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Review Article

Factors Affecting and Optimization Methods used in Machining Duplex Stainless Steel - A Critical Review

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Abstract

Due to exclusive universal value and usefulness, the combination of good mechanical properties and manufacturing characteristics, Stainless steel is an indispensable tool for design engineers to design components. In oil and gas companies, power plants such as nuclear and thermal, equipment's used in chemical processing industries: such as heat exchangers, seawater processing industries, Pipeline systems, face an incredible and exceptional challenge and the most important one is the reduction of thickness due to corrosion. In order to overcome this complexity, researchers developed a metal called duplex stainless steel (DSS). DSS is a mixture of Chromium – Nickel – Molybdenum - Ferric alloys that consists of an equal quantity of Face Centred Cubic (FCC) - austenite and Body Centred Cubic (BCC) - ferrite grains. DSS is designed to provide improved corrosion resistance, primarily stress corrosion and chloride pitting corrosion and superior resistance to other standard austenitic stainless steels. The DSS material is very difficult to perform machining operations due to high austenite, nitrogen content, alloy composition, high strength, work hardening rate and toughness. High hardness requires high cutting force which tends to reduce machinability characteristics such as tool wear, surface finish, low MRR, etc. This review article provides an overview of the research conducted during last one decade by the researchers and the optimization methods used to examine the machinability characteristics of DSS to predict surface unevenness wear in tool, machinability, MRR and chip volume ratio. Furthermore, this article indicates an efficient means of machining behavior, future scope and the fruitful methodology for the successful machining of duplex stainless steel.

Keywords: Duplex stainless steel, Austenite, Ferrite, Lean DSS, Standard DSS, Super DSS, Hyper DSS, Surface roughness, wear in Tool, Machinability, Material removal rate (MRR), Chip volume ratio.

1. Introduction

Machinability relates to how easily a metal may be machined to achieve a satisfactory surface finish., requires less energy to cut, can cut faster and less wear of the tools. Machinability is challenging to forecast during machining since there are too many factors that control it. They are the two sets of factors: work-related materials and physical properties of the material. Microstructure, grain particle sizes, heat treatment, chemical properties, processing, stiffness, yield strength, and tensile strength are the eight factors that make up the work content, and the physical properties are modulus of elasticity, thermal conductivity, thermal expansion, and work hardening. Operating environments, cutting instrument content and geometry, and machining operation specifications are also critical considerations. Other important factors include operating conditions, cutting tool material and geometry, and machining process parameters. The process converts working materials from one shape to the next by adding value through machining. Machining is the collection of the process where the cutter removes the material in the form of a chip. Relative motion between both the workpiece and tool is needed to achieve this.

The working materials are divided into metals and nonmetals. Metals are iron, aluminum, gold, silver, copper, lead, pewter, magnesium, titanium, zinc and nickel, mercury, tungsten, alloy metals: stainless steel, carbon steel, duplex stainless steel, brass and bronze. Non-metals are plastics, wood, glass, polymers, ceramics, synthetic fibers, composites. The metals are divided into ferrous and non-ferrous metals. Although ferrous materials have great applications in the engineering field. Besides, ferrous materials are categorize into cast iron, ductile iron, malleable iron, gray irons, austempered ductile iron, compacted graphite iron, white iron, carbon steels: High-Carbon, medium-Carbon, low carbon, and alloy steels: Low-alloy steels, High strength low alloy steels, Micro Alloyed Steels, Advanced High - strength steels, Maraging steels, Stainless steels. Nowadays the non-ferrous materials such as ceramics, composite materials, and plastics place an outstanding and have sprung up in various applications in the field of engineering due to their physical, mechanical and chemical properties. At the time of steel production, the process involved oxidation with a minimum combination of chrome of about 10.50%, manganese of about 01.65%, silicon of about 0.60%, or copper of about 0.60% and other alloys known as alloy steel. One of the alloy steels known as stainless steels is a very tremendously useful material in engineering applications; it offers high toughness, stiffness and durability. Low-alloy steel includes less than 8% of the total alloy added, whereas high-alloy steel contains more than 8% of the total alloy added. Austenitic, ferritic, duplex, martensitic, and precipitation hardened stainless steels are classified into five groups depending on their crystalline form. In addition duplex stainless steel (DSS) is a new and

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rapidly growing family. Duplex stainless steels contain chromium, nickel and molybdenum and It's quenched with water at a high operating temperature, resulting in a microstructure that's around half austenite and half ferritic. The ferritic content is 50%. The figure 1 and 2 shows the longitudinal and transversal direction of microstructure of Sandvik SAF 3207 HD tube material and figure 3 shows the grain structure in a SAF 3207 HD umbilical tube [1]. Color grains are austenitic phase and grey grains are ferritic phase. DSS is specifically intended for stress corrosion cracking induced by surface infectivity by iron and pitting corrosion caused by chloride, and is engineered to provide improved good durability, higher yield strength, and greater corrosion resistance.

