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Experimental Investigation of U Bolt used in Leaf Spring of an Automobile for Various Loads

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ABSTRACT

Threaded fastener such as U bolts are probably the best choice to apply a desired clamp load to assemble a joint or connection. The main characteristic of holding U-bolt of automobile wheel is being under cyclic load which are applied by bumpy rods. So it is necessary to prevent the failure of U bolt under different condition. To do experimental testing for every new design of bolted connection.

KEYWORDS: *Stress Analysis, loading condition*

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1. INTRODUCTION

To improve mechanical properties of fastening parts material and processes showed constant development. This tendency has also been observed in the production of suspension systems of automotives vehicles, which are constituted of leaf springs kept together using U-bolts. In the same way, this method has also been observed in suspension systems of an automobile production, which are set of sheets that are kept together by using bolts, this set forms which is called spring steels. To maintaining the spring steel attached to axis of vehicle forming a solid group of three components such as axle, spring steel and supporting plate by using bolts. It forms a complex union with the bolt some components are combined in the suspension of the vehicles. Each one of these components has its effect on the performance of union of this system with the bolt. The bolts and other components act with the forces of action and reaction and always in the opposite direction than that of the springs of the suspension; and the bolts themselves support all the tension forces.

1.1. Problem Definition

It is found that most of mechanical failure caused by dynamic loading. Fatigue is one of the most dangerous mechanical failure because it occur under load that are lower than static strength of material. The U bolt of automobile are failed due to jerk because U-bolt are under compressive loading and when it is subjected to jerk it fails.

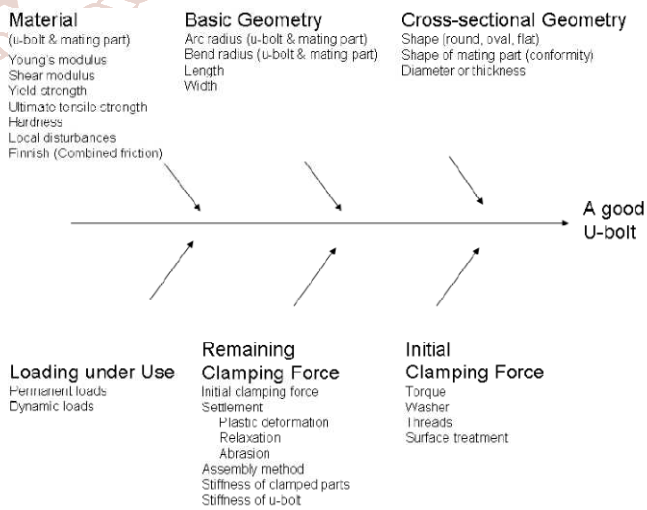

Figure 1.1 describing the cause and effect relationship of the u-bolt

The function of any joint is to join two or more parts. In order to keep everything together in pre-tensioned joints, as a u-bolt, the pre-tension and strength of the joint has to counteract the service loads. Even if a joint ultimately can collapse it is not satisfactory to view a joint as either functioning or malfunctioning. A measurement of how a pre-tensioned joint performs is the clamping force. A target value for the initial required clamping force can be set for a joint, which is dependent on the service loads experienced by this joint. The clamping force has to be larger than the external forces acting on the joint and also withstand dynamic effects. If the clamping force is exceeded, a gap appears. This gap can either be closed again or remain open, either way the clamped material can have been disturbed and the function of the joint is lost.

1.2. Influencing Factors

Basic geometry

The basic geometry category entails all geometry considerations apart from the cross sectional data. The dimensions are indicated in Figure.

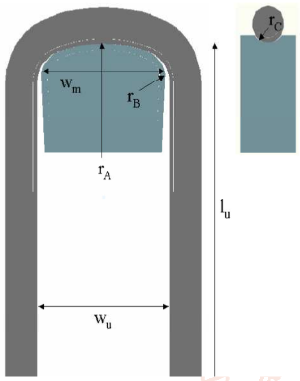

Fig1.2 Identification of the dimensions included in the basic geometry

The arc radius, r_A, of the u-bolt and the mating part is their most outstanding feature. This radius is what has given the u-bolt its name. For the u-bolt, the bend radius, r_B, describes the transition from the arc radius to the legs. The bend radius does not have to be described clear cut by one single radius, for example: the u-bolt can move directly from the arc radius into the legs (full arc radius) and cast mating parts can have a gradual transition described with more than a single radius.

The arc- and bend radius are of interest for both the u-bolt and the mating part together. Actually one does not say much without the other. Two other variables that interact are the widths: the internal distance between the legs of the u-bolt, w_u, and the width of the mating part, w_m. The remaining parameter included in basic geometry only describes the u-bolt itself, namely the length of the u-bolt, l_u.

