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Experimental investigation of the effect of coating on surface roughness and drill life in drilling of AISI 4140 steel

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KEYWORDS

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ABSTRACT

In this study, the effects of the coating on the hole surface roughness and drill life were investigated in the drilling of AISI 4140 steel workpieces with 14 mm diameter internally cooling uncoated, mono-layer TiN, double-layer AlTiN+TiN and three-layer AlTiN+TiAlN+TiN solid carbide drills on a CNC lathe. Experimental study was carried out with 0.10 and 0.20 mm/rev feed rate and 80 and 90 m/min cutting speed parameters. With the three-layer coating applied to the drills, it is aimed to increase the hole surface quality and cutting tool life. In this study, as a new and different method, the contact areas on the flank face of coated carbide drills were determined. When evaluated in terms of hole surface quality and cutting tool life, they can be listed as three-layer AlTiN+TiAlN+TiN coated solid carbide, double-layer AlTiN+TiN coated solid carbide, mono-layer TiN coated solid carbide and uncoated solid carbide drills, from best to worst. As a result, when comparing uncoated and coated solid carbide drills, coated solid carbide drills have higher chip removal performance, 300% better hole surface quality and 34 times higher cutting tool life.

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1.0 INTRODUCTION

The main purpose of this study is to investigate the increase of cutting tool life and hole surface quality. The most important problem that causes the reduction of cutting tool life and hole surface quality is cutting tool wear. Today, cutting tool wear is a major problem in the machining industry. Cutting tool wear reduces the cutting tool life and operating performance and reduces the hole surface quality. It causes rapid blunting of the cutting tool, reducing productivity and the number of productions. Today, demands for more production with less cost, higher productivity, higher cutting tool life and better hole surface quality have increased in the manufacturing industry. High hardness steel and steel alloys are difficult to machine. The coating process is applied to solid carbide drills to reduce cutting tool wear, increase tool life and hole surface quality, and drill high hardness steel workpieces. With the coating process, the cutting tools are given features such as high wear resistance, low friction, high strength, and high temperature resistance. In this study, for this purpose, solid carbide drills are coated with single-layer or multi-layer Titanium Nitride (TiN), Aluminum Titanium Nitride (AlTiN) and Titanium Aluminum Nitride (TiAlN). It has been observed that with the TiN, AlTiN, TiAlN coating process, extremely significant increases in tool life and hole surface quality of solid carbide drills are achieved. In this study, it was observed that the cutting tool life and hole surface quality were significantly improved. With the increase in TiN, AlTiN, TiAlN coating thickness and the number of layers, tool life and hole surface quality increased in direct proportion. Academic studies to increase the tool life and hole surface quality of solid carbide drills continue intensively.

The machinability of High Strength Low Alloy (HSLA) steel material was investigated (Sherje et al., 2020) in CNC machine drilling of (HSLA) steel workpieces with uncoated and TiAlN coated HSS drills; It has been observed that better surface quality is obtained with TiAlN coated HSS drills compared to uncoated HSS drills. The effects of the coating on the hole surface roughness were investigated (Aamir et al., 2021) when drilling of Al2024 alloy in dry conditions in a vertical machining center with 6 mm diameter uncoated and TiN, TiCN, TiAlN and TiSiN coated solid carbide drills; better hole surface roughness was obtained at low cutting speeds with uncoated carbide drills, better hole surface quality at high spindle speed was obtained with TiCN, TiN, TiAlN and TiSiN coated carbide drills, respectively. In the review study (Alphonse et al., 2021) the wear of uncoated and TiN, TiAlN, TiAlZrN coated HSS drill bits were examined, it was seen that coated drill bits had higher tool life and higher machining performance than uncoated drill bits. It has been found that multi-layer TiN coated drill bits have higher wear resistance than single-layer TiN coated drill bits. It has been found that TiAlN layer coated drill bits have higher wear resistance than uncoated HSS drill bits.

The effect of the coating on the hole surface roughness was investigated (Masooth et al., 2019) when drilling of AA5052 alloy workpieces with 5 mm diameter uncoated and TiN, AlCrN, TiAlN coated HSS drills in dry conditions in a vertical machining center; better hole surface quality and higher tool life has been obtained with TiAlN, TiN and AlCrN coated drills, respectively, compared to uncoated drills. The effects of the coating on the surface roughness and tool life were investigated (Arif et al., 2020) when drilling of High Resistant Austenitic Stainless Steel (HRASS) workpieces in a vertical machining center with 5.1 mm diameter AlCrN, TiAlSiN and TiAlN coated WC-Co drills; higher tool life and better hole surface quality has been obtained with TiAlSiN, AlCrN and TiAlN coated drills, respectively**.** The effects of the coating on the hole surface quality were investigated (Wang et al., 2019) in the drilling process of AISI 304 austenitic stainless-steel workpieces with 8 mm diameter uncoated, TiN/MoN and TiAlN/MoN coated HSS drills; better hole surface quality has been obtained with TiN/MoN and TiAlN/MoN coated HSS drills compared to uncoated HSS drills.

