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Numerical study of heat transfer aspects in cutting tools made of Al_2O_3, ZrB_2, TiB_2, TiN using ANSYS fluent software

ANSYS fluent yazılımı kullanılarak Al_2O_3, ZrB_2, TiB_2, TiN'den yapılmış kesici takımlarda ısı transferi yönlerinin sayısal çalışması

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Abstract

In this study, the effects of heat transfer and heat flux on cutting tools with materials of Al_2O_3, ZrB_2, TiB_2, TiN are investigated numerically by ANSYS fluent software. The numerical model was validated with the previous study. The influence of the machining parameters such as cutting speed and feed rate on the temperature and tool life has been investigated to indicate the optimum cutting tool and situation. The results show that Zirconium diboride (ZrB_2) and Titanium diboride (TiB_2) have a temperature less than the aluminum oxide (Al_2O_3) so that the productivity will increase with the diboride materials utilizing as cutting tool. The maximum temperature for aluminum oxide is 1300 K while the Titanium Nitrite achieved 1100 K. The lowest and maximum temperature was measured at a cutting speed of 180 m/min and 220 m/min, respectively. The optimum cutting condition has been obtained with TiN cutting tool material at 180 m/min cutting speed and 0.138 mm/ rev feed rate. Titanium diboride (TiB_2) materials achieved the maximum cutting tool life comparing to other materials.

Keywords: Cutting tool, Diboride material, Insert, Temperature distribution, Heat flux, Tool life.

Özet

Bu çalışmada, ısı transferi ve ısı akısının Al_2O_3, ZrB_2, TiB_2, TiN malzemelerden üretilmiş kesici takımlar üzerindeki etkileri ANSYS sonlu elemanlar analizi programı yardımıyla sayısal olarak araştırılmıştır. Sayısal model bir önceki çalışma ile doğrulanmıştır. Kesme hızı ve ilerleme gibi kesme parametrelerinin kesici takım ömrü ve sıcaklık üzerine etkileri araştırılmıştır. Sonuçlar, Zirkonyum diborid ve Titanyum diborid'in alüminyum oksitten daha düşük sıcaklığa sahip olduğunu, böylece kesici takım olarak kullanılan diborid malzemeleriyle verimliliğin artacağını göstermiştir. Alüminyum oksit için maksimum sıcaklık 1300 K iken, Titanyum nitrit için 1100 K sıcaklık elde edilmiştir. En düşük sıcaklık 180 m/dak kesme hızında, en yüksek sıcaklık da 220 m/dak kesme hızında ölçülmüştür. Optimum kesme koşulları TiN kesici takımla 180 m/dak kesme hızında ve 0.138 mm/rev ilerleme hızında elde edilmiştir. Titanyum diborid (TiB_2) malzemeler diğer malzemelere kıyasla maksimum kesme takımı ömrüne ulaşmıştır.

Anahtar kelimeler: Kesici takım, Diborid malzeme, Insert, Sıcaklık dağılımı, Isı akısı, Takım ömrü.

1 Introduction

The high-temperature values disturb the performance and quality of numerous engineering processes such as the machining process in which cutting tool has high temperature. This leads to change the tool physical properties and microstructure during machining. The disadvantages of those changes represent in reduction of material resistance of mechanical stresses so that performance and lifespan of cutting tool decrease. The processing impacts increase the operation cost and decrease the products quality. The study of heat flux as well as the temperature at different machining parameters can be useful for efficient cooling systems development and determining the optimum operation parameters. Valvo et al [1] studied a multiple method to estimate the temperatures in the ceramic tools cutting process. He evaluated the temperature lines with 3D cutting approach experimentally by applying constant melting point powders dispersed on planes parallel to rake face. Numerical analysis was completed to determine the percentage of heat transfer to the cutting tool during the operation and the temperature distribution of the insert and cutting holder. Temperature distribution was examined with SEM microscopy to confirm the numerical results. The results showed that at cutting speed equals to 11 m/s, metal appeared in the fractures of the inserts so that the cutting temperatures exceeded 1540 ºC. Battaglia et al [2] studied the diffusion of heat for coated cutting tool analytically for modeling and to quantifying the coating thermal effect without tribological effect. The heat flux is analyzed depending on the deposit thermo-physical properties and the thickness. It was found out that the tribological phenomena at the tool-chip interface is the key reason why variations in the heat flux transferred to a substratum are clarified. Grzesik [3] studied the thermal and mechanical properties of orthogonal metal material tool by Lagrangian finite elements code. He investigated the effect of plane faced coated carbide tools and uncoated tools with continuous chip formation. The findings of the FEM