Material

The material category simply lists all material properties. Apart from having two parts with different geometry coming into contact when the u-bolt is mounted, two different materials meet. The modules describe the stress-strain relationships. The yield strength and the ultimate tensile strength are important data points for the development of plastic strains. Local disturbances can arise during production in the bending phase of the u-bolt. Hardness and local disturbances affects the materials adaptability. The role of the surface finish of the u-bolt is reduced with the application of surface treatment. The U-bolts are made of boron steel and Stainless steel.

Material Specification:-

Material Properties	Stainless Steel		Boron Steel	
	Min	Max	Min	Max
Density(mg/m^3)	7.87	8.07	2.3	2.55
Young Modulus(Gpa)	190	205	210	220
Poisson Ratio	0.265	0.275	0.18	0.21

The nonlinear curve for this steel is based on tensile tests performed by Pol-Necks. These tests have given the yielding point and the standard stainless steel curve has then been adapted with the data from Pol-Neckstensile tests. The curve is shown in Figure 1.3 below.

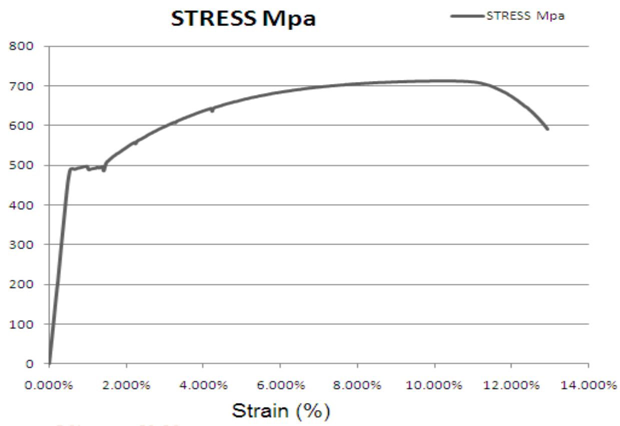

Fig 1.3 The stress-strain curve for the Stainless steel

2. MATHEMATICAL MODELING

2.1. Stress Analysis

The concepts of stress analysis will be stated in a finite element context. That means that the primary unknown will be the (generalized) displacements. All other items of interest will mainly depend on the gradient of the displacements and therefore will be less accurate than the displacements. Stress analysis covers several common special cases to be mentioned later. Here only two formulations will be considered initially. They are the solid continuum form and the shell form. Both are offered in SW Simulation. They differ in that the continuum form utilizes only displacement vectors, while the shell form utilizes displacement vectors and infinitesimal rotation vectors at the element nodes. As illustrated in Figure 2.1,

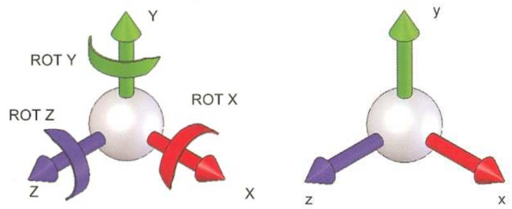

Fig 2.1 Nodal degrees of freedom for frames and shells; solids and trusses

Stress transfer takes place within, and on, the boundaries of a solid body. The displacement vector, *u*, at any point in the continuum body has the units of meters [m], and its components are the primary unknowns. The components of displacement are usually called *u, v,* and *w* in the x, y, and z-directions, respectively. Therefore, they imply the existence of each other, u↔ *(u, v, w).* All the displacement components vary over space. As in the heat transfer case (covered later), the gradients of those components are needed but only as an intermediate quantity. The displacement gradients have the units of [m/m], or are considered dimensionless. Unlike the heat transfer case where the gradient is used directly, in stress analysis the multiple components of the displacement gradients are combined into alternate forms called strains. The strains have geometrical interpretations that are summarized in Figure 2.2 for 1D and 2D geometry. In 1D, the normal strain is just the ratio of the change in length over the original length, εx = ∂u / ∂x. In 2D and 3D, both normal strains and shear strains exist. The normal strains involve only the part of the gradient terms parallel to the displacement component. In 2D they are εx = ∂u / ∂x and εy = ∂v / ∂y. As seen in Figure 2.2 (b), they would cause a change in volume, but not a change in shape of the rectangular differential element. A shear strain causes a change in shape. The total angle change (from 90 degrees) is used as the engineering definition of the shear strain. The shear strains involve a combination of the components of the gradient that are perpendicular to the displacement component. In 2D, the engineering shear strain is γ = (∂u / ∂y + ∂v / ∂x), as seen in Figure 2.2(c). Strain has one component in 1D, three components in 2D, and six components in 3D. The 2D strains are commonly written as a column vector in finite element analysis **ε** = (εxεy γ)T.