The effects of cutting conditions on hole surface quality and cutting temperature were investigated (Uçak et al., 2018) when drilling Inconel 718 workpieces with 5 mm diameter uncoated and TiAlN coated solid carbide drills using cooling water; better hole surface quality and higher tool life has been obtained with TiAlN coated solid carbide drills compared to uncoated drills. The effects of TiN and TiAlN coating on tool life were investigated (Puneeth et al., 2017) when drilling of EN8 workpieces with uncoated, TiN and TiAlN coated 10 mm diameter HSS drills; it has been observed that TiN and TiAlN coated HSS drills have a higher life than uncoated HSS drills. In the drilling of AISI D2 tool steel (Osman et al., 2017) in vertical machining center with 11 mm diameter TiN, TiCN and TiAlN coated HSS drills, optimum hole parameters were examined, and the best performance has been obtained with coated drills compared to uncoated drills. The effects of TiN coating on cutting tool life were investigated (Puneet et al., 2017) in the CNC machine drilling of EN 24 steel workpieces with 6 mm diameter HSS and 5 mm diameter WC drills with TiN coating; because of the experiment, it was seen that the TiN coating increased the drill life 3 times. The performance of uncoated and coated drills were investigated (Karthik et al., 2016) in the drilling of EN8 steel workpieces with 10 mm diameter uncoated and TiN, TiAlN coated HSS drills on a radial drilling machine; compared to TiN coated and uncoated HSS drills, TiAlN coated drill bits have been found to have the least tool wear and the best hole surface quality. The effects of uncoated and coated solid carbide drills on the surface roughness were investigated (Kumar et al. 2016) when drilling of Titanium Grade 2 alloy workpieces with 6 mm diameter uncoated and TiAlN coated solid carbide drills in CNC machining center; it was seen that much better surface roughness has been achieved with TiAlN coated solid carbide drills than with uncoated drills.

The optimum cutting parameters were investigated (Şeker et al., 2015) for drilling of AISI 1050 steel workpieces in dry conditions in a vertical machining center with 6, 8 and 10 mm diameter uncoated and TiAlN coated HSS drills; compared to uncoated drills, the best hole surface quality was obtained with coated drills**.** The effects of cutting parameters on hole surface roughness were investigated (Motorcu et al., 2014) when drilling of Waspaloy superalloy with 8 mm diameter uncoated and TiN coated solid carbide drills; better hole surface quality and higher tool life has been obtained with TiN coated solid carbide drills compared to uncoated drills**.** The hole surface quality were investigated (Çiçek et al., 2013) in the drilling of AISI D2 cold work tool steel workpieces with 5 mm diameter uncoated and TiN, TiAlN mono-layer and TiAlN/TiN multi-layered cemented carbide drills in a vertical machining center; better hole surface quality has been obtained with TiN single-layer and TiAlN/TiN multi-layer coated drills compared to uncoated drills. The best wear resistance and 3 times higher tool life than uncoated drills has been achieved obtained with TiAlN/TiN multilayer coated drills.

The effects of uncoated, single-layer and multi-layer coating were investigated (Kivak et al., 2012) on hole surface roughness and cutting tool life in the drilling of AISI 316 steel workpieces with 6 mm diameter uncoated and mono-layer TiN, TiAlN and multi-layer TiAlN/TiN coated HSS drills in dry cutting conditions in a vertical machining center; as a result of the experiment, it was observed that better hole surface quality and higher cutting tool life were obtained with coated drills compared to uncoated drills**.** The effects of the coating on the hole surface roughness and drill life were investigated (Çaydaş et al., 2011) when drilling of AISI 304 austenitic stainless steel workpieces with 5 mm diameter HSS, TiN coated HSS and K20 solid carbide drills in a CNC vertical machining center in dry conditions; better hole quality, lower hole surface roughness and higher drill life have been obtained with TiN coated HSS drills compared to K20 solid carbide and HSS tools. The tool life between coated and uncoated drills were compared (Braic et al., 2010) in the drilling of carbon steel with 8 mm diameter uncoated, mono-layer TiN, TiAlN/TiAlZrN coated and multi-layered TiN, TiAlN/TiAlZrN coated HSS drills; it has seen that the life of the drills with multi-layer coating was 2.3 times and the life of single-layer TiN, TiAlN/TiAlZrN coated drills was 1.8 times higher than the uncoated drills.

The performance of coated and uncoated HSS drills were investigated (Barshilia et al., 2009) in drilling of AISI 304 stainless steel with 7 mm diameter uncoated and TiAlN coated HSS drills in wet and dry conditions; better hole surface quality and higher tool life have been obtained with TiAlN coated HSS drills compared to uncoated drills in dry and wet drilling conditions. The effects of the coating on the surface roughness and tool life were investigated (Sharif et al., 2007) in the drilling of Ti-6Al4V alloy with a 6 mm diameter uncoated and TiAlN coated carbide drill in a CNC vertical machining center using cooling water; much better hole surface quality and much higher tool life have been obtained with the TiAlN coated drill compared to the uncoated drill.

The improvement of tool life were investigated in drilling of AISI 304 austenitic stainless steel workpieces (Lin et al., 2000) in a vertical machining center using cooling water with 8 mm diameter TiN, TiCN, CrN and TiAlN coated HSS drills; it has been observed that the TiN coated drill has higher tool life than the TiAlN, TiCN and CrN coated drills. The effects of the coating on the life of the drill were investigated (Chen et al., 2000) in the drilling of AISI 204 steel workpieces with TiN mono-layer, TiN multi-layer (TiN/TiCN/TiN/TiCN/TiN five-layer) and TiCN multi-layer (TiN/TiCN/TiN/TiCN/TiN/TiCN six-layer) coated HSS drills in a vertical machining center in dry conditions; it was observed that the life of the drill increased with the increase in the number of layers. The effects of CVD and PVD multilayer (TICN+Al2O3+TiN) coated carbide inserts on the surface roughness and cutting tool wear were investigated (Najar et al., 2021) when turning of AISI 4340 steel workpieces in dry conditions. As a result of the experiment, it was observed that the feed rate and cutting speed had a significant effect on the surface roughness of both CVD and PVD coated tools, respectively. In addition, it was observed that the cutting speed and feed rate, respectively, had a significant effect on the cutting tool wear in both coated tools.

