Journal of Sustainable Construction Materials and Technologies

J. Sustain. Construct. Mater. Technol. 1(2) (2016) 46–56 www.yildiz.dergipark.gov.tr/jscmt

An Experimental Investigation of the Effect of Depth and Diameter of Pre-drilling on Friction Drilling of A7075-T651 Alloy

Zülküf Demir [1,*]

[1]*Faculty of Technology, University of Batman, Batı Raman Campuse, Batman, Turkey*

Received April 4, 2016, accepted May 30, 2016

Abstract

Friction drilling is a non-traditional drilling process, in which specimens are drilled by means of frictional heat, which is obtained from friction effect in between rotating conical tool and workpiece area. The main purpose of current study was to investigate the effect of pre-drilling depth and diameter on the bushing shape, initial deformation and frictional heat in friction drilling of A7075-T651 aluminum alloy, known as a brittle material. Results showed that the effect of pre-drilling depended on the geometrical dimensions of the tip of the tool. The initial deformation was reduced, frictional heat was generated regularly and bushing shape was in the form of cylindrical with less cracks and petal formation in conditions pre-drilling diameter close to the end diameter of the tip of the tool and pre-drilling depths bigger than its length. The highest temperature was recorded at 3000 rpm spindle speed and 40 mm/min feed rate.

Keywords: Friction drilling; Pre-drilling diameter and depth; Initial deformation; Temperature, Bushing shape

1. Introduction

Friction drilling is a non-traditional, thermal, flow, form or friction stir drilling method, in which it has no-chip, no pollution, short machining time, and long tool life [1-4]. In the process, a bushing forms from thin-walled workpiece. The help of bushing increases the thickness of threading and clamp load of thin-walled materials. Cracks and petal formation, which generate a bushing with limited surface area, come into existence in ductile material encompassing the tool, the brittle one begins to fracture during friction drilling processes [2].

The thermal properties of work-materials affect the frictional heating. High thermal conductivity of the workpiece reduces the temperature and ductility for bushing formation. During the friction drilling process, the frictional heat dissipates into the tool, workpiece, and their surroundings [1]. The maximum temperature generated in friction drilling is noticed to be about 1/2 to 2/3 of the work-material melting temperature, thus the melting temperature of the work-material also becomes important. At the elevated temperatures, the plasticity of the work-material has increased while the fracture has decreased. The temperature of the tool and the workpiece is high and the workpiece deformation is very large in friction drilling [2].

As the strain of bushing reaches a critical level, the bushing burst into petals. Petal formation decreases under great ration of the thickness of the workpiece to the hole diameter (t/d). Pre-heating of brittle workpiece causes more cylindricality, less fracture to decrease cracks, petal formation, and radial displacement of bushing. The main reason for the deformation of the workpiece and tool wearing is stress-strain, which occurs during the friction drilling process [2].

* Corresponding author: Tel.: +90-488-217-4023.
E-mail address: zulkuf.demir@batman.edu.tr (Z. Demir)

While the high feed rates cause incomplete melting of the workpiece, the slow feed rates cause internal melting temperature of the material having different cooling speeds. When the feed rates are too slow or too fast, an uneven melting temperature is obtained from friction drilling process. Spindle speed is the most significant parameter, which causes to obtain more heat in friction drilling process [5]. The frictional heat transfer to the tool and the workpiece increases at high spindle speeds, thus the workpiece temperature increases during the process [6]. The contact, due to the effect of friction, which generates frictional heat, increases in between rotating conical tool and workpiece when the spindle speed is increased per unit time, thus the hole area temperature increases. As the shear stress and the friction coefficient, which is in between conical tool and workpiece, drop, the temperature increases [7]. In friction-drilling process, when the number of holes drilled increase, the surface temperature of tool increases as well, and this leads to a high surface roughness of conical tools. The temperature obtained at high spindle speeds reduces the hardness of the cutting tool, which causes to undermine its wear resistance. At high rotation speeds, more frictional heat energy is produced, and melting occurs on large area of both workpiece and tool being heated and hole wall to achieve better roundness. However, the effect of feed rate on the results is less than rotating speed, mentioned above [8].

The deformation of workpiece is very severe at the stage of the tip of tool region proceeding into the workpiece in friction drilling (Miller et al., 2007). Increases in conical angle cause to increase distortions in washer geometry because of extrusion forces act on workpiece by rotating conical tool [9]. Surface delaminating occurs with severe scoring and plastic deformation, which have micro cracking below the deformed layer in friction drilling of Al5052 [10}.

The geometry of friction drilling tool, as called the tip, conical and cylindrical regions, affects the hole inner diameter, bushing shape, and cylindricality of the hole [11]. High tool conical angles cause the pressure in a narrower area between rotating conical tool and workpiece. Thus, the workpiece is to be drilled swiftly and the contact, which is in between tool and workpiece, decreases during the operation. However, it has not a significant effect on the results of friction drilling such as temperature, bushing shape, surface roughness, and cylindricality of the friction-drilled hole [12].

Pre-drilling eliminates the initial deformation and provides an appropriate melting temperature, in contrast to in pre-drilling friction drilling; there is a friction heat deficiency. With choosing higher spindle speeds, the deficiency of heat can be compensated [13].

The main purpose of this experimental study was to investigate the effect of both the depth and diameter of traditionally pre-drilling on the frictional heat, bushing shape, and the initial deformation in friction drilling of A7075-t651 aluminum alloy, which can be classify as a brittle material. The specimens were prepared traditionally pre-drilled with HSS (High Speed Steel) drills in diameters of 1.5, 2, 2.5, 3, 3.5 and 4 mm and in depths of 1, 2, 3 and 4mm.In addition, the experiments applied to the specimens, which were not pre-drilled. During the operations, the temperature of the workpiece, which was friction drilled at 8 and 10 mm in diameter, was measured by using two different kinds of thermocouples. The thermocouples were inserted into the workpiece, on both sides, which were 8 mm (right side) and 9 mm (left side) mm away from the centre of the friction-drilled hole of 8 mm in diameter. On the other hand, they were inserted into the workpiece, on both sides, which were 9mm (right side) and 10mm (left side) for the workpiece with a friction-drilled hole of 10 mm in diameter.

2. Materials and Methods

HESSAP True-Trace C-360 3D 1095 Model Copy milling machine was used for the friction drilling, in which the specimens were without pre-drilling and traditionally pre-drilled 1.5, 2, 2.5, 3, 3.5, and 4 mm in diameters, and 1, 2, 3, and 4 mm in depths. Spindle speeds of 1800, 2400, and 3000 rpm, and feed rates of 40, 60, and 80 mm/min were as operating conditions due to choose. The experimental set up is shown in Fig. 1. The A7075-T651 aluminum alloy specimens, which were 6 mm in thickness, were prepared in size of 70x500 mm, were used in experimental study having a composition of 0.08 % Si, 0.28 % Fe, 1.67 % Cu, 0.61 % Mn, 2.37 % Mg, 0.19 % Cr, 5.76 % Zn, 0.036 % Ti, balance (89.004) Al by weight.

The rotating conical tool was manufactured from HSS with the following dimensional characteristics 8 and 10 mm in diameters (d), 36º conical angle (ß), and 16 mm cylindrical region length (hl). The pictures of the tools, which were 8 mm in diameter is seen in Fig. 2 (a) and 10 mm in diameter in Fig. 2 (b), additionally, their geometrical dimensions are seen in Fig. 2 (c). The length of the tip of the tool, which was 8 mm in diameter, was 1.40 mm and the other tool, which was 10 mm in diameter, was 1.75 mm in length of the tip.

Figure 1– Experimental set up.

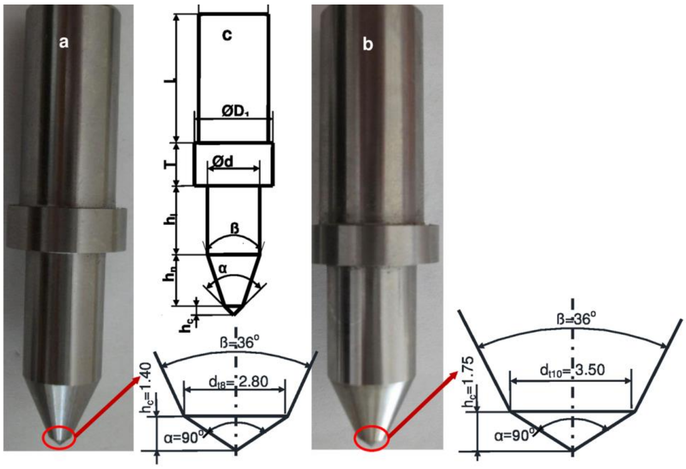


Figure 2–Geometrical dimensions of conical tools and their tips, a) the tool 8 mm in diameter, b) the tool 10 mm in diameter, c) geometrical dimensions of friction-drilling tools.

During the experimental study, the frictional heat was measured by using two different kinds of thermocouples. The thermocouples were inserted into the workpiece as shown in Fig. 3 (a, b).

Before applying friction drilling to specimens, they were pre-drilled at four different depths and six different diameters as seen in Fig. 4 (a, b), Fig.4 (a) as indicated 8 mm and Fig. 4 (b) 10 mm in diameters friction drilled holes. The pre-drilling depths were symbolized as t_0=0, t_1=1, t_2=2, t_3=3, and t_4=4 mm, while the diameters were d_0=0, d_1=1.5, d_2=2, d_3=2.5, d_4=3, d_5=3.5, and d_6=4 mm. The contact area, represented with surrounding by green lines, in between the tip of tool and workpiece, causes initial deformation, as shown in Fig.4 (a, b). The depths and diameters are shown in Fig. 4 (a), which are less than 1.40 mm in depths and 2.8 mm in diameters for 8 mm in diameter friction drilled holes, while in Fig. 4 (b) they are exhibited less than 1.75 in depths and 3 mm in diameters for 10 mm in diameter friction drilled holes.