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and analytical models are shown to have very adequate and physically validated tests, for both uncoated and three-layered coated materials, for cutting temperature values and distributions. Nonetheless, the best result would probably be obtained by adjusting the friction parameter and heat partition to coated tools with real thicknesses. In this analysis, they were based on data from the manufacturer and not on measurement utilizing, for example, microscopy scanning. Filice et al [4] modeled the cutting process numerically and by Lagrangian Eulerian approach. Experimental studies were performed to classify internal temperatures and cutting forces. A mild steel was cut using an uncoated tool (WC) as well as a coated tool (TiN). The heat transfer coefficient global model was developed at the tool-workpiece interface based on both experimental and simulative results, as a function of local pressure and temperature. Kountanya [5] has investigated the transient tool temperatures in disrupted machining processes. The practical solution technique for the Green's function approach involved the heat convection rate from outside surface. The findings showed that modulation at an upper variation frequency decreased the cutting temperature. However, heat conduction over convection to the ambient dominated the device. The instantaneous uncut chip thickness has been indicated to gap the highest temperature, suggesting that the model will theoretically change the cutting tool's thermal softening without an associated decline in material removal pace. The same model of tool temperature applied to face molding suggested the Peak temperature only occurred at the exit of the cut. Carefully planned hard-facing experiments were conducted which varied frequency and duration of the interruption. Data on tool life stated the beneficial effects of lower temperatures due to a slight interruption. Carvalho et al. [6] studied the effects of heat in cutting tools, taking into account the difference in the thickness of coating and heating flux. The K10 and the diamond substrates were used with TiN and Al_2O_3 coatings. The simulation approach makes use of the ANSYS software under the boundaries and constant physical thermal conditions. The experiments are used to test the suggested technique. After a continuous cut, the TiN and Al_2O_3 coatings did not produce satisfactory results. The heat flux for the 10 µm TiN and Al_2O_3 coatings showed a marginal reduction. Noor et al. [7] studied the dry cutting where no lubricant or coolant is utilized. They studied the dry cutting impact on the cutting tool life cutting force and while by means of two separate carbide coated tools such as TiAlN and TiN / MT-TiCN / TiN in the aerospace material machining. The surface-response method has been utilized to reduce the total experiments. TiAlN Swarm Optimization models have been established for machining parameters optimizing such as federate, cutting speed, and axial depth and to find the optimal cut force and durability. Compared with TiN / MT-TiCN / TiN, it is found that carbide cutting tool coated with TiAlN worked better in dry cutting. On the other side, using 100% water-soluble coolant, TiAlN performed higher. The cutting tool still needed lubricant to support the heat transfer from the workpiece because of the high temperature created by the aerospace materials. Cheng et al. [8] studied the temperature distribution with a cooling system in a smart cutting tool process by determining the cooling fluid temperature at the outlet and inlet passes. They investigated the efficiency of the micro-cooling construction and the possibility of evaluating and adjusting the cut temperature experimentally and numerically. The results showed that the increase of the flow rate leads to a decrease in the resolution of the tool as a temperature sensor. It is indicated that there is a high accuracy with utilizing the numerical prediction model. The suggested micro-internal structure decrease the cutting tool temperature during the process. The new design and cooling solution is suggested for machining of different materials such as titanium and composites. Deiab et al. [9] investigated the distribution of the temperature on the cut insert with dry air cooling at low temperature numerically. Minimum quantity of lubrication of the cutting tool as internal cooling studied in this study. Results showed that the forced convection air increase the speed. Conduction and convection of heat modes are simulated for the metal cut machining. It is indicated that it is more important for the heat transfer by radiation to be explored in the CFD simulation. Carvalho et al. [10] investigated the temperature field in the insert, shim, and cutting-holder and the estimation of the cut interface heat flux. They improved a method for heat fluxes and temperature estimation in a cut machining. The use of COMSOL for the numerical solutions of differential equations that control the physics is effective. It is possible to adjust any boundary conditions and model the geometry. Yang et al. [11] investigated the heat transfer and flow shape of high-speed cutting machining with viscous coolant fluid and air and compared between the temperature gradient in the two cases. The results showed that the temperature gradient increase with the rise of Pr number with the coolant fluid comparing to natural air convection. They finished the heat transfer model that can be useful for understanding cooling process characteristics. Magalhães et al. [12] investigated the highest, minimum, and average temperatures for the connection zone between the ship and the insert by the help of COMSOL software. For validation of the results, comparing the heat flux of this study and the heat fluxes of other works was applied. They studied the temperature variation of coated carbide tools throughout the thicknesses. The results indicated that the coated carbide cutting tool presented higher temperatures for the flux contact area than the uncoated carbide tool. It is indicated that the increase of thicknesses has more effect on the cemented carbide. It can be concluded that the Al_2O_3 coating is better than TiN because of the low thermal conductivity value and protective for the cutting tool concerning heat. The uncoated and coated carbide cutting tool performed a peak difference for the cut area of 12.7 °C for the TiN and 75.5 °C for the Al_2O_3. Berezvai et al. [13] investigated a method to determine the contact length during the cutting process experimentally and numerically by using Abaqus software. Theoretical expressions with orthogonal cutting test and FE simulations were introduced. The results showed a good agreement between the FE simulations and the Lee and Shaffer model of contact length based on the Minimum