The effects of cutting parameters on cutting tool wear were investigated (Haron et al., 2019) in CNC machine turning of Inconel 718 workpieces with PVD TiAlN coated tungsten carbide inserts in dry and cryogenic conditions; as a result of the experiment, when compared to dry cutting, higher tool life was obtained under low cutting speed and cryogenic conditions. The effects of machining parameters on cutting tool wear and surface roughness were investigated (Mir et al., 2018) in the turning of AISI D2 steel material using cooling water with multi-layered (TiC/TiCN/Al2O3) coated carbide tools with TiN in the over layer; as a result of the experiment, it was seen that the cutting speed has an extremely important effect on the wear of the cutting tool and the feed rate has an extremely important effect on the surface roughness. The effect of cutting parameters on surface roughness were investigated (Kamal et al., 2018) when machining hypereutectic Al-Si A390 workpieces on CNC machine without cooling water. According to Analysis of Variance (ANOVA), it has been determined that the cutting speed and feed rate have a significant effect on the surface roughness.

The aim of this study is to investigate the effect of uncoated and coated solid carbide drills on drill life and hole surface quality when drilling of AISI 4140 steel. It was observed that the coating significantly increased the hole surface quality and drill life. This study will be beneficial to researchers and academicians working in the manufacturing industry.

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2.0 EXPERIMENTAL PROCEDURE

2.1 Workpiece Used in Experimental Study

AISI 4140 steel, which contains Cr and Mo alloying elements in its structure, is widely used in the machinery manufacturing industry due to its excellent properties such as high strength, high wear resistance and toughness. The workpieces were supplied as heat treated.

In this study, 8 experiments were carried out. As the test sample, AISI 4140 hot forged steel workpieces with a diameter of 20 mm and a length of 30 mm, hardened up to 30 HRC by heat treatment, were used. Hole drilling was carried out with each drill until the end of the tool life. The surface roughness of the hole was measured from four different points of the workpiece when the drill started to dull**.** The same procedure was performed in all experiments. Figure 1 shows the workpieces used in the experimental study. The chemical properties of AISI 4140 steel supplied from the manufacturer are given in Table 1.

Figure 1: Workpieces used in the experimental study.

Table 1: The chemical composition of AISI 4140 steel.

Elements	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**mo**	**Ni**	**Al**	**Cu**	**Sn**
wt.%	0.41	0.24	0.84	0.011	0.025	1.05	0.21	0.16	0.019	0.17	0.011

2.2 Cutting Tool Used in Experimental Study

In this study, internally cooled, uncoated and coated Toolex brand solid carbide drills with a diameter of 14 mm, a full length of 107 mm and a cutter length of 60 mm were used. The drills have two helical flutes, a tip angle of 140^{o} and a helix angle of 30^{o}. Solid carbide drills with technical code BE1400U2C60AS6N107 were used in the experimental study. Uncoated solid carbide drills were coated as a thin film with hard materials such as mono-layer TiN, double-layer AlTiN+TiN and three-layer AlTiN+TiAlN+TiN by PVD (Physical Vapor Deposition) method for experimental work. The thickness of each coating layer is about 3.5 µm. In the experimental study, 1 uncoated and 3 coated drills were used. Experimental study was carried out with uncoated carbide drill first and then with mono layer TiN, double layer AlTiN+TiN and three-layer AlTiN+TiAlN+TiN solid carbide drills, respectively.

In the experimental study, cooling water brand MASTER FLUIDS and type TRIM MICRISOL 515 was used. The cooling water, water/oil ratio is 100 liters water/5 liters oil and the cooling water pressure is 7 bar. Coolant water/oil ratio and cooling water pressure were selected according to the manufacturer's recommendations. Drilling was performed with each drill until the end of the tool life.

Figure 2: Drills used in the experimental study.

2.3 Machine Used in Experimental Study

The CNC lathe used in the experimental study is 2005 model Takisawa Taiwan EX-108 with a speed of 4200 rpm, 12 cutting tools can be connected, and it is seen in Figure 3. CNC machine is three-axis and works with the help of Fanuc control unit.

Figure 3: Drilling of workpieces on a CNC machine.

2.4 Cutting Parameters

In this study, AISI 4140 steel workpieces were drilled with a feed rate of 0.10 mm/rev and 0.20 mm/rev and a cutting speed of 80 m/min and 90 m/min. Drilling parameters are given in Table

2. In experimental study, the hole length was determined as 30 mm. Cutting speed and feed rate values and levels were determined according to the recommendations of the cutting tool company.

Table 2: Drilling Parameters.

Exp. No.	**Drill Type**	**Feed Rate (mm/rev)**	**Cutting Speed (m/min)**
1	Uncoated	0.10	80
2	Uncoated	0.20	90
3	Single layer (TiN)	0.10	80
4	Single layer (TiN)	0.20	90
5	Double layer (AlTiN+TiN)	0.10	80
6	Double layer (AlTiN+TiN)	0.20	90
7	Three-layer (AlTiN+TiAlN+TiN)	0.10	80
8	Three-layer (AlTiN+TiAlN+TiN)	0.20	90

2.5 Determination of Wear in The Cutting Tool by Optical Microscope

After drilling, the 14 mm diameter Toolex brand solid carbide drills used in the experimental study were examined in the Zeiss Axio Zoom V.16 optical microscope and their wear was measured. The wear amounts on the drill bits were calculated in μm^2 by the optical microscope, and the measurement values in μm^2 were converted to mm^2.

