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Geometry influence on strength of thermal drilled threaded holes

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Abstract. This paper focuses on thermal drilling technology for fabricating threaded holes. Furthermore, experiments presented here focus on the influence of geometrical constraints in such bolted joints and their effect on the joint strength. The experimental results are analysed and compared to different types of geometry. The experiments are done on both mild and high strength steel types ensuring a further set of variables to the problem.

Introduction

There are not many standards regarding thermally drilled threaded holes. It is therefore difficult to predict strength and reliability in general of the joints with bolts screwed in thermally drilled threaded holes. Some of the assumptions from ISO 898 [1] can be extended to the case as it was done in a previous study [2] to this matter by these very authors, even though the ISO standard presents predictions on standard bolted joints (bolt and a nut).

According to ISO 898 [1], bolted joints failures are categorized to three types: Failure in the bolt shank, thread stripping on the bolt and thread stripping in the nut (threaded hole in this case). Any joint failure is undesirable; however, if a bolt breaks in the shank, it can be easily replaced. If thread stripping on the bolt occurs, it may not be as easily detected and it may damage the thread in the hole. However, the least desirable failure is the thread stripping in the hole, thus damaging the part as a whole.

According to studies by Alexander [3] and Hagiwara [4], a sufficient length of engagement of the thread has to be achieved in order to raise the bolt stripping strength above the bolt shank strength. This way, the bolt shank breaks always before thread stripping occurs.

Achieving sufficient length of engagement is particularly difficult for thin plates, where the ratio of the thread size and depth of the hole is poor. The thermal friction drilling technology [5] can partly overcome this difficulty by extruding a sleeve from the removed material while creating hole, thus extending the depth of the hole and the effective length of engagement with it. It was discovered in the previous work [2] that there is another often occurring type of failure typical for this type of technology characterized as a breakage of the extruded sleeve, which splits from the base material.

Previous study [2] showed also a relatively large deflection of the plates which apparently influenced the effective length of engagement and thus lowered the joint bearing capability. The purpose of this work is to study if tighter constraints could result in strength of such joints and if so, how is the strength by the geometry influenced.

Method of Evaluation

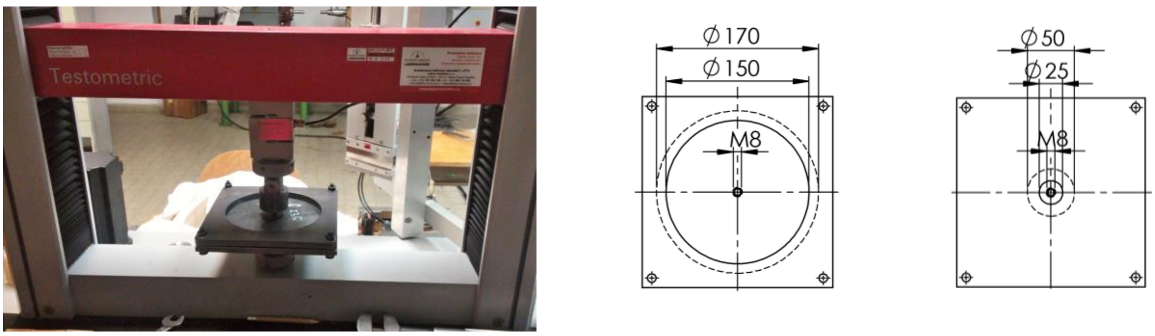
According to the standards for bolted joints [1], the measure of such joint strength is the amount of axial tensile force at failure for each size and property class. Since this paper focuses mainly on thread stripping, the property class was not an object of variations and the highest property class of 12.9 was used to maximize the bolt shank strength. There are three flange material types considered in this study. Two mild steel grades S235JRG and S355J0 according to EN 10025 [6] and a DOCOL 1200M high strength steel acc. to its datasheet [7]. The reference values of their tensile strengths are used from previous paper [2], where they were measured additionally.

Thickness of the base material before hole fabrication plays a major role as well on the resulting depth of the manufactured hole. 2mm thick specimen were used for all steel types, and 3mm thick specimen for mild steels (high strength steel of 3mm thickness was not standardly available).

To extend the results in the previous paper [2] for comparison, the same thread sizes were assumed, e.g.M5x0.8, M6x1, M8x1.25. All these parameters listed above were included into the specimen fabrication.

Experimental setup

A tensile testing device is a convenient device for axial tensile force measurements. It was already mentioned above, that this paper focuses on the geometrical constraints. In order to isolate the dependency, the same clamping adapter as the one used earlier [2] was used with different hole dimensions, see fig 1. It is assumed, that a tighter flange would suppress the deformation of the hole more and therefore would result in higher strength.



a) test rig b) original geometry c) altered geometry

Fig. 1: The tensile testing device with the interface for a clamped specimen.

Results

The tabled values of a wider geometry are used from the previous paper [2]. The tighter flange clamp results are used from the present study. Each failure is marked with its type marked below.