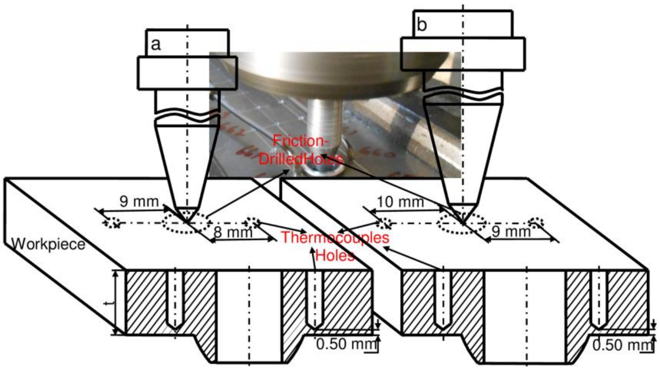


Figure 3–The thermocouples set up a) for 8 mm in diameter friction-drilled hole, b) 10mm in diameter friction-drilled hole.

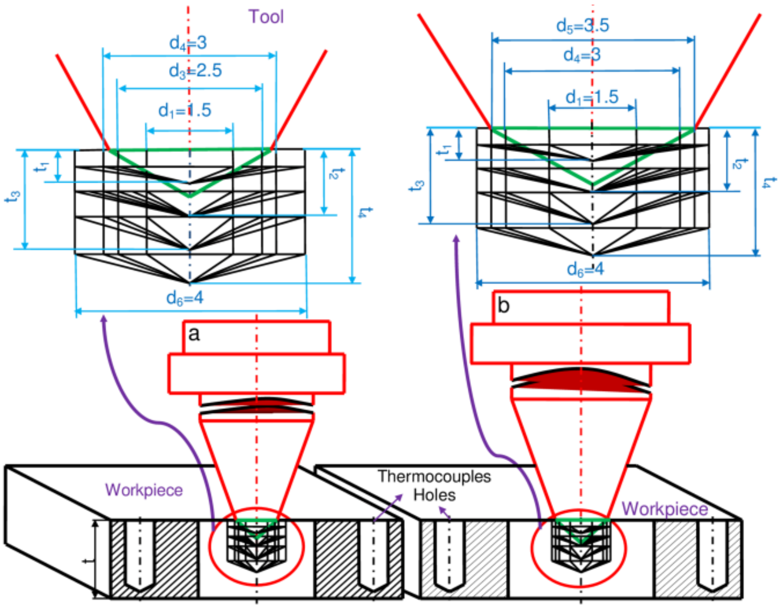


Figure 4–The depths and the diameters of pre-drilling a) for 8 mm in diameter and b) for 10 mm in diameter friction-drilled holes.

3. Results and Discussion

3.1 The effect of pre-drilling depths and diameters on the initial deformation

In friction drilling, the initial deformation is vitally important to affect the results of the process such as bushing shape and temperature. Therefore, in order to investigate the effect of pre-drilling depth and diameter on the bushing shape and frictional heat, at the beginning stage, the pictures of friction drilling process were captured in the first four seconds duration. The effects of pre-drilling depths and diameters on the initial deformation, in conditions at different spindle speeds and feed rates, are shown in Fig. 5 and 6, indicating 8 mm and 10 mm in diameters friction drilled holes, respectively.

Friction drilling operations were carried out by using tools, which were manufactured from HSS 8 mm and 10 mm in diameters, additionally, with 1.40 mm and1.75 mm lengths and 2.80 mm and 3.50 mm end diameters of the tips of the tips, as shown in Fig. 4 (a) and (b), respectively. According to the pictures, which were captured in 4 seconds from the time as soon as the tip of the tool touched to the workpiece surface (see Fig. 5 and 6), the initial deformation decreased as the length and end diameter of the tip of the tool was closer to the pre-drilling depths and diameters. No sooner had the tip of the tool contacted on the surface of the workpiece, than deformation started and material moved off from the sample in the case of without pre-drilling (d0=0, t0=0) friction drilling. The severity of the deformation continued until the amount of frictional heat, which was generated, by the contacting effect between tool and workpiece, reached to about 1/2 to 2/3 of the work-material melting temperature. After the amount of frictional heat reached to the melting level, mentioned above, the process temperature was started generating regularly, however, with generating regular frictional heat, the severity of the deformation decreased. By the effect of deformation and moment of rotating conical tool, the material, which was broken from the specimen, was surrounded around the tip of the tool, as seen in Fig. 5 and 6. However, in case of pre-drilling, the contacting the tip of the tool on the workpiece started at the depths (1, 2, 3 and 4 mm) of pre-drilled and when the peripheral diameter of the tip of the tool was equal to the pre-drilled diameters (1.5, 2, 2.5, 3, 3.5 and 4 mm). As seen in Fig. 5 and 6,the effect of initial deformation decreased with less cracks, decelerations and petal formation, in case of specimens, were pre-drilled higher than 1.40 mm and 1.75 mm in depths and 2.5 – 3 mm and 3.5 mm in diameters for 8 mm and 10 mm in diameters friction drilled holes, respectively. However, the number of the cracks and decelerations increased with increasing both spindle speed and feed rate, which created momentum and driving force, in turn. In conditions specimens were pre-drilled higher than 3 mm and 3.5 mm in diameters for 8 mm and 10 mm in diameters friction drilled holes, respectively, deformation was started at the depth where the pre-drilling diameter was equal to the peripheral diameter of the tip of the tool. In case of the specimens were pre-drilled at 3.5 mm and 4 mm in diameters for 8 mm and 4 mm in diameter for 10 mm in diameters friction drilled holes, respectively, and at depths higher than 2 mm, cracks and petal formation generated on bushing shape and washer, because of insufficient soften and flown material. Nevertheless, in case of pre-drilling diameters were smaller than 2.80 mm and 3.50 mm for 8 mm and 10 mm in diameters friction drilled holes, respectively, as soon as the tip of the tool touch to the workpiece, with the effect of impacting, the severity of deformation increased depending on magnitude of spindle speed and feed rate. At the beginning stage of friction drilling, because the softening and flowing of the material did not start, the generation of cracks, decelerations and petal formation increased on the washer, which came into existence from the material flown upward.

The material, which flowed upward to shape the washer, was increased with increasing the diameter of friction-drilled holes. As seen in Fig.6, the volume of material, which flowed upward, in 4 seconds from the time the tip of the tool contacting on the workpiece, increased in friction drilling of 10 mm in diameter, because of increasing peripheral size of the drilled hole. At the constant material thickness (6 mm), with increasing the diameter of friction-drilled holes, because of insufficient material, which shaped the washer and bushing, cracks, decelerations and petal formation increased. Additionally, the number of cracks increased with increasing spindle speed and feed rate, with the effects of momentum and driving force, respectively. Therefore, in order to drill large diameter holes, great material thicknesses should be selected in friction drilling operations.

Consequently, the pictures in Fig. 5 and 6 showed that, pre-drilling provided a soften transition between the tip and conical regions of the tool, during its proceeding into the workpiece. As pre-drilling diameter was close to the end diameter of the tip and pre-drilling depth was higher than the length of the tip (hc), the initial deformation decreased in pre-drilling friction drilling of A7075-T651 aluminum alloy.

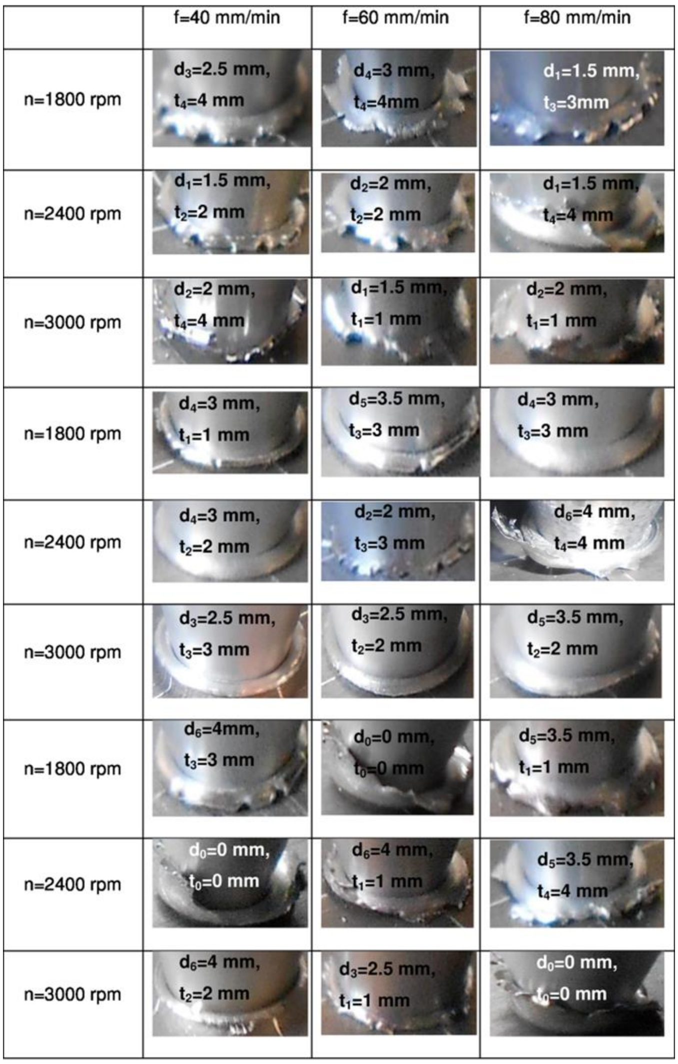


Figure 5–The effect of initial deformation (in the first four seconds) for 8 mm in diameter friction drilled holes.