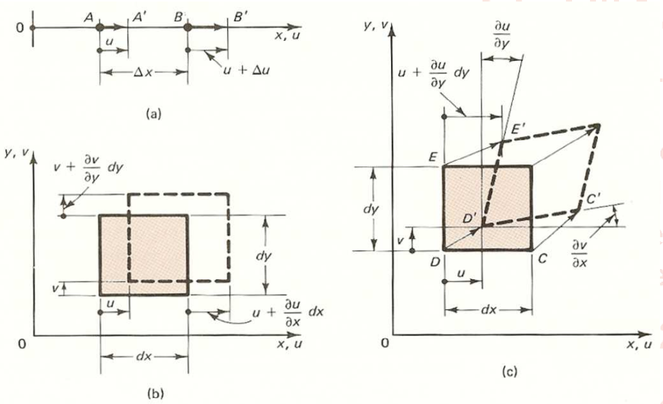

Fig 2.2 Geometry of normal strain (a) 1D, (b) 2D, and (c) 2D shear strain

Stress is a measure of the force per unit area acting on a plane passing through the point of interest in a body. The above geometrical data (the strains) will be multiplied by material properties to define a new physical quantity, the stress, which is directly proportional to the strains. This is known as Hooke's Law: σ = E ε,(see Figure 2.3) where the square material matrix, E, contains the elastic modulus, and Poisson's ratio of the material. The 2D stresses are written as a corresponding column vector, σ = (σxσyτ)T. Unless stated otherwise, the applications illustrated here are assume to be in the linear range of a material property. The 2D and 3D stress components are shown in Figure 2.3. The normal and shear stresses represent the normal force per unit area and the tangential forces per unit area, respectively. They have the units of [N/m^2], or [Pa], but are usually given in [MPa]. The generalizations of the engineering strain definitions are seen in Figure 2.3. The strain energy (or potential energy) stored in the differential material element is half the scalar product of the stresses and the strains. Error estimates from stress studies are based on primarily on the strain energy

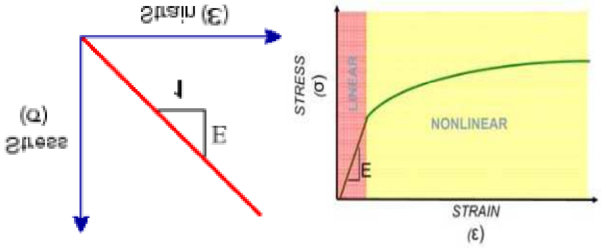

Fig 2.3 Hooke's Law for linear stress-strain, σ = E ε

The structure with bolted joints to be analyzed is discretized with a number of elements and then assembled at nodes. The elements of different type and shape with complex loads and boundary conditions can be used simultaneously using FEM.

The governing equations for the plane elasticity problems are given by

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \sigma_{xy}}{\partial y} + f_x = \rho \frac{\partial^2 u}{\partial t^2}$$
$$\frac{\partial \sigma_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} + f_y = \rho \frac{\partial^2 v}{\partial t^2}$$

Where f_x and f_y denote the body forces per unit volume along the x and y directions, respectively and ρ isthe density of the material. σ_x , $\sigma_y$are the normal stresses and u, v are the displacements in x and ydirections respectively, σ_{xy} is the shear stress on the xz and yz planes. Strain-displacement relations aregiven by

$$\varepsilon_x = \frac{\partial u}{\partial x} \quad , \quad \varepsilon_y = \frac{\partial v}{\partial y} \quad , 2\varepsilon_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

For plane stress problems, stress and strain are related by the constitutive matrix **D**, in the followingmanner:

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{Bmatrix} = \begin{bmatrix} d_{11} & d_{12} & 0 \\ d_{21} & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ 2\varepsilon_{xy} \end{Bmatrix}$$

whered_{ij} ($d_{ij} = d_{ji}$) are the elasticity (material) constants for an orthotropic material with the material principal directions coinciding with the co-ordinate axes (x,y) used to describe the problem. For anisotropic material in plane stress d_{ij} are given by

$$d_{11} = d_{22} = \frac{E}{1-v^2}, d_{12} = d_{21} = \frac{Ev}{1-v^2}, d_{33} = \frac{E}{2(1+v)},$$

where E is Young's modulus of the material and v is Poisson's ratio. For plane strain problems:

$$d_{11} = d_{22} = \frac{E(1-v)}{(1+v)(1-2v)} \quad , \quad d_{12} = d_{21} = \frac{Ev}{(1+v)(1-2v)} \quad ,$$
$$d_{33} = \frac{E}{2(1+v)},$$

