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THE USE OF DETACHABLE CONNECTIONS IN HEAT EXCHANGERS – ANALYSIS OF VARIANTS AND STRENGTH

1. Introduction

High-efficiency heat exchangers are virtually always associated with other components of industrial systems. Some of the most popular connections are bolted connections, which are used to connect exchangers into batteries and also to connect them to other equipment or transfer systems. Using this type of connection, accessories such as fans, control cabinets and platforms are also mounted to them. Due to the need to ensure the best quality of connections, the correct selection and quality of workmanship is required. The following presents the methodology for preparing bolted connections in three technologies and an analysis of the strength of the connections. The first way is to carry out installation using weldable nuts. The second method is to use rivet nuts, which require making a pre-drilled hole and then installing the rivet nut inside it and tightening it with a rivet gun. The third process described, is flow drilling with a flowtap, in which the drilling tool, with the help of pressure force, increases the temperature of the material allowing the hole to be formed through plastic deformation. In this hole, a thread is then formed by plastic deformation. Carbon steel and acid-resistant steel materials were used for testing.

2. Description of connections

The first method described is connections using welded nuts. This is one of the most popular methods of preparing detachable connections in heat exchangers, which is quite simple and does not involve high manufacturing costs.

The process is carried out in the following steps:

– drilling a hole for a weld nut in the material which is to be joined,
– seating the welded nut in the target location,
– welding the nut to the material.

The use of welded nuts is a common method because of the good strength of the connection. The disadvantage of this type of connection is usually the need to purchase large quantities of nuts and the possible distortion of the material due to welding.

The described method can also not be used inside closed profiles due to the lack of access to the nut and thus the inability to weld.

Fig. 1. Welded nut

The second method, also often used, is the use of rivet nuts. They are used when it is necessary to make a threaded connection on an existing coating (e.g. galvanized) without exposing it to damage, and when joining different types of materials together.

The process is carried out in the following steps:

– drilling and chamfering the hole (later coating the material, as required),
– seating the rivet nut in the hole,
– installation of the rivet nut with a rivet gun.

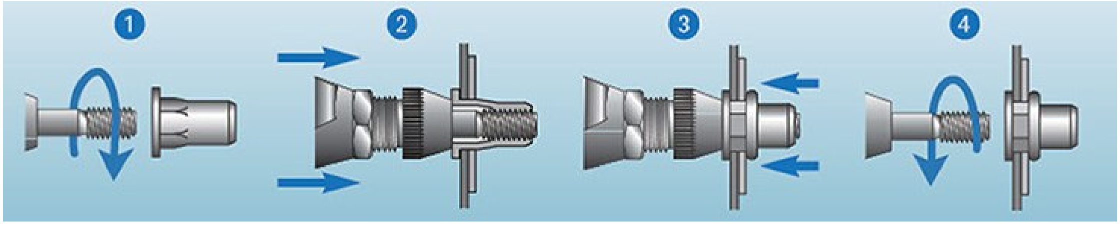


Fig. 2. Rivet nut installation method [1]

Rivet nuts are characterized by relatively simple installation. During the process, there are also no hazards associated with the accompanying impact of large quantities of heat as in the case of welding. Nevertheless, they have less stability and unskillful bolt tightening can cause them to twist and thus fail to tighten the component properly.

Another method is a procedure that uses flow drilling. This is an alternative way to allow materials to be joined. The full cycle of making a threaded hole is performed in two steps:

– drilling the hole with a friction drill,
– making a thread with a forming tap.

A properly formed threaded hole should exhibit good strength properties and it should be a very efficient process. Nevertheless, a precision machine is required for machining, which will allow the drill to be plunged to a certain height, taking into account the variable feed parameters. It is also important to position the tap correctly. The distinguishing feature of this process is that it is completely chip-free. During the drilling process, the structure of the material changes, which affects its hardness. [2]

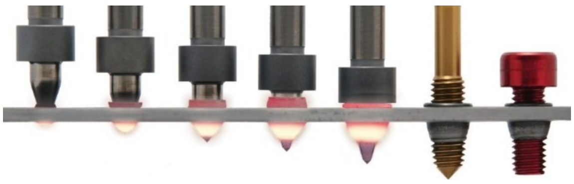


Fig. 3. The process of drilling and thread tapping [3]

3. Testing of connections

6 mm thick flat bars made of S235JR and 1.4301 steel were used to verify the connections. The rupture test was performed using an upgraded EDZ20 testing machine. The tested S235 grade materials were subjected to Vickers hardness testing with a Zwick tester alongside thread stripping tests. Testing was performed on 5 coils (Fig. 4). The results are presented in table no. 1, 2 and 3.