Energy Principle (MEP) shear angle model. Parida and Maity [14] discovered an easy and simple model for heating the work-piece by flame heating with study. They studied the influences of speed of cutting, feed rate, and temperature on cutting force and specific energy. Nickel based alloy was examined in room temperature and high-temperature conditions during the turning process with the aid of DEFORM software. A respectable correlation between the numerical and experimental results was achieved. The results indicated that energy of performing the machining process and cutting force in the case of hot processing is less than the case of room temperature condition. Therefore, the shear stress with heating reduce gradually. Moghanlou et al. [15] studied the heat transfer, temperature distribution, and maximum temperature for cutting processes in diboride-based materials such as HfB_2, ZrB_2, and TiB_2 as well as HfB_2–20 vol% SiC, ZrB_2–20 vol % SiC and TiB_2–20 vol% SiC composites by using COMSOL Multiphysics software. The results indicated that the rising slope of temperature for HfB_2 is higher than those of ZrB_2 and TiB_2 where the lowest maximum temperatures were achieved for ZrB_2–SiC and TiB_2–SiC composites materials that leads to increase the cutting speed. Maximum temperature reduces with SiC addition in all cases of diborides which causes an increase in cutting speed and efficiency. Zhang et al. [16] investigated a different technology for drilling with the ultra high speed diamond tool which can accomplish a high penetration rate with minor power. ABAQUS program was used to investigate the influence of ultra high cutting velocity on the rock break performance and heat of cutting. It is indicated that the heat flux and specific energy drop with the increase of the rotary speed at cutting speed exceeds equals to 8 m/s. Fernandes et al. [17] studied thermal conductivity enhancement of a novel cemented carbide cutting tool during the design and building processing by using COMSOL Multiphysics software. It is concluded that WC-Co/Cu achieved 127 W/m•K for the thermal conductivity and this value is upper than WC-Co thermal conductivity that follow the number of 36 W/m•K. Thermal conductivity increasing as indicated to be more effective with the method specially for the cut zone vicinity. Xia and Gillespie [18] used the quasi static method for modelling the workpiece chip thermal distribution at equilibrium conditions and the heat transfer equation is solved by an in-house Multiphysics FEM solver, FenicsSolver. Periodic boundaries were chosen for study the shear plane and that decreases the temperature and velocity change without extra mesh refinement. The boundaries of the straight chip decrease the heat flux resulted from the non realistic material flow crossing the air material. From the above mentioned previous literature review, it is indicated that many papers studied the temperature distribution in cutting tool experimentally with the aid of COMSOL or some other softwares. Also, some researchers investigated the effect of heat flux and the maximum temperature on cutting tools for Al_2O_3 and steel. ANSYS software wasn't utilized for studying the temperature distribution. In addition, fewer papers studied the cutting of diboride materials.

Therefore, in this study, a numerical approach by using ANSYS software for the first time will be utilized to study the temperature distribution and heat transfer parameters in cutting tool fabricated from Aluminum-Oxide, Zirconium Diboride, Titanium Diboride and Titanium Nitrite. The effect of changing the type of the material of the cutting tool will be investigated on four materials. The heat transfer characteristics and temperature distribution to determine the minimum, maximum, and optimum values of the temperature of the cutting tool have been investigated. The effect of the cutting speed on the temperature of the cutting process will be investigated while the speed will be varied from 180 to 220 m/min and feed rate will be studied with three different values such as 0.138, 0.277, and 0.554 mm/rev. The study of cutting tool life with the different type of materials will be introduced. An optimization will be performed to determine the superlative cutting tool and the machining parameters.

2 Materials and methods

In this research, the temperature and heat flux distribution in cutting tool processing four materials (Al_2O_3, ZrB_2, TiB_2, TiN) have been examined. Two diboride materials will be utilized as they have good properties such as wear-resistance and withstand against ultra-high temperatures as seen in Table 1. The workpiece and the tool holder are made from the AISI1045 steel with properties as stated in Table 2.

Table 1. Specifications of the cutting tool materials.

Material	Chemical form	Density kg/m^3	K W/m•K	CP J/kg•K
Aluminum oxide	Al_2O_3	3950	12	651
Zirconium diboride	ZrB_2	6080	18	587
Titanium diboride	TiB_2	4520	24	554
Titanium nitrite	TiN	5400	27	327

Table 2. Properties of workpiece and tool holder materials.

AISI1045 steel properties	Value	Unit
Density	7870	kg/m^3
Thermal conductivity	51.9	W/m•K
Tensile strength	585	MPa
Yield strength	450	MPa
Poisson's ratio	29	

2.1 Geometry of the tool

Figure 1 shows the 3D model of a cutting tool consisting of insert, shim, and tool holder, where the shim is positioned between the insert and the tool holder. SOLIDWORKS software was used to construct the three-dimensional model that was utilized in the tests. The specific dimensions of the insert and the holder are similar to the model utilized in [12] are illustrated in Figure 2 and Figure 3 where the elevation and side views as well as the plan view show the thickness of the inserts with 4.7 mm and about 110 mm length of the steel holder.

2.2 Physical model

The model was drawn by SOLIDWORKS software then the ANSYS fluent software was utilized to set up the boundary conditions and the simulation performed to obtain the heat flux between the insert and the workpiece and temperature distribution.

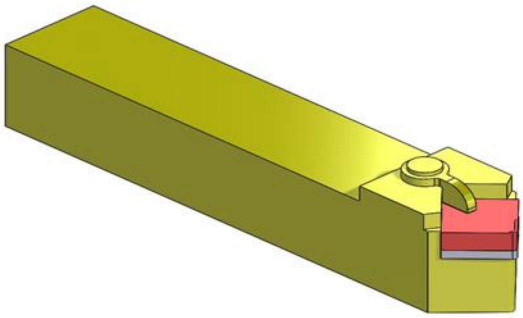

Figure 1. Three dimensional model of the geometry of insert and cutting holder.

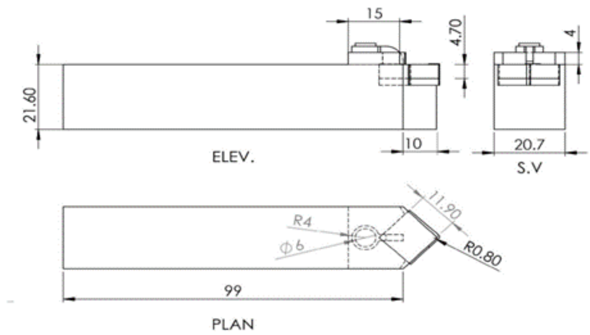

Figure 2. The dimensions of the cutting tool with insert and tool holder.

