IOP Conf. Series: Materials Science and Engineering **423** (2018) 012034 doi:10.1088/1757-899X/423/1/012034

Analysis of Fatigue Life of a Torsion Beam Based on nCode Design-Life

ZHANG Gong-xue[1], NIU Gu-gen[1, a] , GUO Shan-shan

[1]Shannxi University of Science & Technology, Shannxi Xi'an, 71002, China

[2]Shannxi University of Science & Technology, Shannxi Xi'an, 71002, China

[3]Shannxi University of Science & Technology, Shannxi Xi'an, 71002, China

*Corresponding author: [a]NIU Gu-gen1159348600@qq.com

Abstract: The rear torsion beam of a car was taken as the research object, and its fatigue life was estimated by nominal stress method.In ANSYS Workbench, the strength of the torsion beam was checked through analysis, and the dangerous part and the nominal stress spectrum were obtained. The load time series was obtained in Admas. The SN curve of composite material and fatigue cumulative damage theory were analyzed in ncode Designlife to obtain the fatigue life of the torsion beam. The calculation results show that the minimum fatigue life of the torsion beam is 564,000 kilometers, which is higher than the national number of scrapped cars and meets the use requirements. This method can provide the basis for the optimal design of the torsion beam.

1. Foreword

The rear torsion beam of the vehicle is a key component that carries the weight of the vehicle body. Due to its light weight, low production cost, and small vehicle footprint, it is favored by automobile manufacturers and widely used in small cars. The working principle of torsion beam is to install two left and right wheels on both sides of the torsion beam. When the vehicle is running, the left and right wheels will behave in different phases. This kind of jump will cause the torsion beam to twist and will rotate around the shaft to drive another. One side of the wheel also beats accordingly, thereby reducing the entire body tilt or shake. Because the torsion beam itself has a certain torsional stiffness, it can play the same role as the lateral stabilizer, which can increase the roll stiffness of the vehicle and improve the roll stability of the vehicle[1]. The torsion beam bears most of the weight of the car body, which may cause accidents due to its insufficient strength. At the same time, due to the impact of the road load during the normal driving of the car, fatigue failure often causes damage to personal and property. Therefore, it is very necessary to do a research for the torsion beam .

Some scholars have also studied the torsion beam of the automobile. Fan Weiwei[2]and others used the

ANSYS Workbench to simulate and analyze the force of a torsion beam when the wheel was bouncing up and down in the opposite direction. However, the analysis was simple and did not consider the torsional conditions. Chen Kun[3] and others used the finite element tool MD NASTRAN2010 to perform simulation calculations and optimized the torsion beam only from the strength aspect. Yi Siwu[4] studied the problem of fatigue fracture of a torsion beam rear suspension of a certain type of vehicle, but did not give a fatigue life calculation. Based on the above problems, the strength of the torsion beam was checked through uneven pavement and torsion conditions, and the fatigue life of the torsion beam was estimated by the nominal stress method, which provides a basis for optimizing the torsion beam.

2. Torsion beam finite element model

The torsion beam is mainly composed of a longitudinal arm, a cross beam, a shock absorbing seat, a torsion bar, a hub frame and a sleeve. When establishing a finite element model, the more consistent the model with the actual model, the more accurate the result, but it may increase the workload of the analysis; the simpler the model, the higher the calculation efficiency. For some complicated parts, it is possible to simplify the holes and chamfers that do not affect much without affecting the accuracy. In this paper, the mesh is divided freely. The element size is controlled to 50, and the minimum edge length is 5mm. A total of 48,528 nodes and 14,621 elements are generated. The torsion beam mesh model is shown in figure 1.

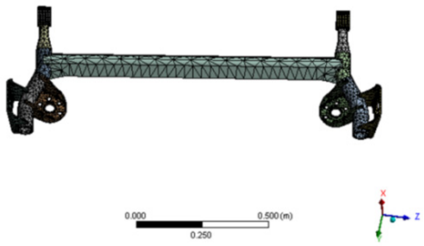


Figure1. Torsion beam mesh model

The material of the torsion beam is high-quality carbon steel. The material properties are shown in table1.