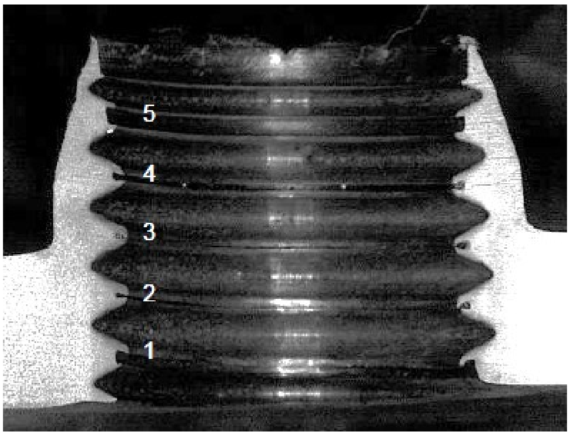
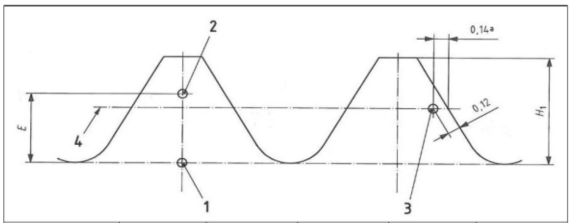


Fig. 4. Cross-section of a plastically formed hole with coil numbering

Table 1. Results of rivet nut hardness testing



Sample No.	Coil 1 [HV]	Coil 2 [HV]	Coil 3 [HV]	Coil 4 [HV]	Coil 5 [HV]
1	135	129	140	125	133
2	127	136	145	125	145
3	140	123	135	129	133

Table 2. Results of hardness testing of welded nut

Sample No.	Coil 1 [HV]	Coil 2 [HV]	Coil 3 [HV]	Coil 4 [HV]	Coil 5 [HV]
1	138	111	125	123	140
2	121	127	129	127	135
3	138	133	133	131	138

Table 3. Results of hardness testing of threads made by flow drill method

Sample No.	Coil 1 [HV]	Coil 2 [HV]	Coil 3 [HV]	Coil 4 [HV]	Coil 5 [HV]
1	193	195	189	193	197
2	214	234	210	221	219
3	224	257	234	226	224

The results clearly indicate an increased hardness of the joint made by flow drilling (mean 215 HV) compared to the rivet nut (mean 133 HV) and the welded nut (130 HV). As a result of the drilling process, the material is heated to ~750°C (seen as a red to orange color) [4]. The rapid cooling that follows drilling results in increased hardness. A unique feature for thermal flow drilling is the incomplete closure of the thread coils seen in Figure 4. This is due to the characteristics of the process.

In the case of standard threaded hole, the drill makes a hole of a certain diameter and then the threadtapper cuts the desired thread into the material. Flow drill technology requires the creation of a smaller diameter hole. As the forming tap plunges into the material, some of the material is pressed inside and some outside the hole, creating a threaded outline. Consequently, it is not always possible to achieve full coil closure.

In the next step, testing of joint strength was performed. The results for S235 JR steel are presented in Tables 4, 5, 6, while the results for 1.4301 steel are presented in Tables 7, 8, 9.

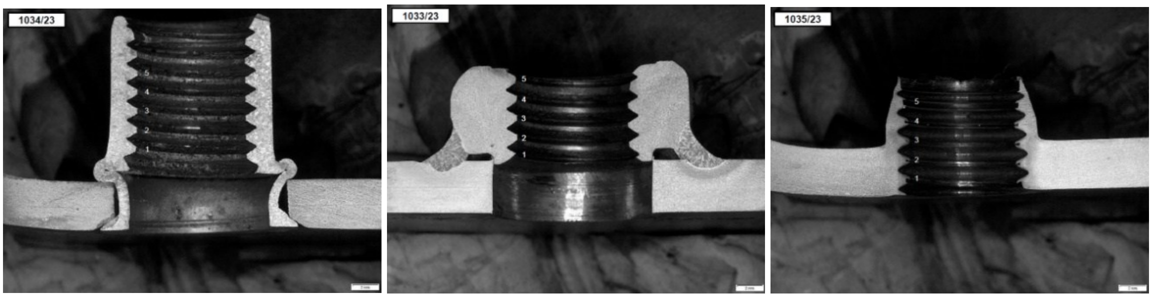


Fig. 5. Cross sections of threads in sheet S235JR material. Rivet Nut / Welded Nut / Flow Drilling.