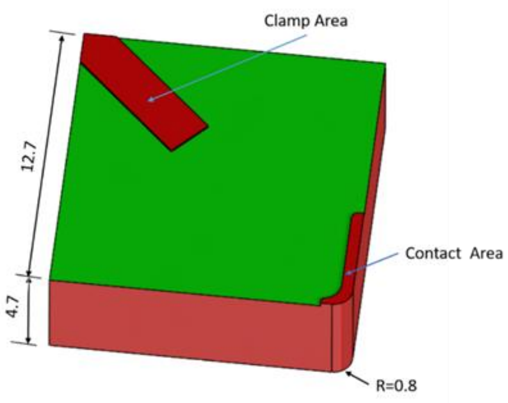

Figure 3. Dimensions of the insert and contact area between the inset and the workpiece.

2.3 Meshing

The unstructured meshing was chosen for the computational domain because of the complexity of the model. The mesh generation in the regions of heat flux and clamp area have refinement to increase the quality of the grids. Simulation results can be seen in Figure 4 and Figure 5. To confirm the solution independency of the mesh, the grid-dependency is checked for three different grids: 456187, 625471, and 820142 cells, respectively. It is indicated that there is no difference in results between the second and the third configurations, so that the number of 625471 cells was chosen for the simulation. The specific details of the meshing of the insert were indicated in Figure 6.

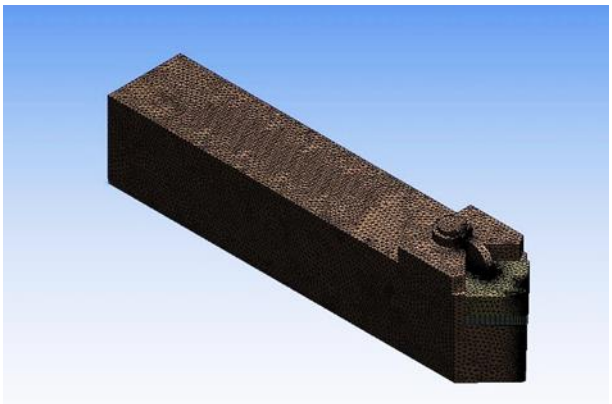

Figure 4. 3D of mesh generation grids.

Figure 5. Elevation view of the grid generation.

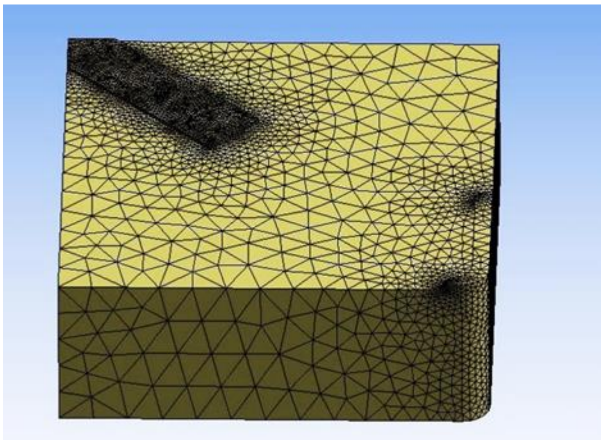

Figure 6. Mesh generation of the insert.

2.4 Governing equations

Heat conduction equation that describes the thermal model can be determined by the nonlinear transient three-dimensional diffusion as given in Equation (1):

$$\rho C_p \frac{\partial T}{\partial t} = \vec{\nabla}\left(K \vec{\nabla} T\right) + \varphi \qquad (1)$$

where t is the time in second and T is the temperature in Kelvin unit while K expresses the thermal conductivity in

W/m•K and C_p indicates the specific heat in J/kg•K and ρ determines the density of the material in kg/m^3, φ is the radiative source term (W/m^3).

Heat convection and radiation can be calculated by the following relation:

$$-K\frac{\partial T}{\partial n} = (T - T_\infty) + \sigma\,\varepsilon\left(T^4 - {T_\infty}^4\right) \quad (2)$$

Heat flux was applied for the contact between the insert and the workpiece can be determined by:

$$\dot{q} = C_p\frac{\partial T}{\partial t} \quad (3)$$

Where the equation of the heat flux that was used in the User Defined Function (UDF) code generated by excel software:

$$\dot{q} = .4926t^5 - 97.19\,t^4 + 6914t^3 - 232532t^2 + 4000000t + 10000000 \quad (4)$$

The cutting tool life can be calculated based on the cutting speed and parameter constants by the following Taylor's Formula:

$$v\,t^n = C \quad (5)$$

where v is the cutting velocity, t is the cutting tool life in minute. The parameters of n and C depend on feed, cutting depth, workpiece and cutting tool materials. n is the plot slope and C is the interrupt on the velocity axis at one-minute of tool life.

2.5 Boundary and initial condition

To simulate the heat transfer and temperature distribution for cutting, the heat flux equation at the connection zone between the insert and the workpiece was generated by excel program from the study [10] and [12]. UDF in ANSYS fluent was utilized to determine the boundary of the heat flux at the flux area according to the equation of flux. All the outer surface of the cutting tool was performed as a heat convection boundary equation where the surfaces between the insert and the holder was established as conduction heat transfer. The next assumptions are used for the simulations:

- At the initial condition, the cutting insert, shim, and cutting holder have room temperature which is equal to 300 K.
- Heat flux was applied at the contact area interface according to the heat flux Equation (4) at t = 0 s.
- The cutting process continues up to 60 seconds and then the heat load is removed.
- The heat transferred by conduction between the tool-shim and tool-holder interface.
- The cutting speed was changed from 180 to 220 m/min and the feed-rate has three different values such as 0.138, 0.277, and 0.554 mm/rev.