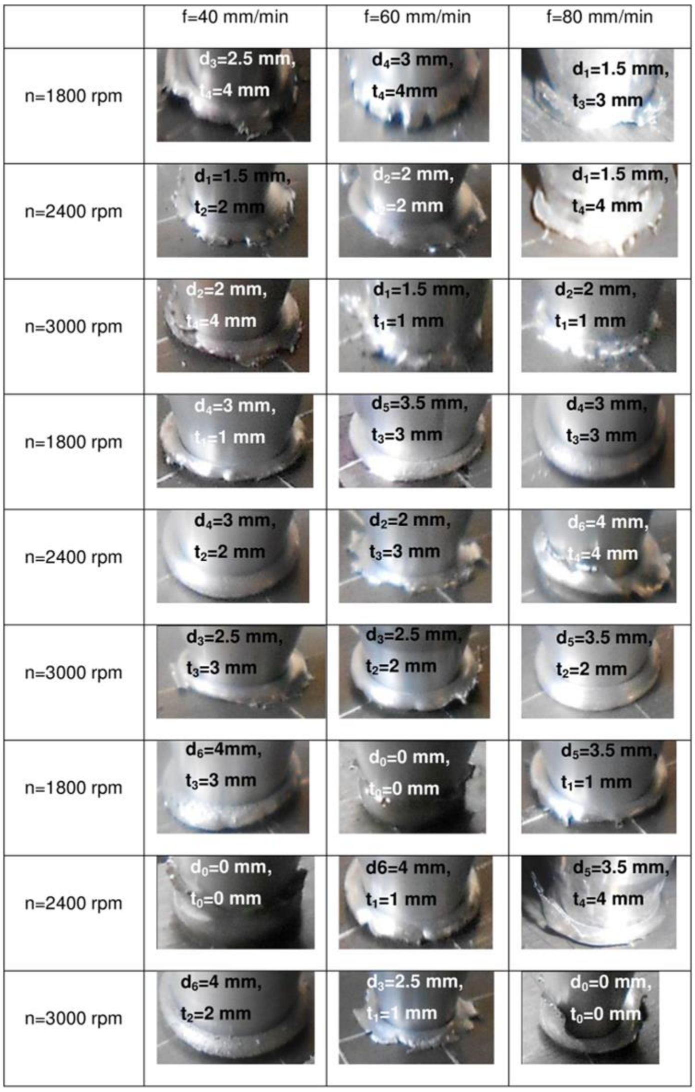


Figure 6–The effect of initial deformation (in the first four seconds) for 10 mm in diameter friction drilled holes.

3.2. The effect of pre-drilling depths and diameters on the bushing shapes

Friction drilling is a non-traditional drilling method, which can be applied to sheet cast material, on the purpose of increasing threading height and clamp load, in case of connecting two or more parts, by virtue of bushing shape underside of the material, thus, the bushing shape has a vital importance in the process. In the bushing shape, cracks and petal formation come into existence in friction drilling of brittle materials, while ductile materials are more appropriate than brittle ones to obtain cylindrical bushing shape with less or without cracks and petal formation. On the purpose of achieving cylindrical bushing, shapes with less or without cracks and petal formation, in friction drilling of A7075-T651 alloy, which is known as a brittle material, specimens were traditionally pre-drilled at the stage of preparation. The effect of pre-drilling depths and diameters on the bushing shapes is shown in Fig. 7 and 8, for 8 mm and 10 mm in diameters, friction drilled holes, respectively, at different spindle speeds and feed rates.

As the length and diameter of the tip of the tool was close to pre-drilling depths and diameters, as seen in Fig. 7 and 8, the bushing shape improved in cylindrical form with less cracks and petal formation. Because of the initial deformation, the length of cracks on the bushing shapes increased in friction drilling, in which specimens were not pre-drilled. According to the pictures of bushings in Fig 7 and 8, when the depths of pre-drilling were higher than 1.40 mm and 1.75 mm, the diameters of pre-drilling were 2.5-3 mm and 3.5 mm for 8 mm and 10 mm in diameters friction drilled holes, respectively, the bushing shapes were consisted of cylindrical form with less cracks and petal formation.

The cracks and deceleration in bushing shapes increased with increasing both spindle speed and feed rate.

However, in conditions specimens pre-drilled at 3.5 and 4 mm in diameters for 8 mm and 4 mm for 10 mm in diameters friction drilled holes, even at low spindle speeds and feed rates, bushing shapes distorted, in which cracks and petal formations occurred, because of insufficient softened and flowed material. Because either pre-drilling eliminated or reduced the deformation, which came into effect during the tool progressing into the workpiece, the bushing shape came into existence cylindrically and with less or without cracks and petal formation. Throughout the friction-drilling operation from the time the tip of the tool contacted to the workpiece until the bushing shape was completed, there were deformation effect, which caused cracks and deceleration in the bushing shape. Thus, even in pre-drilling at 2.5 – 3 mm for 8 mm and 3.5 mm for 10 mm in diameters, at depths higher than 1 mm, there were petal formations at the tip of the circle of bushing. As in pre-drilling friction drilling processes, when the tip of the tool passed the end of the pre-drilled hole, the tool feed and rotating motions caused even a slight deformation effect. The roundness of the bushing increases with less or without cracks and petal formation, because of the effect of the deformation is eliminated or decreased in case of the specimens are pre-drilled throughout the thickness (Demir and Ozek, 2014).

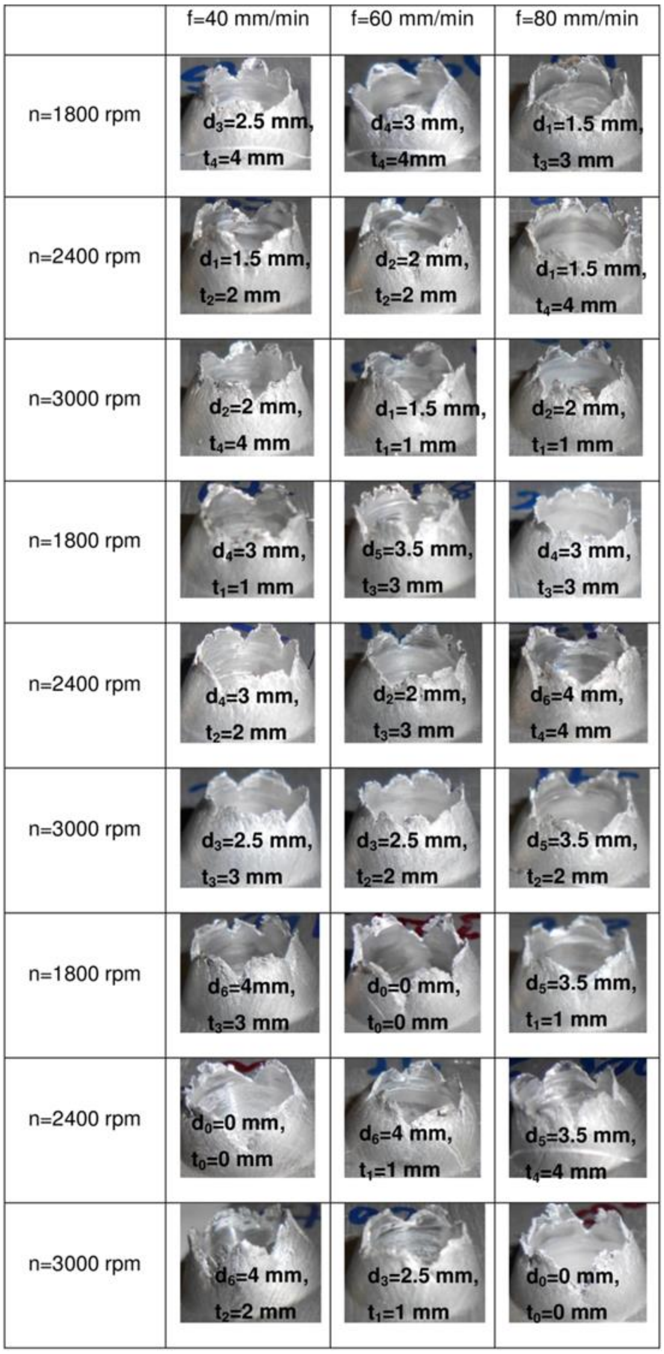


Figure 7–The bushing shapes in pre-drilling friction drilling of 8 mm in diameter.

