Fatigue life of Axle beam die

Mr. Rohit A. Gargade [1], Dr. Sanjaykumar S. Gawade [2]
[1]M.Tech–Student, Department of Mechanical Engineering, Rajarambapu Institute of Technology, Sakhrale, India,
[2]Associate Professor, Department of Mechanical Engineering, Rajarambapu Institute of Technology, Sakhrale, India,

Abstract

This paper describes the selection of appropriate material with help of experimental tests of the Axle beam die. Wear & crack are some major problems for failure of die in hot forging processes. In last decades researchers does not focused on material selection of forging dies to improve die life. This paper focuses on the material properties of different materials theoretically and selected best material for the forging dies with experimental comparison. Tensile test was conducted on the selected material and fatigue life of die is calculated with the help of theoretical calculations.

Keywords: Axle beam die, fatigue life, UTM

1. INTRODUCTION

A beam axle is a dependent suspension design, in which a set of wheels is connected laterally by a single beam or shaft. During forging operations impressions are generated on the surface of walls and edges of the die as well as surface of die subjected to wear. Forging impression and wear on axle beam creates geometrical discontinuity and hence stress concentration occurs. Also the wear is caused by local bonding and hot work piece and die. When the die is used continuously under cyclic loading, all these factors will generate and propagate cracks which will ultimately results into fatigue failure.

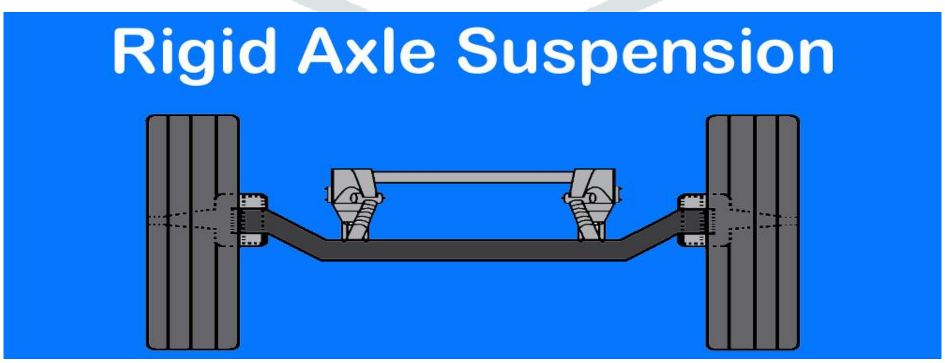

Figure 1. Axle beam connected to two wheels

The principal advantage of the beam axle is its simplicity. This simplicity makes it very space-effective and generally simple to fabricate. They are about all around utilized in transports and rock solid trucks. Most light and medium-obligation pickup trucks, SUVs, and vans additionally utilize an axle beam, in any event in the back. Shaft axles have a significant favourable position for rough terrain applications, as they give better vehicle articulation and durability in a high burden condition. Researchers have analyzed several failure mechanisms regarding wear, crack propagation, tensile strength, etc. In recent years researchers have focused on the finite element method or experimental techniques, but does not validate or compare the results by FEA and experimental techniques. Enhancing die life of axle beam, with the use of case hardening, hence it is necessary to investigate and analysis of Axle beam die for dissertation work.

This research is mainly divided into three parts viz. material selection, experimentation & fatigue life calculations based on author's experimental and analytical results. At last experimental results are used for the fatigue life calculations.

2 Material selection and experimentation

Most common failures are observed in axle beam dies are wear, crack, high-cycle fatigue, low-cycle fatigue, high temperature oxidation, hot corrosion, etc. by considering these things material is selected from available materials. Die steel material is the common in forging dies because of its strength in high temperature and also the cost of this material is less as compared to others. Hyper steel material is the recent trend in most of the forging companies, because hyper steel have more efficient properties than the die steels. Therefore hyper steel is taken for the research. Three types of hyper steels are compared theoretically viz. H10, H11, H13. The chemical composition, physical properties, mechanical properties, thermal properties are taken from the different literatures available. By considering all possible failures at the time of forging, best material is selected that the material will sustain in high temperature. From all above materials H13 steel is found to be best. H13 has the excellent combination of more toughness and resistance to fatigue.

2.1 Properties of H13 steel

Table 2.1 Mechanical properties

Properties	Unit
Ultimate Tensile strength	1200 – 1590 Mpa
Yield Tensile strength	1000 – 1380 Mpa
Modulus of elasticity	215 Gpa
Poisson's ratio	0.27-0.30
Density	7.75 g/cm^3
Melting point	1427°C
Thermal expansion	10.4 x 10^{-6}/ºC
Thermal conductivity	28.6 W/mK

2.2 Tensile test of selected material (H13 steel)

In tensile testing the sample of material to be tested is subjected to tension under controlled manner upto failure. Ultimate tensile strength, breaking strength, maximum elongation, reduction in area etc. these properties can be directly measured via tensile test. As per ISO 6892: 1998, tensile samples with a gauge length of 30mm and a diameter of 6mm were prepared.

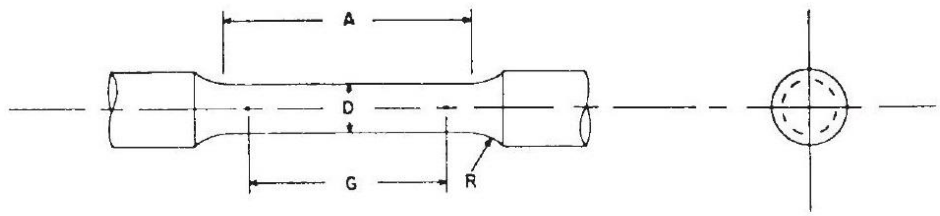

Fig. 6.Tensile test specimen (A- length of narrow section, D-Diameter, G-Gauge length, R-Fillet radius).