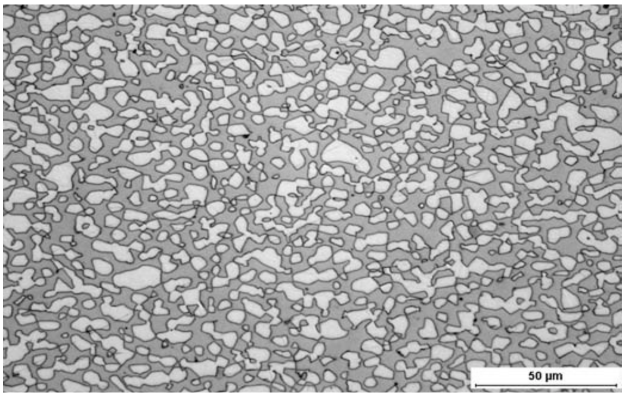

Fig.1. Longitudinal direction Microstructure of Sandvik SAF 3207 HD tube material. The white phase is called austenite, and grey phase is called ferrite: (Source: Guocai Chai et al, (2009), Sandvik Materials Technology)

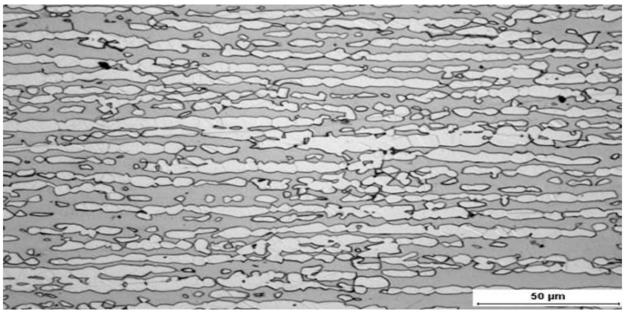

Fig. 2. Transversal direction Microstructure of Sandvik SAF 3207 HD tube material. The white phase is called austenite, and grey phase is called ferrite: (Source: Guocai Chai et al, (2009), Sandvik Materials Technology)

The chemical composition of 18 to 30% chromium is added to increase corrosion resistance, although the increase in chromium ferrite content also increases by forming dispersed second-phase carbides. 4 to 8% nickel is added to change the crystalline structure of ferrite to austenite and it has increased toughness and impact resistance. Figure 4 shows how increasing nickel content affects the microstructure of a stainless steel from ferritic to duplex to austenitic. The addition of less than 5% molybdenum improves pitting corrosion resistance and makes the material avoid brittleness. A minimum of 0.14% nitrogen is added to increase the corrosion resistance of pitting and crevices. Zirconium, cerium and calcium may also enhance toughness. Forming manganese sulfides by incorporating lead, bismuth, selenium, or tellurium may increase machinability. Other compounds, on the other side, may be used to minimize ferrite or austenite in grain.

Fig. 3. Grain structure in a SAF 3207 HD umbilical tube Austenitic phase - Color grains are ferritic phase - grey grains. (Source: Guocai Chai et al, (2009), Sandvik Materials Technology)

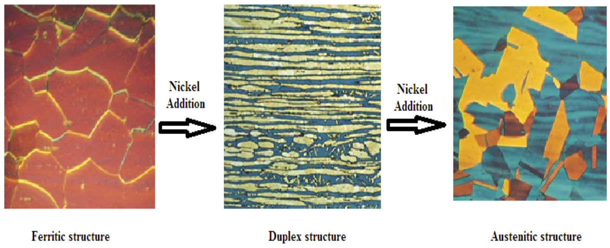

Fig. 4. The microstructure of a stainless steel transitions from ferritic to duplex to austenitic as the nickel content rises. (source: IMOA - International Molybdenum Association, 2014)

2. Types of DSS and their properties.

Duplex Stainless Steel primarily divided into four basic alloy categories ranging from Lean DSS (LDSS), Standard DSS (Std DSS), Super DSS (SDSS) and Hyper DSS (HDSS).

2.1. Lean Duplex Stainless Steel (LDSS)

Lean DSS (LDSS) contains a higher percentage alloy blend of chromium, a lower level of molybdenum and nickel. Nitrogen is applied to alloys with low nickel concentrations to increase austenite content. To lower the expense of the LDSS content, a small amount of molybdenum and nickel is applied. It offers to pitting resistance equivalent number (PREN) of approximately 26. [2] stated that nitrogen is added to provide a concentration of austenites in alloys. Due to the reduction in carbon content and the high chrome content, the machining and welding are much easier than other grades. The LDSS has a strong degree of mechanical efficiency, corrosion tolerance, and tensile deterioration resistance to cracking, as well as decent weldability and durability. The LDSS categories are S32001, S32101, S32202, S32304, S82011, S82012, S82122, Molybdenum-containing lean duplex are S32003, S81921, S82031, S82121, S82441, Er.no 1.4655. 1.4669,316L. Lean DSS materials are needed for applications that require high strength, such as construction projects, storage tanks, containers, etc., which requires long-term corrosion resistance is needed.