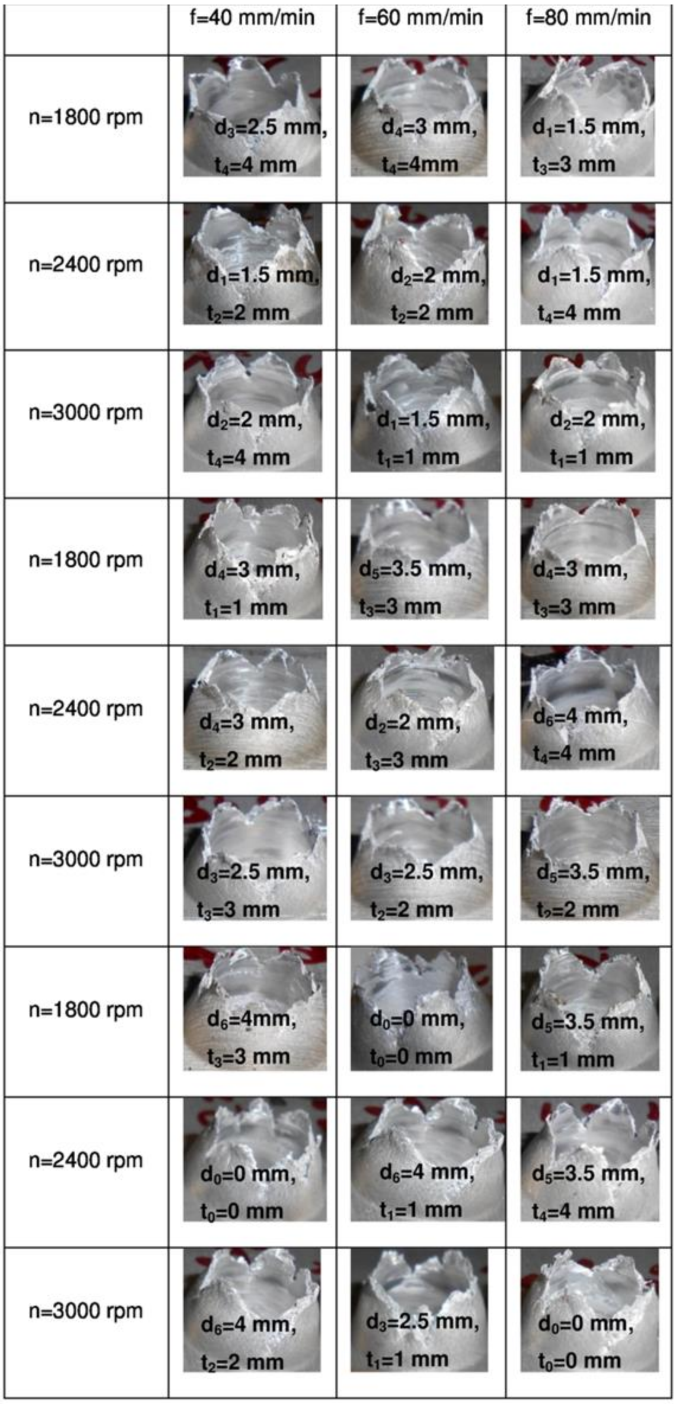


Figure 8– The bushing shapes in pre-drilling friction drilling of 10 mm in diameter.

3.3. The effect of pre-drilling depths and diameters on temperature

Friction drilling comes true by virtue of temperature, which is generated in area between tool and workpiece by the effect of friction. Frictional heat has a vital importance in friction drilling to provide melting and softening the specimens to flow. In the process, when the temperature is generated regularly, the bushing shapes occur in the form of cylindrical with less cracks and decelerations. The effect of pre-drilling depths and diameters on temperature is shown in Fig.9 for 8 mm (at left diagrams) and 10 mm (at right diagrams) in diameters pre-drilled friction drilling holes, respectively. The temperature, in case of without pre-drilled friction drilling for 8 mm and 10 mm in diameters, is shown in Fig10.

The tools were used in this experimental study, had 2.80 mm and 3.50 mm end diameters of the tips of the tools for 8 mm and 10 mm in diameters pre-drilled friction-drilling holes, respectively. Therefore the highest temperature recorded in friction drilling of specimens, which were pre-drilled deeper than 1 mm in depths, 2.5 mm and 3 mm in diameter pre-drilled for 8 mm (Fig. 9 at left diagrams) and 3 mm and 3.5 mm in diameter pre-drilled for 10 mm (Fig. 9 at rights diagrams) friction drilled holes, respectively. In pre-drilled friction drilling operations, applied to A7075-T651 alloy, it was investigated that 2 mm and bigger pre-drilling depths were appropriate. As these values were higher than 1.40 mm and 1.75 mm, which were the lengths of the tips of the tools 8 mm and 10 mm in diameters, respectively, the process temperature was decreased due to the deficient of material and the effect of friction, caused to obtain frictional heat. The highest temperature was achieved in friction drilling specimens, which were pre-drilled 2.5 – 3 mm for 8 mm and 3 – 3.5 mm for 10 mm in diameters friction drilling diameters, as these pre-drilling values equal or close to the end diameter of the tip of the tools. Small pre-drilling diameters, as 2.5 mm for 8 mm (Fig. 9 (a)) and 3 mm for 10 mm in diameters friction drilling holes, were appropriate, at 1800 rpm spindle speed, according to the temperature criterion. However, the highest temperature values were recorded at 2400 and 3000 rpm spindle speeds in friction drilling of specimens were pre-drilled 3 mm (Fig. 8 (b, c, and d)) and 3.5 mm (Fig. 9 (b, c, and d)) in diameters for 8 mm and 10 mm in diameters friction drilled holes, respectively. In case of the diameters of pre-drilling were higher than 3 mm for 8 mm and 3.5 mm for 10 mm in diameters friction drilled holes, because of insufficient contact area between tool and workpiece, there were deficient of friction and thus the process temperature decreased. As the pre-drilling depth was bigger than 1.40 mm and at the same time, it got closer to this value, the initial deformation decreased and the process temperature was generated regularly.

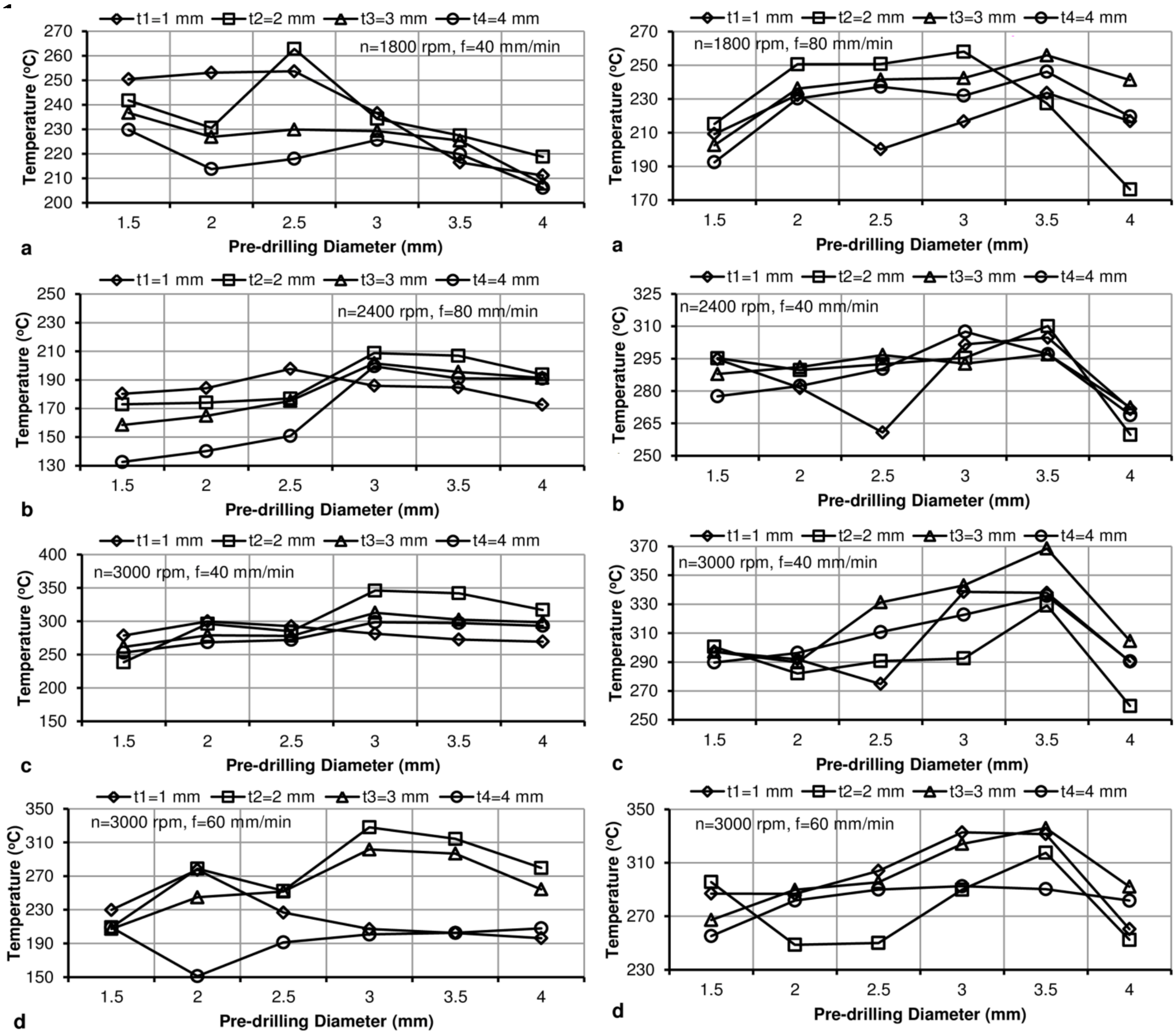


Figure 9–The effect of pre-drilling depths and diameters on temperature, 8 mm in diameter (at left a, b, c, d diagrams), 10 mm in diameter (at right a, b, c, d diagrams), friction drilled holes.

As high spindle speeds provided more friction in contact area between tool and workpiece, because of numerous cycle of tool in per unit of feed rate, the process temperature was high. As seen in Fig. 9 with increasing the diameter of the tool, the process temperature increased, as the contact area in between tool and workpiece increased and hence the maximum temperature was obtained from 10 mm in diameter friction drilled holes. Additionally, the temperature increased as spindle speed increased and feed rate decreased, therefore, the highest temperature values were recorded at 3000 rpm spindle speed and 40 mm/min feed rate as 346.1 ^{o}C (Fig. 9 (c)) and 368.5 ^{o}C (Fig. 9 (c)) in pre-drilling friction drilling of 8 mm and 10 mm in diameters holes, in turn. However, in friction drilling, in which specimens were pre-drilled 1 mm in depths and in diameters smaller than 2.5 mm and 3 mm for 8 mm and 10 mm in diameters friction drilled holes, respectively. Because of initial deformation effect, the process temperature decreased.