2.6 Validation

For validation of the simulation results, the heat flux of the present study was compared with the previous studies [10] and [12] as seen in Figure 7. The temperature of the insert as an average value was compared with the same studies as shown in Figure 8. It is indicated that the deviation between the results is very limited. Therefore, the present numerical results have enough realistic accuracy. The regular differences between numerical and previous results for heat flux are around 4.32%. The highest dissimilarity for heat fluxes 7.51% and the smallest dissimilarity is 2.31%. The validation results explained that the differences between the numerical and the experimental results are acceptable where the regular differences between numerical and previous results for average temperature is around 3.21%. The highest dissimilarity for average temperature is 6.01% and the smallest dissimilarity is 1.54%. In general, the differences are acceptable for simulation errors.

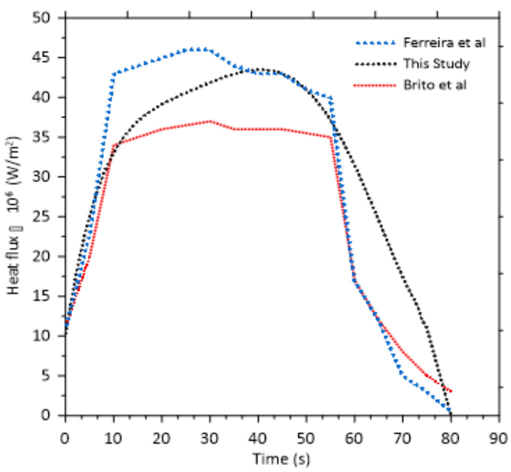

Figure 7. Comparison between the numerical results and the previous studies of Brito [10] and Ferreira [12] for the heat flux.

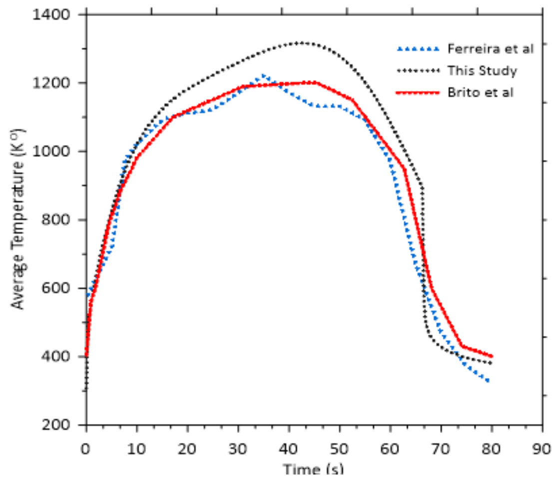

Figure 8. Comparison between the numerical results and the previous studies of Brito [10] and Ferreira [12] for the average temperature.

3 Results and discussions

In this section, the results obtained to estimate the heat flux, temperature distribution, maximum, and minimum temperature by using the inverse function of heat flux with the use of software ANSYS FLUENT have been analyzed. At the beginning of the process, the cutting tool and holder were found at uniform room temperature. The cutting machining continues up to 60 seconds which is enough for reaching the steady-state and the maximum temperature can be determined. Heat flux is applied on the tool then the cutting is stopped and the cutting tool moves off the workpiece.

3.1 Temperature variation with time

Figure 9 shows the average temperature of the contact area during the cutting for Al_2O_3, ZrB_2, TiB_2, and TiN. It is indicated that the aluminum oxide achieved the highest temperature for the following figure about 1100 K comparing to other insert materials where the Titanium Nitrite scored the lower values of temperature as near to 900 K.

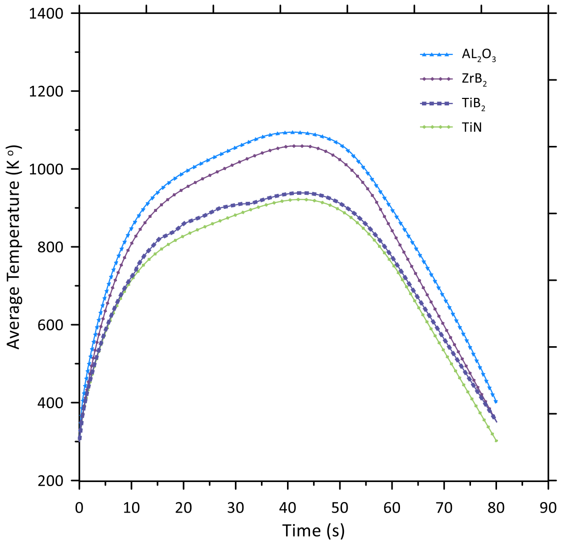

Figure 9. The average temperature of the contact area during the cutting of various materials.

