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Experimental Investigation of Flow Drilling and Flow Tapping of Thin-Walled Square and Circular Hollow Sections

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Research Article

Abstract

One of the most important problems of automotive engineering is joining metal sheets, thin-walled tubes or profiles simply, efficiently, and economically. After conventional drilling and tapping in thin-walled materials, the strength remains low due to the small number of teeth and the connection can be easily unfastened. For increasing the strength there are several solutions such as using welded nuts, tapped rivets and welding extra nuts. Since nut welding cannot be done on the inner surfaces, these solutions are inadequate for square and circular tubes. In this study, holes of various diameters were drilled on 1.5 mm thick AISI 304 stainless steel and EN AW-6060 square and circular profiles by flow drilling at various rotational speeds, and then flow tapping was applied to the holes. The same processes were repeated with conventional drilling method to compare bushing heights and clamping strengths of the parts as well as the hardness values and capillary crack formations around the holes. According to the results obtained, the strength in flow drilling and tapping increases by 50-55% compared to the classical drilling method. The reason for this is that as the hole diameter increases, the amount of material plastered and the number of threads required for screwing increases approximately 2.5-3 times. Capillary cracks, which are observed in holes drilled with the traditional method as the hole diameter increases, are not observed with this method and thus increasing the strength of the connection.

Keywords: Bushing height; Clamping strength; Flow drilling; Flow tap; Traditional drilling; Traditional tapping

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1. Introduction

The use of thin-walled materials and their interconnection are of great importance, especially in the automotive industry [1-6].

The conventional drilling processes belong to the machining process group. The chips were removed during drilling. The pitch lengths remain incapable of tapping, particularly in thin-walled materials, and poor joints are achieved. In addition, capillary cracks formed around the hole during the drilling process because of the wear of the drill tip, and which decreased the strength of the material. There are several alternative methods to strengthen the joint such as welding nuts, tapping rivets, bonding, and using blind bolts [7]. In thin-walled materials, the nut is welded to the exterior surface of the profile to provide a screw joint, and this leads to an inappropriate construction. Welding of thin-walled materials is a process that requires expertise. Over welding leads to puncture in the sheet material while deficient welding results with a decrease in the strength of the material. The cost of the riveted nut and blind bolt is quite high since the joint part is single use.

In the Flowdrill method, a specially manufactured drill bit contacts the material at high speeds and opens holes using the friction method. Because no chips are removed during drilling, unlike in the traditional drill method, the required pitch length for screwing can be obtained as seen on Figure 1. With this method, there is no need to add extra parts to the thin-walled materials. In addition, the risk of capillary cracks around the hole is prevented by high temperatures [7]. In the flow tapping process, warping and cracking risk is also prevented. The most important parameters in the flow drilling process are the determination of appropriate flow drill tips and speeds for various hole diameters and thicknesses.

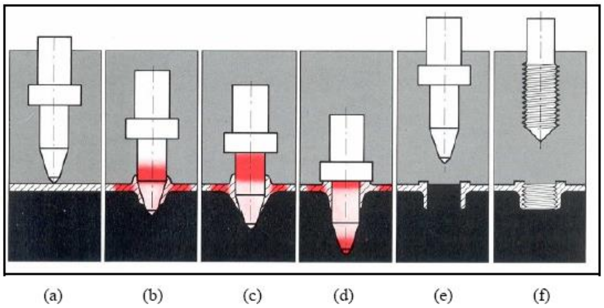


Fig. 1. Plastic deformation of the material in flow drilling process a) Initial contact of the flow drill bit with the material b) Beginning of flow drilling, plastic deformation c) Progress of flow drill bit in the material d) Complete drilling of the material by the flow drill bit e) Flow drill bit coming out of the material f) Flow tapping process [8]

By evaluating manufacturing processes under two different categories, namely forming and assembly, the main purpose of every enterprise is to obtain high quality with low cost via lower labor times and material usage. Flow drilling method positively affects these main factors with its' manufacturing processes. Flow tapping without chip removal to fasten a screw to thin-walled materials is an important step on behalf of material agglomeration and obtains higher strength material.

Although drilling materials is a common process used in the machine sector, there are not enough satisfactory studies in the literature about the flow drilling and flow tapping of various profile type thin-walled materials. Enterprises manufacturing or selling flow drill tips publish information about the appropriate flow drill tips to be used for various thicknesses in their catalogs, nevertheless, these catalog values have no scientific qualification [7].

There are experimental and theoretical studies in the literature to increase the strength of the connection in thin-walled materials [8-12. Davison et al. compared the flowdrill method with bolt-nut methods and they indicated that flowdrill method is more suitable [13]. Sonstabo et al. compared the bonding hollo bolt, welding and nutted rivet methods with the flowdrill method in thin-walled aluminum materials using static and dynamic tests and proved the accuracy of their work using the finite element method. [14,15]. Wang and Chen compared blind bolt connections and flowdrill method in square and circular profile pipes of various wall thicknesses experimentally [16]. Lee et al. examined the flowdrilling with finite element method in T-type connections [17]. France et al. carried out some tests to investigate the moment capacity and rotational stiffness of the end plate connections using flowdrilled connectors [18-19]. Li et al. studied a new type of splice joints for square hollow section columns and doing moment resistance tests [20]. Wang et al. studied hollow bolts in square hollow sections [21]. Thais et al. simulate the behavior of blind bolt end plate connections between composite beams and concrete-filled steel tubular (CFST) columns. Some researchers developed various apparatus such as extended hollow bolt, slip-critical blind bolt, and tube bolt and showed that these applications further increased the strength of the joint [22]. Tizani et al. worked on the extended hollo bolt to determine the feasibility of obtaining blind bolted rigid connections and increased the tensile stiffness of the joints [23]. Wang et al. studied a Slip-Critical Blind Bolt (SCBB) in square hollo sections (SHS) [24]. Jeddi and Sulong proposes a new blind bolt known as TubeBolt for beam-CFT column connections up to 8 mm thicknesses [25]. Wang et al. presented experimental research on beam-column blind bolted end plate connections using a Slip-Critical Blind Bolts (SCBB) [26]. Researchers that are interested in the flow drilling method which is developed as an alternative to the conventional drilling method made experimental and theoretical studies on tool wear and flow drilling parameter (friction angle, tool translator motion, tool angle, drilling speed, tool rotational speed, thrust, and axial force) subjects. In the studies investigating the tool wear in flow drilling; effects of the angle, material and operating time of the flow drill tip used in the drilling process on the surface roughness of the part, bushing shape and micro hardness around the hole were examined. Miller et al. examined the effects of the drilling tip on the microstructure and wear on the part by drilling holes with various materials using the flowdrill method [27,28]. Ozek and Demir studied the effects of the drilling tip with the flowdrill method on the surface roughness and bushing shape in the holes. Effects of flow drill tip feed rate, drilling speed, flow drill tip material, rotational speed, thrust and axial force, hole diameter and material thickness on the surface roughness of the drilled surface, washer shape, bushing height, chip morphology, micro hardness and microstructure were investigated in the studies made about flow drilling parameters [29]. Demir investigate the effect of pre-drilling depth and diameter on the bushing shape in friction drilling and shows the highest temperature was recorded at 3000 rpm spindle speed and 40 mm/min feed rate. Demir worked on the effect of feed rate, spindle speed, and point angle on the fluctuation size of tool wear and chip morphology. He explained that higher point angles provided optimum outputs such as lower fluctuation size in thrust force, less tool wear, better surface quality and continuous chip form, the effect of feed rate and spindle speed on these outputs varied depending on each other [30-31]. Sua et al. investigate the feed rate and spindle speed on friction drilling [32]. El-Bahloul et al. studied the optimal process parameters of thermal friction drilling, based on the design of the test method combined with the analysis of fuzzy logic and variance techniques, considering the resulting axial force and bush length [33]. Haynes and Kumar numerically analyzed the bush formation quality in the thin-walled copper and estimate the temperature distribution, thrust force and torque in the workpiece. They confirmed their theoretical results with experimental results [34].