In friction drilling, in which specimens were not pre-drilled the process temperature increased regularly with increasing spindle speeds and decreasing feed rates as seen in Fig. 10. Naturally, the highest temperature values were recorded at 3000 rpm spindle speed and 40 mm/min feed rates, as 286.3 ^{o}C and 298.2 ^{o}C for both 8 mm and 10 mm in friction drilled holes, respectively. Because of the effect of deformation, the temperature values were smaller than, that of recorded in pre-drilling friction drilling.

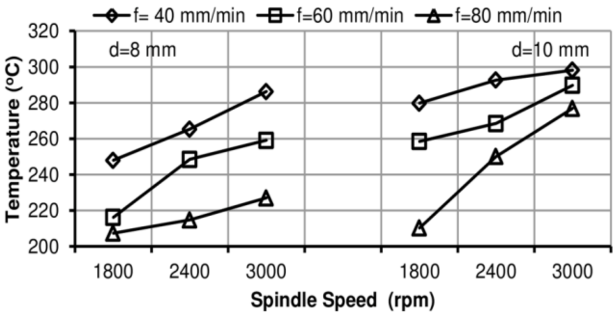


Figure 10–The temperature values in without pre-drilled friction drilling of 10 mm in diameter.

4. Conclusions

Brittle materials, such as A7075-T651 alloys, are not appropriate to achieve bushing shape in the form of cylindrical with less or without cracks in friction drilling. With the intention of improving bushing shape in friction drilling of A70759T651 alloy specimens, they were pre-drilled at four different depths and in six different diameters. Results showed that that pre-drilling diameters and depths had a vital correlation with the end diameter and length of the tip of the tool. In case of specimens were pre-drilled 2.5 – 3 mm and 3 – 3.5 mm in diameters for 8 mm and 10 mm in diameter friction drilled holes, in turn, the initial deformation was eliminated or decreased substantially and the process temperature was generated regularly. As the pre-drilling values were close to the geometrical dimensions of the tip of the tool, the highest temperature was recorded in pre-drilling friction drilling, in which specimens were pre-drilled 2 mm or higher in depths, 2.5 mm and 3 mm in diameters for 8 mm, 3 mm and 3.5 mm in diameters for 10 mm in diameter friction drilled holes.

According to the criterion of the temperature, the compliance of pre-drilling diameter changed depending on spindle speed. At 1800 rpm spindle speed, 2.5 mm and 3 mm pre-drilling diameters for 8 mm and 10 mm in diameters friction drilled holes, respectively, were appropriate, while, at 2400 rpm and 3000 rpm spindle speeds, 3 mm and 3.5 mm pre-drilling diameters for 8 mm and 10 mm in diameters friction drilled holes were appropriate, respectively. The highest temperature values were recorded at 3000 rpm spindle speed and 40 mm/min feed rate, as 346.1 ^{o}C and 368,5 ^{o}C, in conditions specimens were pre-drilled at depth bigger than 2 mm and 3 mm and 3.5 mm in diameters for 8 mm and 10 mm in diameters friction drilled holes, respectively.

Despite of melting temperature, generated in contact area to cause the workpiece soften and flow, there were even smaller amount of deformation effect. Although pre-drilling depths and diameters provided decreasing or eliminating deformation, this small amount of deformation was active, until the bushing shape was completed and it caused to form small cracks and petal formation on the tip of the bushing. Therefore, on the purpose of achieving bushing shape in form of cylindrical, with less cracks and petal formation, it was recommended that specimens must be pre-drilled throughout the thickness of the material in friction drilling of brittle materials such as A7075-T651 alloy. In friction drilling of brittle materials, pre-drilling must be implement in two stages. At the first stage, specimens must be drilled throughout the thickness in small diameters such as 0.5, 0.75, 1, 1.5, etc. At the second stage: the upper side of the drilled hole must be drilled in depth size, equal to the length of the tip of the tool, and in diameter, equal to the end diameter of the tip of the tool.

References

[1] Miller, S, F.; Blau, J.; Shih, A, J.; Microstructural alteration associated with friction drilling of steel, aluminium, and titanium. J. Mater. Eng. and Perform., (14) (2005) 647-653.

[2] Miller, S, F.; Tao, J.; Shih, A,J.; Friction drilling of cast metals. Int. J. Mach. Tools & Manuf., (46) (2006) 1526-1535.

[3] Van Geffen, J.A.; Piercing Tools. US Patent 3,939,683. (1976)

[4] Van Geffen, J.A.; Method and apparatuses for forming by frictional feat and pressure holes surrounded each by a boss in a metal plate or the wall of a metal tube. US Patent 4,175,413. (1979)

[5] Chow, H.M.; Lee, S.M; Young, L.D.; Machining characteristic study of friction drilling on AISI 304 stainless steel. J. Mater. Proc. Technol., (207) (2008) 180-186.

[6] Boopathi, M.; Shankar, S.; Manikandarkumar, S.; Ramesh, R.; Experimental investigation of friction drilling on brass, aluminum and stainless steel. Procedia Eng., (64) (2013) 1219-1226.

[7] Ozler, L.; Doğru, N.; An experimental investigation of hole geometry in friction drilling. Mater. and Manuf. Proc., (28) (2013) 470-475.

[8] Lee, S, M.; Chow, H, M.; Huang, F,Y.; Yan, B, H.; Friction drilling of austenitic stainless steel by uncoated an PVD AlCrN- and TiAlN- coated tungsten carbide tools. Int. J. Mach. Tools & Manuf., (49) (2009) 81-88.

[9] Miller, S, F.; Blau, P,.J.; Shih, A,J.; Tool wear in friction drilling. Int. J. Mach. Tools & Manuf., (47) (2007)1636-1645.

[10] Miller, S, F.; Shih, A, J.; Thermo-mechanical finite element modelling of the friction drilling process. J. Manuf. Sci. and Eng., by ASME, (129) (2007) 531-538.

[11] Miller, S, .F.; Wang, H.; Li, R.; Shih, A,J.; Experimental and numerical analysis of the friction drilling process. ASME J. Manuf. Sci. and Eng., (128) (2008), 802-810.

[12] Kaya, M,T.; Aktas, A.; Beylergil, B.; Akyildiz, H,K.; An experimental study on friction drilling of st12 steel. Transact. Can. Soc. for Mech. Eng., (38) (2014) 319-329

[13] Demir, Z.; Ozek, C.; Investigate the effect of pre-drilling in friction drilling of A7075-T651. Mater. and Manuf. Proc., (29) (2014) 593-599.

Journal of Sustainable Construction Materials and Technologies

J. Sustain. Construct. Mater. Technol. 1(2) (2016) 57–59 www.yildiz.dergipark.gov.tr/jscmt

Analysis of safe distance of flue from combustible construction parts in terms of fire safety in the European standards

Ing. Zuzana Lišková [1, a], doc. Ing. Juraj Olbřímek, PhD.[1, b, *]

[1] *STU – Stavebná fakulta, Radlinského 11, 810 05 Bratislava, Slovak republic*
[a]zuzana.liskova@stuba.sk, [b]juraj.olbrimek@stuba.sk

Received January 8, 2016, accepted March 20, 2016

Abstract

This topic is very actual due to the high number of chimney and flue fires, including radiators especially during the heating season. The aim of the article is to compare and assess the strictness of the regulations in selected European countries in terms of safe separation distance of the flue from the combustible construction parts.

Keywords: flue, combustible construction parts, fire safety, safe distance

1. Introduction

Technical development of the design of chimneys and flues was influenced by the needs of saving energy and environmental protection [1]. At present, many people returned to solid fuel heating appliances because they more and more realize the fuel efficiency and the related costs. This change brings risks, especially in the case of leaving the original flue that does not meet the requirements of the newly installed appliance.

Flues and chimneys are designed to withstand the chimney fire, which occurs during the burn out of soot. The manufacturer prescribe the fire resistance of chimney or flue in product documentation. It also provide the information about the safe separation distance from combustible products determined by examination. However, the old and historic chimneys and flues do not have determined it.

The chimney fires are one of the most common causes of fires in ressidential buildings and it can cause great damage to property, health, or even lifes. The causes of fire include burn of soot, the flue wear (failure of the compactibility), immured rafter in the chimney, inadequate separation distances from the combustible products (ceilings, floors, walls, furniture ...) improper installation or poorly maintained chimney and other failures [2].

Creosote (a mixture of soot, ash and tar) settles in the chimney by using the appliance during operating life. Burn of soot is the most common cause of all fires caused by radiators, chimneys and flues. The chimney fire occurs by ignition of flammable creosote - unburned fuel residues settled on an internal surface of chimney, which are formed by thermal decomposition of hydrocarbon compounds.

2. Safe Separation Distance from Combustible Building Products

2.1 General Requirements in Slovakia.

Flue pipes and chimneys may be installed in the direct contact (the maximum temperature rise of 52 ° C, or temperature class T80) or in the safe separation distance from combustible structures with the fire classification B, C, D, E or F [3]. The fire classification F include materials with unspecified reaction to fire. The use of the

* Corresponding author. Tel: +421 (2) 59 274 450
E-mail address: azuzana.liskova@stuba.sk (Z. Lišková)

products with this reaction to fire is limited in some European countries and there is a proposal for the abolition of this class.

In *Decree of the Ministry of the Interior of the Slovak Republic No. 401/2007 Coll. on technical conditions and requirements for fire safety during installation and operation of fuel appliances, electric thermal appliances and central heating appliances and during construction and use of chimneys and smoke-ducts and on cleaning and inspection intervals* is indicated, that the safe separation distance prescribe the manufacturer according to *STN EN 1443 Chimneys – General Requirements* [3].