In the evaluation of tool wear, flank wear was referred to, and the wear areas on the cutting tools were precisely calculated with an optical microscope. The flank wear was measured by the depth of the wear band. Since more sensitive data are obtained with the optical microscope than the weight difference, the measurement was made with flank wear.

2.6 Measurement of Hole Surface Roughness

Surface roughness of AISI 4140 steel workpieces subjected to drilling processes on a CNC lathe was measured with the Mitutoyo Surftest SJ-210 brand surface roughness device shown in Figure 4. In order to increase the reliability of the experimental study, the hole surface roughness of the workpieces was measured from four different points and the Average Surface Roughness (Ra) values were calculated. The surface roughness device was calibrated before the measurements, and the hole surface roughness values of the workpieces were measured parallel to the hole axis with the Mitutoyo Surftest SJ-210 brand diamond-tipped surface roughness device. For the measurements of the hole surface roughness values of the workpieces, the cut-off length was taken as 0.25 mm and the sampling length as 2.5 mm. In this study, based on the experimental studies in the literature, the hole surface roughness of the workpieces was measured according to the Average Surface Roughness (Ra).

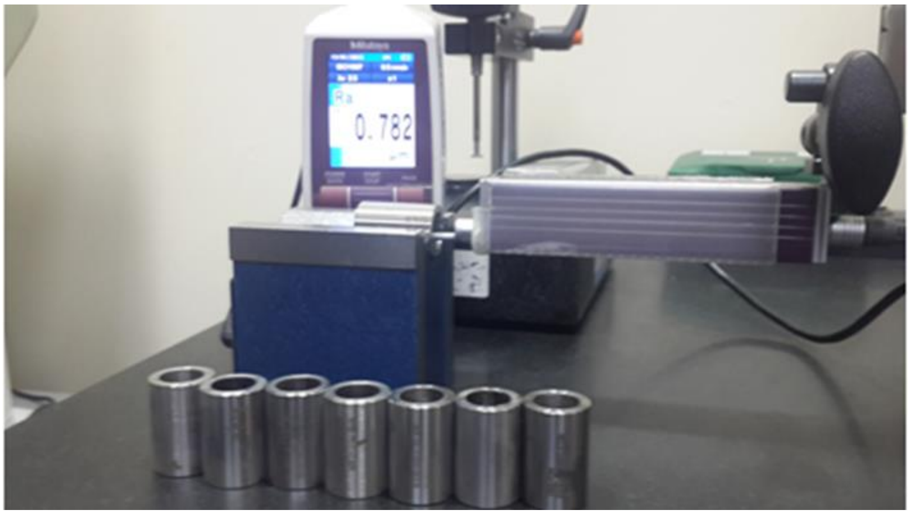

Figure 4: Measurement of hole surface roughness of workpieces.

3.0 RESULTS AND DISCUSSION

3.1 Investigation of The Effect of Coating on Hole Surface Roughness

In this study, the effects of the coating on the hole surface roughness and cutting tool life were investigated. The effect of the coating on the hole surface roughness is shown in Figure 5. For each cutting tool in Figure 5, Figure 6, Figure 7 and Figure 10 the first columns represent the feed rate of 0.10 mm/rev and the cutting speed of 80 m/min, the second columns represent the feed rate of 0.20 mm/rev and the cutting speed of 90 m/min. When Figure 5 is examined, under the conditions of 0.10 mm/rev feed rate and 80 m/min cutting speed, the lowest hole surface roughness value is 0.463 μm with a three-layer AlTiN+TiAlN+TiN coated solid carbide drill, and the highest hole surface roughness value was obtained as 1.388 μm with uncoated solid carbide drill. This is because; it can be attributed to the low thermal conductivity of AlTiN+TiAlN+TiN coating, high temperature resistance, high strength, low friction coefficient and high wear resistance properties (Sherje et al., 2020). PVD coated drills are cutting tools with high temperature resistance up to 400-600 °C. When evaluated in terms of hole surface quality, the performance of the cutting tool coatings is ranked from best to worst as three-layer AlTiN+TiAlN+TiN coated, double layer AlTiN+TiN coated, mono layer TiN coated and uncoated solid carbide drills (Arif et al., 2020).

When Figure 5 is examined, it is seen that the hole surface roughness values obtained with uncoated solid carbide drills are at the peak point, while the hole surface roughness values in coated solid carbide drills draw a gradually decreasing graph (Wang et al., 2019).

Three-layer AlTiN+TiAlN+TiN-coated solid carbide drills coated with PVD method, double-layered AlTiN+TiN-coated solid carbide drills and mono-layer TiN-coated solid carbide drills have minimum friction, minimum tool-chip interface temperature, thus lower hole drilling surface roughness values were obtained (Çiçek et al., 2013). There is a direct proportional relationship between the friction coefficient and the hole surface roughness. As the friction coefficient of the cutting tool decreases, the surface roughness of the hole decreases at the same rate (Karthik et al., 2016).

