OPTIMIZING TOOL PERFORMANCE IN DUPLEX STAINLESS STEEL TURNING FOR IMPROVED MACHINING EFFICIENCY

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ABSTRACT
Duplex stainless steel is an important part of metal cutting in many different industries; this research aims to examine the variables that affect tool wear and life when turning this material. The study is centered on wear processes including abrasion, adhesion, and diffusion, with the goal of enhancing tool design and machining efficiency. The research aims to fill gaps in understanding and give solutions for better tool design. The findings are expected to significantly advance metal cutting technology, particularly for duplex stainless steel, which requires an exceptionally high level of corrosion resistance and mechanical properties. A comparison was made between the two tool points' wear results and the flank wear breadth as a function of the tool point's constant-state wear. We did this to find out how the two were related. Various processes, such as abrasive wear and adhesive wear, have been recorded in the past. Tools coated with Al2O3 had a longer tool life and higher resistance to abrasive wear when machining without a cooling lubricant was done. Furthermore, the tool's lifespan was increased. The scanning electron microscopy (SEM) has been used to examine the wear.

Keywords: -Work piece, Stainless steel, Tool life, Machining, Surface Roughness.
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I. INTRODUCTION

The area of metal cutting and machining is an essential component of a wide range of industrial processes. The estimation of tool life and research wear is an essential component in the process of maximizing both efficiency and productivity. The purpose of this introduction is to dig into the complexities of tool life assessment and wear research, with a particular emphasis on duplex stainless steel turning, which is an essential machining activity in modern production. The use of duplex stainless steel has become more popular as a result of the continued demand from many sectors for materials that possess outstanding mechanical qualities and excellent resistance to corrosion. On the other hand, owing to the inherent toughness and high strength of duplex stainless steel, the process of machining it provides the particular obstacles that it poses. In this context, it is essential to have a solid grasp of the tool behavior and wear processes that occur during turning operations in order to increase the efficiency of the machining process and the longevity of the tool. There are many different industries that make extensive use of duplex stainless steels. These steels are distinguished by their dual-phase microstructure, which includes both austenitic and ferritic phases. Some of these industries include chemical processing, oil and gas, and maritime engineering. Due to the fact that it has both high strength and exceptional corrosion resistance, duplex stainless steel is a suitable material for use in applications that are situated in harsh environments. In spite of this, the process of machining duplex stainless steel includes intricate interactions between the cutting tool and the work piece, which results in particular wear patterns and particular issues for the tool's lifespan. In order to provide useful insights that may be used to improve tool design, cutting parameters, and overall machining methods, the purpose of this study is to uncover the mysteries surrounding tool wear in duplex stainless steel turning. In the context of machining processes, the term "tool life" refers to the amount of time that a cutting tool is in use before it becomes unsuitable for future use. This is an essential performance statistic. When determining the life of a tool, it is necessary to conduct a comprehensive examination that takes into account a variety of characteristics, including wear, chipping, and breaking. When it comes to turning duplex stainless steel, it is vital to have a thorough grasp of the complex relationship that exists between the cutting tool and the work piece in order to precisely forecast the tool's lifespan. During the process of machining duplex stainless steel, a number of different wear processes come into play. These mechanisms include abrasion, adhesion, and diffusion, and each of these mechanisms contributes to the overall development of wear. In order to provide a full knowledge of the issues that are presented by duplex stainless steel machining, this study strives to identify the predominant wear mechanisms and the significant impact that these mechanisms have on tool life.