Table1. Material properties of torsion beams

Density (kg/m^3)	Elastic modulus (N/m^2)	Poisson's ratio	Yield Strength (MPa)	Tensile strength (MPa)
7850	2.1E11	0.3	375	600

3. Strength analysis

Torsion beam force parts mainly include shock absorption seats, hub brackets and sleeves. The shock-absorbing seat receives the load from the shock-absorbing spring, the hub frame is subjected to a vertical upward force from the road surface, and the sleeve is connected to the body to fix the force. Considering that the torsion beam is a symmetrical structure, the torsion force beam side is used for force analysis. The force analysis chart is shown in figure 2.

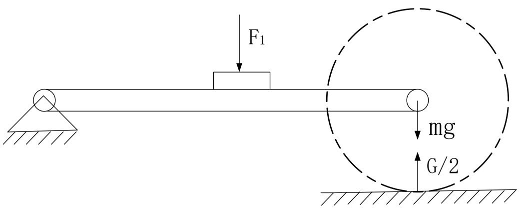


Figure2. Force analysis of unilateral torsion beam

When the load on the torsion beam is calculated as static load, the load F_1 at the damping seat is:

$$F_1 = \frac{G}{2} - mg$$

In the formula:

G—Rear axle load when fully loaded;

m—Wheel weight (including hubs, brakes, etc.);
g—Gravity acceleration;
Condition 1：torsion beam strength analysis under uneven road load

Generally, when the front engine of a pre-engined engine is unloaded, the front axle load is 56% to 66%, and the rear axle load is 34% to 44%[5]. The car with a certain model has a full-load mass of 1815 kg. The axle load of the front axle takes 60%, and the axle load of the rear axle accounts for 40%.

$$m_1 = 1815 \times 40\% = 726\text{kg}$$
$$F_1 = m_1 \div 2 = 726 \div 2 \times 9.8\text{N} = 3557.4\text{N}$$

In the formula:
m_1—Rear axle load when fully loaded;
F_1—Shock absorber seat load;
g—Gravity acceleration, take 9.8N/kg;;

On an uneven road, the torsion beam receives impact from the road surface in addition to the static state load. The impact load of the shock absorption seat under the combined action of these two loads[6] is:

$$F = k_d F_1 = 3 \times 3557.4N = 10672.2N$$

In the formula:
F—Shock mount shock load;
k_d—Dynamic load factor, 3 for passenger cars;

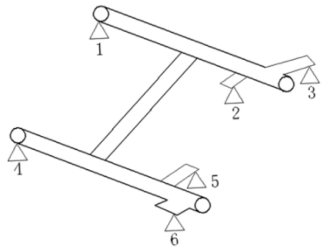


Figure 3. Load constraint diagram

Load boundary conditions: the constraint diagram is shown in figure 3. A fixed restraint is applied at 1, 3, 4, 6 and a vertical downward load of 10672.2N is applied at 2, 5, that is, at a shock-absorbing seat at a vertical direction.

Simulation and result analysis: from the equivalent stress cloud diagram in figure 4, the maximum stress at the shock absorbing seat is 307.15 MPa, which is less than the yield limit of the carbon structural steel 375 Mpa. Therefore, the strength of the torsion beam under the uneven road load meets the requirements.

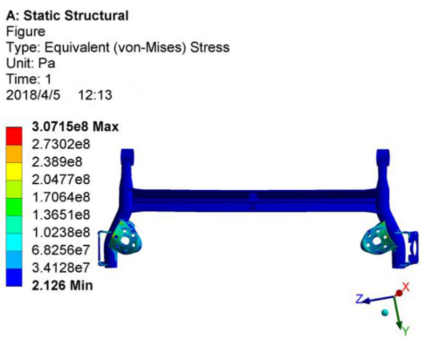


Figure 4. Equivalent Stress Cloud

Condition 2：strength analysis under extreme torsional conditions

When the car is driving in a pit zone, one wheel of the rear axle is on the convex hull and the other wheel is in the pit. In this case, twisting of the torsion beam occurs. Due to the hysteresis of the shock absorber, the spring on the automobile's shock absorbing seat is still in a compressed state, and the impact load on the shock absorbing seat is:

$$F \approx \frac{m_1}{2} g = \frac{726}{2} \times 9.8N = 3557.4N$$

Load boundary conditions: the constraint diagram is shown in figure 3. Apply a fixed restraint at 1, 3, 4 and a vertical downward load of 3557.4N at 2, 5, that is, vertically downward at the shock mount.

