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Case studies of auto battery connector behavior subjected to various loads

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In the present paper we present 3D models of three types of components, parts of power supply system found in automobiles. Components were designed and dimensioned according to the needs of their rational exploitation. The three parts under analysis are battery connectors used in petrol or diesel automobiles. Material used for designing is nickel. Case studies consider a comparison between components behavior in terms of von Misses stresses, displacements, elongation, damage, life cycle, load factor or safety factor, when subjected to constraints and different loads.

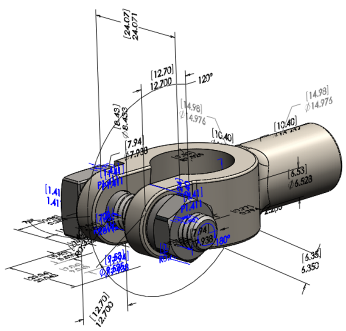
Keywords: *automobile, battery, safety, constraint, damage*

1. Theoretical background of battery connector

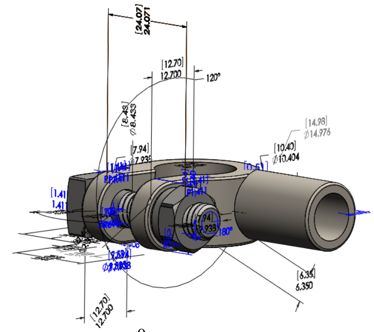
In present paper we will build 3D design and model three types of connectors used at automobile battery found at power supply system. For case studies we have chosen a simple straight shaped connector, a simple 90^0 shaped connector and a double 90^0 shaped one.

Simple connector is used mostly as end-to-end point with 12/24 V battery of low and medium weight auto vehicles. Simple 90^0 connectors are usually found at petrol automobiles, where a 50-55Ah battery is mounted. Double 90^0 connectors are specific to Diesel cars or to high capacity auto vehicles [1, 2].

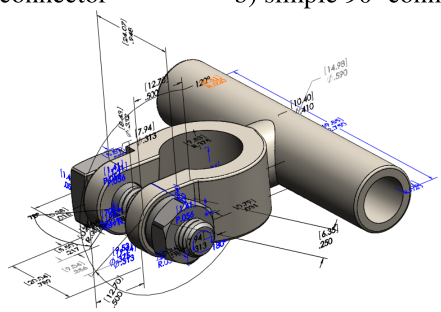
For designing components SolidWorks software was used. At dimensioning stage, mechanical and electrical specifications were taken into account and the obtained designs are according to Figure 1. Case studies consider a static linear analysis, determining displacements, elongations and von Misses stresses and a fatigue analysis determining life cycles, damage and load factor. Factor of safety can be determined only for unique events of fatigue study [3, 6]. Loads are gradually increasing applied, varying from 100N to 1000N. Constraints are defined on the inside contact surface of connector with battery terminal. Material used for testing is nickel [4].



a) simple straight connector



b) simple 90^0 connector

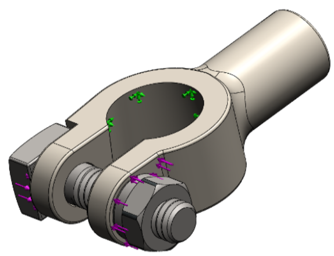


c) double 90^0 connector

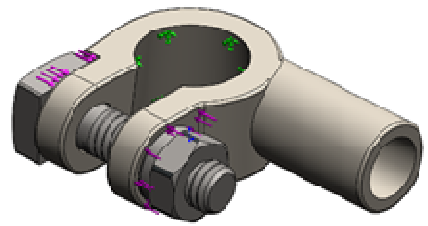
Figure 1. Dimensioned designs of three connector types

