Failure Study of Trunnion-Hub Assemblies for Bascule Bridges

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Background

Leafs of bascule bridges are constructed by fitting a trunnion and hub into the main girder (Figure 1). There are two distinct ways the trunnion-hub-girder (THG) assembly can be fabricated:

- The trunnion is first shrink-fit into the hub and then the trunnion-hub assembly is shrink-fit into the main girder.
- The hub is first shrink-fit into the main girder and then the trunnion is shrink-fit into the hub-girder assembly.

Each of these methods has been used throughout the United States on the construction of Bascule Bridges. Using the first method mentioned above, cracking failure of the hubs of trunnion assemblies occurred during the assembly of three bridges in the state of Florida. The economic losses due to these trunnion-hub failures were of the order of hundreds of thousands of dollars. Florida Department of Transportation (FDOT) is interested in finding the reason of these failures and then use the information thus obtained to develop specifications for the THG assembly.

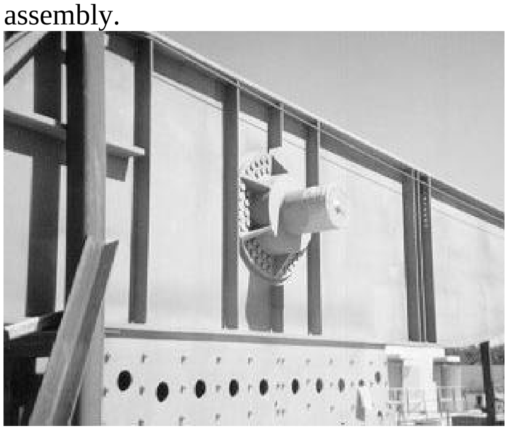

Figure 1. Trunnion-Hub-Girder Assembly of a Bascule Bridge

Objectives & Research

In the THG assembly that is found to crack in Florida bridges, the trunnion is first shrink-fit into a hub, and then the trunnion-hub assembly is shrink-fit into the girder. Due to the shrink-fits, radial compressive stresses are developed at the trunnion-hub and hub-girder interfaces. Such radial compressive stresses at the interfaces determine part (other part is due to the bolt assembly between the hub and girder) of the torque taking capability during the opening and closing of a bascule bridge.

In this work, we develop the formulas for calculating the radial compressive stresses at the trunnion-hub and hub-girder interfaces based on the interference [1] at these two interfaces. The amount of the interference for the THG assembly is based on two types of standard interference fits – FN2[1] or FN3[2]. More importantly, maximum hoop and Von-Mises stresses are calculated in each of the three components – trunnion, hub and girder. These determine whether the stresses created by interference fits are within tolerable limits.

Note a larger interference at the interfaces creates a larger compressive radial stress at the interface for desirable larger torque taking capabilities. At the same time, larger interference creates larger hoop and Von-Mises stresses in the components that may be more than the safe limits of stress - determined by the yield strength of the material of the components and the factor of safety. Hence the amount of interference at the trunnion-hub and hub-girder interfaces needs to be optimized.

If a cylinder 'B' is fit into cylinder 'A', then the limit, 'L', in thousands of an inch for outer diameter of cylinder 'A' and inner diameter of cylinder 'B' is given by $L = CD^{1/3}$, where D is the diameter given in inches and C is given in the following Table 1 [1].

Table 1: Coefficient of C to calculate limits

CLASS OF FIT	CYLINDER 'A'		CYLINDER'B'	
	Lower	Upper	Lower	Upper
FN2	0	+0.907	2.717	+3.288
FN3	0	+0.907	3.739	+4.310

For each interface, there will be four possible extreme limits of radius. For example, at the trunnion-hub interface, there will be a lower and upper limit of the outer diameter of the trunnion and

[1] FN2 designation [1]: "Medium-drive fits are suitable for ordinary steel parts or for shrink-fits on light sections. They are about the tightest fits that can be used with high-grade cast-iron external members."

[2] FN3 designation [1]: "Heavy drive fits are suitable for heavier steel parts or for shrink-fits in medium sections".

there will be an upper and lower limit of the inner diameter of the hub. Also, there are two interfaces. Hence there are sixteen extreme combinations of the interference for each combination of fits.

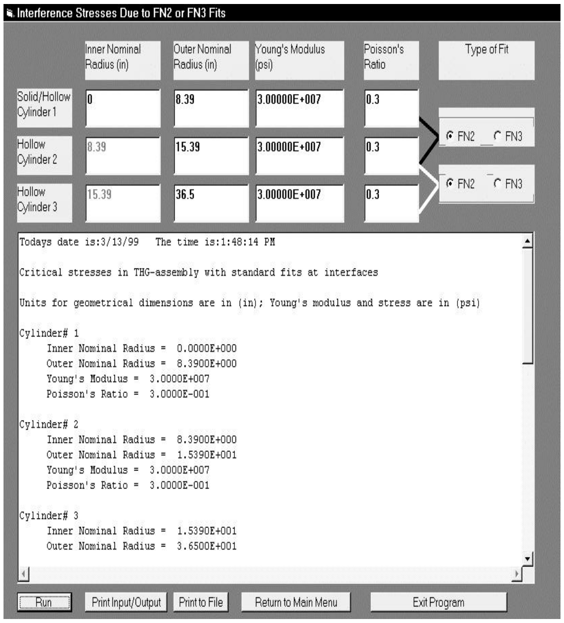

Figure 2. Graphical User Interface (GUI) for finding steady-state stresses in THG assembly

Considering the above sixteen combinations of interferences, approximate steady state stresses in the trunnion-hub-girder assembly are calculated by approximating the assembly as three axisymmetric circular cylinders. Typical Lame's equations [2] are used with plane stress conditions. A graphical user interface (GUI) program written in Visual Basic™ has been developed for easy interpretation of the results (Figure 2).

The following stresses are calculated for each of these sixteen combinations.

- Minimum and maximum hoop stresses in each cylinder.
- Maximum Von-Mises stress in each cylinder.
- Maximum and minimum radial stress at the two cylinder interfaces.

Following the steady-state analysis, a two-dimensional thermal analysis of shrink-fit assembly of selected trunnion-hub-girder configurations using the finite element code, ANSYS™, was done. Hoop and Von-Mises stresses are calculated for the two assembly procedures, that is,

1) The trunnion is first cooled by placing it over a bath of liquid nitrogen, and then it is shrink-fit into the hub. Then the whole trunnion-hub assembly is shrink-fit into the main girder.

2) In the second case, the hub is cooled over a bath of liquid nitrogen, and then it is shrink-fit into the main girder. Then the trunnion is cooled over a bath of liquid nitrogen and then shrink-fit into the hub-girder assembly.

Transient hoop and Von-Mises stresses in both of these procedures are calculated to show which procedure develops less stress.

Note that in the transient analysis, material properties such as elastic modulus, specific heat, thermal conductivity and coefficient of thermal expansion are nonlinear functions of temperature. This is the reason that even if the trunnion, hub and assembly are of the same grade of steel, their properties will be different to make it essentially a *composite cylinder problem*.

Preliminary results have been obtained for the transient analysis at the time of submitting this abstract. Complete results will be available for presentation at the ICCE/6 conference.

References

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