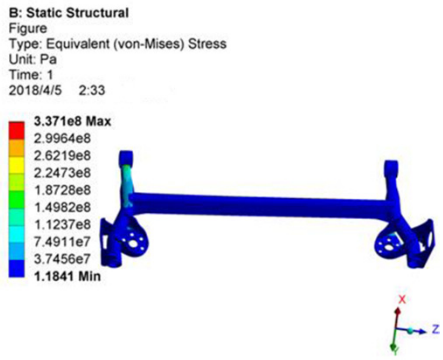


Figure 5. Equivalent Stress Cloud

Simulation and result analysis: from the equivalent stress cloud diagram in figure5, the maximum stress is 337.1 MPa at the junction of the longitudinal arm and the bush, which is less than the yield limit of the carbon structural steel 375 Mpa. The strength of the torsion beam under the extreme torsion conditions meets the requirements.

4. Fatigue life analysis

The fatigue failure of torsion beams mainly occurs under uneven road loads. This paper mainly studies the estimation of fatigue life under uneven road loads.

4.1 Material S-N curve

The curve representing the relationship between stress amplitude or maximum stress and fatigue life is called a fatigue curve or S-N curve. The fatigue curve is generally determined experimentally. Some scholars have drawn a number of commonly used materials out of the S-N curve through a large number of experiments. According to the data[7], the S-N curve of the carbon structural steel survival rate at P=50% is shown in figure6.

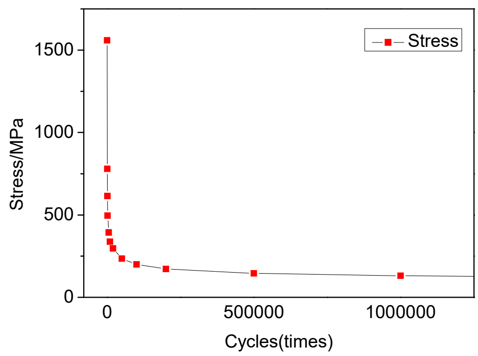


Figure 6. S-N curve of material

4.2 Time series load spectrum

The acquisition of time load is generally obtained through measured data. Due to limited conditions, the dynamic force of each load of the torsion beam is obtained through the Adams vehicle virtual prototype. The analysis shows that the car runs at a speed of 50km/h on the Class C road surface, and the number of times the peak force is obtained within 20s is eight. Therefore, the peak-valley method[8] is used to simplify the load and the obtained time series load spectrum is shown in figure7.

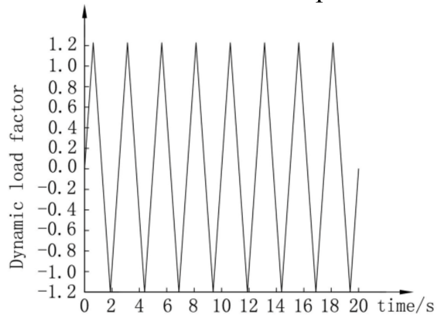


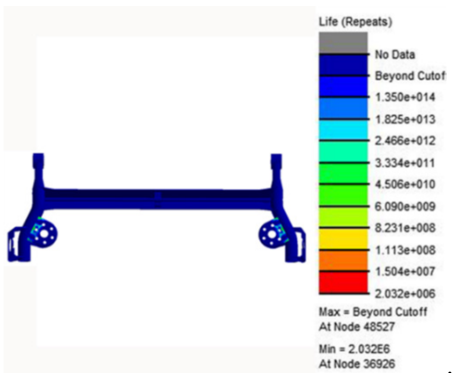
Figure 7. Time series load spectrum

4.3 Fatigue cumulative damage theory

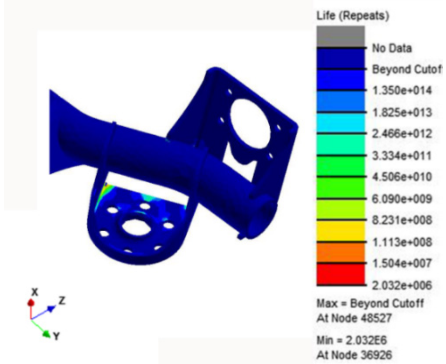
According to the theory of cumulative fatigue damage, the damage can be accumulated linearly. When the accumulated damage reaches the point of failure, the specimen will be destroyed[9]. Considering the actual working conditions of torsion beams, it is known that torsion beam damage belongs to high cycle fatigue. Therefore, the nominal stress method is used to calculate the fatigue life of a torsion beam. The ideal constant amplitude load defined in this paper is much lower than the natural frequency of the torsion beam (6~15Hz)[10]. Therefore, the method of net stress fatigue analysis is used in this paper.