As a result of the literature, it is observed that the flow drilling process was evaluated sufficiently; however, comparison of flow drilling and conventional drilling applications of thin-walled square and circular profile materials is deficient. In this study, square and circular cross-sectional profile AISI 304 stainless steel and EN AW-6060 materials having 1.5 mm thickness were flow drilled and flow tapped in various diameters at various rotational speeds. Same processes were repeated with conventional drilling method. Obtained results were compared in terms of the bushing heights, the strength of the joints via clamping tests, micro hardness around the holes, and observation of the capillary crack formations around the holes via penetrant tests.

2. Experimental Method

In this study, AISI 304 stainless steel, EN AW-6060 square hollow section (SHS) and circular hollow section (CHS) profiles having 40x40x1.5 mm dimensions were drilled with flow drill tips having 4.6 mm, 5.4 mm and 7.3 mm diameters. Subsequently, the holes were flow tapped using M5, M6 and M8 flow tappers. The same materials were drilled conventionally by removing chips from the material and threating them. The flow-drilling and tapping tools used in the study are uncoated, long collar type and made of solid carbide material. Drilling and tapping operations were carried out on PRATIC PDE-CNC 4500 model (China) CNC bridge type vertical machining center. The technical properties of the materials used in the study are shown in detail in Table 1.

Table 1. Technical properties of the materials used in the study [7]

Properties name	AISI 304 stainless steel	EN AW-6060
Hardness (HB)	201	50
Ultimate Tensile Strength (MPa)	505	120
Ultimate Yield Strength (MPa)	215	-
Elongation at Break (%)	70	10
Modulus of Elasticity (GPa)	193	69.5
Poisson Ratio	0.29	0.33
Shear Modulus (GPa)	86	
Density (g/cc)	8.00	2.7
Specific Heat Capacity (J/g°C)	0.5	0.08
Thermal Conductivity (W/mK)	16.2	20
Melting Point (°C)	1455	615
Tempering Temperature (°C)	-	375

Flow drilling was conducted at 2000, 2500, and 3000 rpm for each hole diameter. Because the conventional drilling process is not dependent on rotational speed, it was performed at 2000 rpm, which is consistent with the literature [7]. The flow drill tip feed rate was maintained at 125 mm/min. Table 2 presents the test plan procedure for this study.

Table 2: Test plan

Material	Hole & tapping dia. (mm)	Spindle speed (rpm)	Method
AISI 304 stainless steel (SHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000, 2500, 3000	Flowdrill&Flowtap
AISI 304 stainless steel (SHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000	Traditional Drilling&Tapping
EN AW-6060 (SHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000, 2500, 3000	Flowdrill&Flowtap
EN AW-6060 (SHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000	Traditional Drilling&Tapping
AISI 304 stainless steel (CHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000, 2500, 3000	Flowdrill&Flowtap
AISI 304 stainless steel (CHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000	Traditional Drilling&Tapping
EN AW-6060 (CHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000, 2500, 3000	Flowdrill&Flowtap
EN AW-6060 (CHS)	Ø4.6-M5 Ø5.5-M6 Ø7.3-M8	2000	Traditional Drilling&Tapping

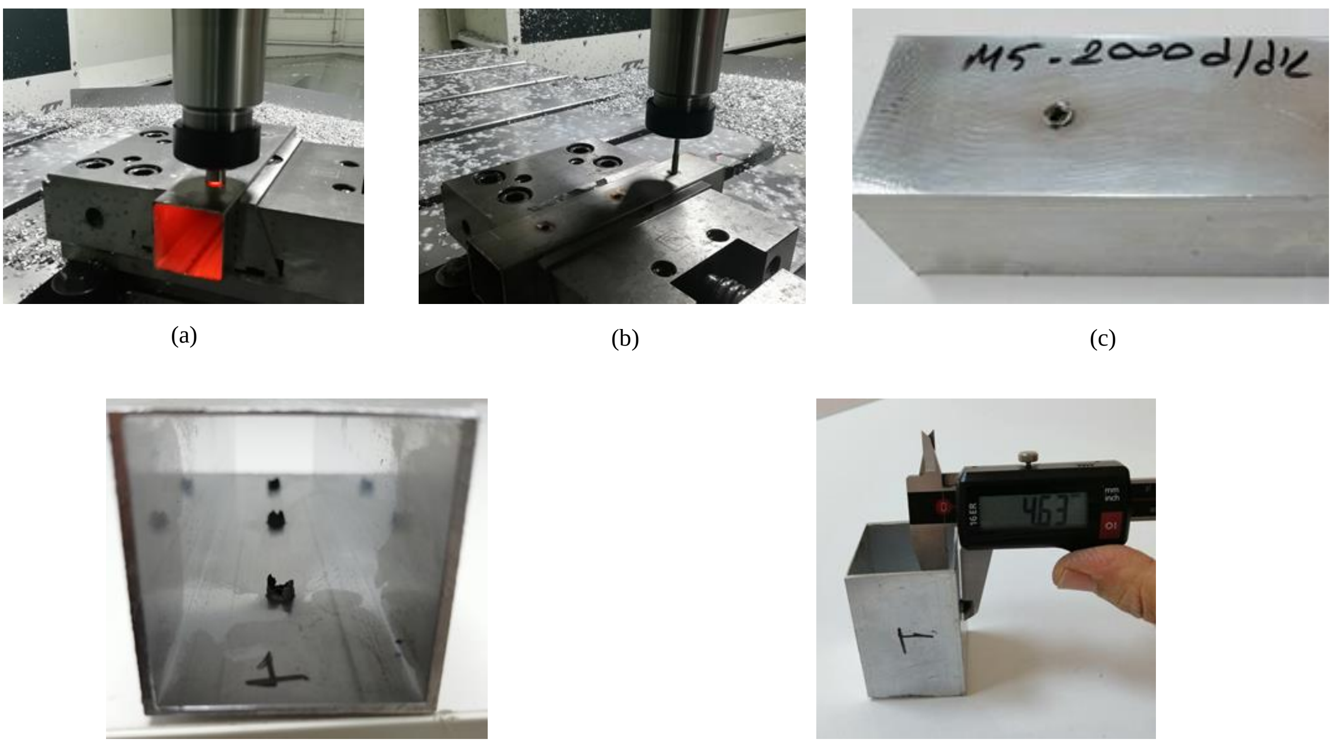
The bushing heights of the test samples were measured with a Mitutoyo (0-150 ±0.01 mm) digital caliper (Japan), and the differences between the traditional drilling method and flowdrill methods were compared. The important stage of the study was to determine and compare the clamping strength of holes drilled and tapped using both methods. For comparison, the holes drilled and tested with a Shimadzu AGS-X 10kN model (Japan) device, and the effect of the plastered material and teeth added in the flowdrill method on the strength was determined and compared with the traditional method. The hardnesses of the holes were measured and compared with using the Accud RBV 150C model (China) hardness measuring device.