The temperature begins to increase when the heat flux was applied until it reaches the maximum values near 50 seconds from the starting of the machining process. The temperature begins to decrease when the cutting tool goes away from the workpiece and there is no heat flux. It is indicated that the Zirconium diboride and Titanium diboride experienced lower average temperatures than aluminum oxide because of the low thermal conductivity of diboride materials. As it was mentioned, maximum temperature affects the machining speed and the productivity rate. Figure 10 shows the maximum temperature of different materials aluminum-oxide, Zirconium diboride, Titanium diboride, and Titanium nitrite. It is indicated that the ZrB_2 and TiB_2 have improved performance and can work at higher speeds and increase the productivity. The minimum temperature for the face of the insert at the heat flux was directed for the aluminum-oxide, Zirconium diboride, Titanium diboride and Titanium nitrite was illustrated in Figure 11. The maximum temperature for aluminum oxide is 1300 K, where the Titanium nitrite achieved 1100 K. At first, the applied heat flux heats the tip of the tool, and then the thermal heat is dispersed in the cutting tool as time passes. The tool's hot point is the chip interface at any given time. The contours reveal that most holder feels a change in temperature at low temperature. By conduction, the bulk of the produced heat is transmitted to the cutting holder and shim. This can also be inferred that the tool holder's higher mass has resulted in lower temperature increase within it. Radiation is essential, and the maximum heat losses are related to the radiation after the conduction process.

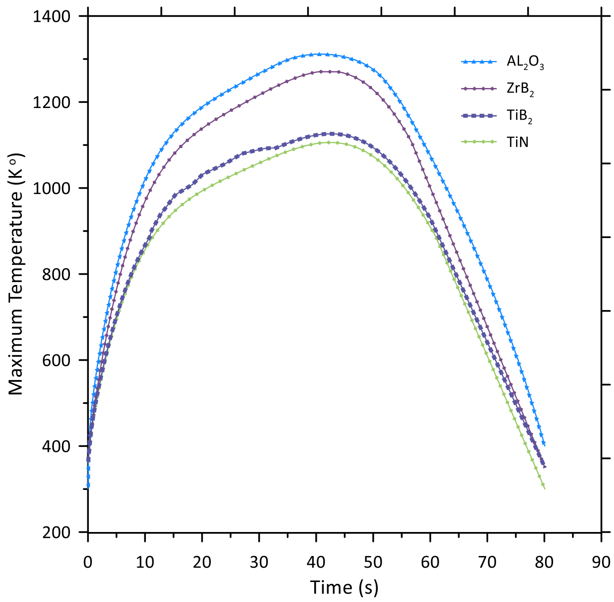

Figure 10. The maximum temperature of the contact area during the cutting of various materials.

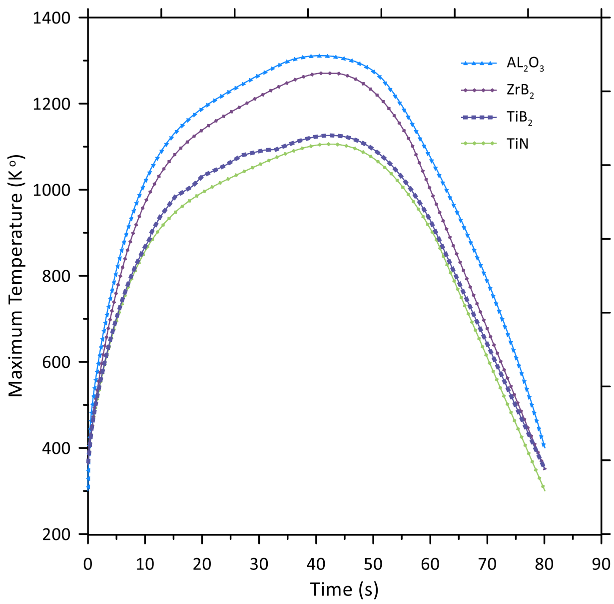

Figure 11. The minimum temperature of the contact area during the cutting of various materials.

3.2 Influence of cutting conditions in the temperature estimation

Cutting speeds lead to change the temperature distribution changes as seen in Figure 12. The temperature gradually increases with the rise of cutting speed for all the materials. The smallest temperature was attained at a speed of 180 m/min and the maximum temperatures were achieved at a cutting speed of 220 m/min. It can be observed that the TiN material is the better choice comparing to the other materials depending on the temperature distribution versus the cutting speed. As the TiN achieved a better performance than the other materials, the feed-rate (FR) of the cutting tool with TiN was studied. The relation between the temperature and the FR of the cutting tool for TiN is given in Figure 13. The higher the feed rate the higher the contact temperature of the interface. This behavior is due to higher feed rates and higher strain rates in primary and secondary shear zones.

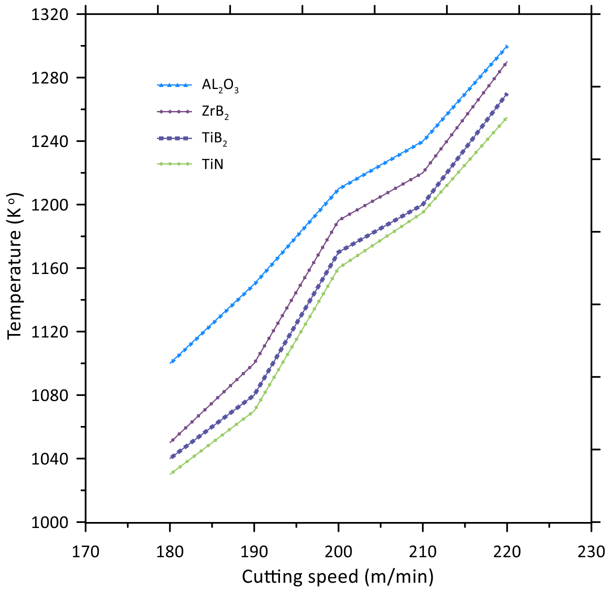

Figure 12. The relation between the temperature and the cutting speed of the cutting tool.