A typical kind of wear mechanism in metal cutting is called abrasion. This wear mechanism takes place when hard particles on the surface of the work piece contact with the cutting tool, which results in the loss of material from the edge of the tool. When it comes to turning duplex stainless steel, the abrasive character of the material that makes up the work piece may have a considerable influence on the tool life. In these kinds of situations, the abrasive wear resistance of cutting tools becomes of the utmost importance. As a result, it is necessary to investigate the development of innovative tool materials and coatings that are capable of withstanding the abrasive pressures that are experienced throughout the machining process. Additionally, the cutting parameters, such as cutting speed and feed rate, have a crucial influence in determining the degree of abrasive wear. This further highlights the need of having a deep grasp of the dynamics of the machining process. The transfer of material from the work piece to the cutting tool is an example of adhesive wear, which is another essential component of tool wear in duplex stainless steel turning. Built-up edge (BUE) is formed on the rake face of the tool as a result of the close contact that occurs between the tool and the work piece when the temperatures and pressures are high. Not only does the presence of BUE include a change in the geometry of the tool, but it also plays a role in the development of larger cutting forces and higher temperatures. In order to protect against adhesive wear, it is necessary to use novel strategies, such as the utilization of sophisticated coatings and lubricants, in order to reduce the amount of material that is transferred between the tool and the work piece surfaces. In the process of turning duplex stainless steel, the purpose of this study is to develop efficient ways for decreasing adhesive wear and increasing tool life. During the process of turning duplex stainless steel, the phenomena of diffusion wear, which is caused by the chemical interactions that occur between the tool material and the work piece material, adds an additional layer of complication to the process of determining the tool life. The high temperatures that are produced during the process of machining may make it easier for elements to diffuse between the cutting tool and the work piece. This can result in the creation of intermetallic compounds, which can then contribute to the deterioration of the tool over time. For the purpose of developing solutions that successfully minimize this kind of wear, it is essential to have a solid understanding of the kinetics of diffusion wear and its dependency on elements such as temperature, cutting speed, and tool material. The purpose of this study is to contribute to the creation of tool materials that have better resistance to chemical interactions in situations that include duplex stainless-steel machining. This will be accomplished by unraveling the complexities of diffusion wear over time.

The assessment of tool life and research wear in duplex stainless-steel turning is a complicated and diverse activity that demands a complete knowledge of the particular problems provided by this material. In conclusion, this material presents a unique set of issues that must be adequately addressed. The purpose of this study is to investigate the complex relationship that exists between cutting tools and duplex stainless steel, with a particular emphasis on wear processes such as abrasion, adhesion, and diffusion. The goal is to get insights into these wear processes in order to influence the design of cutting tools, the selection of optimal cutting settings, and the creation of creative ways to optimize tool life and overall machining efficiency. This will be accomplished by acquiring these insights. This study is positioned to make major contributions to the progress of metal cutting technology in the context of duplex stainless-steel machining. This is because industries are continuing to push the limits of material performance, and the results of this research are poised to make such contributions.

II. REVIEW OF LITERATURE

Dyl, Tomasz. (2019). within the context of the technical process, it is essential to form the surface layer in accordance with the desired qualities. Because of the capability of the kinematic pair components to enable the needed dependable functioning of machine parts, this issue is a significant challenge that has to be addressed. The gadgets of the most recent generation are able to function with growing operating demands. This necessitates the hunt for ever-more-recent building materials or cutting-edge production engineering solutions that would guarantee the components of machines have a high level of dependability and durability. Continue to be used on steel constructions of machine components for the purpose of mechanical engineering. Shipbuilding and the petrochemical sector are two industries that make extensive use of stainless steels. These materials are used in the building of seawater and acid installations, according to the specifications. The two-phase stainless steel that is now available is a more recent material that has more advantageous features. This kind of steel is referred to as duplex steel. Pump shafts in liquids including acid or saltwater may be treated with this substance. Steel that is cast in duplex is a material that is tough to cut. Determining the influence that cutting parameters have on the surface quality of the shafts and the amount of wear that the cutting edge experiences is a crucial step. Traditionally, the surface treatment of shafts is completed by the use of machining techniques such as turning, grinding, and superfinishing. Taking into consideration the many options available for outfitting a workshop for a maritime power plant, the most effective method of machining would be turning. In addition to the kind of tool material that was used and the form of the cutting inserts, the study details the link that exists between the wear of the cutting edge and the geometrical structure of the surface that has been machined.

Subhash, N. et al., (2019) Super-duplex stainless steels, also known as SDSSs, are the second generation of duplex stainless steels (DSSs), and they provide an exceptional combination of high mechanical strength, high toughness, and strong resistance to corrosion. Machineability of SDSSs, on the other hand, is very poor because of the large quantities of a variety of alloying elements there are. The machinability of SDSS SAF 2507 is investigated in this research for the purpose of turning operation under a variety of different machining circumstances. Under both dry and wet circumstances, temperature is monitored at a variety of cutting speeds throughout the whole range. When it comes to surface roughness, the approaches of response surface methodology (RSM) and artificial neural network (ANN) are used in order to create and compare prediction models. The use of Genetic Algorithm (GA) allows for the optimization of cutting settings, which ultimately results in the highest possible surface polish. In light of the findings that were collected, it was discovered that the feed rate was the most important element in determining surface roughness. In a study that was conducted after a certain amount of time had passed for a number of different cutting speeds, it was discovered that the amount of flank wear considerably increased as the cutting speed rose.