To investigate possible capillary cracks around the holes drilled with both methods, penetrant micro crack tests were performed on the test samples and the results were compared for each diameter and rotation speed.

3. Results

3.1. Comparison of flow drilling and conventional drilling methods in terms of bushing height

In thin-walled materials, enough teeth are required during tapping to ensure that the joint will not unfasten. In the flow drilling process, chip particles melted with the help of heat during drilling pile under the part and enable more bushing height for tapping. Figure 2 shows comparative photographs of flowdrill and flowtap methods. After the flowdrill process, the flowtap tip is attached to the machine for tapping and the process continues. Guidance fluid was used to provide easy tapping in the holes (Figure 2)

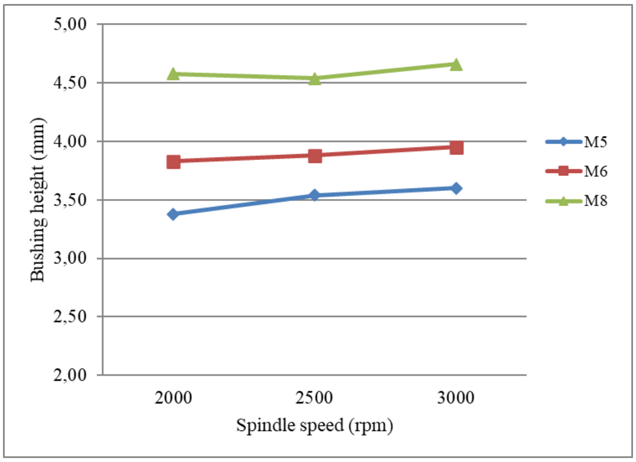


(a) (b) (c)

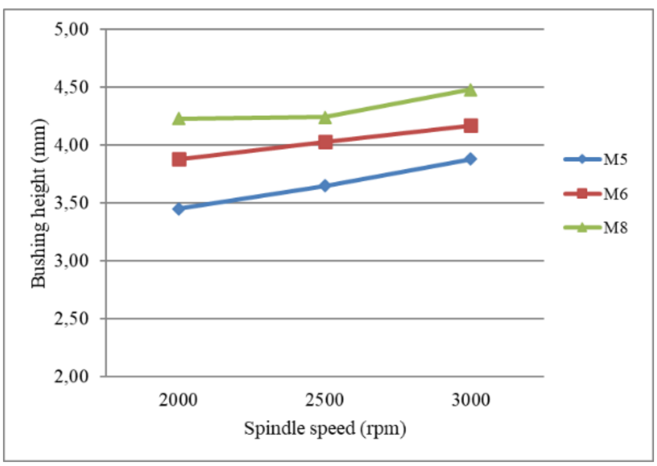
(d) (e)

Fig. 2. Drilling operations in SHS profiles
(a) flowdrill (b) flowtap (c) external view of the profile (d) bushing height (e) bushing height measurement

In the first test group, tapping was made to AISI 304 stainless steel and EN AW-6060 square profile materials using respectively M5, M6, and M8 flow tappers after drilling holes on them using flow drill tips having 4.6, 5.4 and 7.3 mm diameters at 2000, 2500 and 3000 rpm rotational speeds. Every test was repeated 3 times and the average of the obtained values was calculated to ensure the accuracy of the test results. Bushing heights were measured with digital caliper separately for all the diameter and rotational speed values as seen on Figure 3. The same profiles were drilled and tapped conventionally under similar conditions at a rotational speed of 2000 rpm. The difference of the bushing heights in the flow drilling and conventional drilling methods are shown in Figure 4. The bushing height measurements of the drilled sheets were made from the outside of the sheet with a digital caliper (Figure 2e).



(a)

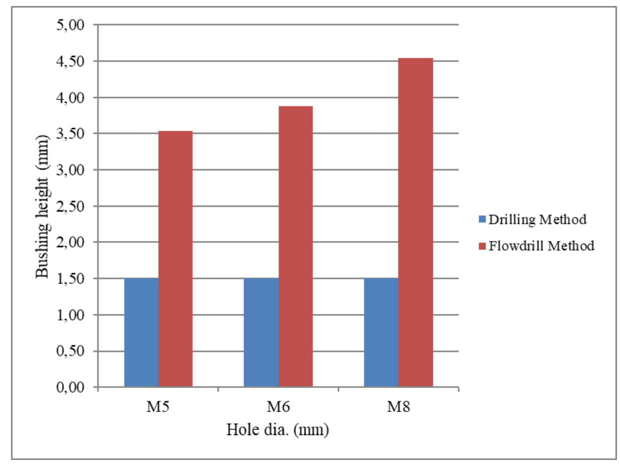


(b)

Fig. 3. Bushing height test results of (a) AISI 304 stainless steel SHS, (b) EN AW-6060 SHS

Similar processes were made in the second test group to circular profiles and bushing heights were measured with digital caliper separately for every diameter and rotational speed values. The same circular profiles were drilled and tapped conventionally. The difference of the bushing heights in the flow drilling and conventional drilling methods are compared in Figure 5.