4.4 Fatigue life estimation

According to the analysis of condition 1, it is known that the maximum stress position of the torsion beam is located at the shock absorption seat, which is the dangerous part. The stress load spectrum obtained here, the stress load spectrum and the time load sequence are imported into ncode Design-Life fatigue analysis software, and then the use of Miner cumulative damage theory to integrate the SN curve of the torsion beam material for lifetime estimation. The fatigue life curve obtained from the analysis is shown in figure8.



(a) Overall life cloud



(b)Local life cloud

Figure 8. Torsion beam lifetime cloud

From the fatigue life curve of the torsion beam, the minimum life is (2.032E6) times, and the position is at the transition between the bottom and the edge of the shock absorption seat. The load history used in the analysis is 20s, and the vehicle speed is 50km/h, which can calculate the minimum life span of the torsion beam is about 564,000 kilometers [11]. According to China's auto scrap standard, the mileage of the car is 500,000 kilometers [12]. Therefore, it is known that the fatigue life of the torsion beam satisfies the use requirements. Seen from the cloud image color, the blue part accounts for most of the torsion beam. This part indicates that the service life is far reaching the fatigue life requirement. In order to save unnecessary waste, this part can be optimized. Therefore, this paper provides a method for estimating fatigue life and provides a basis for further optimization of torsion beams.

5. Conclusion

The strength analysis of the torsion beam under the effect of uneven road load and extreme torsional conditions was carried out to find the dangerous part and provide basis for fatigue life estimation. Nominal stress method was used, and the stress load spectrum and time load sequence were imported into nCode Design-Life, and the minimum fatigue life of the torsion beam was 564,000 km, satisfying the application requirements. This paper provides a complete set of methods for fatigue calculations. It also points out the need for optimization and provides the basis for further optimization.

References

[1] L. Xu. *Analysis on the Fracture of Rear Car Brid-Ge Torsion Beam*[D]. Chongqing: Chongqing Uni-versity of Technology,(2005)

[2] F. Weiwei, J. Hongwei. *Torque beam structure optimiztion design simulation analysis after a vehicle model*[J]. Light vehicle technology, **Z2**, 27-29+56(2016)

[3] C. Kun. *Analysis of Strength Optimization of Rear Torsion Beam of Passenger Car*[A]. Henan Automotive Engineering Society etal, **2**(2015)

[4] Y. Siwu, H. Miaohua, Z. Jiwei, etal. *Study on Met- hod of Integrated Fatigue Life of Torsion Beam Suspension*[J]. Automotive Technology, **6**,38-42(2013)

[5] Z. Gongxue, B. Yuan, M. Che. *Analysis of Vehicle Damping Ratio and Vibration Response*[J]. Mechanical design and manufacturing, **1,** 56-59(2017)

[6] X. Haoxuan. *Torsion beam suspension structure a- nd movement characteristics analysis*[D]. Chongqing: Chongqing University(2012)

[7] X. Jinbiao,Y. Weixing. *Double Weighted Least Sq- uares Fitting Fatigue S-N Curve Fitting*[J]. Journal of Astronautics, **31(06)**,1661-1665(2010)

[8] Z. Meishi, Z. Tiezhu,Y. Huaishan, etal. *Analysis of Fatigue Life of Electric Passenger Car Frame Ba- sed on nCode Design-Life*[J]. Journal of Qingdao University(Natural Science Edition), **30(04)**96-100(2015)

[9] Z. Chunhua, Z. Shijian. *Fatigue analysis method and application*[M]. Beijing: National Defense In- dustry Press, 26-30(1991)

IOP Conf. Series: Materials Science and Engineering **423** (2018) 012034 doi:10.1088/1757-899X/423/1/012034

[10] L. Cheng lin, S. Sha sha etal. *Fatigue Reliability Analysis of Frame Based on nCode Design-Life*[J]. Journal of Engineering Graphics, **35(01)**42-45(2014)
[11] Z. Guodong, W. Tie, L. Baoqian, etal. *Analysis of Fatigue Life of Frame of Dump Truck for Engineering*[J]. Mechanical design and manufacturing, **(04)**73-76(2017)
[12] C. Tao, M. Wenhao. *Comparative Study on Sta- ndards and Regulations of Disposal Vehicle Disposal at Home and Abroad*[J]. Traffic Energy Saving and Environmental Protection, **13(03)**9-14(2017)