Zawada-Michałowskaet al., (2019) During the process of turning stainless steels, the tribological features of cutting tool wear are discussed in the study article. Upon conducting an analysis of the findings obtained with the VBBmax direct indicator, it was discovered that in the case of each of the inserts, the majority of the time, the progression of their wear was of a character that was comparable to linear trends. After making a comparison between the VBBmax direct indicator and the Ra parameter that was measured, it was determined that the two indicators were convergent. Greater values of the chosen geometric measure of wear on the flank face were also discovered as a result of the degradation of the surface quality observed.

Gamarra, José & Diniz, Anselmo. (2018).the super duplex stainless steels (SDSS) are characterized by their strong resistance to corrosion, high strain-hardening coefficient, and low thermal conductivity. These characteristics are achieved by the simultaneous mixing of several alloying elements. Due to these characteristics, they are often used in sectors that fall within the oil and gas sector. On the other hand, the same features make it more difficult to machine them because they result in the production of a built-up edge and a significant notch wear on the tools that are used to cut these steels while they are being cut. The purpose of this study was to find the optimal combination of machining techniques, tool geometries, and cutting feeds by using a high pressure coolant jet (70 bars), with the primary objectives of achieving a long tool life and high process productivity while simultaneously achieving the lowest surface roughness that was attainable.

Kannan, Ramesh & Padmanabhan, P. (2015). A study is conducted in this research on a milling machine in order to analyze the tool wear, tool life, material removal rate, and cutting force utilizing a stainless-steel work piece via a variety of machining processes employing a carbide insert tool in face milling operation. The flank wear and the crater wear that occurs during a certain amount of machining time are evaluated using a variety of speed, feed, and depth of cut parameters. To achieve machining that is both cost-effective and efficient, it is required to detect and quantify changes in the machining properties of the work piece material. Due to the fact that it results in an increase in productivity as well as an improvement in the surface quality of the work piece, high speed machining has garnered a significant amount of attention. On the other hand, while cutting at high speeds, the tool wear is significantly increased because of the high temperature at the interface between the tool and the component being cut. Wear on tools causes the surface finish to become less smooth, which in turn reduces the tool's lifespan. Because of this, one of the primary goals of research on metal cutting has been to investigate the processes and patterns of tool wear. The wear performances of carbide tools in face milling using Duplex 2205 stainless steel are reported in this research. The paper focuses on the cutting process. The tool maker microscope was used in order to investigate the wear patterns of the tools.

III. RESEARCH METHODOLOGY

Work piece and cutting tool materials

A ferritic–austenitic structure with around fifty percent austenite was present in the machined material, which consisted of cylindrical billets made of duplex stainless steel 2507. billets were approximately 256 millimeters in length and 35 millimeters in diameter. When the ultimate tensile strength (UTS) is equal to 700 MPa, the Brinell hardness is equal to 293 HB.

In Tables 1 and 2, respectively, the elemental makeup of the material that has been machined and the technical specifications of the cutting tools are shown. Clamping cutting tool inserts with the designation TNMG 160408 into the tool shank of the ISO-MTGNL 2020-16 type was the operation that was carried out. Several cutting parameters were chosen on the basis of suggestions from the industry.

T1: vC = 50/150 m/min, f = 0.2/0.4 mm/rev, and ap = 1/ 3 mm were the values that were chosen. In the studies that were carried out with the T2 tool point, comparable tests were carried out, which is why the cutting parameters were as follows: vC = 50, 100, and 150 meters per minute; f = 0.2, 0.3, and 0.4 millimeters per revolution; and ap = 2 millimeters.

Inside of a manufacturing plant was where the research was carried out. Pleszew plc used a lathe with a CNC 400 CNC Famot for the purpose of carrying out the study program.

A preliminary investigation was carried out before to the main study in order to ascertain the importance of the cooling impact on tool life after DSS rotation.

The mixture was used as a cooling-lubricant liquid that did not include any chlorine-based refrigerant mineral oils.