When the graphs of the first test group are examined, it was observed that the bushing heights increased when the diameter of the holes increased in both materials (Figure 3). In the flow drilling process, the amount of the perfused material increases with the increasing hole diameter, and bushing height for flow drilling also increases as a result of this. Low rotational speed in the flow drilling process leads to a deficiency in the friction between the flow drill tip and material which results in perfused chip particles not to pile properly under the hole. As for that, high rotational speed leads to the formation of capillary cracks around the hole and formless bushing shape [8]. The bushing heights in both materials did not show much change in the rotational speeds selected in this study. It is proper to make flow drilling process at selected rotational speeds for the material thickness used in the application. When conventional drilling and flow drilling methods are compared, in square profile AISI 304 stainless steel material, bushing heights showed an increase of 2.3, 2.5 and 3.1 times in M5, M6, and M8 holes, respectively (Figure 4a). In EN AW-6060 material, bushing heights showed an increase of 2.6, 2.8 and 3.0 times in M5, M6, and M8 holes, respectively (Figure 4b).



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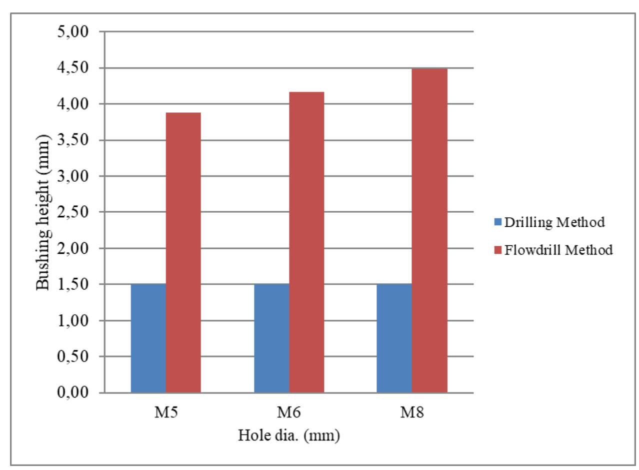
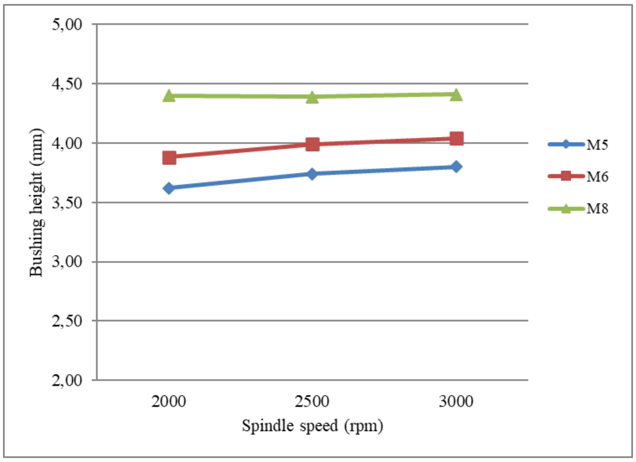


(b)

Fig. 4. Bushing height comparison of flow drill and conventional drilling (a) AISI 304 stainless steel SHS, (b) EN AW-6060 SHS



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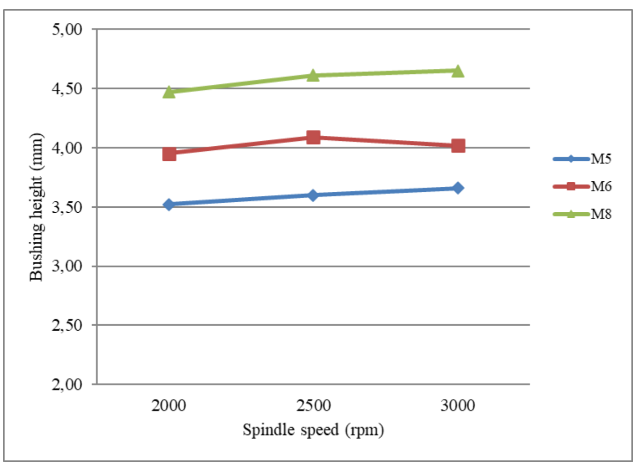
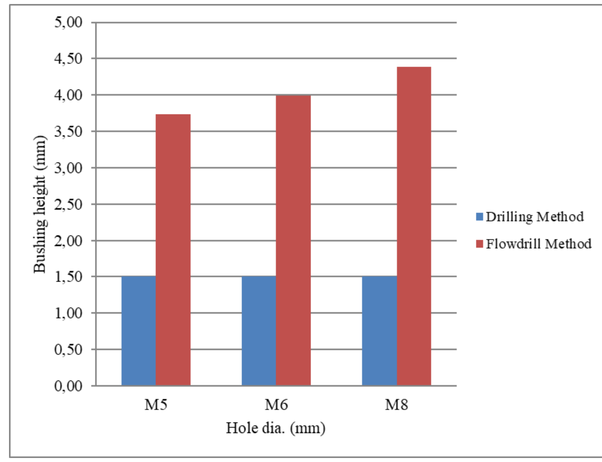


(b)

Fig. 5. Bushing height test results of (a) AISI 304 stainless steel CHS, (b) EN AW-6060 CHS



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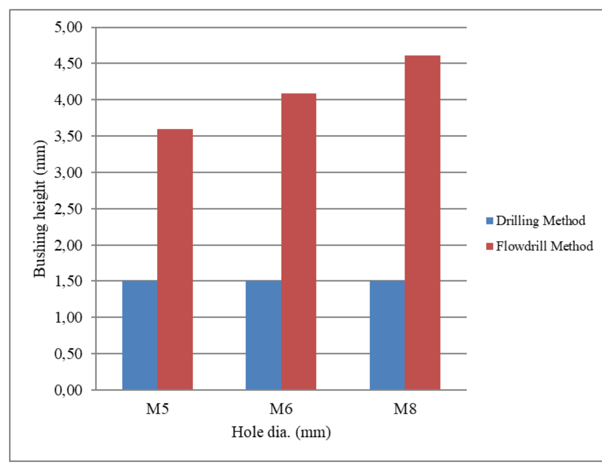


(b)

Fig. 6. Bushing height comparison of flow drill and conventional drilling (a) AISI 304 stainless steel CHS, (b) EN AW-6060 CHS

Graphs of first and second test groups have similar results, and this shows that the performed tests are consistent (Figure 5). When conventional drilling and flow drilling methods are compared, in circular profile AISI 304 stainless steel material, bushing heights showed an increase of 2.5, 2.7 and 2.9 times in M5, M6, and M8 holes, respectively (Figure 6-a). In EN AW-6060 material, bushing heights showed an increase of 2.4, 2.7 and 3.1 times in M5, M6, and M8 holes, respectively (Figure 6-b).

