EFFECT OF SIZE OF BOLT ON THE RELATIVE CRITICAL SLIPPAGE OF BOLT-NUT JOINT UNDER TRANSVERSE LOADING

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This Report Is Submitted In Partial Fulfillment of Requirements For the Bachelor of Mechanical Engineering (Structure & Materials) with Honor

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MEI 2011

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Stricture Materials)"

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

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Special for

My lovely Mom and Dad

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ACKNOWLEGEMENT

Assalammualaikum and Salam Satu Malaysia

Thanks to Allah, for giving me permission to complete this project. In here I would like to record my graceful thank to all the support, encouragement and inspirations that I have received during completing this project.

I would like to express greatest thankful and appreciation to my supervisor, Mr. Hairul Bin Bakri of which we had a good working relationship, and who had offered me a wonderful help and encouragement. He also gives me full of support and advice.

I also would like to express my gratitude to technician for Faculty of Mechanical Engineering for giving me his cooperation and help in order to complete this project. Last but not least to my family and all my fellow friends, for their concern, encouragement and understanding.

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ABSTRACT

The thread joint has been frequently used for the efficient productivity and maintainability as a machine element. However, many troubles such as loosening of bolted joints or fatigue failure of bolt were often experienced. Many attentions must be paid on the improvement of the strength and the reliability of the thread joints. It is generally said that the fastening axial force rapidly decreases by the rotation loosening of nuts if the relative slippage on the interfaces between nuts and fastened body goes beyond a certain critical limit. This critical relative slippage (Scr) that prescribes the upper limit for preventing the loosening behavior has been estimated according to the theoretically obtained equation considering the bending deformation of bolt and the geometrical constraint condition. In this paper, firstly is to provide the database for Finite Element Analysis (FEA). Then, the experimental method is to determine the Scr. After that, the behavior effect of the size bolt was determined and analyzes the result. From the result, it can be confirmed with good agreement with calculation coincided well with the experimental result.

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ABSTRAK

Sendi bebenang telah sering digunakan untuk produktiviti cekap dan kestabilan sebagai unsur mesin. Namun, banyak masalah seperti melonggarnya sendi baut atau kegagalan kelelahan baut sering dialami. Banyak perhatian perlu dibayar pada peningkatan kekuatan dan kebolehpercayaan dari sendi benang. Hal ini umumnya mengatakan bahawa gaya paksi pengikatan cepat berkurang oleh melonggarkan putaran kacang jika selip relatif pada antara muka antara kacang dan tubuh diikat melampaui batas kritis tertentu. Selip ini relatif kritis (Scr) yang mengatur batas atas untuk mencegah perilaku melonggarkan telah dijangka berdasarkan persamaan teori diperolehi mengingati deformasi lentur dari baut dan keadaan sekatan geometri. Dalam makalah ini, pertama adalah untuk menyediakan database untuk Analisis Elemen Hingga (FEA). Kemudian, kaedah eksperimental untuk menentukan Scr. Setelah itu, kesan perilaku dari baut saiz ditentukan dan analisis hasilnya. Dari hasil tersebut, dapat disahkan dengan perjanjian baik dengan perhitungan bertepatan dengan baik dengan keputusan eksperimen.

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LIST OF SYMBOLS

NOTATION	**DESCRIPTION**
S_{cr}	Critical Relative Slippage
E	Young Modulus of bolt
I_g	Second Moment of Area of Bolt's Cylindrical Portion
I_p	Second Moment of Area of Thread Portion
μ_b	Coefficient Friction of Bolt Bearing Surface
k_w	Bolt Head's Inclination Compliance
W	Load

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CHAPTER I

INTRODUCTION

1.1 Background

Bolt-nut joint, one of the joint structures is widely used as it's easiness to install and remove, produces big fastening power with small force and low price in production. Disadvantage of bolt-nut, when vibration and thermal load applied to the thread joint, bolt will lose and fastening became unsustainable. In FE method, substitute for a simplified and accurate numerical model to predict load share on every joint. So, this method can investigated the results of the sliding and loosening behaviour and bending moment at the bolt neck which are the critical relative slippage S_{cr} and bending moment of bolt.