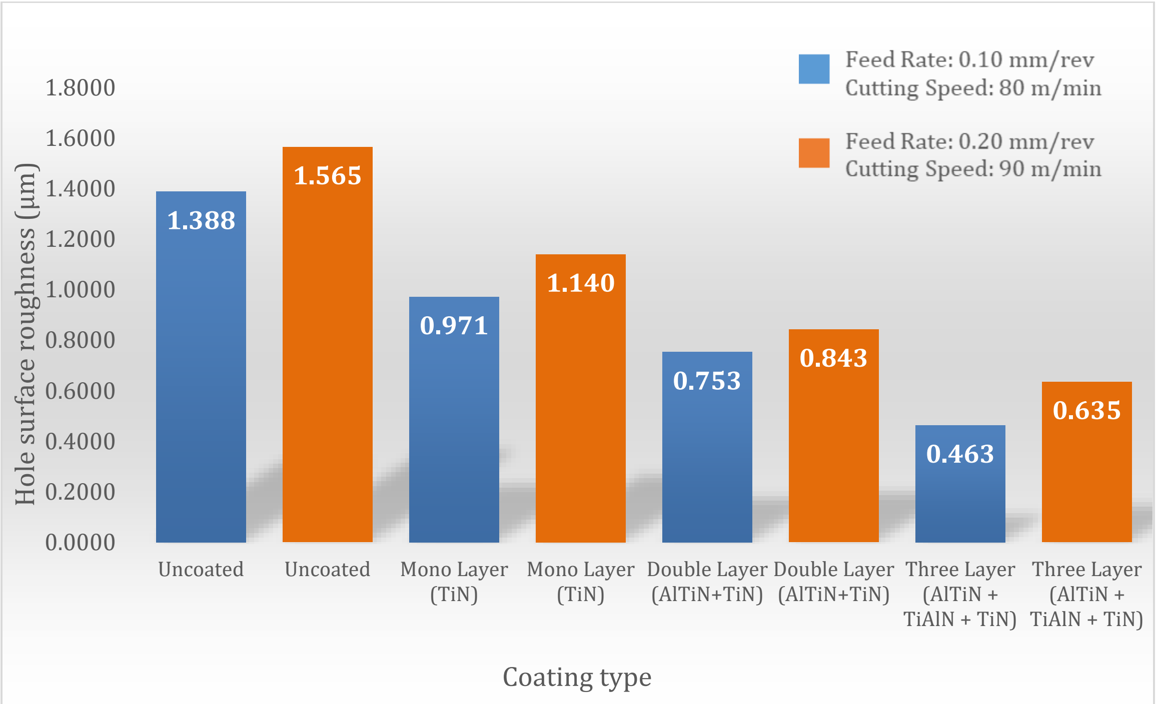

Figure 5: The effect of the coating on the surface roughness.

The coating and the number of layers have a significant effect on the hole surface quality. It is seen that the hole surface quality increases as the coating thickness and the number of layers increase. When Figure 5 is examined, it is seen that the coating has an extremely important effect on the hole surface roughness when drilling high hardness workpieces. Lower hole surface roughness values were obtained with three-layer ALTiN+TiAlN+TiN-coated solid carbide drills compared to double-layered AlTiN+TiN-coated solid carbide drills, mono-layer TiN-coated solid carbide drills and uncoated drills (Kumar et al., 2016). The reason for obtaining low surface roughness values with the three-layer AlTiN+TiAlN+TiN coated solid carbide drill is; it can be attributed to its low coefficient of friction and high temperature resistance properties. Lower hole surface roughness values were obtained with coated solid carbide drills compared to uncoated solid carbide drills (Motorcu et al., 2014). Compared to uncoated drills, coated drills have better hole surface quality with the coating process (Barshilia et al., 2009).

As a result of this experimental study, it was observed that better hole surface quality was obtained with the coating process applied to the cutting tools, and the coating improved the hole surface quality by 300%.

3.2 Investigation of The Effect of Coating on Cutting Tool Life

For this purpose, 1 uncoated solid carbide drill and 3 coated solid carbide drills were used. When Figure 6 is examined, under the conditions of 0.10 mm/rev feed rate and 80 m/min cutting speed, the highest wear amount with uncoated solid carbide drill is 1.04 mm^2 and the lowest wear amount was obtained as 0.23 mm^2 with the solid carbide drill with three layers of AlTiN+TiAlN+TiN coating. Wear values of uncoated and coated drills are given in Figure 6.

Figure 8a-b shows the minimum amount of wear of the three-layer AlTiN+TiAlN+TiN coated carbide drill at a feed rate of 0.10 mm/rev and a cutting speed of 80 m/min. Figure 9a-b-c shows the highest wear amount of the uncoated solid carbide drill at a feed rate of 0.10 mm/rev and a cutting speed of 80 m/min. When Figure 8a-b and Figure 9a-b-c are examined, it is seen that the wear amount in the three-layer AlTiN+TiAlN+TiN coated solid carbide drill is less than the wear amount in the uncoated solid carbide drill at 0.10 mm/rev feed rate and 80 m/min cutting speed conditions (Alphonse et al., 2021). Likewise, it was observed that the wear amount of the three-layer AlTiN+TiAlN+TiN coated solid carbide drill at 0.10 mm/rev feed rate and 80 m/min cutting speed conditions was 4.52 times (452%) less than the wear amount of the uncoated solid carbide drill. It was determined that the wear resistance of uncoated solid carbide drills increased by 4.52 times (452%) with the three-layer AlTiN+TiAlN+TiN coating process (Puneet et al., 2017). It is seen that the three-layer AlTiN+TiAlN+TiN solid carbide drill has the highest cutting tool life compared to other cutting tools (A.R. Motorcu et al., 2014). Since the AlTiN+TiAlN+TiN coating has high wear resistance, low thermal conductivity, high temperature resistance and low friction coefficient, less wear and higher cutting tool life have been achieved in the cutting tool (Karthik et al., 2016). In addition, the achievement of higher cutting tool life can be attributed to the number of layers, layer thickness and high temperature resistance (Braic et al., 2010). As the coating thickness increases, the wear resistance of the cutting tool increases. Since the drill with three layers of AlTiN+TiAlN+TiN coating has more layers and more coating thickness, the wear resistance and consequently the cutting tool life have increased (Çaydaş et al., 2011). Due to all these superior properties, higher wear resistance and higher cutting tool life have been achieved with AlTiN+TiAlN+TiN coating (Barshilia et al., 2009).