2. Case studies for static analysis and obtained results

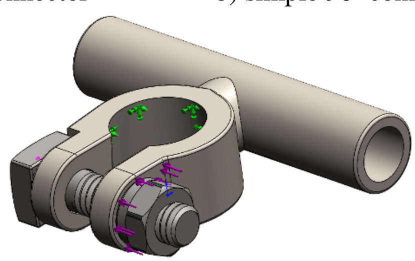
As previously mentioned we considered for three types of components a nickel material, constraints applied on the inside contact surface of connectors and battery terminal, and increasing various loads in (100-1000) N interval, as shown in Figure 2. Considering nickel characteristics, flow limit will be established at 59MPa. Results obtained from simulations for the three modeled parts, for above mentioned analysis indicators will be shown in following data tables. Studying the outcome values of simulations, it can be noticed that for minimum load value of 100 N resulted a maximum von Misses stress of 9.637 MPa for simple straight connector, 9.273 MPa for simple $90=^0$ connector and 9.904 MPa for double 90^0 connector, differences being very small, according to Table 1. In case of displacements, as Table 2 reflects, for the same load we have a similar situation: $2.53 \cdot 10^{-4}$ mm for simple straight connector, $2.55 \cdot 10^{-4}$ mm for simple $90=^{0}$ connector and $2.53 \cdot 10^{-4}$ mm for double 90^{0} connector. Applying first load of 100 N, for the elongation indicator we obtained $2.80 \cdot 10^{-5}$ mm for simple straight connector, $3.10 \cdot 10^{-5}$ mm for simple $90=^{0}$ connector and $3.12 \cdot 10^{-5}$ mm for double 90^{0} connector.



a) simple straight connector



b) simple 90^{0} connector



c) double 90^{0} connector

Figure 2. Applying constraints and loads

In Table 1 there can be found von Misses stress values obtained from simulations, for the three types of designed components. Regarding flow limit, issues seem to appear from a load of 500 N for the 90^{0} models and from 600 N for the straight design. Safety factor decreases with the increase of load applied on simulated models. According to restraints of SolidWorks software it can be considered an issue for situations in which safety factor decreases below value if 2, if applied load value is doubled.

Table 1. Values for von Misses stress [Mpa] for various applied loads

Load [N]	Simple straight connector	Simple 90^{0} connector	Double 90^{0} connector
100	9.673	9.904	9.273
200	19.346	19.810	18.545
300	29.020	29.714	37.091
400	39.693	39.619	46.364

500	48.366	49.524	55.736
600	58.039	59.429	64.999
700	67.712	69.334	74.182
800	77.385	79.239	74.182
900	87.059	89.104	83.455
1000	96.732	99.001	92.728

Thus, we can consider a safety issue starting with load of 200N for all under discussion designs, where we obtained values: 3.050 for simple straight connector, 3.181 for simple 90^0 connector and 2.980 for double 90^0 connector.

Analyzing graphical representation from Figure 3 we can make following remarks: all three types of designs subjected to linear increasing loads present a linear variation pattern and very similar values for considered load value.

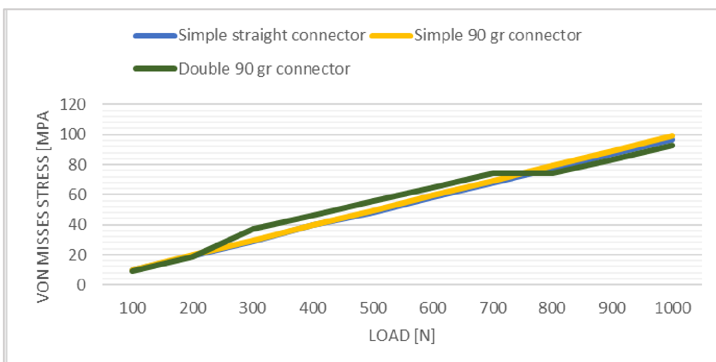


Figure 3. Von Misses stresses variation comparison

Data centralized in Table 2 represent displacement values resulted from simulations, for the three types of designed parts. Displacement variation with load, though not linear, is similar for the three designs under discussion. A fluctuation in pattern can be noticed for straight and simple 90^0 connectors at loads of 400N and 500 N and the same situation for double connector at load of 900N.