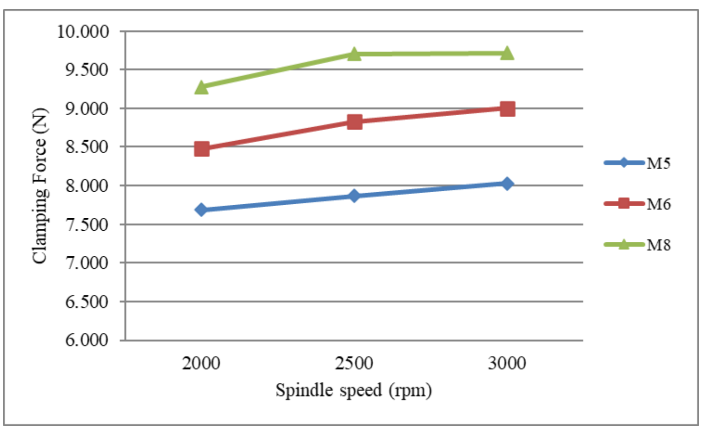
It is seen that bushing heights are approximately 2-3 times increased in both materials drilled and tapped by flow drilling and tapping methods compared to the conventional methods. Thanks to this increase, more teeth can be tapped to the material. It is foreseen that the joint will be strengthened with such an increase of bushing height and number of teeth in the parts.

3.2. Comparison of flow drilling and drilling methods in terms of clamping strengths

Clamping tests were performed to the thin-walled square and circular specimens prepared by the conventional and flow drilling and tapping methods specified in Section 3.1 to measure the strengths of the joints. Special clamping apparatus was made to prevent the deformation of the holes during the clamping tests with the effect of clamping force since the wall thicknesses of the parts are small (Figure 7). Clamping tests were carried out at a constant speed of 1 mm/min. Every test was repeated 3 times and the average of the obtained values was calculated to ensure the accuracy of the test results. Clamping strength test results of the first test group and comparative graphs of the conventional and flow drilling methods are shown in Figures 8-9 and clamping strength test results of the second test group and comparative graphs of the conventional and flow drilling methods are shown in Figures 10-11.

(a) (b)

Fig. 7. Clamping tests (a) SHS test apparatus, (b) CHS test apparatus



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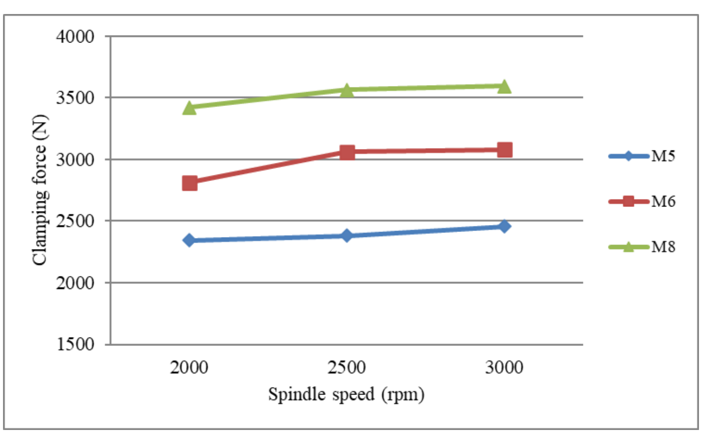
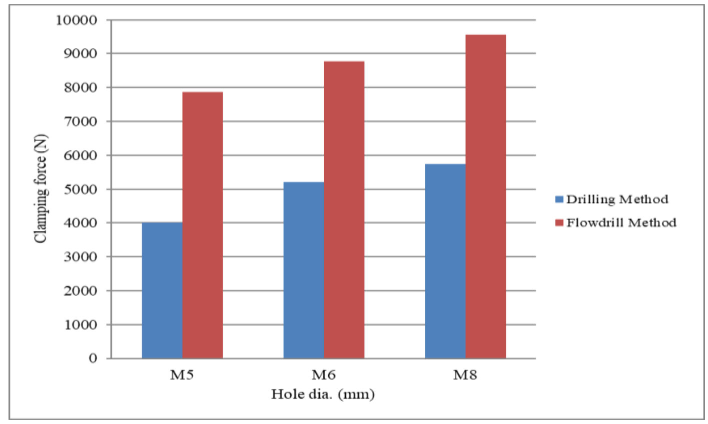


(b)

Fig. 8. Clamping test results of (a) AISI 304 stainless steel SHS, (b) EN AW-6060 SHS



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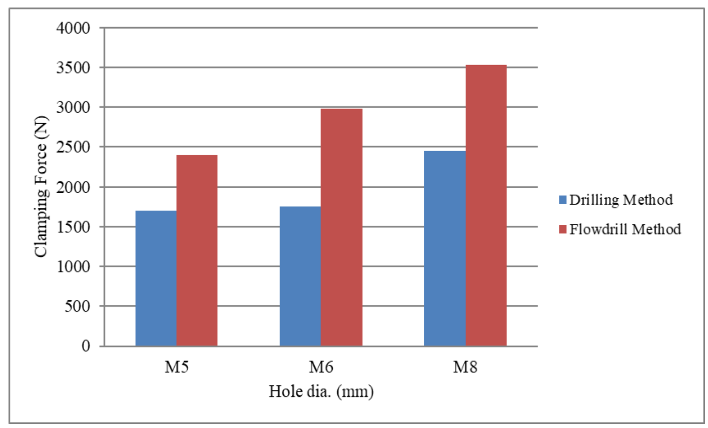
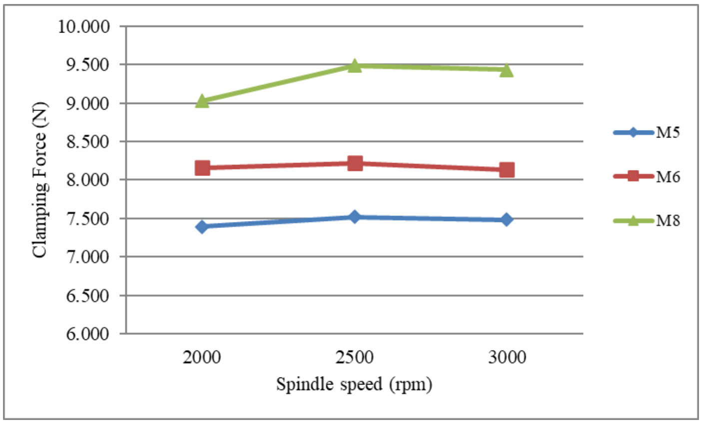


(b)

Fig. 9. Comparison of the clamping test results of flow drill and conventional drilling (a) AISI 304 stainless steel SHS, (b) EN AW-6060 SHS

When the graphics of both test groups were examined, it is seen that as the hole diameter increases, the clamping forces also increase due to the increase in screw size. The reason for this is increasing bushing height due to the more amount of material perfusion with the increasing hole diameter as explained in Section 3.1. Increasing bushing height increases the number of teeth obtained by tapping and by this means clamping force bearing capacity of the teeth increases.