The manufacturer prescribe the safe separation distance based on the fire resistance from the inside resulting from the operating conditions as well as from the inside under the terms of burnout of soot.

This safe separation distance shall be verified according to STN EN 13216-1 or according to an appropriate standard by material. The maximum surface temperature of combustible products can not exceed 100 °C (under the terms of burnout of soot) or 85 °C (at the operating conditions) with the ambient temperature of 20 °C [1].

If the safety distance is not prescribed in the documentation by the manufacturer, may be determined according to Annex in *Decree of Ministry of Interior of the Slovak Republic No. 401/2007 Coll.*

2.2 Safe Separation Distance According to Temperature Class of Appliances

The minimum clearance is not required for the temperature class T80, for the maximum surface temperature rise of 52 ° C or for the plastic flue pipes [3, 5]. According to the German standard DIN 18 160-1 is permissible direct contact to the flue gas temperature of 85 °C [4]. In the French standard NF DTU 24.1 P1 is for the metal chimney flue pipe with the temperature class of T80 prescribed safe separation distance of 20 mm. For the temperature class T100-T160 it is 40 mm [6]. This is more benevolent compared with 50 mm in *Decree of Ministry of Interior of the Slovak Republic No. 401/2007 Coll* or 50 mm in standard DIN 18 160-1.

There is prescribed minimum separation distance from combustible materials for flue pipes with temperature class above or equal T200. It is the distance of three times the nominal diameter of flue pipe, but minimum 375 mm for Slovakia and French or 200 mm for United Kingdom of Great Britain and Northern Ireland [7-10]. For the class T300 is in Slovakia determined the minimum heat resistance 0,22 m^2.K/W [5].

The requirement of DIN 18 160-1 at the 400 mm distance for the flue pipes with temperature class up to T400 is stricker than requirement for the distance of three times the nominal diameter in Slovak regulations only up to the flue pipe diameter 135 mm. For insulated flue pipes is 100 mm distance allowable. In the Slovak standard STN EN 15287-1 +A1 is except 20 mm thickness of the insulation defined even a thermal conductivity of 0,04 W/(m.K) [4, 5]. If the manufacturer specifies a different distance, important is that which is indicated in the documentation of the appliance [5].

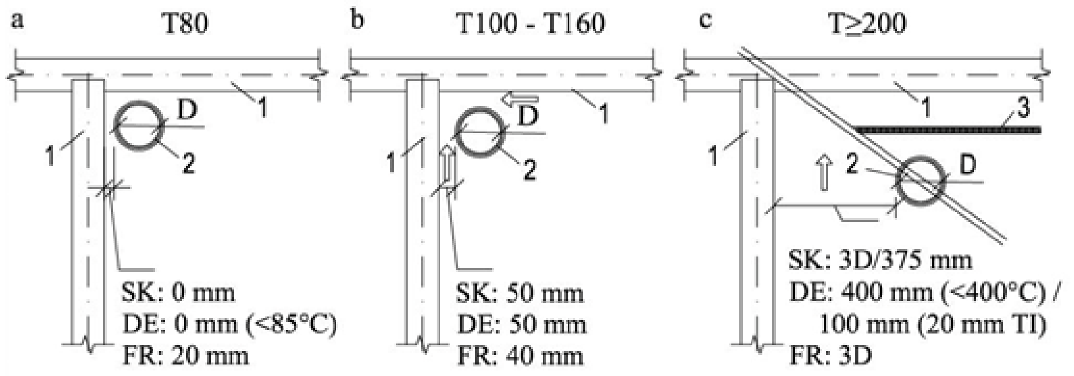


Figure 1. Safe Separation Distances according to Temperature Class, (a) Condensing Appliances; (b) Low-Temperature Flue Gas Appliances; (b) High-Temperature Flue Gas Appliances; 1 – wooden beams; 2 - flue; 3 – non-combustible shield

2.3 Minimum Allowable Distance

In *Decree of Ministry of Interior of the Slovak Republic No. 401/2007 Coll* is generally determined 50 mm as the safe separation distance or 10 mm for the insulated gap. In an appendix of this Decree is specified separation distance depending on the connected appliance, which means 800 mm for solid fuel appliances [3].

In DIN 18160-1 is requirement for safe separation distance in insulated gap more stricter, because there is allowable 20 mm gap filled with low thermal conductivity insulation [4].

Separation distance can be reduced to 1,5 times the diameter of the flue pipe if there is used protection made from non-combustible material between the flue and combustible construction products. In STN EN 15287-1 is it limited by the value of 200 mm [5]. In the regulations of United Kingdom of Great Britain and Northern Ireland is even prescribed the minimum distance of the protection from protected structures 12,5 mm [7, 9, 10].

Figure 2. Flue pipe after fire

3. Summary

According to statistics of Ministry of Interior of the Slovak Republic are the chimneys and flue pipes still one of the most frequent causes of fire. To reduce the risk of fire because of the flue is necessary to correctly determine the temperature class of connected appliance and to prescribe the safe separation distance of flue from combustible construction parts. The article points out on the differences in the regulations and the need to abolish shortage.

References

[1] STN EN 1443: Komíny. Všeobecné požiadavky

[2] Information on http://www.minv.sk/?hasici-zachranari

[3] Vyhláška MV SR č. 401/2007 Z.z. o technických podmienkach a požiadavkách na protipožiarnu bezpečnosť pri inštalácii a prevádzkovaní palivového spotrebiča, elektrotepelného spotrebiča a zariadenia ústredného vykurovania a pri výstavbe a používaní komína a dymovodu a o lehotách ich čistenia a vykonávania kontrol

[4] DIN 18 160-1 Abgasanlagen – Planung und Ausführung, ERLUS. [online] [cit. 11-6-2015]. <http://www.erlus.de/downloads/2/141/650/1-5559/erlus_din_18160.pdf>

[5] STN EN 15287-1 +A1: Komíny. Navrhovanie, montáž a prevádzkovanie komínov. Časť 1: Komíny pre otvorené spotrebiče palív

[6] AFNOR. ceramique.com. [online] 13.3.2006. [cit. 11-6-2015]. <https://www.google.sk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&ved=0CEIQFjAEahUKEwjCy9GryIjGAhUBFRQKHbENAJA&url=https%3A%2F%2Fwww.ceramique.com%2Fforum%2Fposts%2FdownloadAttach%2F516.page&ei=8_p5VYKGGIGqULGbgIAJ&usg=AFQjCNHom_B23yvBE_XQPvbmv3v_0oR4OQ&sig2.>

[7] LABC. Guide to installing solid fuel stoves. Technical guidance for homeowners and trade. carlisle.gov.uk. [online] [cit. 11-6-2015]. <http://www.carlisle.gov.uk/downloads/Guide_to_installing_solid_fuel_stoves.pdf>

[8] Topstak. Regulations. [online] [cit. 11-6-2015]. <http://www.topstak.co.uk/regulations-1/#backtotop>

[9] Building Regulations 1997. Technical Guidance Document J. Heat Producing Appliances. environ.ie. [online] 2005. [cit. 11-6-2015]. <http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,1650,en.pdf>

[10] Combustion appliances – relationship to combustible materials. gov.scot. [online] [cit. 11-6-2015]. <http://www.gov.scot/resource/buildingstandards/2013NonDomestic/chunks/ch04s20.html>

Journal of Sustainable Construction Materials and Technologies

Journal of Sustainable
Construction Materials
and Technologies

J. Sustain. Construct. Mater. Technol. 1(2) (2016) 60–63 www.yildiz.dergipark.gov.tr/jscmt

Roof Surface Color and Its Influence on Indoor Temperature

Jana Šabíková[1, a,] * Lucia Krčmárová [1, b]

[1]*STU, Civil Engineering Faculty, dept. of Building Services, Radlinského 11, 810 05 Bratislava, Slovakia*
[a]*jana.sabikova@stuba.sk*, [b]*lucia.krcmarova@gmail.com*

Received January 8, 2016, accepted March 20, 2016

Abstract

The paper presents results of simplified small-scale modelling of three buildings with different roof colour - covering. The aim of the measurement is to compare the influence of different roof covering (material, colour) onto the indoor temperature. The models are very simplified, used only to compare results among themselves, especially heat gains via conduction, and not between models and the real buildings under real conditions.

Keywords: solar gains, colour, model

1. Introduction

The energy saving nowadays plays an important role as has already been for many years. There are already known ways how to come to such a solution. One of the them considers savings during summer (hot weather) due to neccesity to cool down buildings. Therefore it is very important to considere this aspect already during the building design phase. Utilization of *passive cooling* offers, for instance, proper orientation towards Cardinal points, shadings, proper glassing, and many other tools, including colour. The colour „counts" in the calculation of cooling load, as external solar gain through non-ransparent structures. The simplified caculation method is given, for instance, in Slovak standard STN 73 05 48:1986 [1]. The amout of transphered gains into interior is influenced not only by the solar intensity but also the colour via, „ε" factor. For instance, for aluminium it is 0,4 whereas 0,9 goes to red brick [2]. How high the impact could be in reality, was the targit for a small-scale experiment presented further which was done as a of diploma work [3].

The theme of modelling effect of colour on interior temperature is not the latest idea. It has been done, for instance, by Givoni [4] 40 years ago with the result the low heat capacity envelope is more dependant on curface colour than high capacity ones. The experiment also resulted in the fact that in such a case indoor air temeprature is influenced by ventilation and direct solar radiation. Later, Bansal [5] came with results of modelling and simmulation of the colour effect on indoor thermal comfort, with 6°C temperature diference, during summer, between black and white combinations.