Table 2. Values for displacement [mm] for various applied loads

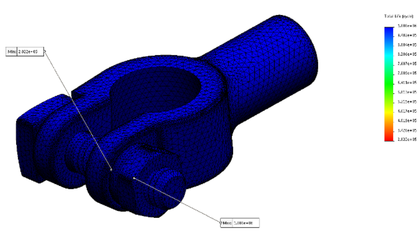
Load [N]	Simple straight connector (10^{-4})	Simple 90^0 connector (10^{-4})	Double 90^0 connector (10^{-4})
100	2.53	2.53	2.55
200	11.01	12.14	11.44
300	12.54	12.22	13.65
400	11.24	18.54	17.72

500	10.21	22.23	12.56
600	23.20	25.41	22.21
700	27.84	26.65	25.21
800	24.12	25.84	21.27
900	27.85	22.10	23.02
1000	33.65	35.41	32.14

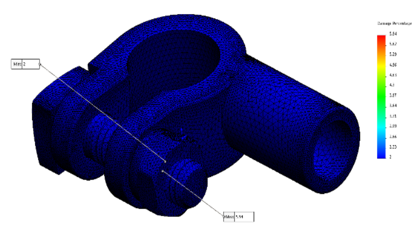
3. Case studies for fatigue analysis and obtained results

For fatigue study we will consider life cycle factor as number of functioning cycles of components under discussion subjected to load, without appearance of material defects and damage factor as percentage of cumulative deterioration factor or percentage of consumed lifespan [5, 6].

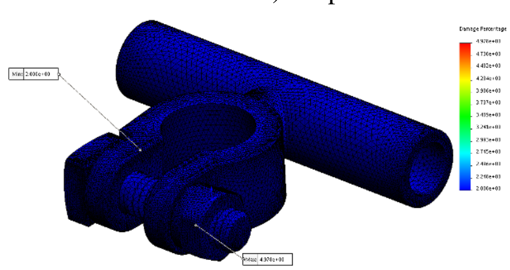
Representations from Figure 4 show damage results for three types of component designs, when a load value of 1000 N is applied. For simple straight design we obtained a maximum damage of 4.475 for a life cycle number of $4.47 \cdot 10^5$ and for double 90^0 connector a maximum damage of 4.978 for a life cycle number of $4.02 \cdot 10^5$, while for simple 90^0 component result was sensitive higher, of 5.94 for a life cycle number of $3.364 \cdot 10^5$.



a) simple straight connector



b) simple 90^0 connector



c) double 90^0 connector

Figure 4. Damage results for 1000 N load

For determined low and high load factor for designs subjected to fatigue analysis the results were according to values recorded in Table 3. If we draw graphical representations for maximum load factor of the three components designs subjected to initial load values considered for presented case studies, we obtain Figure 5 for simple straight connector, Figure 6 for simple 90^0 connector and Figure 7 for double 90^0 connector.

Table 3. Values of load factor for various load values

Load	Simple straight connector		Simple 90^0 connector		Double 90^0 connector	
[N]	Min	Max	Min	Max	Min	Max
100	21.28	2.78□10^6	21.10	3.56□10^6	21.90	18.12□10^8
200	10.75	1.22□10^6	10.50	1.78□10^6	11.01	9.31□10^8
300	7.47	8.45□10^5	7.02	1.19□10^6	7.31	6.04□10^8
400	5.82	7.38□10^5	5.27	8.90□10^5	5.48	4.47□10^8
500	4.05	6.16□10^5	4.21	7.12□10^5	4.38	3.68□10^8
600	4.78	5.63□10^5	5.31	5.93□10^5	3.65	3.01□10^8
700	3.12	5.12□10^5	3.01	5.08□10^5	3.13	2.57□10^8
800	2.84	4.87□10^5	2.63	4.45□10^5	2.74	2.25□10^8
900	2.55	4.48□10^5	2.34	3.95□10^5	2.44	1.56□10^8
1000	2.24	5.21□10^5	2.11	3.56□10^5	2.19	1.08□10^8