The first test group of flow drilling and conventional drilling methods were compared, clamping strengths of square profile AISI 304 stainless steel material showed an increase of 82% for M5, 72% for M6, and 67% for M8 (Figure 8a). Clamping strengths of EN AW-6060 material showed an increase of 65% for M5, 53% for M6, and 45% for M8 (Figure 8b).



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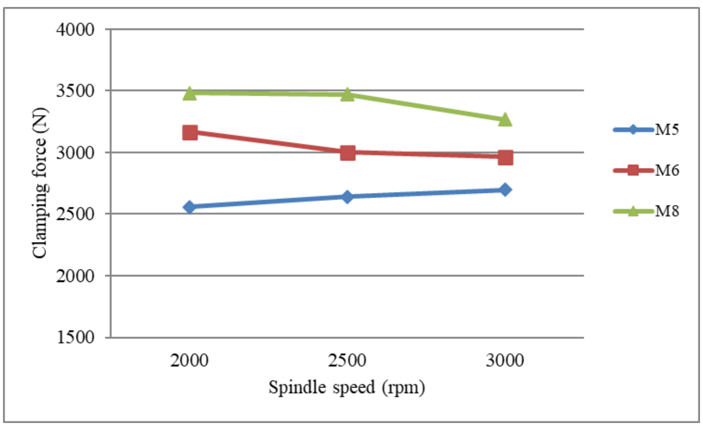
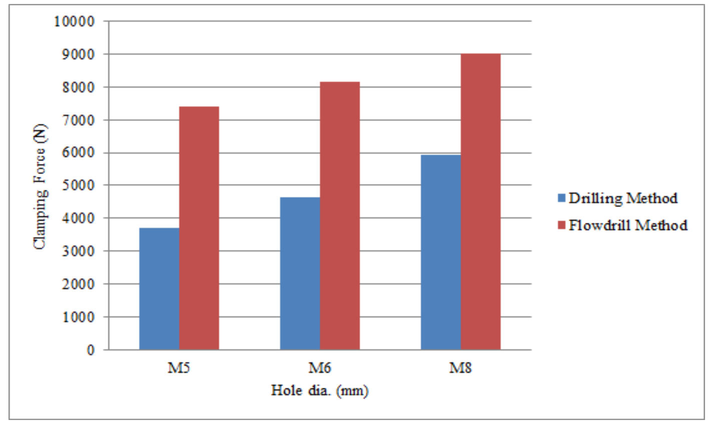


(b)

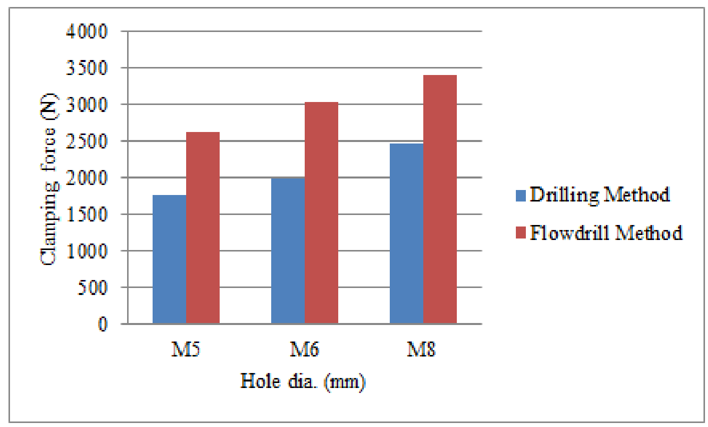
Fig. 10. Clamping test results of (a) AISI 304 stainless steel CHS, (b) EN AW-6060 CHS

The second test group of flow drilling and conventional drilling methods were compared, clamping strengths of circular profile AISI 304 stainless steel material showed an increase of 89% for M5, 76% for M6, and 62% for M8 (Figure 10-a). Clamping strengths of EN AW-6060 material showed an increase of 61% for M5, 53% for M6, and 39% for M8 (Figure 10-b).

Both test groups were examined, an increase of approximately 50-55% in clamping strengths of the holes obtained by the flow drilling method compared to conventional drilling was observed. The difference between the clamping strengths is more in smaller holes. This difference decreases with the increasing hole diameter since the strengths of the teeth obtained by the conventional drilling also increase with the increasing hole diameter.



(a)

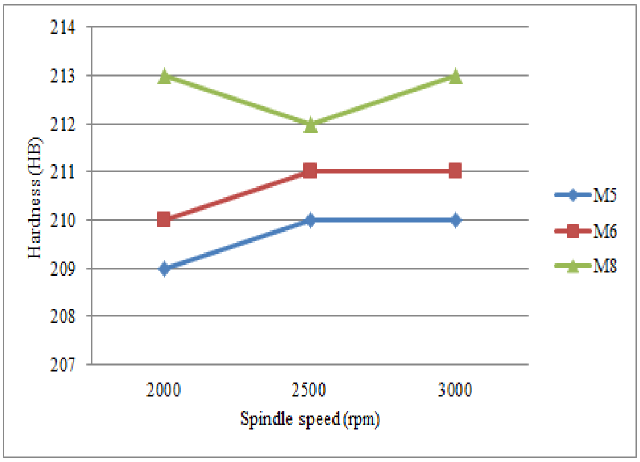


(b)

Fig. 11. Comparison of the clamping test results of flow drill and conventional drilling (a) AISI 304 stainless steel CHS, (b) EN AW-6060 CHS

3.3. Comparison of part hardness

Hardness varies in a wide range as a result of cold forming and heat treatment in all metals. Vice versa, conclusions can be drawn about the internal structure of the material from the hardness values. During the flow drilling operation, approximately 300~400 ºC temperature occurs around the drilled holes due to the high-speed friction between the flow drill tip and part [30]. Since there may be a change in hardness around the holes due to the sudden warming and cooling, hardness tests were carried out on the materials of both test groups. After the flow drilling and conventional drilling processes, the parts were kept to cool down to room temperature and hardness tests were carried out by calculating the arithmetic means of the three hardness values taken from the points close to the holes for each diameter and rotational speed as shown in Figures 12-15.