2.2. Standard Duplex stainless steel (DSS)

The standard duplex stainless steel microstructure has almost equal ratios of austenite and ferrite and is thermally treated properly during production. Their characteristics are twice as high as those of other austenite stainless steels for excellent toughness, mechanical strength and high yield strength [3]. Standard DSS includes more than chromium 22%, molybdenum 3%, nickel 5–6% and nitrogen, whose microstructure guarantees greater stress-corrosion cracking tolerance, greatly improves pitting and crevice-corrosion resistance in the presence of chloride, and provides good resistance to hydrogen sulphide stress corrosion. It provides a Pitting Resistance Equivalent Number (PREN) of about 35. The temperature at which normal DSS transitions from ductile to brittle is -50oC, and it embitter between 300oC and 550oC after its properties shift, forming sigma and chi phases between 550º C and 1000º C.

The application temperature of the standard DSS should therefore range from -50ºC to 300ºC. S31803, S32205, S32950, and S32808 are the regular DSS types. Normal DSS uses include digesters for the pulp and paper industry, bleaching machines, thermal exchangers in the chemical manufacturing industry, pressure reservoirs, reservoirs, plumbing and pipes, tubing and gas and oil handling, and stock handling devices, rotors, fans, blades, and pressing rolls, freight tanks for ships and vehicles, food processing machinery, and so on.

2.3. Super Duplex stainless steel (SDSS)

Duplex is a mixed microstructure of austenite and ferrite (50/50) that has increased the stability and durability of ferritic and austenitic steels. Super Duplex Stainless Steel (SDSS) is a mixed microstructure of austenite and ferrite (50/50) that has improved the resistant of ferritic and austenitic steels. The biggest distinction is that the super duplex produces a higher amount of molybdenum (3–4%), chromium (24–26%), and nickel (5.5–8%). The need for smaller thicknesses and low costs without compromising quality and lighter materials with higher mechanical and chemical properties resulted in the more frequent use of SDSS. The resistance to corrosion, tensile, yield strength, ductility, toughness and stress corrosion cracking resistance is higher than other duplex stainless steel. The SDSS is produced using an isothermal aging treatment at temperatures between 400°C and 600°C and a processing time between 3 to 120 hours. Super duplex stainless steels (SDSS) have a PREN of more than 40. S32506, S32520, S32550, S32750, S32760, S32906, S39274, and S39277 are the mega DSS groups. Super Duplex is used in the oil and gas industry in heat exchangers, chemical refining devices, pressure vessels, and boilers, and is ideal for usage in hostile conditions such as hot acidified ocean water and toxic environments with chloride.

2.4. Hyper Duplex stainless steel (HDSS)

Hyper duplex is also known as HDSS and the latest type of two-phase stainless steel. Hyper DSS has about 25.08 percent chromium, 3.82 percent molybdenum, 6.880 percent nickel, and 0.5 percent nitrogen and has the highest corrosion resistance, strength, and mechanical properties, including improved tensile and fatigue resistance, resistance to both chlorine and sulfur stress cracking, erosion-corrosion, and general acid corrosion resistance. The SDSS is made by aging it at temperatures ranging from (800 - 1300)°C in an isothermal setting. Hyper duplex stainless steel is described as having a PREN value of around 50. S32707 and S33207 are two Hyper DSS groups. The HDSS has been developed to address the growing demand for chemicals, deep umbilical waters, oil and gas industries. The DSS family of chemical composition, pitting resistance equivalent number (PREN) and material used to conduct experimental work is given in Table 1 [4].

3. Machining of DSS

Owing to fragmentation, heat creation inducing plastic deformation during manufacturing, and severe wear craters, duplex steels are more complicated to process in general. The aim of this article is to review recent research on duplex stainless steel in the field of metal cutting in the turning phase, as well as optimization methods for predicting various performance dependable factors such as surface roughness, cutting power, machinability, chip volume ratio, and material removal rate over the last decade. The international conference was held in Grado, Italy, in 2007 to investigate the recent developments in the field of duplex stainless steel [5], unfortunately, no paper is examined in the field of metal cutting and optimization methods used to predict various output dependable factors. The researchers conducted experimental work by using duplex stainless steel material to predict surface unevenness, wear in tool, machinability, MRR and chip volume ratio is shown in Table 2. Various factors used in experimental work and optimization of DSS are shown in Table 3.

3.1.Factors affecting Surface Roughness

Cutting criteria, as well as the condition and grain texture of the working material, decide the surface quality of the machined component. Surface roughness is a vital metric for measuring cutting efficiency in turning operations. The greatest emphasis has been placed on research in the area of superficial roughness in the previous decade, to obtain the maximum level of surface finishing, various optimization techniques were used.