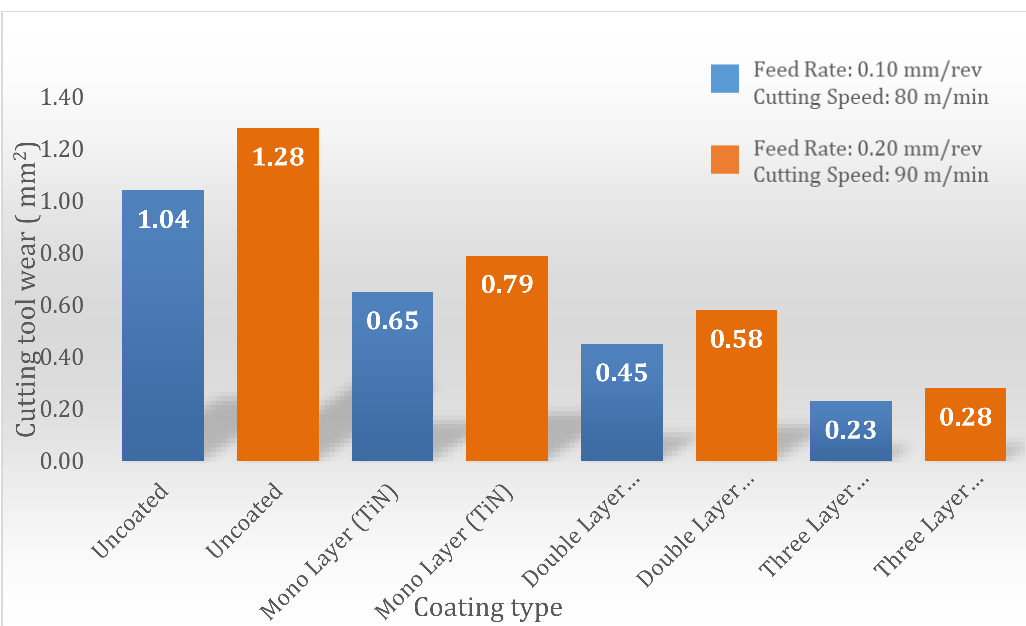

Figure 6: Effect of coating on cutting tool life.

In this study, when Figure 6 and Figure 7 are examined, it has been determined that mono-layer TiN, double-layer AlTiN+TiN and three-layer AlTiN+TiAlN+TiN coatings have an extremely important effect on drill life and significantly increase drill life (Çaydaş et al., 2011). With the coating process, high strength, high temperature resistance and high wear resistance are provided to the uncoated carbide drill. The coating has an extremely important effect on cutting tool life. As the number of layers and coating thickness increases, the amount of wear on the cutting tool decreases (Barshilia et al., 2009). There is an inversely proportional relationship between the amount of wear and cutting tool life. As cutting tool wear decreases, tool life increases. Since single-layer TiN, double-layer AlTiN+TiN and three-layer AlTiN+TiAlN+TiN coatings have low thermal conductivity, high wear resistance, high strength, low friction coefficient and high temperature resistance properties, it has been observed that the amount of wear on the cutting tools is low and the life of the cutting tool is high (Sharif et al., 2007). Since TiN coating reduces the friction between tool and chip, it is preferred to be in the top layer in multi-layer coatings.

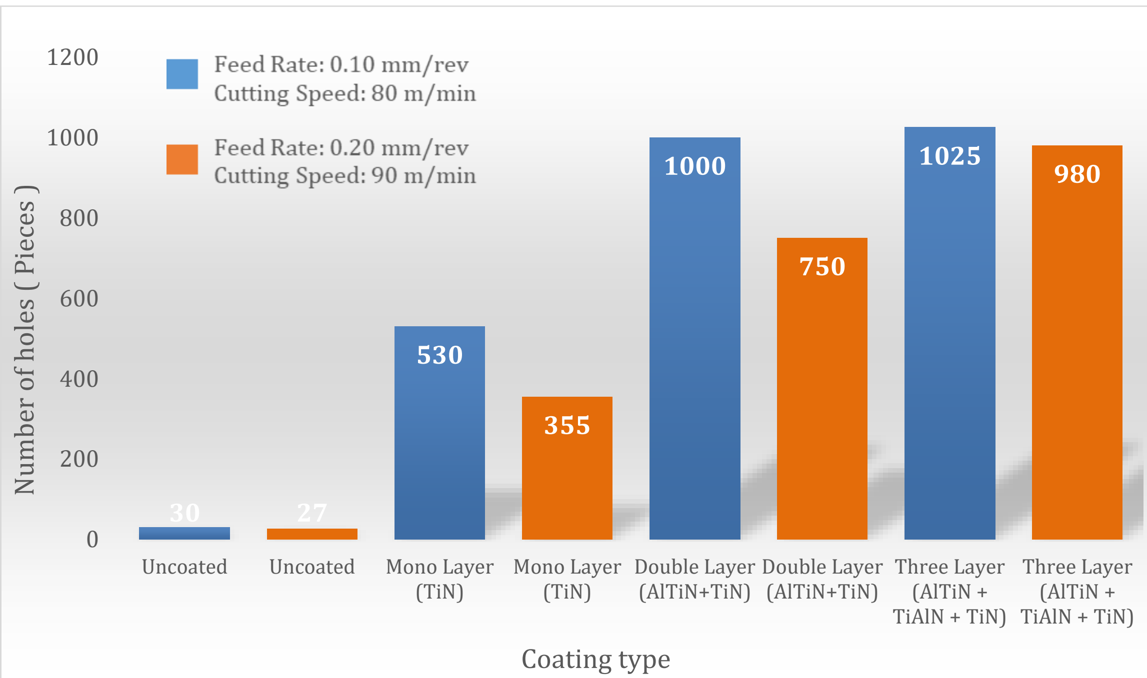

Figure 7: Coating type and number of holes.

