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STIFFNESS OF PRESTRESSED BOLT PLATE CONTACT

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ABSTRACT

In mechanical as well as in civil engineering structures plate members are often assembled by prestressed bolts. When the external load on the bolt is static, the design of the bolt is straightforward and controlled by the maximum stress in the bolt. With dynamic load, the stress amplitude in the bolt is an important quantity that controls the design of the bolt. The amplitude in the bolt load, ΔP_b, is directly related to the amplitude of the external load, ΔP_{ex}, through a ratio that is defined by the member (plate) stiffness k_m and the bolt stiffness k_b. In the case of a centrally loaded bolt this simplifies to

$$\Delta P_b = \frac{k_b}{k_b + k_m} \Delta P_{ex} = \frac{1}{1 + k_m/k_b} \Delta P_{ex} = \Phi \cdot \Delta P_{ex} \tag{1}$$

The ratio Φ only holds for an external load that acts on the symmetry line directly under the head of the bolt. Other expressions can be found in [1] for other loading conditions, but the ratio is still controlled by the stiffnesses of the bolt and the member.

From (1) it is directly observed that a high ratio k_m/k_b will decrease the bolt stress amplitude, and thus, increase the fatigue life of the assembly. The task of design is, therefore, to increase the stiffness of the member relative to the stiffness of the bolt. This is done through a study on the influence of geometry and material parameters on this ratio, through the determination of k_m and k_b. The parameters of the model, as seen in Figure 1, are nominal bolt diameter d, thickness of the plate members L, non dimensional clearance parameter α, non dimensional bolt head/washer parameter β, non dimensional bolt head and washer thickness parameters γ and ζ, diameter of the plate members d_a, diameter of the contact between plate members d_c. The pressure distribution at the bolt/plate contact surface $p = p(r)$ is determined as part of the solution.

The important issue in determining the ratio k_m/k_b is, therefore, to determine the stiffness of the bolt and the stiffness of the member. The determination of the bolt stiffness is rather straightforward since the bolt is in an approximate uniform stress field. Thus, the simplified formulas found in the literature can be used directly. In the present work a small improvement of this formula is included. The determination of the stiffness of the member, i.e., the assembled plates, is more involved and has a long history that

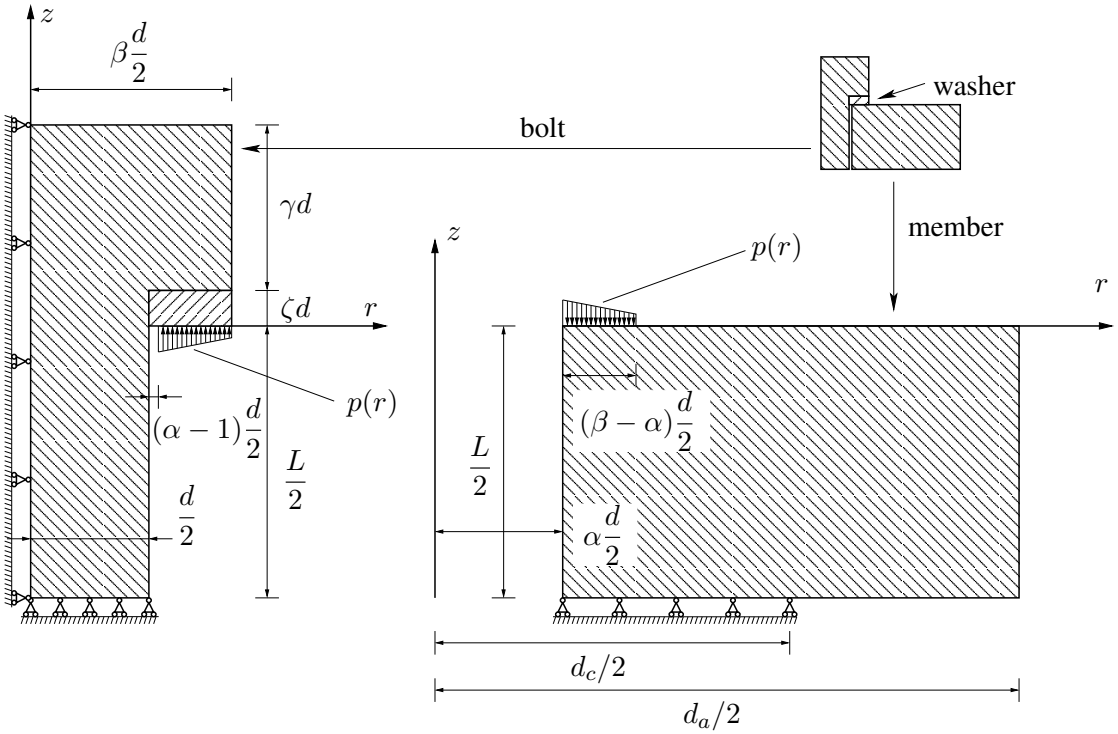

Figure 1: Left: the symmetric part of a bolt including an integrated washer, and Right: the member plate for the symmetric problem.

dates back to [2], see also [3]. The assumption behind most formulas of the stiffness is that the diameter, d_a, of the member is infinite or so large that there is no elastic energy in the outer part of the member.

With finite element (FE) analysis it is possible to find the stress field in a bolt-plate assembly and thereby the elastic energy used to evaluate the stiffness. The FE analysis should include contact analysis both between the bolt/washer head and the member and between the two assembled member plates. In determining the stiffness from a FE calculation the elastic energy together with the applied load expresses directly the stiffness without relating the load to some deflection in the assembly. The question of increasing the stiffness is a matter of designing a gap for a better stress field for the member. The involved contact problems are solved directly without iteration and incrementation, using super elements in an in-house FE program. Practical result of the member stiffness is found and the influence from Poisson's ratio ν on the results is presented. Two simple practical formulas are suggested for the stiffness of bolt and member plates and their accuracies are documented for different bolts and different materials (Poisson's ratio). It is also shown how a simple gap design can have a positive influence on the ration k_m/k_b.

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