Table 1. Family of DSS with Chemical Composition (Source: IMOA – International Molybdenum Association)

Types of DSS	Grade/Commercial Name-DSS	UNS Number-DSS	EN Nr.-DSS	C-Carbon	Cr-Chromium	Ni-Nickel	Mo-Molybdenum	N-Nitrogen	Mn-Manganese	Cu-Copper	W	PREN
First generation duplex stainless steel	329	S32900	1.4460	.08%	23% – 28%	2.5% – 5%	1% – 2%	–	1%	–	–	30 to 31
	3RE60	S31500	1.4424	.03%	18% – 19%	4.3%– 5.2%	2.5% – 3%	.05% – .10%	–	–	–	28 to 29
	324	S32404		.04%	20.5%– 22.5%	5.5% – 8.5%	2% – 3%	.20%	2%	1%– 2%	–	29 to 30
Lean duplex stainless steel	A789	S32001	1.4482	.03%	19.5% – 21.5%	1%– 3%	.6%	.05% – .17%	4 % – 6 %	1%	–	21 to 23
	LDX 2101	S32101	1.4162	.04%	21% – 22%	1.35% – 1.7 %	.1% – .8%	.20% – .25%	4%– 6%	.1% – .8%	–	25 to 27
	A815	S32202	1.4062	.03%	21.5% – 24%	1%– 2.8 %	.45%	.18% – .26%	2%	–	–	25 to 28
	EDX 2304	S32304	1.4362	.03%	21.5% – 24.5%	3% – 5.5%	.05% – .6%	.05% – .2%	2.5%	.05% – .6%	–	25 to 28
	ATI 2102	S82011	-	.03%	20.5% – 23.5%	1% – 2%	.1% – 1%	.15% – .27%	2%– 3%	.5%	–	25 to 27
	FDX 25	S82012	1.4635	.05%	19%– 20.5%	0.8% – 1.5%	.10% – .6 %	.16% – .26%	2%– 4%	1%	–	24 to 26
	NSSC 2120	S82122	-	.03%	20.5% – 21.5%	1.5% – 2.5%	.6 %	.15% – .2%	2%– 4%	.50% – 1.5%	–	24 to 26
	A815	S31803	1.4655	.03%	22% – 24%	3.5% – 5.5%	.1% – .6%	.05% – .2%	2%	1%– 3%	–	25 to 27
		-	1.4669	.045%	21.5% – 24%	1% – 3%	.5%	.12% – .2%	1% – 3%	1.6% – 3%	–	25 to 27
	316L	-	1.4404	.03%	16.5%-18.5%	10% –	2 %-2.5%	≤ 0.11%	2%	-	-	

						13%						
Molybdenum -containing Lean duplex stainless steel	A790	S32003	-	.03%	19.5% – 22.5%	3%– 4 %	1.50% – 2%	.14% – .2%	2%	–	–	27 to 31
	A240	S81921	-	.03%	19%– 22%	2% – 4%	1% – 2%	.14% – .2%	2%– 4%	–	–	27 to 28
	FDX 27	S82031	1.4637	.05%	19% – 22%	2% – 4%	.60% – 1.4%	.14% – .24%	2.5%	1%	–	27 to 28
	A790	S82121	-	.035%	21% – 23%	2% – 4%	.30%– 1.3%	.15% – .25%	1%– 2.5%	.2 – 1.2%	–	27 to 28
	LDX 2404	S82441	1.4662	.03%	23% – 25%	3% – 4.5%	1%– 2%	.20% – .30%	2.5 % – 4%	.1 % – .8%	–	33 to 34
Standard duplex stainless steel	2205	S31803	1.4462	.03%	21% – 23%	4.5% – 6.5%	2.5% – 3.5%	.08% – .20%	2%	–	–	33to 35
	2205	S32205	1.4462	.03%	22% – 23%	4.5% – 6.5%	3% – 3.5%	.14% – .20%	2%	–	–	35 to 36
	A473	S32950	-	.03%	26% – 29%	3.5% – 5.2%	1% – 2.5%	.15% – .35%	2%	–	–	36 to 38
	DP28W	S32808	-	.03%	27% – 27.9%	7% – 8.2%	.8% – 1.2%	.30% – .4%	1.1%	–	2.1% – 2.5%	36 to 38
Super duplex stainless steel	NAS 64	S32506	-	.03%	24% – 26%	5.5% – 7.2%	3% – 3.5%	.08% – .2%	1%	–	.05% – .30%	40to 42
	F255	S32520	1.4507	.03%	24% – 26%	5.5% – 8%	3% – 4%	.20% – .35%	1.5%	.50% – 2%	–	40 to 43
	255	S32550	1.4507	.04%	24% – 27%	4.4% – 6.5%	2.9% – 3.9%	.10% – .25%	1.5%	1.5% – 2.5%	–	38 to 41
	2507	S32750	1.4410	.03%	24%– 26%	6% – 8%	3% – 5%	.24% – .32%	1.2%	.5 %	–	40 to 43
	F55	S32760	1.4501	.03%	24% – 26%	6% – 8%	3% – 4%	.20% – .3%	1%	.5 % – 1%	0.5% – 1%	40 to 43
	SAF 2906	S32906	1.4477	.03%	28%– 30%	5.8% – 7.5%	1.5% – 2.6%	.30% – .4 %	.8 %– 1.5%	.8 %	–	41 to 43
		S39274	-	.03%	24% – 26%	6.8% – 8%	2.5% – 3.5%	.24% – .32%	1%	.20% – .8%	1.5% – 2.5%	40 to 42
	A790	S39277	2-	.025%	24%– 26%	6. %5 – 8%	3% – 4%	.23% – .33%	.80%	1.2% – 2%	.8% – 1.2%	40 to 42
Hyper duplex stainless steel	SAF 3707 HD	S32707	-	.03%	26%– 29%	5.5% – 9.5%	4% – 5%	.3 % – .5%	1.5%	1%	–	49 to 50
	SAF 3207 HD	S33207	-	.03%	29% – 33%	6% – 9%	3% – 5%	.40% – .6 %	1.5%	1%	–	52 to 53