It was called Blasocut 4000CF, and it was a universal emulsion that was used for medium-heavy and hard machining of steel. In order to ascertain the duration of the tool's useful life, the value of the wear parameter VBB was accepted as 0.2 millimeters.

Table 1 – Chemical composition of 2507 duplex stainless steel.

Element	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
At.%	max 0.03	max 1.00	max 3.00	max 0.040	max 0.010	31.0 22.0	54.0 5.06	5.02 5.03	1.01 22.0	-

Table 2 – Cutting tool specification.

Tool	Substrate	Coatings	Coating technique
MM 2025 Code: T1	Hardness: 1350 HV3 Grade: M25, P35	Ti(C,N) – (2 mm) (top layer) Al2O3 – (1.5 mm) (middle layer) TiN – (2 mm) (bottom layer)	CVD

CTC 1135 Code: T2	Grade: M35, P35	TiN – (2 mm) (top layer) Ti(C,N) – (2 mm) Ti(N,B) – (2 mm) TiN – (2 mm) Ti(C,N) – (2 mm) Ti(C,N) – (2 mm) (bottom layer)	CVD

Wear analysis

We used an optical microscope to find the flank wear values after the cutting effort was finished.

Then, an ESEM TMP scanning electron microscope was used to look at the surfaces of an index able tool insert.

IV. RESULTS AND DISCUSSIONS

Cooling effect on tool life

Following the machining of the DSS with tool T1 in both wet and dry cutting situations, Figure 1 illustrates the corded tool lifetimes for the center point cutting settings. These conditions were used for both environments.

As a result of doing an analysis of the data shown in Figure 1, it has been determined that dry turning results in a much longer tool life when dealing with DSS in comparison to wet cutting turning.

When compared to cooling during turning with liquid application, turning without cooling-lubricant liquid application resulted in a tool life that was more than sixty-five percent longer. For index able tool inserts, it is possible to draw the conclusion that the chip is hard and serves as an abrasive.

This conclusion is based on the observations that were acquired during the process of machining. The quantity of chip breakage that takes place during turning machining is unaffected by the very low sulfur content of 2507 steel, which accounts for no more than 0.015 percent of the total concentration.

One further item that reduces the tool's lifespan is the chip breaker that is located on the rake face. This occurs while the tool is spinning while it is cooling.

One of the characteristics of the index able tool insert that was used for the experiment was that it presented a chip breaker with a positive shape. When it was rotated without being cooled, it performed far well than when it was cooled while being milled.

As a consequence of this, rotating while cooling results in chips that are colder, which have a tendency to tilt the material of the cutting tool and form a chip that is continuous and long.

This is the culmination of the fact that ferrite constitutes fifty percent of DSS.

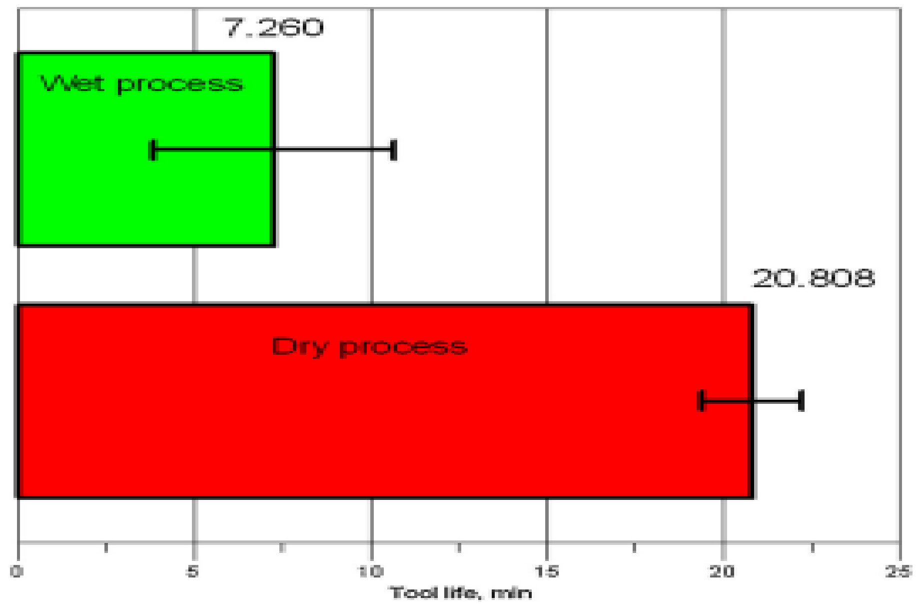

Figure. 1 – Effect of Cooling on T1 Tool Life in Turning Duplex Stainless Steel (DSS) at vC = 100 m/min, f = 0.2 mm/rev, ap = 2 mm: Error Bars Representing Measured Tool Life Range.