There have 2 type of load acting which is tensile load and transverse load. Tensile load is line of forces is parallel to axes of the bolt. Transverse load is line of action forces is perpendicular to the axes of the bolt. From other research, transverse load loosen to the bolt-nut joint more than tensile load.

The problem occurs is bolt-nut is model as unit and thread of bolt and nut do not exist at the corresponding portion. This problem can simplify presume that relative between fastened plates. In order to predict the sliding behaviour and relative critical slippage, consideration of clearance between bolt and nut thread surface must be made. The bending moment stress needs to be considered due to fatigue failure. The

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new model must be considered both critical relative slippage and bending moment generated at the bolt neck.

The loosening behaviour of bolt-nut joint shows the same occurrence if the transverse load applied in the opposite direction. The axial tension will decrease when transverse cyclic load applied to the joint. At the worst stage, fatigue failure also will occur.

In this project, firstly we present the equation for estimating the Scr based on the fundamental cantilever deformation model. Then we present the investigated results of the deformation behaviour of bolt-nut joint under transverse loading condition considering the reaction moment by nut. Finally, we can confirm that these estimated results of critical relative slippage coincided well with the experimental results.

1.2 Problem Statement

When vibration and thermal load applied to the thread joint, bolt loosening occurs which lead to failure of the joint. There were analysis had been done by using a CAE software which is low cost and can shorten analysis time. However many of the joints were analyze with the CAE simulation recently but the method was insufficient. This is because the mechanical property for database for bolted joint is not sufficient. Furthermore the reliability of the CAE analysis database cannot be used in order to study the effect. The database for the CAE can be provide by using experimental method in order to study the effect of length of bolt nut joint under critical slippage.

1.3 Objective

Objective of this study is to find the effect of size of bolt on the relative critical slippage, ΔScr of bolt-nut joint/fastener experimentally. Second, Provide database for CAE analysis to make a comparison at the end of the study.

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1.4 Scopes

Scopes of this study are:

1. Literature review on deformation behavior of bolt-nut joint under transverse loading.
2. Design and conduct experiment to obtain ΔScr for various size of bolt.
3. Investigate and conclude the effect of size of bolt on ΔScr when transverse load applied to the joint.

1.5 Project Outline

Chapter 2 is the literature review for this project. This chapter will describe the theory of bolt-nut loosening behavior and others. All materials that used in this project will completely explain to give more understanding about this project.

Chapter 3 would describe the method and procedures that used for this project experiment. This chapter includes the study of preparation for the specimen, calibration the apparatus and lastly is study about the experimental method.

Chapter 4 is includes the analysis and result. This chapter will introduce the result and study to find the effect of size of bolt on the relative critical slippage, ΔScr. The graph will shown the result about the ΔScr.

Chapter 5 is the result and discussion. This chapter will discuss about the result from the chapter 4 and provide this experimental data for data base for CAE analysis. And then, compare the result between experimental and CAE analysis.

Chapter 6 is the conclusion and recommendation of this project. This chapter will concludes all results discussion, decision and also recommendation for the future work to further this study.

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CHAPTER II

LICTERATURE REVIEW

2.1 Introduction

In this chapter will describe the theory of bolt-nut joint and others. All materials that used in this project will completely explain to give more understanding about this project.

2.2 Theory of Bolt-Nut Joint

The bolt-nut joint is a very popular method of fastening components together. The prime reason for selecting bolts as opposed to welding, or rivets are that the connection can be easily released allowing disassembly, maintenance and/or inspection. The bolts are generally used in groups to fasten plates together. A bolt is a screwed fastener with a head, designed to be used with a nut. A screw is a fastener designed to be used with a formed female thread in one of the components being attached. These notes generally relate to bolts and nuts and hex headed screws