The experimental work is carried out by considering the different cutting speed, the rate of feed with a constant cutting depth of S32205 and S32750 duplex cast stainless steels using Titanium Carbo Nitride coated cemented carbide and Titanium carbide tools. The author suggests that during the experiment of texture analysis, the increasing cutting speed decreases the roughness of the surface, the roughness of the surface decreases with decreasing feed speed [6]. The experiment was conducted to analyze the hardness of duplex coated carbide tools during the machining of 1.4462 steel using statistical techniques. Hardness measurements were carried out at varying cutting speeds and under both wet and dry environments. [7]. The author [8] built a mathematical model using the Response surface method to quantify surface roughness while turning the DSS using the turning mechanism, taking into account cutting speed, feed, and cutting depth. The main factor influencing surface roughness, according to the source, is feed velocity. The cutting pace, rate of feed, and cutting depth of SAF 2507 super duplex stainless steel bars were measured using uncoated carbide cutting equipment, with the feed rate being the parameter that has the largest effect on surface roughness. The work is designed and the analysis is conducted using variance analysis (ANOVA) and the surface roughness and S/N ratio were measured using the L18-Taguchi method during optimization. [9]. The ANOVA statistical technique is used to identify significant variables and optimization was performed using the full factorial design of Taguchi experiments to measure surface roughness. The super duplex SAF 2507 stainless steel bars with uncoated carbide cutters are used in turning operation. Cutting speed, feed speed and cutting depth are the parameters used in wet, dry and gas-cooled cutting conditions to optimize surface roughness and tool wear. When liquid CO_2 is used as a coolant, the surface unevenness and flank wear on the tool are minimized, according to the results [10]. The evaluation made by the author [11] to compare the EN (1.4404) austenitic steels, duplex standard EN (1.4462) and super duplex EN (1.4410) in turning operation by facilitating ANOVA and optimized using the Taguchi coupled with fuzzy-multiple attribute decision-making methods (FMADM). The ANOVA predicted that the feed speed is an impact on surface quality and finally concluded that EN 1.4404 stainless steel was best considered for machining the part. The experiment is performed by considering the cutting speed and low and high fluid pressure cooling conditions of the super duplex UNS32750 stainless steel to determine the parameters that have the greatest impact on corrosion resistance. The results indicate that extended life of tool, good surface unevenness and high resistance due to corrosion is achieved while turning with high-pressure-cooled PVD - physical vapor deposition coated inserts [12]. The study was conducted using dry machining of duplex stainless steel to determine surface roughness using the load curve with different cutting speeds, feed and cutting depth according to cutting conditions using TNMG 160408 cutting tool inserts and detected that rate of feed is the major parameter influencing surface unevenness [13]. An experiment was conducted by [14] to reduce surface roughness and cutting force using 2205 DSS material and multilayer milling cutter PVD CNMG 120408 SM grade 1115 by taking into an account of cutting speed, rate of feed, cutting depth and tool nose radius. The optimization was performed using ANOVA, BBD and RSM. The author suggests that an increase in the speed, rate of feed influences the roughness of the surface. The author optimized the machining parameter: cutting speed, rate of feed and cutting depth to predict surface unevenness and force due to cutting of cast material DSS ASTM grade 995 4A and 5A utilizing the Taguchi and ANOVA method. The outcomes revels that rate of feed is the most considerable parameter that affects the surface unevenness and cutting force [15]. Wet and dry longitudinal turning tests are carried out using duplex grades of stainless steel EN(1.4462) and EN(1.4410) using carbide inserts to analyze the unevenness of the surface, the wear in the tool, the forces, the power using the input variables: feed, cutting speed and cutting conditions. The optimization technique called bat algorithm is used to achieve multi-objective optimization of adversarial performance. The author ensures the most appropriate cutting configuration for making efficient turning operation [16]. The EN (1.4404), EN (1.4462) and EN (1.4410) duplex material are considered for turning operation, the ANOVA analysis is carried out to model the performance characteristics. The MADM methods such as GTMA and AHP - Technique for order preference by similarity to ideal Solution (AHP-TOPSIS) are simultaneously adapted to associate well-known surface excellence features into a single index called MSQCI .The author suggested that the performance of multiple machining and surface qualities could be optimized efficiently using MADM methods are coupled to the fuzzy set theory [17]. The author [18] tested different rate of feed and cutting speeds using SAF 2507 DSS materials and concluded that the maximum surface finish is achieved with a high cutting speed and lower rate of feed. The turning operation is formed using 1.4462 duplex stainless steel, to analyze the optimal machining conditions, which cut back pollution generated by the coolant and lubricant. The surface unevenness, cutting force and tool wear are analyzed. The results indicate that higher parameters necessary to energy consumption minimization will also result in an increase in surface unevenness [19]. The cutting operation is accomplished on the SAF2507 duplex stainless steel by considering the cutting speed, feed and cutting depth to analyze the wear of the tool and the roughness of the surface. The comparison is done by the author [20] of three PVD coating tool: TiAlSiN, AlTiN and AlTiN using HiPIMS method, results shows that the presence of the buildup edge for the surface roughness are aggravated at a slower speed. Dry and wet turning work are carried out [21] to examine the effect of the cutting fluid and lubricant using the MQCL turning process to ensure the clean production of DSS (1.4462) by using the surface morphology examination using an IFM and found that MQCL cooling improves surface effects over dry machining. Researcher [22] performed the experiment using the super duplex EN (1.4410) to analyze the machinability and surface roughness using a cooling and lubrication fluid. ANOVA was used to create the mathematical model, RSM was used to create the predictive model, and GA was used to optimize the model. When machining DSS 2205 in a conventional turning unit, the author [23] looked at the impact of surface unevenness and tool wear. Comparison of machining output between normal coolant and cold air coolant using TiAlN coated carbide with constant cutting pace, feed, and cutting depth. In comparison to the traditional flood coolant, the findings indicate that the cooled air coolant generated a better surface finish. The TiAlSiN PVD coated tool (3.3 micrometer), AlTiN (3.0 micrometer), and AlTiN (7.0 micrometer). To test tool life and surface roughness, the super DSS (2507) material is used under dry cutting conditions with parameters such as cutting pace, rate of feed, and cutting depth. The authors [25] have developed a strategy for the best combination of tool geometries, feed, coolant used to increase life of tool life, productivity, to reduce surface roughness. The longitudinal, tapered section is made using UNS S32750 DSS. This results in the shortest life of the tool life and lowest roughness values for longitudinal cuts with reduced feed rates. Using ANOVA and the Taguchi L9 orthogonal matrix, a predictive model is created to determine the surface texture of 2205 DSS content. Cutting speed, rate of feed, and approach angle are all seen as input process parameters. For longitudinal cuts with decreased feed speeds, this result is the shorter tool life and the lowest roughness values [26]. S32205 is a nitrogen alloyed DSS that was used in this study. Input parameters include cutting tempo, feed rate, and cutting depth. The mathematical model is developed using ANOVA and optimization is performed using the Taguchi technique to forecast surface unevenness. The researcher proposes that rate of feed is the most significant variable that affect surface unevenness [27]. The author [28] developed a predictive model by means of ANOVA and RSM to examine the interaction effect of each parameter: cutting speed, feed, cutting depth of EN 1.4410 super duplex stainless steel. The ANFIS is convened using fuzzy logic systems. Lastly, the accuracy of the predictive models is based on comparative examination and concludes that feed speed has the greatest effect on surface unevenness. In dry and cryogenic conditions, turning operations were performed on the DSS 2205 using PVD coated nano-multilayer TiAlN. As opposed to dry spinning, cryogenic cooling improves roughness by around 18-23 percent [29]. The machining is performed by means of vegetable oil (Neem and Coconut oils) as cutting fluid to measure surface roughness, tool wear and tool temperature, while turning AISI 2205 DSS, considering the spindle speed, feed rate, cutting depth and type of cutting fluid. The Taguchi L27 methodology is used to improve the parameters. Coconut oil-based cutting fluid was found to be more effective at increasing surface roughness [31] analyzed the M.R.R, surface unevenness, feed rate, thrust force and cutting force using Duplex 2205. The author concluded that surface roughness are high in high spindle speed and cutting depth by considering the spindle rate, feed rate, and depth of cut, of turning operation. The analysis is carried out using DOE, ANOVA and RSM. The experiment was carried out using SAF 2507 - DSS to measure the surface texture, using RSM and ANN technique. The validation is done by the author using a genetic algorithm. The findings show that perhaps the feed rate has been the most important element in reducing surface quality [32]. The researcher [33] performed the study to determine the impact of surface unevenness and residual stresses on coated and uncoated carbide tools. The experiment conducted under dry working condition and material considered for turning is 2205 Duplex Stainless Steel and cutting tool as Cemented carbide tools. The effect of reduced surface unevenness was three times greater in uncoated tools than in coated tools. The experimental work is performed by [34] to focuses on the practical analysis to turn SDSS UNS S32760 with nano-coated MEGACOAT carbide insert. The surface unevenness, force due to cutting and MRR are analyzed using ANOVA and the results are optimized using Taguchi Analysis to predict the experimental values. The result emphasized that the feed rate is a predominant constraint for Ra. Machining carried out under dry turning to examine surface unevenness, MRR by considering velocity due to cutting, rate of feed and approach angle. ANOVA was used for mathematical research, and the Taguchi process of the DSS material was used to refine the WC-Co coated carbide inserts.