For the given problem, essential or geometric boundary conditions are

$u = \bar{u}, v = \bar{v}$ on Γ_u

and natural boundary conditions are

$$t_x = \sigma_x n_x + \sigma_{xy} n_y = \bar{t}_x \text{on} \Gamma_t$$
$$t_y = \sigma_{xy} n_x + \sigma_y n_y = \bar{t}_y \text{on} \Gamma_t$$

where n_x , n_y are the components of the unit normal vector **n** on the boundaryΓ . $\Gamma_u$and $\Gamma_t$are portions ofthe boundary Γ ($\Gamma = \Gamma_u \cup \Gamma_t$). $\bar{t}_x$, $\bar{t}_y$are specified boundary stresses or tractions, and$\bar{u}$, $\bar{v}$arespecified displacements. Only one element of each pair, (u, t_x) and (v, t_y) may be specified at a boundary point.

3. EXPRIMENT

3.1. Experimental Setup

The UTM (Instron 1342) is a servo hydraulic fluid controlled machine, consists of a two column dynamically rated load frame with the capacity of load up to 200kN (dynamic), hydraulic power pack (flow rate 45 litre/minute) and 8800 Fast Track 8800 Controller test control systems is stand alone, fully digital, single axis controller with an inbuilt operating panel and display. The controller is fully portable and specifically designed for materials testing requirement. This controller has position, load and strain control capability. The software available with the machine are:

A. Merlin Testing Software for Tensile Test
B. da/dN Fatigue Crack Propagation Test.
C. Kic Fracture Toughness Test.
D. Jic Fracture Toughness Test.

The deformation of the structure is recorded by the ESPI system. Using digital analysis and correlation methods, the specimen displacements and deformations are calculated automatically from the changes in the pattern on the specimen surface. The visual information obtained by Q-100 is ideal for the comprehension of the behavior of the specimen. The numerical values of displacements and deformations can be employed for a comparison of the real behavior of the specimen with the calculations obtained by finite elements. The tests were realized with a universal testing machine (Figure No. No.4.1) equipped with a 200 KN load sensor. Several parameters can be acquired a same time (time, applied load); data acquisition needs to use an extensometer and data processing equipment.

Fig.3.1. Universal Testing Machine (UTM)

3.2. Result of Experimental work For Stainless Steel Round U-bolt

Sr. No.	Case	Load Applied (N)	Max. Stress (N/mm^2)	Total Deformation (mm)
1	Point Load	500	110.06	0.04584
2		1000	212.015	0.09169
3		1500	330.18	0.13752
4		2000	435.24	0.18336
5	Edge Load	500	14.81	0.012196
6		1000	29.62	0.02439
7		1500	44.43	0.03635
8		2000	59.24	0.048784

Table 3.1 Reading of Round U-bolt of stainless steel on UTM

3.3. Result of Experimental work For Boron Steel Round U-bolt

Sr. No.	Case	Load Applied (N)	Max. Stress (N/Mm^2)	Total Deformation (Mm)
1	Point Load	500	104.177	0.04420
2		1000	208.35	0.08840
3		1500	312.53	0.1326
4		2000	416.71	0.1768
5	Edge Load	500	14.17	0.011762
6		1000	28.34	0.02352
7		1500	42.51	0.035286
8		2000	56.68	0.04705

Table 3.2 Reading of Round U-bolt of stainless steel on UTM

4. RESULT AND DISCUSSION

4.1. Result of UTM for Stainless Steel U-bolt

Sr. No.	Case	Load Applied (N)	Max. Stress (N/mm^2)	Total Dseformation (mm)
1	Point Load	500	109.06	0.04584
2		1000	211.15	0.09169
3		1500	328.18	0.13752
4		2000	436.42	0.18336
5	Edge Load	500	14.81	0.012196
6		1000	29.62	0.02439
7		1500	44.43	0.03635
8		2000	59.24	0.048784

Table 4.1 Result table of UTM for Stainless Steel U-bolt

4.2. Result of UTM for Boron Steel U-bolt

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6		1000	28.34	0.02352
7		1500	42.51	0.035286
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Table 4.2 Result table of UTM for Boron Steel U-bolt

5. CONCLUSION

The conclusion mainly finding more suitable material, geometrical shape of U bolt used in leaf spring with the help of experimental work.

For shape finding; a larger contact area and distributed pressure of contact does not necessarily lower strains and sharp bent radius gives more concentrated contact pressure towards the edges, as result higher strains in bent and top therefore it is concluded that semi round U bolt is preferable against round and square shape U bolt. Also boron steel is more economical than stainless steel material for u bolt.

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