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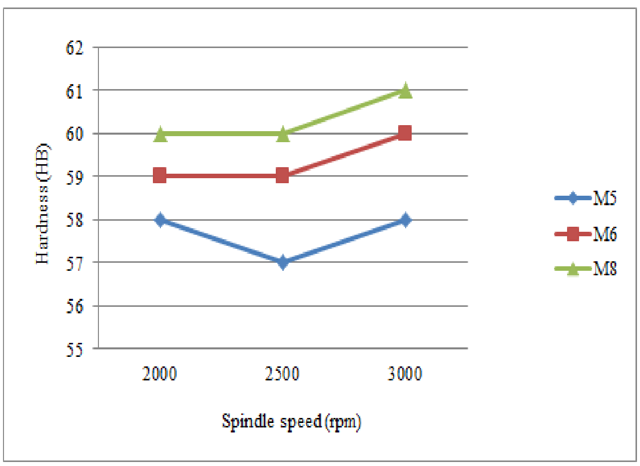
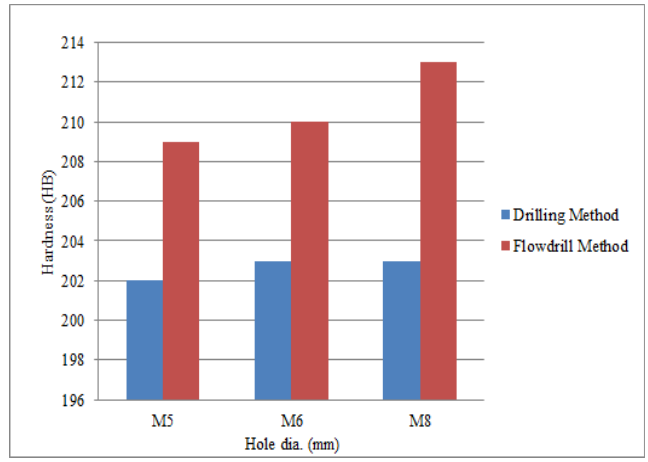
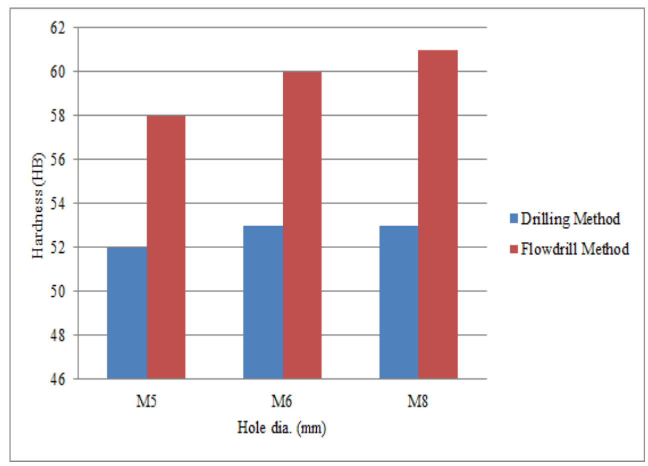


(b)

Fig. 12. Hardness test results of (a) AISI 304 stainless steel SHS, (b) EN AW-6060 SHS



(a)



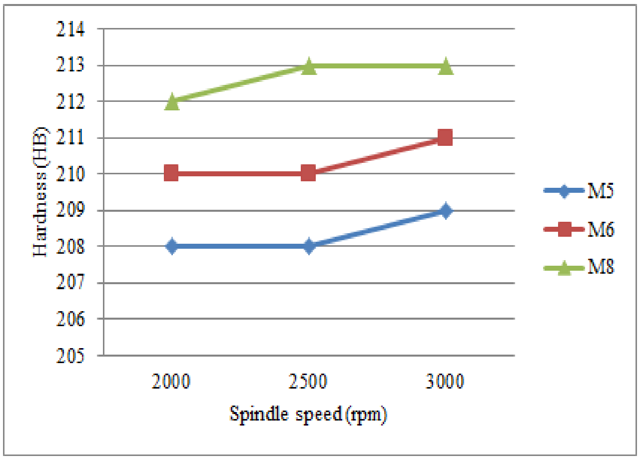
(b)

Fig. 13. Comparison of the hardness test results of flow drill and conventional drilling (a) AISI 304 stainless steel SHS, (b) EN AW-6060 SHS

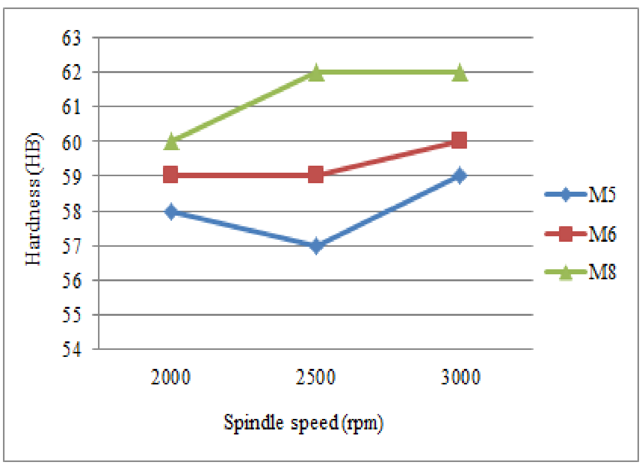
The hardness values increased with the increasing hole diameter in both test group materials (Figures 12-15). When the hardness values of the first test group flow drilling and conventional drilling methods are compared, an increase of approximately 4% is seen in AISI 304 stainless steel material and approximately 12% in EN AW-6060 material. Hardness values of the second test group have similar results with the ones of the first test group. In the second test group, the difference between the hardness values of the flow drilling and conventional drilling methods is approximately 5% in AISI 304 stainless steel material and approximately 12% in EN AW-6060 material. It is foreseen that the joint strength of the materials will increase with increasing hardness values.

