetrically. This does not change the results and values of displacement strains and stresses since the model is symmetric.

Static structural analysis is done with the boundary conditions that make the operation similar to the real-life application. For the housing insertion, the displacement of 7mm is applied in the Z direction, and the Y direction is constrained on the facing node, whereas the cut section faces nodes for denying in the X- direction. Graphs are plotted with the results of Z displacement and reaction forces. Maximum Housing Insertion force without terminal is found to be 3.8N for full model

3.2 Hosing retention

Just like the previous case the analysis of the connector housing retention is done where the loads are applied respectively, and the following figures show the simulation of housing retention while the meeting parts are being pulled out from the groove where the locking mechanism happened. In the respective loads applied on the contacts will be deflecting due to the pull out action. The same contact fraction of 0.2 is being used for the case and also in this case of model is considered since the scenario is same because of the symmetric nature of the model. The static structural analysis is done with the boundary conditions where the real life

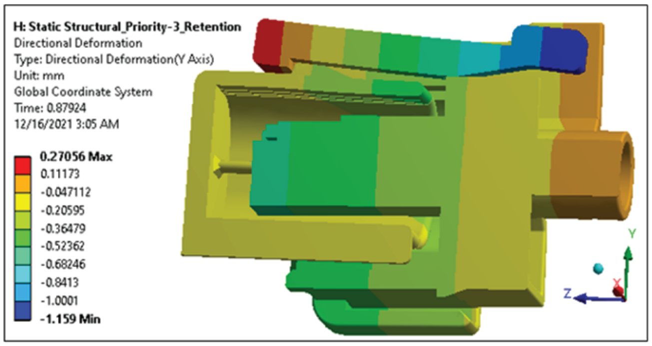

Figure 9: Housing retention simulation

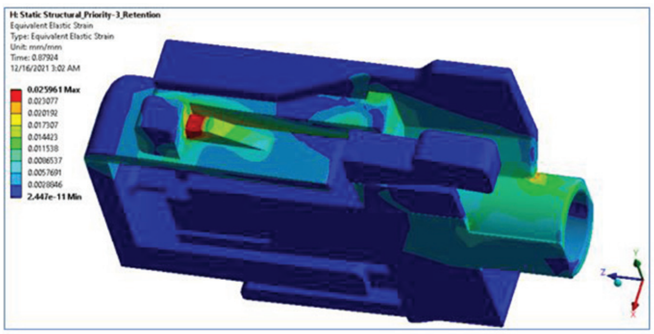

Figure 10: Housing retention simulation

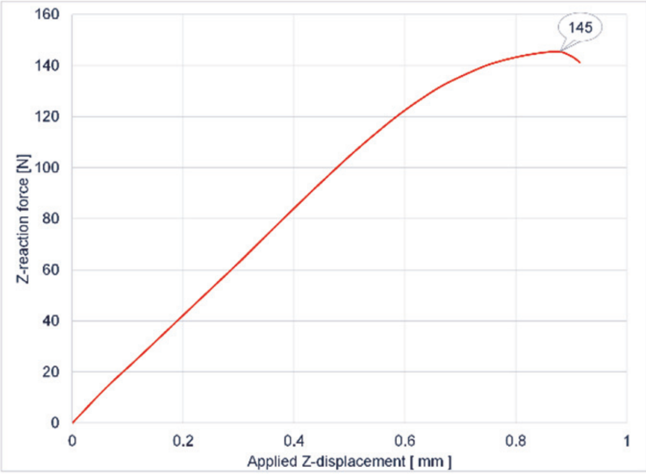

Figure 11: Z-Reaction force [N] Vs Z-displacement [mm]

application is met. The displacement of 7MM is applied in Z direction and Y direction is constrained on face node. The cut section face nodes are also constrained in X direction. Along with this the backside face nodes are constrained in Z and Y direction. Along with the above forces a Graph is plotted between Z direction force in newtons versus Z displacement in MM on Y axis and X axis respectively.

4.0 Conclusion

During Housing Insertion: Maximum strain developed is well within the breaking strain, i.e 6.7 per cent of the material. Therefore, both parts are safe during insertion process. Maximum Housing Insertion force developed is 3.8N for full model During Housing Retention/Pullout: Maximum strain developed is well with in the breaking strain 6.7 per cent of the material. Therefore latch part will slip out during pullout process without braking of locking latch. Maximum Housing Pullout force developed is 145N for full model.

References

[1] Duan, K, Zhu, F, Li, Y. Contact resistance investigation of electrical connector with different shrink range. In: Proceedings of the IEEE 15th international conference on electronic packaging technology (ICEPT), Chengdu, China, 12–15 August 2014.

[2] Slade, PG. Electrical contacts: principles and applications. 2nd ed. Boca Raton, FL: CRC Press, 2013.

[3] Beloufa, A. Influence of shapes, contact forces and high copper alloys on the contact resistance and temperature. In: Proceedings of the 2nd international conference on engineering mechanics, structures, engineering geology, Rodos, 22–25 July 2009.

[4] Li, Y, Zhu, F, Chen, Y. Analysis of insertion force of electric connector based on FEM. In: Proceedings of the IEEE 21st international symposium on the physical and failure analysis of integrated circuits (IPFA), Singapore, 30 June–4 July 2014.

[5] Monnier, A, Froidurot, B, Jarrige, C. A coupled-field simulation of an electrical contact during resistance welding. In: Proceedings of the 52nd Holm conference on electrical contacts, Montreal, QC, Canada, 25–27 September 2006.

[6] Beloufa, A. Design optimization of electrical power contact using finite element method. *J Heat Trans*: T ASME 2012.

[7] Interview [or Personal Communication] with Prof. Elmer Hixon, BCE Department, The University of Texas at Austin, March 12, 1995.

[8] Ren, W, Zhi, H, Xue, S. Numerical simulation and experimental verification for contact spot temperature and electrical contact resistance of rivet contacts. In: Proceedings of the 27th international conference on electric contacts (ICEC), Dresden, 22–26 June 2014 Washington, D.C.: Packaging Machinery Manufacturers Institute, 1973. 36.

[9] Wiese, M.; Thiede, S.; Herrmann, C. Rapid manufacturing of automotive polymer series parts: A systematic review of processes, materials and challenges. Addit. Manuf. 2020.

[10] Anthony, C.; Cheung, W.M. Cost evaluation in design for end-of-Life of automotive components. *J. Remanufacturing* 2017.

[11] Monnier, A, Froidurot, B, Jarrige, C. A coupled-field simulation of an electrical contact during resistance welding. In: Proceedings of the 52nd Holm conference on electrical contacts, Montreal, QC, Canada, 25–27 September 2006.

[12] Beloufa, A. Design optimization of electrical power contact using finite element method. *J Heat Trans*: T ASME 2012.

[13] Shravanabelagola Jinachandra N, Sadashivappa Kubsad S, Sarpabhushana M, Siddaramaiah S, Rajashekaraiah T. Modeling and computational fluid dynamic analysis on a non AC bus coach system. *Heat Transfer*. 2020; 1–8. https://doi.org/10.1002/htj.21857.

[14] S. J. Niranjanaa*, S. S. Kubsadb, S. Manjunathac, Y. Nagarajd, I. Bhavie , B. M. Angadie , A. J. Chamkhaf, M. B. Vanarottig," Experimental Investigation and Numerical Simulation of Air Circulation in a Non-AC Bus Coach System". *International Journal of Engineering*. IJE Transactions C: Aspects Vol. 35, No. 03, (March 2022) 572-579. Doi: 10.5829/ije.2022.35.03c.10.