In this study, the relationship between the hole number of the coating and the drill life was investigated. It has been observed that the life of the cutting tool and the hole drilling performance have increased more with the coating process. As the coating thickness and the number of layers increase, the cutting tool life increases due to the number of holes. Figure 7 shows the relationship between the uncoated and coated drill type and the number of holes. When Figure 7 is examined, it is seen that under the conditions of 0.10 mm/rev feed rate and 80 m/min cutting speed, 30 pcs of minimum number of holes with uncoated solid carbide drill and the highest number of holes was obtained as 1025 with the three-layer AlTiN+TiAlN+TiN coated solid carbide drill. When

Figure 7 is examined, it is seen that the number of holes gradually increases from an uncoated solid carbide drill to a three-layer AlTiN+TiAlN+TiN coated solid carbide drill. With the increase in the number of layers and coating thickness, the amount of wear in the drill decreased, more holes were drilled, and the drill life increased greatly (Chen et al., 2000).

As a result of this study, it was observed that the wear resistance of uncoated solid carbide drills increased by 4.52 times (452%) and drill life 34 times more with the coating process.

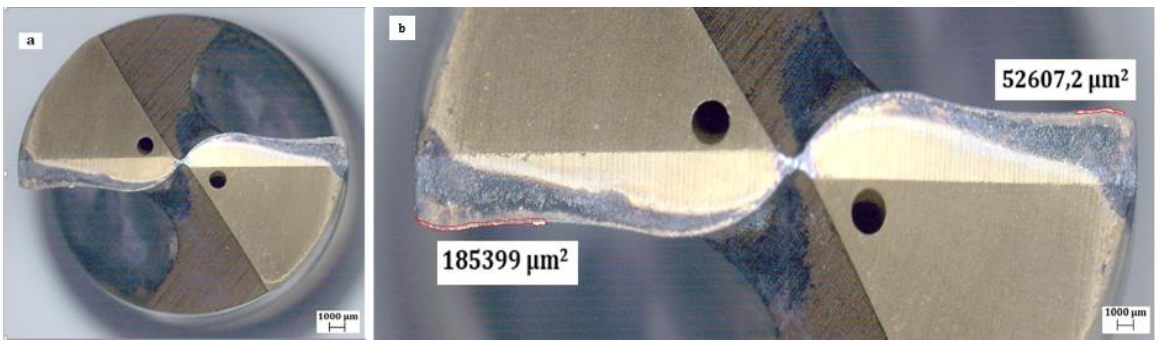

Figure 8: Wear of the three-layer AlTiN+TiAlN+TiN coated carbide drill at a feed rate of 0.10 mm/rev and a cutting speed of 80 m/min.

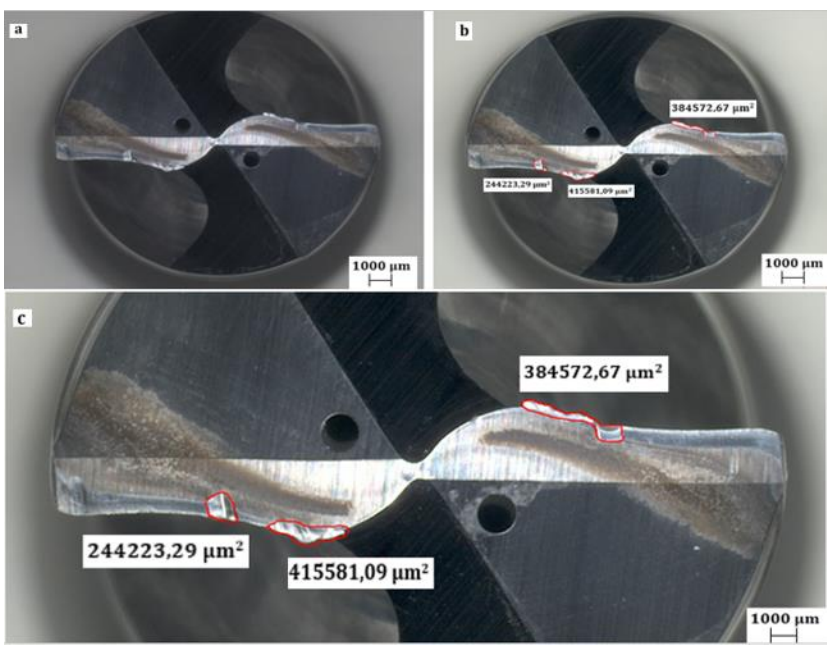

Figure 9: Wear of the uncoated carbide drill at a feed rate of 0.10 mm/rev and a cutting speed of 80 m/min.