3.4. Comparison of penetrant test results

Penetrant test is a non-destructive testing method used in the determination of surface defects which consists of four stages. The area to be tested is cleaned of rust and oil with a cleaning spray in the first stage. In the second stage, the penetrant liquid is applied to the surface and waited for 20-25 minutes for the liquid to penetrate to the cracks. Then the surface of the sample is wiped with a cloth and excess penetrant liquid is removed from the material. Finally, crack seeking process is performed. In this process, a spray is applied and waited on the sample, then the material is examined. Detailed penetrant test results of both materials are shown in Figure 16.



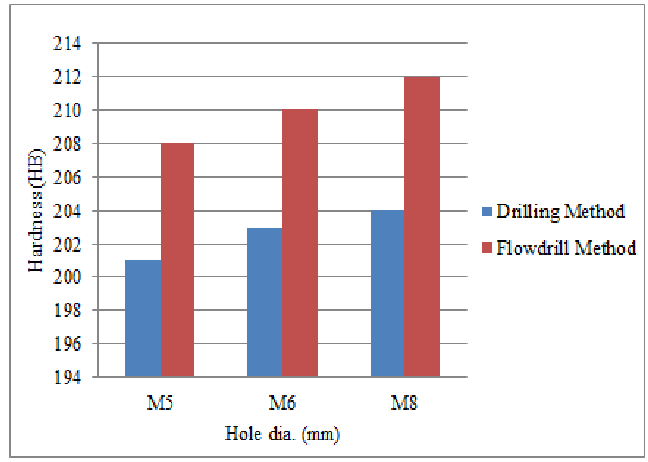
(a)



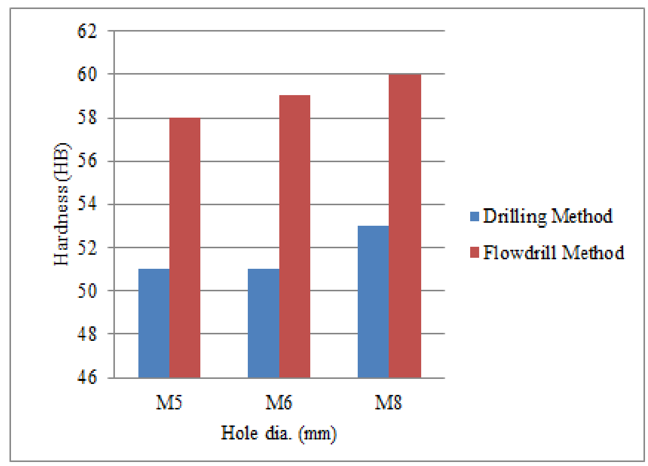
(b)

Fig. 14. Hardness test results of (a) AISI 304 stainless steel CHS, (b) EN AW-6060 CHS

According to the results of the penetrant test, crack formation was not observed in all hole diameters and at every rotational speed of both test group materials prepared via flow drilling and flow tapping (Figure 16). The crack formation was not observed in small hole diameters of both test group materials prepared via conventional drilling and tapping while capillary crack formations were observed with the increasing hole diameter. By examining test samples, cracks are seen at M6 and M8 holes of AISI 304 stainless steel square profile materials and M8 hole of EN AW-6060 square profile material. **C**racks are observed at M8 holes of both materials**.**



(a)



(b)

Fig. 15. Comparison of the hardness test results of flow drill and conventional drilling (a) AISI 304 stainless steel CHS, (b) EN AW-6060 CHS

Fig. 16. Penetrant test samples

4. Conclusions

In this study, tapped holes were drilled on the thin-walled square and circular profile materials using flow drilling and flow tapping. The method is preferred since the joint is quite weak in thin-walled materials due to the insufficient number of teeth when tapping is made after drilling holes conventionally.

Flow drilling and conventional drilling methods were compared from the points of bushing heights, clamping strengths, hardness values, and capillary crack formations, and the results were specified below.

1. The bushing height differences of the thin-walled square and circular profile AISI 304 stainless steel and EN AW-6060 materials which drilled by conventional drilling and flow drilling in various hole diameters at various rotational speed were compared. The bushing heights of the holes obtained via flow drilling showed an increase of approximately 2-3 times compared to conventional drilled counterparts in both of the materials. The number of the teeth obtained by tapping the drilled part conventionally is 1.5-2 while the number of the teeth in the ones obtained by tapping the flow drilled parts is 5.5-6. It is also foreseen that the joints will be stronger with a high number of teeth.

2. The biggest problems of thin-walled materials are the weakness of their joints. Developed methods to strengthen the joint are costly or their application is too time-consuming. It is clear from the results of the executed tests that joints of flow drilling method are approximately 50-55% higher than the ones of conventional drilling. It is seen from the results of the executed tests that joints of the flow drilling method are approximately 50-55% higher than the ones of conventional drilling. The strength of the joint is higher in small hole diameters. For example, the clamping force at M5 hole drilled on square profile AISI 304 stainless steel by conventional drilling and tapping is 4354.17 N while the clamping force at M5 hole drilled on square profile AISI 304 stainless steel by flow drilling and flow tapping is 7956,04 N. The 82% difference between the two methods shows the suitability of the flow drilling method.

3. The bushing heights and clamping strengths of SHS profiles of both AISI 304 stainless steel and EN AW-6060 materials are slightly higher than CHS profiles. The reason for this that due to the flatness of the square surface, the amount of plastering is higher than the circular surface.

4. Hardness values of metals can vary with sudden heating and cooling. An average of 4% increase in AISI 304 stainless steel material and approximately 12% increase in EN AW-6060 material is observed when flow drilling and conventional drilling methods are compared. An increase in the strength of both materials was observed with the increase in hardness.

5. Capillary cracks were investigated at the edges of the holes with the penetrant test. The reason for this is that if crack formation has started, these cracks then grow and reduce the strength of the materials. Crack formation was not observed in all tests performed in the flow drilling method. In the conventional drilling method, capillary crack formation was observed around the hole of the parts especially when the hole diameter increases.

By considering all these results, flow drilling method is an appropriate operation especially for materials having thin profile. High strength holes are drilled with this method quickly. It is more economical compared to other fasteners such as blind bolt, welding, nut rivet, bonding. It removes the distortion risk by tapping easily after the drilling process.

Although flowdrill tips are 30-40% more expensive than classical drilling tips, their usage time is 25-30 times longer. Flowdrill and flowtap processing time on the same workbench is 3-4 times shorter than the classical method.

In the future studies, drilling process can be made by using dry or special lubricants in the flow drilling method, and the tribological properties of the parts can be investigated. The morphological structure of the coating material and the base part can be observed by making flow drilling operations to coated materials.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

Mert Safak Tunalioglu: Conceptualization, Supervision, Validation.
Mehmet Keser: Conceptualization, Writing-first draft.

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