The findings showed that the rate of feed is the most influential parameter [35]. The author [36] discussed an impact on cutting speed, rate of feed and cutting depth to analyze the characteristics of cutting force, surface unevenness and MRR when turning UNS S32760 SDSS using nano-plated MEGACOAT carbide inserts. The ANOVA and Taguchi experimental design helps predict factors. The relationship analysis in Taguchi gray is carried out for simultaneous optimization. The findings indicate that the feeding rate is a dominant constraint for Ra. Experiments were carried out using SDSS- 2507 and a handled cryogenic instrument, with cryogenic coolant explicitly passing through the insert of the changed cutting tool. The findings are compared to those of dry cutting. The effect of cryogenic coolants LN_2 injected into holes drilled in the tungsten carbide cutting tool's flank and rake surfaces. Chip breaking is strong in cryogenic machining, which decreases friction between the device and tool interface while maintaining a good dimensional accuracy [37]. The impact of TiAlN and TiN coated drills, as well as cutting criteria, on drilling performance was examined. In the tests used to quantify cutting force and surface roughness, various cutting speeds and rate of feed were used. An experiment was performed under FFD conditions and optimal situations were determined from the values measured by the GRA method. In addition, ANOVA method was conducted. The feeding rate is calculated to be the most significant element on Ra dependent on the ANOVA data. [38]. In this current work, [39] 2507 super duplex stainless steel was used to examine the carbide inserts have a multilayer coating of MT-TiCN/ Al203.The experiment was conducted at a constant cutting rate and cutting depth. Five different feeding rates were used - Poor surface finishing resulting from dry cutting resulted in higher stress concentration and chloride accumulation in the surface defect area. The use of MQL has improved the surface finish which has helped reduce pit formation. All tests were conducted on a SDSS 2507 hot-forged material. Cutting with CCMT120408MR style inserts is advised, implying that there is an optimum pace beyond which surface roughness does not deteriorate [40]. Wear in the instrument, cutting power, and surface unevenness were all measured when dry turning DSS 2205 with tungsten carbide inserts coated with AlTiCrN and AlTiN. Magnetron with a High Power Impulse Under dry spinning, the sputtering method was used with various cutting speeds, feeds, and a set depth of cut of 0.8 mm as cutting parameters. The lower surface finish was caused by a mixture of high speed (180 m/min) and low feed (0.12 mm/rev) [41].