Tab. 1: Average of measured values of joint strength for base material thickness 2mm

Geometry	Original			Altered		
Material	S235JRG	S355J0	DOCOL 1200M	S235JRG	S355J0	DOCOL 1200M
M5	6 700* N	8 110 N	12 630 N	7 351* N	9 949 N	13 451 N
M6	8 420* N	9 140 N	15 000 N	8 402* N	10 828** N	15 877 N
M8	9 580* N	11 600** N	16 720* N	10 795* N	13 657** N	18 583 N

** failures with dominant internal thread stripping*
***failures with dominant sleeve breakage*

Tab. 2: Average of measured values of joint strength for base material thickness 3mm

Geometry	Original		Altered	
Material	S235JRG	S355J0	S235JRG	S355J0
M5	11 270* N	12 720 N	13 132* N	15 819** N
M6	13 420* N	15 250 N	15 247* N	17 574** N
M8	14 200* N	18 510** N	17 737* N	21 213** N

** failures with dominant internal thread stripping*
***failures with dominant sleeve breakage*

The improvement using the tighter geometry is evaluated below as the ratio of results from present study (altered geometry) to the results from the previous study (Original geometry).

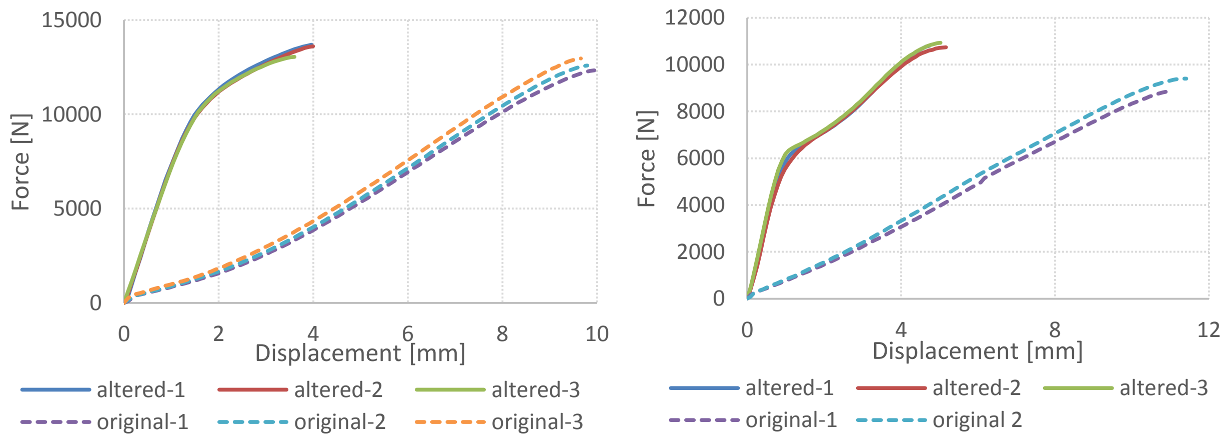
Tab. 3: Percent improvement due to tighter geometry

Thickness	2 mm			3 mm	
Material	S235JRG	S355J0	DOCOL 1200M	S235JRG1	S355J0
M5	10%	23%	7%	16%	24%
M6	0%	18%	6%	14%	15%
M8	13%	18%	11%	25%	15%

The values resulting from the altered geometry are compared to standardized nut values from ISO 898-2 [1] for different strength classes. The table 4 summarizes values equivalent to the strength class for each configuration.

Tab. 4: Equivalent nut strength class (acc. to Table 4 in [1])

Thickness	2 mm			3 mm	
Material	S235JRG	S355J0	DOCOL 1200M	S235JRG1	S355J0
M5	05	6	9	9	10
M6	04	04	6	6	8
M8	<04	< 04	04	04	05



a) DOCOL 1200M, M5 size, Thickness 2mm
b) S355J0, M6 size , Thickness 2mm

Fig. 2: The tensile testing device with the interface for a clamped specimen.

Conclusions

A tighter flange constraint results clearly in an increase of joint strength. However the effect is non-linear in terms of different configurations. It seems quite difficult at this point to find any dependence among the improvements from table 3. It can be observed from table 4 that the equivalent strength class for which can be nuts replaced with the threaded holes, gets better when moving to the right top in the table, while it is getting poor when moving to the opposite direction. This can be concluded as the ratio of the flange thickness to thread size still plays the major role on the strength. The material does as well but not as much as it is evident from values for M8 size.

Again DOCOL high strength steel specimens result now always in bolt thread stripping, which indicates that the flange material Yield strength is near the yield strength of the bolt. It is evident that opposed to the case of last study, the failure modes are now more consistent, because nearly all S355J0 specimens have a sleeve failure, all S235JRG have hole thread stripping and all DOCOL specimens cause a bolt thread stripping indicating that the Alexander's theory [3] might be extended to this case as well, since there is only one discrepancy at S355J0-M5-2mm. The deformation in the hole is in this case is apparently still large enough to damage the bolt thread before damaging the hole itself.

The Force-displacement relationship shows now a very similar shape to an uniaxial material testing curve with spots possibly indicating yield points as well as plastic and elastic regions which were not between examined phenomena. Future studies to this matter may focus to pretensioned specimens or circularly non-symmetrical specimens.

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