1.1. Description/ Methodology

The scale used for modelling three („open space") buildings was 1:24. Since the purpose of the experiment was not comparison between real and model conditions but among scaled buildings

* Corresponding author. Tel: +421 (2) 59 274 631
E-mail address: jana.sabikova@stuba.sk (J. Šabíková)

themselves, the wall, floor and roof basis was the same, made from plywood. Each model has windows, shaded at the level of the second floor. The difference was in the last layer of the roof. The alternatives were as follows: a) *aluminium*, b) „Tatrafoil“ – *roof foil*, and c) *green roof* (soil, grass, moss) (Fig. 1).

The experiment was running in Bratislava (Slovakia), at the end of April, beginning of May 2015. During those days the weather conditions varied a lot, from sunny and warm to rainny, cold, and windy).

Figure 1. Small scale models of buildings (author: L. Krčmárová)

As far as the measured parameters are concerned, there were three of them, the indoor *air temperature, surface roof temperature, and humidity.* At the same time the outdoor temperature was monitored. The measuring instruments – thermo and humidity sensors (Cometsystem, SO122) were used (Fig. 2). The time interval was set up to 60 minutes.

Figure 2. Small scale models of buildings (author: L. Krčmárová)

To avoid the possible influence of the indoor air temperature onto the ceiling surface one, the sensors were insulated from the bottom part.

2. Results

Based on the logged data during the period between April 27th and May 11th 2015, the mathematical evaluation followed. As expected, the lowest values during the day were measured in the case of green roof, 34°C for the indoor air temperature and 37 °C for the temperature of the ceiling. A bit higher temperatures were obtained in the case of the aluminium. The highest, among the three materials, was the temperature of the foil, 35°C for the indoor air and 39 °C for the celing (Fig. 3).

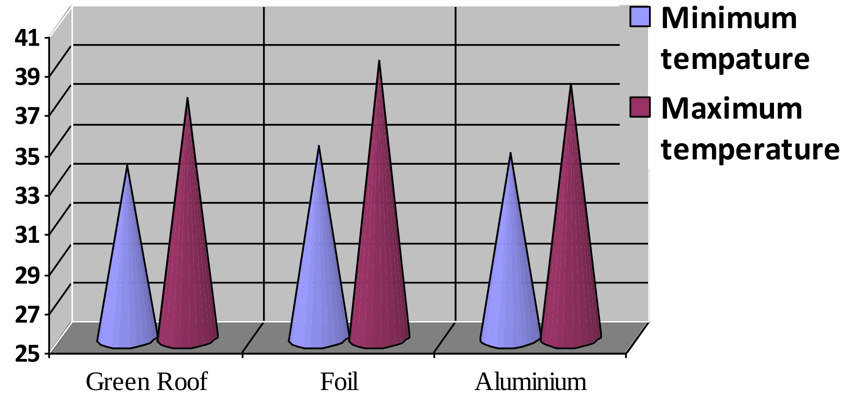
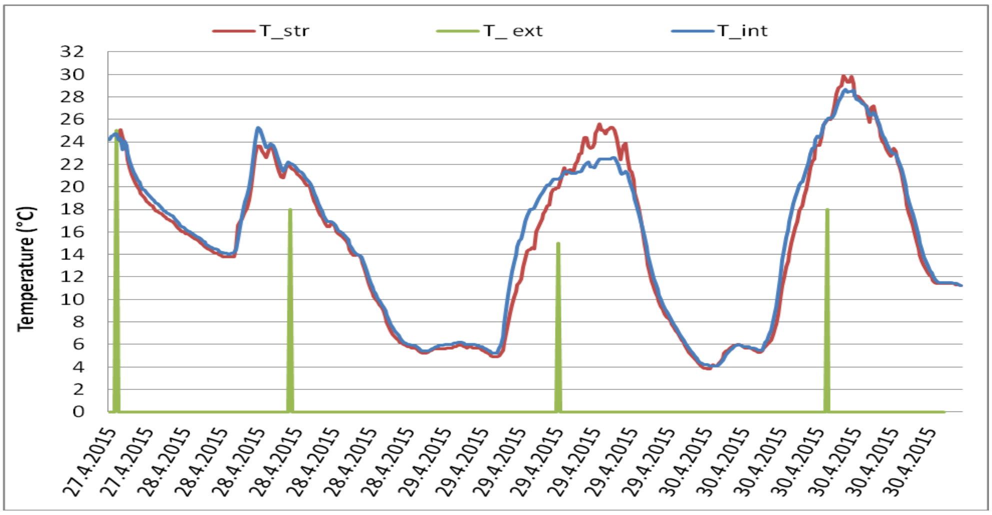


Figure 3. Minimum and maximum measured temperatures during day hours for 3 different types of roof coverings.

Figure 4. gives an example of measured temperatures in the case of a building with green roof. As seen, the indoor air, and roof temperatures follow outdoor temperature, its peak values. The straight values of the outdoor temperature have an symbolic meaning, since for the values for each day were transphormed from the official database of hydrometeorological station with other time intervals than those used for the experiment.



Picture 4. Green roof and an example of the indoor air (T_int), ceiling (T_str), and outdoor temperatures (T_ext) since April 27th, 21:00 till April 30, midnight.

Beside measured values, also calculated ones were compared. The „U-factor“ of roof with foil, and aluminium, equales 0,145 W/m^2*K, for the green roof it is 0,139 W/m^2*K. As far as the solar gains via roof are concerned, the model of the green roof has 13 W of gains. The foil, and aluminium would get almost 14 W. These values show possible tendency the gains would be lower in the case of green roof than via the other two cases. The same character could have been observed in the simplified experiment.

2.1. Analysis

As shown in the graph above (Picture 3), the lowest tempearature value during days was measured in the case of the roof with greenery. This proves its better property to absorb outdoor gains from the air, from the sun. Speaking in percentage, the ceiling surface temperature values for the green roof were lower cca by 1,8 % compare to the alluminium and by 4,8% lower to the foil. As far as the indoor air temperatures are concerned, the lowest values of the green roof was smaller then aluminium covering by 1,7 % and by 2,8% then the foil.

Comparing the values between aluminium and foil, the aluminium roof has during the day lower value by cca 1,15% for the indoor air temperature and 3% for the ceiling temperature.

In most of the cases the peak temperatures are postpond to the outdoor temperature caused by the experiment building envelope. Higher indoor temperature values compared with outdoor ones are also due to the insulation character of the building envelope as well as due to the „covered windows“ (not possible to be open, plast material, on the second floor covered with sunscreen, Picture 1)

3. Conlusion

The experiment was conducted to show the expected influence of the colour onto the solar gains. The values show the lowest values for green roof, and higher in the case of aluminium, and foil. Ofcourse to pronounce the results to be significant, the experiment should be run for longer time, under specific conditions, with logged outdoor temperature and solar intensity data, and detailed statistical analysis.

References

[1] STN 73 0540:1986, Výpočet tepelnej záťaže klimatizovaných priestorov. SÚTN Bratislava, 1985.
[2] M. Halahyja, I.Chmúrny, Z.Sternová, Stavebná tepelná technika, Jaga Group, Bratislava, 1998, ISBN 80-88905-04-4.
[3] L.Krčmárová, Pasívne chladenie z hľadiska povrchovej úpravy obalového plášťa budovy (Passive Cooling via Colour of Envelope), STU, Bratislava, 2015 (diploma work in Slovak).
[4] B.Givoni, Man, Climate, and Architecture, Applied Science Published, Ltd, London, 1976
[5] N.K. Bansal, S.N.Garg, S. Kothari, Effect of Exterior Surface Colour on the Thermal Performace of Buildings. Building and Environment, Vol.27, No.1, pp.31-37, 1992, Great Britain

JSCMT
Journal of Sustainable Construction Materials and Technologies

Journal of Sustainable Construction Materials and Technologies

J. Sustain. Construct. Mater. Technol. 1(2) (2016) 64–67 www.yildiz.dergipark.gov.tr/jscmt

Support Tools for the Building Maintenance

Ing. Zuzana Cúciková[1,a,*], Ing. Martin Hanko [1,b]

[1] *Department of Building Technology, Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Radlinskeho 11, 810 05 Bratislava, Slovakia*

[a] *zuzana.cucikova@stuba.sk*, [b] *martin.hanko@stuba.sk*

Received January 8, 2016, accepted March 20, 2016

Abstract

The philosophy of sustainable development is now part of every area of human life, including construction industry. The current priorities, which can be affected during the period of design, were mainly: energy consumption of the building's operation, characteristics of used building materials and the development of certification systems. Today, scientists are looking for new solutions for the application of sustainable development already in the operation period of buildings. The maintenance process is one of them. Use of advanced information technologies in cooperation with the Maintenance Manual of Buildings is one of the possible ways.

Keywords: maintenance manual, BIM, life cycle of buildings

1. Introduction

The relationship between man and the environment was from the very beginning of human existence very connected. With the evolution of human society gradually leads to weakening of the immediate dependence. The Industrial Revolution marked the beginning of behavioral change towards the environment in which industrial development is more important than examining its impact on the environment. Decades which are characterized by industrial development, negative impacts on the environment and increased awareness have resulted in that people are starting to think how to use existing industries, including construction industry, with minimal impact on the environment.

With the development of knowledge and thinking of human society, the idea of sustainable development began to take shape. In 1968 the Club of Rome was founded, which brings together important personalities from different parts of the world. Their aim is the study and analysis of the evolution of human society and the limits of our planet. Significant events which highlighted the issue of sustainability was the publication of the book The Limits to Growth in 1972. The authors found with the aid of computer simulation, while the upward trend of pollution, industrial development and consumption of natural resources, there will be fatal consequences for the population already during the 21st century. The concept of sustainable development was defined in 1987 at the UNO conference. This organization has under the patronage of sustainable development and helps organizations and countries to implement the ideas into legislation and daily life of the population.