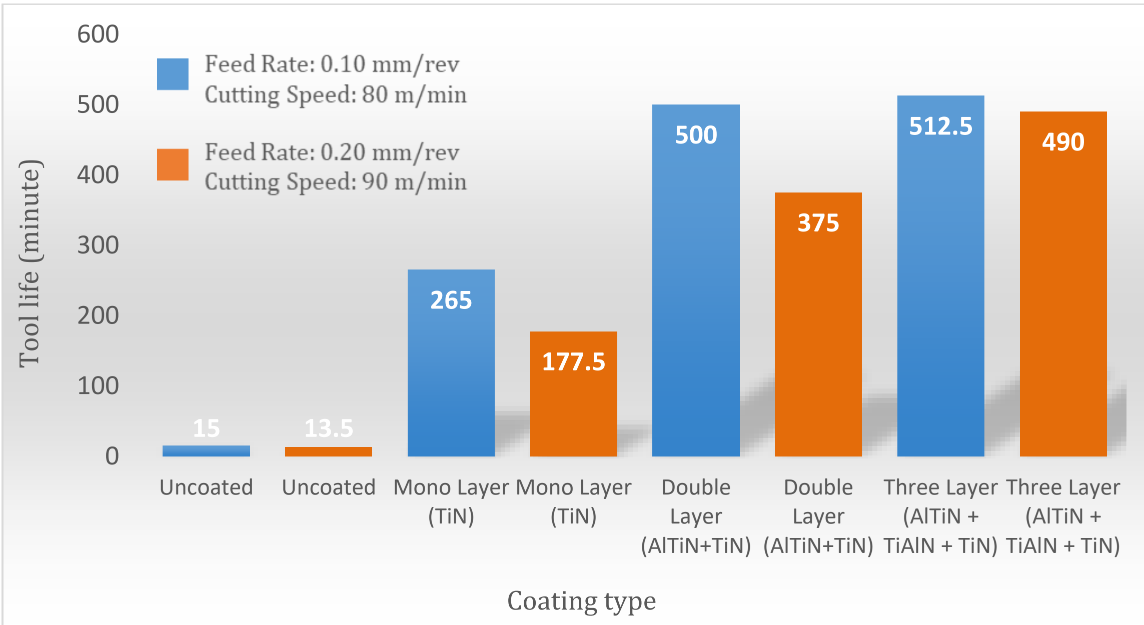

Figure 10: Coating type and tool life.

In this study, AISI 4140 steel workpieces were drilled with uncoated and coated drills on a CNC lathe; the drilling time of each workpiece is calculated as 30 seconds by the control unit of the CNC machine. From Figure 7, the number of holes drilled with each cutting tool is multiplied by the drilling time of each workpiece, 30 seconds; in this way, the tool life of each cutting tool in minutes was calculated. The tool life of each cutting tool in minutes is shown in Figure 10. With the coating process, the cutting tool gains features such as high wear resistance, high temperature resistance, high strength and high drilling performance. As seen in Figure 10, at 10 mm/rev feed rate and 80 m/min cutting speed conditions, the lowest cutting tool life is 15 minutes with uncoated tool, the highest cutting tool life is 512.5 minutes with three-layer AlTiN+TiAlN+TiN cutting tool has been obtained. The coating and the number of layers have a significant impact on cutting tool life. It is seen that the life of the cutting tool increases as the number of layers increases (Puneet et al., 2017). When Figure 10 is examined, it is seen that the cutting tool life gradually increases towards uncoated, single-layer TiN, double-layered AlTiN+TiN and triple-layered AlTiN+TiAlN+TiN coated cutting tools (Chen et al., 2000).

CONCLUSION

In this study, the effects of coating on surface roughness and cutting tool life were investigated in the drilling of AISI 4140 steel workpieces with a 14 mm diameter internally cooling uncoated and coated solid carbide drill on a CNC lathe. It has been observed that the hole surface quality and cutting tool life increase by coating solid carbide drills with single-layer TiN, double-layer AlTiN+TiN and three-layer AlTiN+TiAlN+TiN. The scope of this study is limited to investigating the effect of coating on hole surface roughness and cutting tool life only. In the experimental study, the following results were determined.

(a) At the 0.10 mm/rev feed rate and 80 m/min cutting speed conditions, the life of the three-layer AlTiN+TiAlN+TiN coated solid carbide drill was 512.5 minutes, and the uncoated solid carbide drill was 15 minutes. It has been observed that the life of the solid carbide drill increases approximately 34 times higher with the three-layer AlTiN+TiAlN+TiN coating.
(b) The lowest surface roughness was obtained with a three-layer AlTiN+TiAlN+TiN solid carbide drill of 0.463 µm under the conditions of 0.10 mm/rev feed rate and 80 m/min cutting speed. It is seen that the surface roughness gradually decreases from the uncoated solid carbide drill to the coated solid carbide drill. The coating was found to improve hole surface quality.
(c) The lowest cutting tool wear was obtained as 0.23 mm^2 with a three-layer AlTiN+TiAlN+TiN solid carbide drill under the conditions of 0.10 mm/rev feed rate and 80 m/min cutting speed. It can be seen that the cutting tool wear gradually decreases from uncoated solid carbide drill to three layer AlTiN+TiAlN+TiN coated solid carbide drill. It was observed that the wear of the cutting tool decreased and the tool life increased with the coating process.
(d) It was observed that the minimum number of holes was obtained with an uncoated solid carbide drill as 30, and the maximum number of holes was obtained as 1025 with a three-layer AlTiN+TiAlN+TiN solid carbide drill, at a feed rate of 0.10 mm/rev and a cutting speed of 80 m/min. It was observed that the number of holes increased with the coating process.
(e) As a result, with the three-layer AlTiN+TiAlN+TiN coating process, the best hole surface quality, the least cutting tool wear, the highest tool life and the highest cutting tool performance have been obtained.

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