3.2. Factors affecting Tool wear

The process of wear and tear of the tool depends mainly on the cutting parameters. The wear of the tool point causes worsening in the superiority of the machined surface and therefore reduces effectiveness and production. Irregular wear and accumulated edge (BUE) often occur during processing of duplex stainless steel because of its properties, namely high robustness, low thermal conductivity and a high degree of work strengthening. There are various kinds of wear of the tools during machining. Fatigue-induced failure, diffusion wear, wear in flank, crater wear, notch wear, abrasive wear, wedge wear, notch wear etc. The investigational study is conducted to observe the wear on tool by means of abrasive wear mechanisms, fatigue-induced failure mechanisms and wear mechanisms of the adhesive and diffusion made of duplex 2205 stainless steel. Tin-coated HSS and Tin - coated cemented tools are used for machining purposes. To minimize tool wear, the study concluded that tin-coated HSS is used at low cutting speeds [42]. The experiment was carried out with a X2CrNiMo22-5 (2205) stainless steel duplex cutting tool using DNMG 15 06 08 MF and the cutting factors are the advance, the cutting depth and cutting speed. Cutting force, surface unevenness and wear in the tool are tested. The experiment is conducted by means of a high-pressure water jet assisted turning [43]. The results indicate that chip fragmentation is fine, and tool lifetime is increased. The researcher [44] investigated tool wear behavior during machining of 2507 - SDSS, 2205 - Std DSS and 2101 - LDSS. The wear of the cutting tool, in many serious belongings, has been observed to a certain level on all the dissimilar cutting data is studied. The researcher [45] conducts the research using stainless steel Austenitic ferritic (Duplex) tempered PH. The comparison is performed using four different ceramic cutting tools based on alumina to determine the size of the surface unevenness and life of the tool. The flange, crater and notch wear are studied. The mathematical model is developed by using multi-regression analysis and analyzed by ANOVA. The aim of the study was to find the turning variables affected the reduction of flank wear rate and chip formation. The working material and tools are made of 2507 – SDSS, an uncoated carbide tool. Cutting speed, rate of feed and cutting depth serve as variables to measure flank wear. The optimization was performed using the RSM [46]. The study was conducted by [47] to fix the coated carbide tool surface structure. The cutting material is 1.4462 - DSS and cutting tool inserts are TNMG 160408 taken to do turning operation. The tool wear study examines the wear of the wedge on the rake face as well as the outline of the cutting point. SEM analysis is used to examine the rake and flank wear of the cutting tool, and the results show that cutting edge wear raises as cutting speed increases [48]. The author [49] observes the impact of the cutting parameters: cutting speed, the advance and the cutting depth on the life of the tool in the DSS turning process. This experiment is carried out using DSS (1.4462) using TNMG 160408 as cutter. The factor design of an experiment is used to forecast the lifetime of the tool. The established equations and concluded that cutting speed is the major influencing factor that affect the life of the tool. The author [50] carried out an experimental study in two phases considering 1.4410 EN SDSS, 1.4462 EN DSS and 1.4404 EN austenitic steel. A new methodology based on Mamdani's fuzzy interference is used to classify chip shapes to predict the chip volume ratio. TOPSIS, GRA, VIKOR and UA method was used for optimization. The results showed that the conversion of the results of the different MADM methods is used to determine an optimal combination of cutting parameters. In the next stage, the force exerted due to cutting and current consumption signals of the machine are adopted as indirect techniques used to observe the wear of the cutting tool. The SAF 2507 SDSS is used to allow a detailed distinction between dry, wet, and gas-cooled turning. Cutting speed, rate of feed, and depth of cut are considered as input parameters. It has been revealed that gas-cooled machining performed better than wet and dry machining [51]. The author [12] emphasized experimentation to prevent wear and tear of cutting tools, suggests that the observed that notch wear affected by the chilling effect created by the burr, the use of the high-pressure cooling system has brought advantages, such as the prolonged lifetime of the tool. In the time of machining, it's important to use high-pressure cooling to ensure a long service life. The cutting speed was recognized as the greatest important factor that affects the wear in the tool. The wear on the tools was examined using a SEMI. The author suggests that the wear in the tool is owing to attrition at lower cutting speeds [15]. The study purposeful the cutting conditions of the turning 1.4462 - DSS with coated carbides to predict tool life. The wear results are compared between the two tool points. The author concluded that raising the cutting speed causes the increase cutting edge to wear, particularly at higher feed speeds, and that using mineral oil-based lubricants reduces the cutting tool's durability [52]. In terms of tool wear rate, total wear depth, and tool temperature, the simulation results were obtained. While machining, the TOPSIS, VIKOR, GRA, and UA are used at the same time to maximize the average wear flow of DSS tool. In contrast to EN 1.4410, the tool wear intensity is lower than EN 1.4462 [53]. The document describes the optimization method used to predict tool wear using DSS 1.4462 (DIN EN 10088-1). Experimental design (DOE) is used to create a mathematical model to create the experimental data. An ANOVA examination was established to determine the significance of the processing parameters. The Taguchi method with the orthogonal matrix L9 and the signal-to-noise relationship is used to optimize. The cutting speed and rate of feed are affect the permanence of the tool [54]. The experimental work is performed [55] to optimize using dynamic programming of the cutting variables of 1.4462 - DSS. Dijkstra's modified optimization algorithm results the optimum value of cutting variables using coated carbide tool. The ANOVA method specifies that the cutting speed and feed speed affected the tool lifespan.