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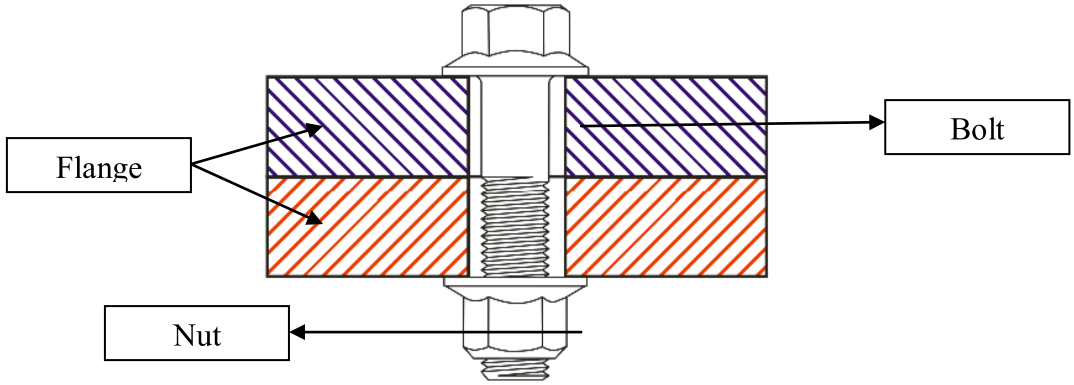

Figure 2.1 Bolt-Nut Joint

(source: http://www.boltscience.com/pages/nutorbolttightening.htm)

2.3 Bolts under Flange Separation

By Jerome Montgomery(2010), when a load tries to separate a bolted flange joint, the job of the bolt is to hold the flanges together. The pretension should be more than the applied load. When the applied load exceeds the pretension, the part will separate. From a simulation standpoint, the surfaces that are in contact must be able to separate. This is where the contact elements are used. For bolt under flange separation, the contact elements are not required for the contact surface between flange and head/nut of the bolt. These surfaces can be glued together. That is, the head contact can share the same surface as the top flange, and the nut contact can share the same surface as the bottom flange. The contact elements are required at the horizontal joint between the top and the bottom flange.

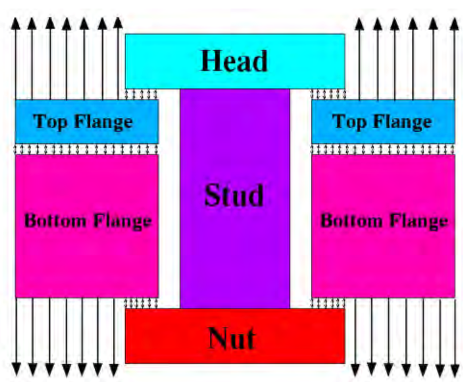

Figure 2.2 Flange Separation

(source: Jerome Montgomery(2010))

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2.4 Bolts under Flange Compression

By Jerome Montgomery(2010), when a flange is under compression, there is no load on the bolt. In this case, the head and nut contact must be able to separate from the flanges, whereas, the horizontal joint contact can share the same surface. The surfaces where the top flange and bottom flange meet (horizontal joint contact surface) can be glued together. Due to non-linear effects of contact elements, the above approach will help in saving considerable computation time during the solution phase.

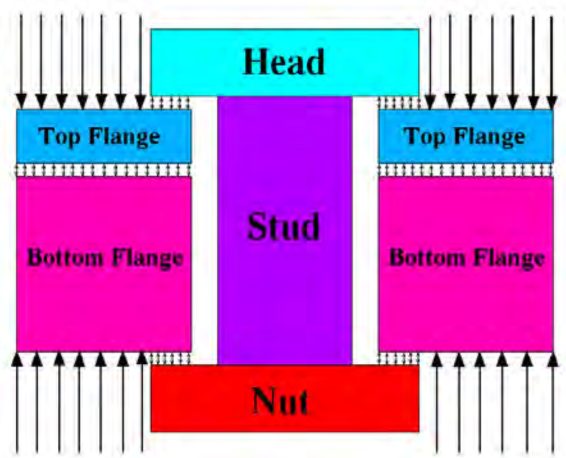

Figure 2.3 Flange Compression
(source: Jerome Montgomery (2010))

2.5 Transverse Direction

By Jerome Montgomery(2010), to incorporate the transverse effects of the bolt when two mating surfaces slide, a node at the bolt near the horizontal joint, and a node at the two mating surfaces are coupled to each other. Friction resists loads in the transverse direction. If we assume that the direction from the head to the nut is the vertical direction Z, then the transverse direction would be the direction X and direction Y. In solid models, the transverse loads are transferred from the bolt head/nut to the bolt. In non-solid head/nut simulations, other means are used to account for the transverse load as described later. Figure 7 shows the case with a solid head/nut assuming friction is

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ignored. To account for the transverse load, a node from the line element of the stud is coupled to a node from the top flange and the bottom flange.