The construction industry is considered one of the biggest polluters of the environment. Therefore, it is necessary to limit of the demolition of buildings has been delayed, what can be achieved with quality and thoughtful maintenance of these buildings during the period of their operation. [1]

Well-executed maintenance will have a positive impact on all areas of human existence.

* Corresponding author.
E-mail address: zuzana.cucikova@stuba.sk (Z. Cucikova)

2. Maintenance of Buildings

The aim of maintenance is to ensure that the building held the post for which it was designed, in the longest period of time with minimal faults. Maintenance also provides for improved of operational safety, optimize operational processes and minimize operational costs.

Maintenance of buildings can be divided into maintenance of building structures and maintenance of technical and technological equipment in the building. Construction structures consists of elements of long service life and short-life elements, the first group is composed of supporting structures, which repair and maintenance is extremely big financially demanding sometimes unrealistic. Therefore, it is necessary to plan and ensure a high quality maintenance of short-life elements to which we include surface treatment, insulation, windows and doors, metalwork, plumbing and joinery. In order to facilitate maintenance processing is used Maintenance Manual of Buildings in which are defined all activities to be undertaken within the framework of high-quality maintenance.

2.1. Maintenance Manual of Buildings

Maintenance Manual of Buildings defines instructions on how to take care of the building and is a tool for the building administrator - Facility Manager. The role of the Facility Manager is to ensure the most efficient maintenance, and that through cooperation with investors, designers and future owners. Nowadays, when emphasis is placed on sustainability in all areas of human life, manual should form an integral part of the documentation when handing over to the investor of the building into use. The contents of the Maintenance Manual of Buildings is proposed in Table 1. [2]

Table1. Composition of Maintenance Manual of Buildings

<table>
<tr><th>Parts</th><th>Definition</th><th colspan="2">Contents</th></tr>
<tr><td rowspan="7">Terms of use of buildings</td><td rowspan="7">Define the requirements for adequate use to prevent early wear and damage to health and property</td><td rowspan="5">Construction part</td><td>bearing capacity, cleaning and management work</td></tr>
<tr><td>education of users</td></tr>
<tr><td>building structures resistance to the action of chemicals</td></tr>
<tr><td>proposal manipulation of doors, windows and fastening objects on building structures</td></tr>
<tr><td>communication for the transport of specific equipment</td></tr>
<tr><td rowspan="2">Technical and technological part</td><td>define requirements for secure, cost effective and trouble-free operation</td></tr>
<tr><td>regulations, instructions, manuals</td></tr>
<tr><td rowspan="3">The technical inspection</td><td colspan="2" rowspan="3">Their task is to determine the current condition and the severity of defects in structures and technical and technological equipment in order to prevent future failures</td><td>Inspections are focused on:</td></tr>
<tr><td>discovery of deficiencies and defects during the warranty period and the subsequent application of remedies by the manufacturer / contractor</td></tr>
<tr><td>finding faults at an early phases, where correction could result in increased financial costs</td></tr>
<tr><td rowspan="5">Rules for building maintenance</td><td rowspan="5">Define the course of planning. Their output is maintenance schedule</td><td rowspan="2">Maintenance Schedule</td><td>elements with long service life: foundations, vertical load-bearing structures, horizontal load-bearing structures and roofs, staircase</td></tr>
<tr><td>elements with short-lived: treated wall surfaces, floors, filling the openings, metalwork, plumbing and joinery</td></tr>
<tr><td rowspan="3">Repair and maintenance</td><td>defined time intervals for preventive maintenance</td></tr>
<tr><td>provides employment and financial resources</td></tr>
<tr><td>setting standards of maintenance</td></tr>
</table>

The decisive parameters affecting quality, cost and the composition individual maintenance processes is the time when the Maintenance Manual of Buildings is included in the building's life cycle and the period during which it is processing (fig.1).

Should not be forgotten cooperation of facility managers with the experts of the individual phases. Communication among specialists help facilitate modern technology, of which at present we include the process of BIM (Building Information Modeling).

3. BIM (Building Information Modeling)

BIM is an advanced technology, with which you can create and manage virtual models consisting of digital information on physical and functional characteristics of a facility. In the BIM process are shared data concerning spatial and legal relationships, geographic and geospatial information, quantities and properties of building components, preliminary costs, the amount of material inventories and timing. In the modeling process can also include information on the ecology and sustainability. This technology facilitates the work of facility managers in the processing and updating Maintenance Manuals of Buildings.

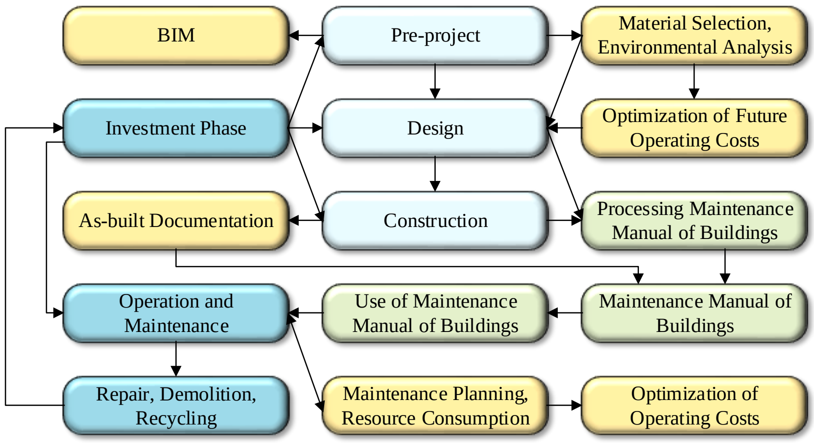


Figure 1. The Involvement of Support Tools in the Life Cycle of the Buildings

Implementation of BIM technology in building maintenance is only at the research stage according to analysis. The most research is carried in Finland and the USA. In these countries, BIM is already in use in design practice. Finland recorded the greatest progress, which are already at a stage that creates manuals related to this issue. Facility managers and owners in the UK, according to surveys, they know about BIM. So far, to them is not obvious how to effectively use this technology for FM. According to them, there are at present not best practices and directives involving FM in the BIM process. One possible approach for FM practice is the transfer of BIM data into existing maintenance management system using a computer (Computerized Maintenance Management System - CMMS). The second approach is to manage maintenance directly in BIM technology, which examined mainly in Australia and Taiwan. Experts from several countries are in agreement on the absence of good directives and the procedures for maintenance of buildings using BIM technology.

Currently in Slovakia it gets to the forefront the use of technology BIM, but mainly in the design phase. [3-10]

Figure 2 shows the strengths and weaknesses of the two support tools for building maintenance.

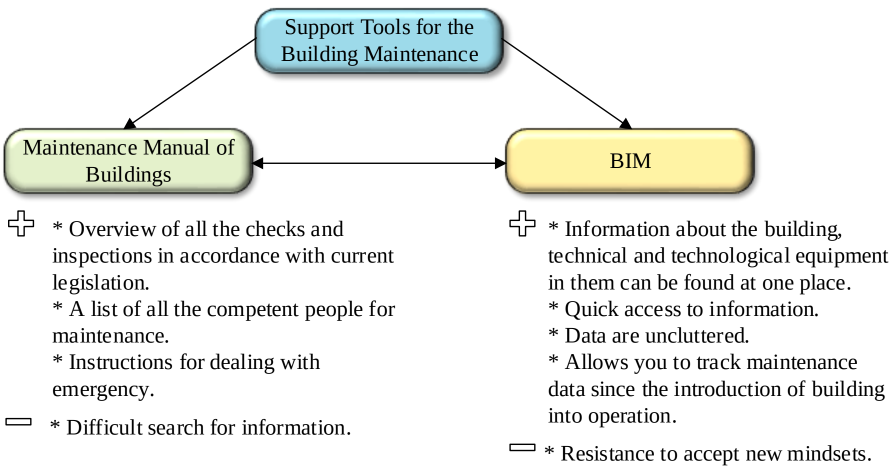


Figure 2. Evaluation of Support Tools

4. Summary

According to the analysis of support tools for building maintenance it can be concluded that the trend of sustainable development, which was initially an exception in organizations, is now an integral part thereof. Maintenance Manual of Buildings is in the building maintenance tool which can not only prolong service life, but also can ensure trouble-free operation of the building during its use phase. Building Information Modeling - BIM provides all relevant information about the building and is such relevant tool for maintenance. Complementarity of these tools can ensure continuous improvement of the maintenance process.

References

[1] L. Akenji, Consumer scapegoatism and limits to green consumerism, *Journal of Cleaner Production*, 2014,. 63: 13-23.

[2] V.Somorová, Facility management, Praha, Professional Publishing, 2014.

[3] Su, Yu Chih, Lee, Yi Chien, Lin, Yu Cheng, Enhancing maintenance management using building information modeling in facilities management, Proceedings of the 28th International Symposium on Automation and Robotics in Construction, 2011.

[4] D.Schmidt, Building Information Modeling, An overview of BIM from the Dutch perspective, TNO innovation for life, 2012.

[5] R.Williams, H. Shayesteh, L. Marjanovic, Utilising Building Information Modeling for Facilities Management, International Journal of Facility Management, London, 2014.

[6] L. Sabol, Building Information Modeling & Facility Management, IFMA World Workplace, 2008.

[7] A.Akcamete, B. Akinci, H. Garrett, Potential utilization of building information models for planning maintenance activities, Proceddings of the International Conference on Computing in Civil and Building Engineering, 2010.

[8] Information on http://www.tzb-info.cz/facility-management/10981-prvni-ceska-bim-prirucka

[9] Information on http://rym.fi/results/utilizing-bim-in-maintenance/

[10] A. Sawhney, State of BIM Adoption and Outlook in India, RICS Research, Dillí, 2014.