Table 2.2 Results of tensile test

Tensile Testing				
Sample	YS (Mpa)	UTS (Mpa)	%EL	%RA
1	1348	1465	7.4	6.9
2	1342	1473	7.6	6.8

Where,

YS- Yield stress

UTS- Ultimate tensile stress

EL- Elongation

RA- Reduction in area

3. Analysis by theoretical method

There are three methods to calculate the fatigue life viz. stress-life method, strain-life method and linear-elastic fracture method. Stress life method is used to calculate the fatigue life.

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = 337.6365 \text{ Mpa} \qquad 3.1$$

$$\sigma_a = \left|\frac{\sigma_{max} - \sigma_{min}}{2}\right| = 265.0735\, Mpa \qquad 3.2$$

Where,

σ_m is Von Mises stress and σ_a is Average principal stress

Then,

$$a = \frac{(f.S_{ut})^2}{S_e} = 4413.66 \qquad 3.3$$

$$b = -\frac{1}{3}\log\left(\frac{f.S_{ut}}{S_e}\right) = -0.3408 \qquad 3.4$$

Where,

a and b are constants,

S_e is endurance limit for infinite life,

f is fraction of S_{ut}

For S_e,

$$S_e = k_a.k_b.k_c.k_d.k_e.k_f.S'_e \qquad 3.5$$

Where,

k_a= surface factor $k_a = a.(S_{ut})^2 = 1.2456$ 3.6

k_b= size factor =

$$\begin{cases} \left(d/7.62\right)^{-0.107} = 1.24d^{-0.107} & 2.79 \le d \le 51mm \\ 1.51d^{-0.157} & 51 < d \le 254mm \\ 1 & For\ axial\ loading \end{cases} \qquad 3.7$$

k_c= loading factor, $k_b = \begin{cases} 1 & for\ bending \\ 0.85 & for\ axial \\ 0.59 & for\ torsion \end{cases}$ 3.8

$= 1$

k_d= temperature factor @ 20^0C k_d is 1

k_e= Reliability factor= 1

k_f= Miscellaneous effects factor= 1

S'_e = Rotary-beam test specimen endurance limit, $S'_e =$

$$\begin{cases} 0.5S_{ut} & S_{ut} \leq 1400\ Mpa \\ 700\ Mpa & S_{ut} > 1400\ Mpa \end{cases} \quad 3.9$$

$= 621.25\ Mpa$

For f,

$$\sigma'_f = S_{ut} + 345\ Mpa = 1587.5\ Mpa \quad 3.10$$

$$f = \frac{\sigma'_f}{S_{ut}} = 1.2776 \quad 3.11$$

Now,

Where S_f is endurance limit for finite life and is given by

$$S_f = \frac{\sigma_a}{1 - \left(\frac{\sigma_m}{S_{ut}}\right)} = 363.974 \quad 3.12$$

By using this S_f value we can find the fatigue life by putting it in above fatigue life equation.

Fatigue life (N) is,

$$N = \left(\frac{S_f}{a}\right)^{1/b} = 1513.38\ cycles \quad 3.13$$

4 Conclusion

After conducting tensile test the conclusion is drawn as fatigue life of axle beam die with H13 steel is coming as 1513 cycles and fatigue life of present material(die steel) is approx 1250 cycles (by observation). Also following conclusions are drawn.

1. After studying the properties of different materials, it is concluded that H13 steel is the better material than other two materials (H10 and H11).
2. After analysis on software it is found that the results are nearly same as experimentation. By calculation with theoretical method we can get to know the fatigue life of the axle beam die is increased by 21%.

References

1. Marek Hawryluk and Joanna Jakubik, 2015, “Analysis of forging defects for selected industrial die forging processes”, Engineering Failure Analysis 59 (2016) 396–409.
2. Siamak Abachi, Metin Akkok and Mustafa ilhan Gokler, 2009,” Wear analysis of hot forging dies”, Tribology International 43 (2010) 467–473.
3. D.H. Kima, H.C. Leeand B.M. Kim, K.H. Kim,2004, “Estimation of die service life against plastic deformation and wear during hot forging processes”, Journal of Materials Processing Technology 166 (2005) 372–380.
4. Ryuichiro Ebara and Katsuaki Kubota, 2007, “Failure analysis of hot forging dies for automotive components”, Engineering Failure Analysis 15 (2008) 881–893.
5. Ryuichiro Ebara, 2009, “Fatigue crack initiation and propagation behavior of forging die steels”, International Journal of Fatigue 32 (2010) 830–840.
6. Hideki Kakimoto and TakefumiArikawa, 2014, “Prediction of surface crack in hot forging by numerical simulation”, Procedia Engineering 81 (2014) 474 – 479.
7. Marek Hawryluk, 2016, “Review of selected methods of increasing the life of forging tools in hot die forging processes”, archives of civil and mechanical engineering 16 (2016) 845-866.
8. S. Lampman, “Introduction to Surface Hardening of Steels”, Heat Treating, Vol 4, ASM Handbook, ASM International, 1991, p 259–267
9. http://blog.metlabheattreat.com/posts/nitriding-and-carburizing.
10. P. C. King, R. W. Reynoldson,2015, “Pin on disc wear investigation of nitrocarburised H13 tool steel” Surface Engineering, 2005 VOL 21 NO 299.