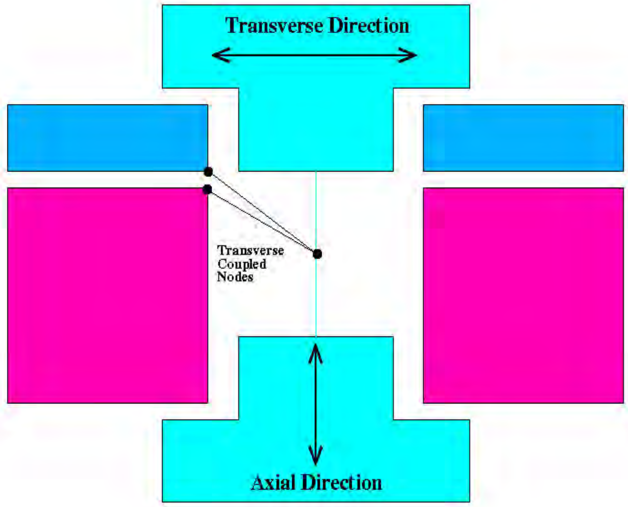

Figure 2.4 Transverse Coupled at Flange Joint

(source: Jerome Montgomery (2010))

2.6 Loosening Behavior of Bolt-Nut Joint

A significant advantage of a bolted joint over other joint types, such as welded and riveted joints, is that they are capable of being dismantled. This feature however, can cause problems if it unintentionally occurs as a result of operational conditions. Such unintentional loosening, frequently called vibration loosening in much of the published literature, is an important phenomenon and is widely misunderstood by engineers. It is important for the designer to be aware of the bolt loosening mechanisms which can operate in order to design reliable joints.

Study of most engineering magazines will reveal the multitude of proprietary locking mechanisms available for fasteners. For the designer without the theoretical knowledge of why fasteners self loosen, this represents a bewildering choice. Presented below is key information, for the designer, on why fasteners self loosen, and, how it can be prevented. It is widely believed that vibration causes bolt loosening. By far the most frequent cause of loosening is side sliding of the nut or bolt head relative to the joint,

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resulting in relative motion occurring in the threads. If this does not occur, then the bolts will not loosen, even if the joint is subjected to severe vibration. By a detailed analysis of the joint it is possible to determine the clamp force required to be provided by the bolts to prevent joint slip.

Often fatigue failure is a result of the bolt self-loosening which reduces the clamp force acting on the joint. Joint slip then occurs which leads the bolt being subjected to bending loads and subsequently failing by fatigue.

Pre-loaded bolts (or nuts) rotate loose, as soon as relative motion between the male and female threads takes place. This motion cancels the friction grip and originates an off torque which is proportional to the thread pitch and to the preload. The off torque rotates the screw loose, if the friction under the nut or bolt head bearing surface is overcome, by this torque. There are three common causes of the relative motion occurring in the threads:

1. Bending of parts which results in forces being induced at the friction surface. If slip occurs, the head and threads will slip which can lead to loosening.
2. Differential thermal effects caused as a result of either differences in temperature or differences in clamped materials.
3. Applied forces on the joint can lead to shifting of the joint surfaces leading to bolt loosening.

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2.7 Critical Relative Slippage

The critical relative slippage (Scr) that prescribes the upper limit for preventing the loosening behavior has been estimated according to the theoretically obtained equation considering the bending deformation of bolt and the geometrical constraint condition. Equation for estimating the (Scr) is based on the fundamental cantilever deformation model. From the investigate results, the behavior of bolt-nut joint under transverse loading by considering the reaction moment by nut (Mn). To confirm the estimated result of critical slippage coincided well with the experimental result.