3.3 Influence of cutting speed on the cutting tool life

The cutting tool life can be determined by many ways such as fracture failure that can be explained as brittle fracture is exposed to extreme cut force, temperature failure while cut temperature is very high, and steady wear where the losses of cutting tool shape and efficiency lead to steady tool wear. In this study, the temperature failure will be used to determine the cutting tool life. Figure 14 shows the relation between the cutting tool life and cutting speed for various materials such as Aluminum-oxide, Zirconium diboride, Titanium diboride, and Titanium nitrite. Cutting tool life decreased with the increase of the cutting speed. The rise in cutting speed leads to an increase in removal materials where the temperature increases rapidly. The Titanium diboride achieved the maximum tool life comparing to cutting tools with the other materials. The maximum cutting tool life is indicated at 180 m/min with 59, 52, 45, and 32 min for Aluminum-oxide, Titanium nitrite, Zirconium diboride, and Titanium diboride, respectively. High temperature was created by the increased cutting speed, which resulted in a rapid deterioration of the quality of the ceramic tool material and the cutting edge was then easily chipped by the cutting force.

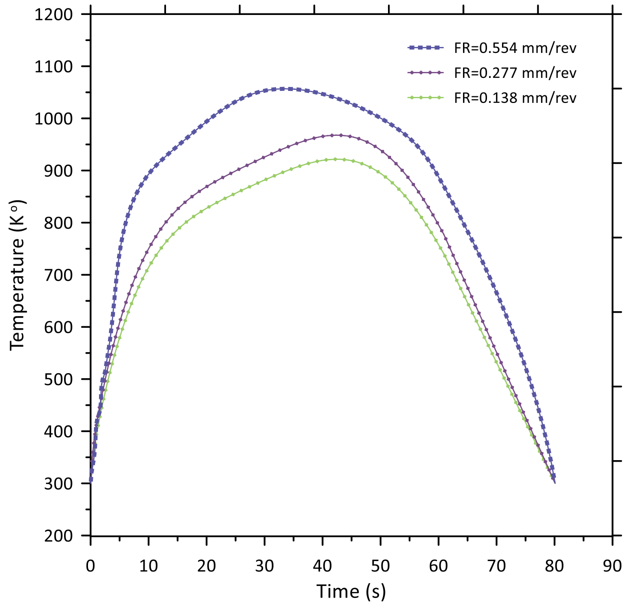

Figure 13. The relation between the temperature and the feed-rate (FR) of the cutting tool for TiN.

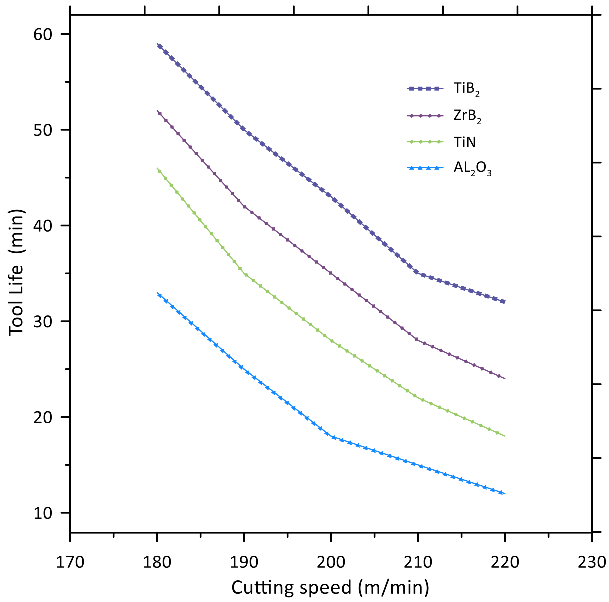

Figure 14. The relation between the cutting tool life and cutting speed for various materials.

3.4 Temperature distribution

The temperature distribution of insert, shim, and tool holder at 5 s from the starting of the cutting process is illustrated in Figure 15. It is indicated that the maximum temperature appeared at the connection surface between the insert and the workpiece where the heat flux effects directly on the insert. It can be shown that most of the body of cutting holders have temperature equals to 300 K and this means that the heat does not reach all the regions of the holder.

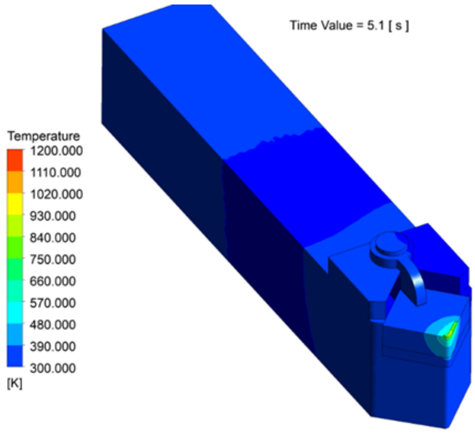

Figure 15. Contour of the temperature at 5 seconds.

Figure 16 shows the temperature distribution of the cutting tool at 20 s from the starting of the machining operation. The temperature distribution of the cutting tool at 30 s, 40 s, and 50 s are illustrated in Figure 17, Figure 18 and Figure 19, respectively. It is indicated that the temperature rises with time for the insert and the heat transfer by conduction through the insert and then to the tool holder. The results show that the contours of the temperature field are similar for the contours of the previous studies obtained at the studies [10] and [12]. The heat transferred by convection from the outer surfaces to the surrounding leads to reduce the temperature of the body of the holder. At the start, the tooltip was warmed by the applied heat flux, and then with the time spending, the thermal energy is dispersed in the tool. The tool's hot points are the points controlled by the devices at any moment. The simulation contours indicate that maximum holder practices a change in low temperature. The temperature profile increases more rapidly, and the average temperature values are reached prior than the reference case for a uniform heat distribution. The maximum interface temperature is found to rely heavily on the average heating intensity based on the estimation of two changed heating distributions. The first one of a stretched friction region leads to a lower average interface temperature, although for the second heating distribution the significantly lower peak temperature is in an upstream position.