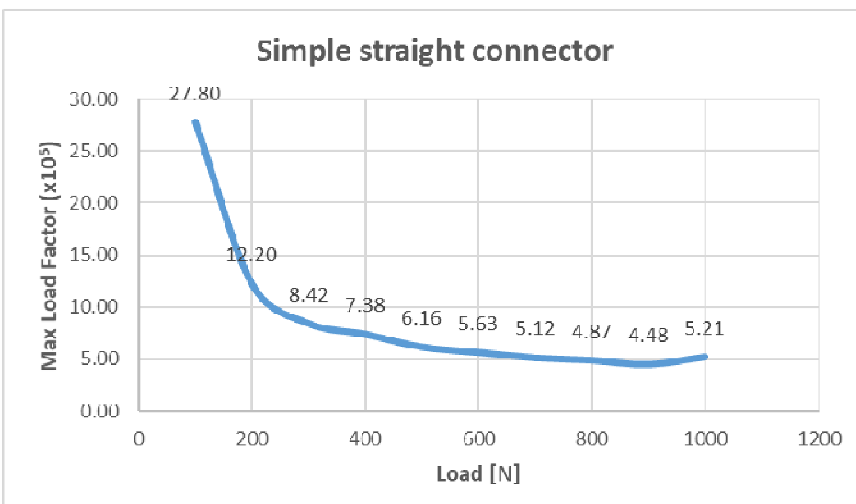


Figure 5. Trend variation of load factor for simple straight connector

Analyzing figures 5, 6 and 7 we can state that for all three components models trend variation of maximum load factor has similar allure which can be approximated with the allure of a logarithmic function. However, values resulted from simulation for maximum load factor of double 90^0 connector are significantly higher, being a normal situation, considering material quantity used for designing its shape.

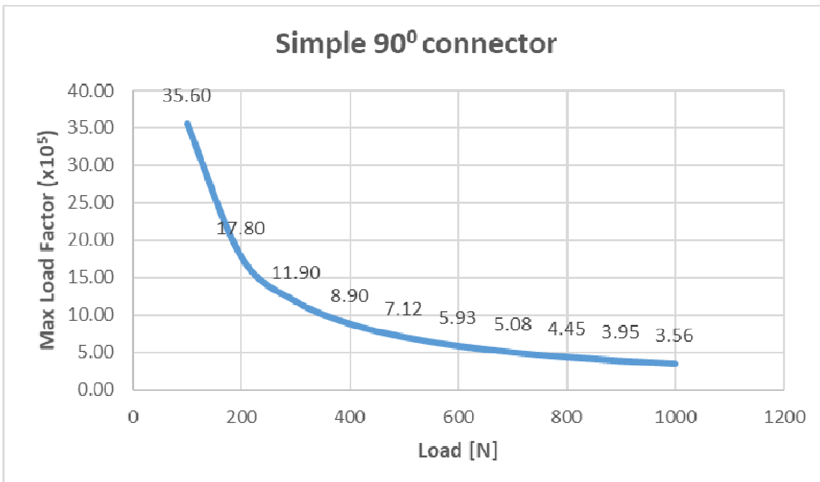


Figure 6. Trend variation of load factor for simple 90^0 connector

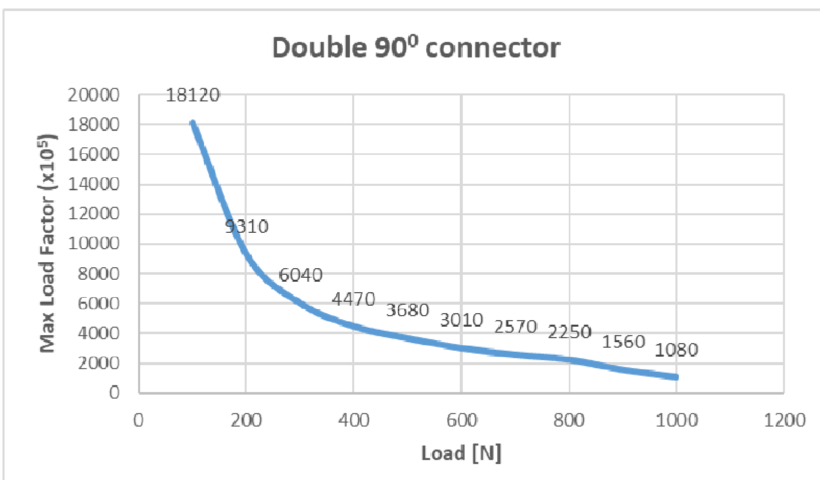


Figure 7. Trend variation of load factor for double 90^0 connector

4. Conclusion

Case studies described in present paper aim at consisting as a primary stage for further analysis regarding cost reduction with automobile connectors production, used at automobile battery found at power supply system, in terms of material mass streamline, without affecting well-functioning of designed parts. For a proper cost optimization all factors analyzed in earlier studies, with impact upon part's tasks in the system, must be taken into account. Studies conducted play a significant role for automotive field, an industry in a continuous development

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