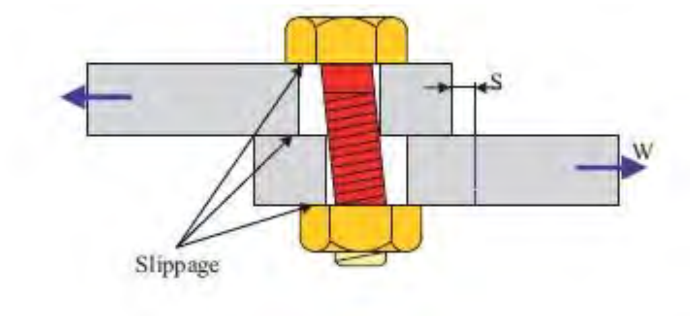

Figure 2.5 Critical Relative Slippage

(Source: Yamashita et al. 2010)

2.8 Mechanics of Bolt-Nut Joints

From Yamashita et al. 2010, the sliding behavior of bolt-nut joint and reverse rotation of nut under transverse load is showed in Fig. 2.5. The deformation behavior of bolt-nut joint is depends on the amount of transverse load level applied on the joint. In figure 3 (a), the load, W is low, bolt and fastened components (fixed plate and movable plate) are deformed. There is no slip occur at the bolt and nut bearing surface. The slip occur only at the contact surface between fixed plate and movable plate when W exceeded the frictional force (Where frictional force = number of bolts, n × friction coefficient, μ × initial axial tension, Fb) is given to the joint. However, in Figure 3(b) when relative displacement, S between upper and lower plate is still small, by the bending deformation of the bolt, sliding at the bolt and nut bearing surface is not occur. Then, load and relative displacement between plates increased and at one stage (relative

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displacement exceeded ΔS (Fig. 3(c)), slip is also occurs at the bolt and nut bearing surface. This slip leads to the reverse rotation of the nut and decrease the axial tension. The loosening behavior of bolt-nut joint shows the same occurrence if the transverse load applied in the opposite direction. When transverse cyclic load applied to the joint, bolt axial tension slowly decreases and at the worst stage, not only loosening occurs but also the fatigue failure of the bolt. So, it is important to evaluate both loosening behavior and fatigue failure of the bolt-nut joint.

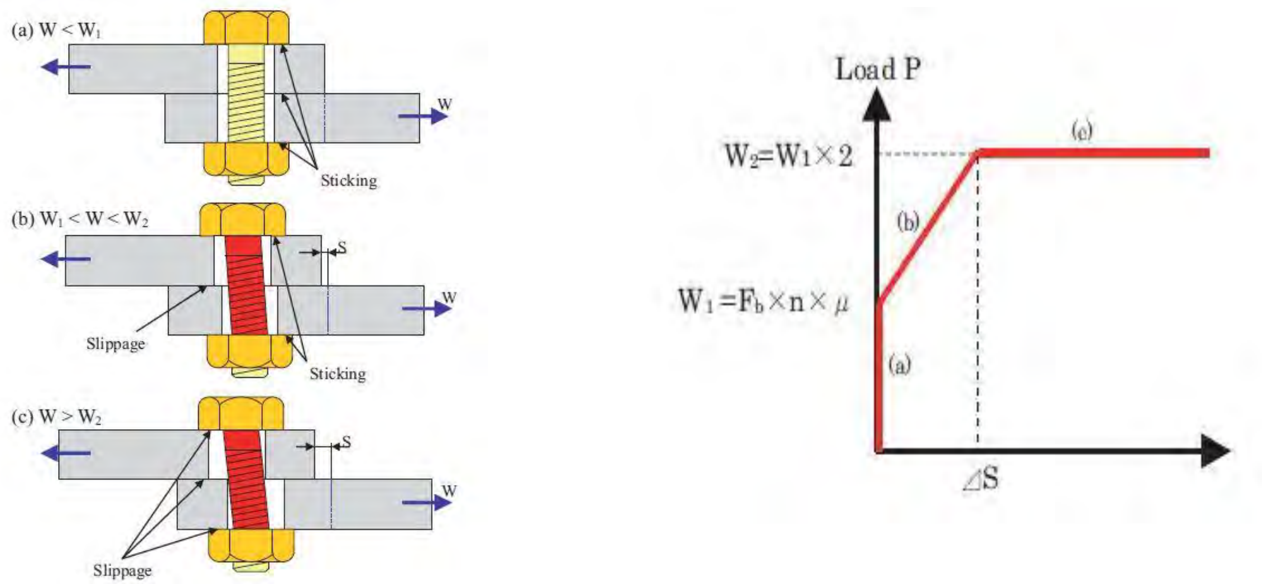

Figure 2.6 Behavior of the bolt-nut joint in different load condition.

(Source: Yamashita et al. 2010)

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