Table 4. Shear forces of tested joints – Rivet nut

Sample No.	Type of threaded connection	Shearing force [kN]	Remarks
1	Rivet nut	44,71	Truncated rivet nut bushing
2	Rivet nut	40,69	Truncated rivet nut bushing
3	Rivet nut	38,71	Truncated rivet nut bushing

Table 5. Shear forces of tested joints – Welded nut

Sample No.	Type of threaded connection	Shearing force [kN]	Remarks
1	Nut	54,27	Truncated nut thread
2	Nut	52,44	Truncated nut thread
2	Nut	50,00	Truncated nut thread

Table 6. Shear forces of tested joints – Threads made by flow drilling

Sample No.	Type of threaded connection	Shearing force [kN]	Remarks
1	Flow drill and flowtap	39,06	Truncated thread in the material
2	Flow drill and flowtap	39,17	Truncated thread in the material
3	Flow drill and flowtap	37,74	Truncated thread in the material

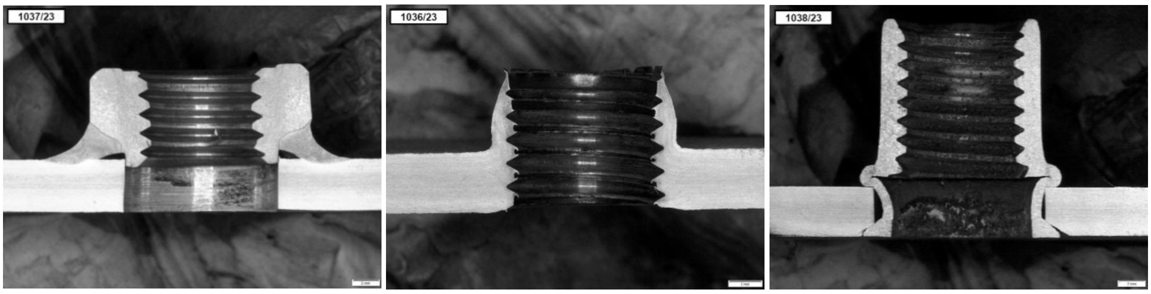


Fig. 6. Thread cross-sections in sheet material 1.4301. Rivet nut/Welded nut/Flow drilling

Table 7. Shear forces of tested joints – Rivet nut

Sample No.	Type of threaded connection	Shearing force [kN]	Remarks
1	Rivet nut	38,35	Truncated rivet nut bushing
2	Rivet nut	34,74	Truncated rivet nut bushing
3	Rivet nut	28,13	Truncated rivet nut bushing

Table 8. Shear forces of tested joints – Welded nut

Sample No.	Type of threaded connection	Shearing force [kN]	Remarks
1	Nut	76,80	Truncated nut thread
2	Nut	71,65	Truncated nut thread
3	Nut	67,65	Truncated nut thread

Table 9. Shear forces of tested joints - Threads made by flow drilling

Sample No.	Type of threaded connection	Shearing force [kN]	Remarks
1	Flow drill and flowtap	42,22	Truncated thread in the material
2	Flow drill and flowtap	46,44	Truncated thread in the material
3	Flow drill and flowtap	44,20	Truncated thread in the material

Strength testing of fasteners was carried out based on PN-EN ISO 898-1. Three strength tests were performed to obtain statistics. In S235JR steel, the average force required to destroy a threaded connection, for a rivet nut is 41.37 kN while for a welded nut it is 52.24 kN and for a connection made by flow drilling is 38.65 kN. In the case of 1.4301 steel, a decrease in strength compared to S235JR was noted for the rivet nut (average result is 33.74 kN). The welded and heat-treated nuts were characterized by increased strength, with an average of 72 kN and 44.3 kN, respectively. For each type of steel, the rivet nuts had the largest scatter in the strength obtained. The other two connections showed greater reproducibility in the results obtained.

When designing detachable connections, of course, the lowest values obtained should be used for assumptions.

4. Summary

A key finding of the testing is that virtually every connection is qualified for use in systems and fixtures associated with heat exchangers. This is due to the fact that, despite the large discrepancies in the results obtained, even the weakest connections have strength of approx. 30 kN. When exchangers are combined into batteries or fixtures are assembled, gaskets are most often used at points of contact. In order for the mentioned connections to have a high level of tightness, it is required to make holes close to each other. In practical terms, this means that the forces acting on each threaded connection are lower than the maximum that can be transferred.

Ultimately, adequate selection of the connection method is also influenced in each case by other factors such as: budget, place of operation, vibrations, etc., which for each operation should additionally be analyzed and taken into account.

5. Bibliography

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