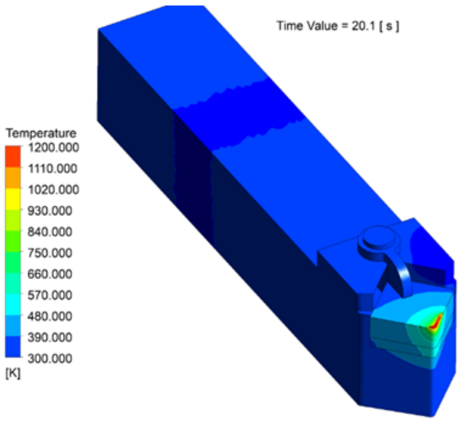

Figure 16. Contour of the temperature at 20 seconds.

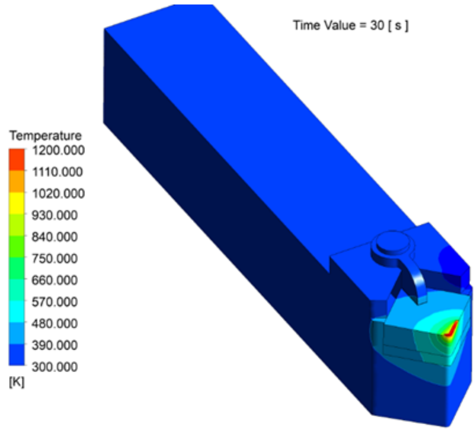

Figure 17. Contour of the temperature at 30 seconds.

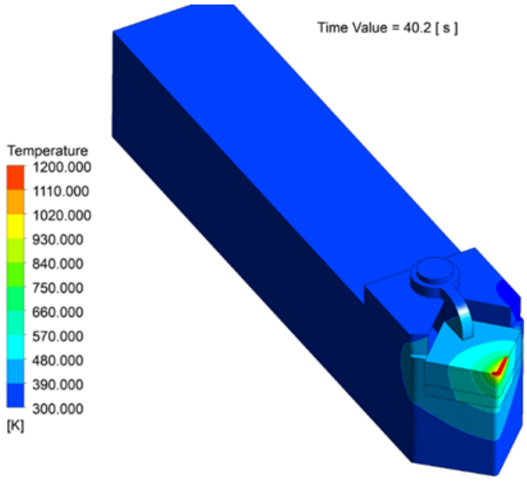

Figure 18. Contour of the temperature at 40 seconds.

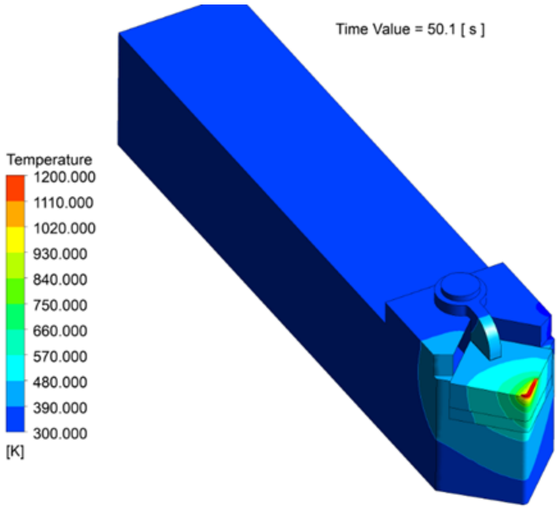

Figure 19. Contour of the temperature at 50 seconds.

4 Conclusions

In this study, the temperature distribution of insert, shim, and tool holder for various materials have been investigated depending on the heat flux of the contact surface of the heat generation. The UDF and ANSYS FLUENT were joined to specify the heat flux and temperature distribution. The various materials are utilized in this study such as Al_2O_3, ZrB_2, TiB_2, and TiN to indicate the effect of diboride content improvement in cutting machining operation. The machining parameters such as the cutting speed varied from 180 to 220 m/min and feed rate with three different values such as 0.138, 0.277, and 0.554 mm/rev were investigated. The study of cutting tool life with the different materials was introduced. The results can be concluded in some points as:

- It is indicated that the aluminum oxide achieved the highest temperature following the number about 1100 K comparing to other insert materials where the Titanium nitrite scored the lower values of temperature with the number near to 900 K.
- It is observed that the minimum temperatures were attained at a cutting speed of 180 m/min and the maximum temperatures were achieved at a cutting speed of 220 m/min.
- The increase in cutting speed contributes to a rise in removal materials where the temperature is growing exponentially.
- Comparing to cutting tools with other materials, the TiN material achieved good behavior with cutting speeds of 180 m/min and 0.138 mm/rev.
- The Titanium diboride obtained the highest tool life so that the optimization process indicated that the TiB_2 is the respectable choice with machining parameters (cutting speed as 180 m/min, and feed rate as 0.138 mm/rev) where the temperature distribution is acceptable.

5 Future study

The study of the temperature and heat flux distribution for the cutting material and workpiece from mixing powders may be advised for the future studies.

Conflict of interest

The authors declare that there is no conflict of interest.

Similarity rate (iThenticate): 6%

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