Tool life

The tool life of T1, which is coated with an Al2O3 layer, is shown in Figure 2. This tool life is the result of machining Duplex Stainless Steel (DSS) using dry cutting settings.

On display is a three-dimensional image that illustrates the outcomes that were accomplished via the use of the PS/DS-P software in the modeling process. Through the use of two charts that are sequential to one another, the cutting speed and depth of cut for parameters that are located around the center point are clearly shown.

At a depth of cut (ap) of 1 mm and 3 mm, respectively, with a constant feed rate (f = 0.3 mm/rev) and cutting speed (vC = 100 m/min), the tool life achieves its maximum. This is the case when the cutting speed is constant. The reason for this is because the depth of cut, also known as ap, is measured in millimeters. At a time of twenty minutes, the minimum tool life value was discovered to be 2.3 millimeters, which is the value of ap.

When f = 0.3 mm/rev and ap = 2 mm are maintained in the feed, the maximum tool life values are seen at vC = 50 m/min and vC = 150 m/min, with T = 44 minutes and T = 24 minutes, respectively. These values are observed when the feed values are maintained.

These values are consistently applied to the stream, which is the reason why this is the case. The tool life with the shortest parameters (T = 19 minutes) is found by the use of vC = 118 meters per second.

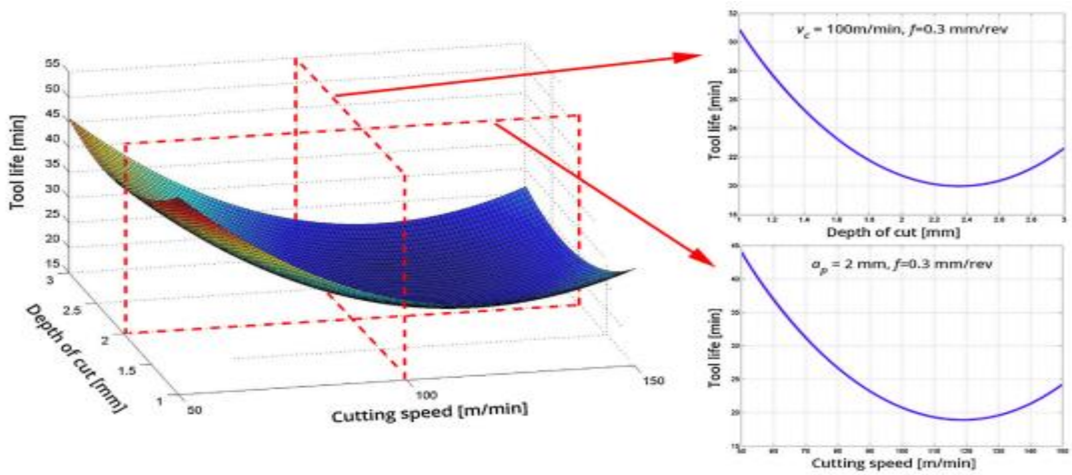

Figure. 2 – Tool Life (T1) at Center Point Parameter with Constant Feed Rate: f = 0.3 mm/rev

V. CONCLUSION

The objective of improving machining processes requires doing research on the tool life and wear that happens during the process of turning duplex stainless steel. This study is needed in order to accomplish the goal of improving machining processes.

Abrasion, adhesion, and diffusion are only a few of the complex wear processes that are investigated in this study. Other mechanisms that are investigated include adhesion and diffusion.

Providing insights that are important for improving the method in which cutting procedures and tool design are carried out, the findings of this research give such insights. An increase in tool life, a decrease in wear, and an improvement in the efficiency of machining processes are the goals that are being sought in the context of duplex stainless steel. These are the aims that are being pursued.

It is essential to have an awareness of these complexities in order to be successful in accomplishing this objective. It is anticipated that the results of this study will make a major contribution to the development of technology for cutting metal, as well as to the use of this technology in sectors that need high levels of corrosion resistance and mechanical qualities.

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