The aim of this research is to find out cause of tool wear and tear. images of worn areas obtained bu using SEM were included in this study. To understand the causes of tool wear using a EDS system Wear has arisen while machining super duplex stainless steels owing to a rough burr [56].The tool comparison is carried out by [57] using 2507 -SDSS by using PVD and CVD coated tools. The author accessed the wear in wear, force exerted, surface integrity and rise in temperature and according to the findings, the MT-TiCN-Al2O3 coating outperforms other coatings. As compared to chilled cooled air coolant, tool life was improved utilizing traditional flood coolant. Despite their low hardness, AlTiN coated tools outperform AlTiSiN coated inserts [23].An experimental study [24] on the 2507 SDSS with non coated and coated with PVD carbide inserts considering rate of feed, cutting speed, and dry cutting depth. The study includes the recognition of the wear mechanism of the tools on the rake and tool flank face. Cutting at a higher speed improves the cutting edge's wear strength dramatically. The usage of cemented carbide turning cutting tool inserts with CVD-TiCN + Al2O3 and TiCN PVD and AlTiN coatings to the 32750 - SDSS content was explored by the author [58]. This activity suggests that AlTiN PVD coated inserts had double the tool life of TiCN + Al2O3 CVD coated inserts. The researcher [59] studied the tribological execution and wear mechanisms of uncoated, coated carbide tools when turning of 2507 SDSS. T chip characteristics are used to evaluate chip width, compression ratio, shear angle, and bottom surface morphology. The show that the wear mechanisms of the AlTiN coating tool perform better than the TiCN + Al2O3 CVD insert. The author [60] discovered that the strain hardening of 2205 DSS content is highly vulnerable to cutting pace during the operation. This paper explores the process of built-up edge forming in the stagnancy area of duplex alloys in order to solve this issue. Experimental studies were carried out in the machining of S32750 DSS using uncoated and coated carbide inserts. The wear and failure mechanisms were studied during turning operations using a comprehensive tool wear analysis. The results indicate that turning with a TiAlN coating applied in PVD on a carbide insert extended the life of the tool, reduced chip thickness and improved the presence of chips below the surface [61]. The author [30] carried out experiments to observe abrasive wear and tear. According to the results, the cutting speed is high, and then there is an increase in flank wear. The cumulative edge was not shaped when the traditional insert was used in the longitudinal cut, according to Investigator [25], and flank wear stayed thin until the tool's useful life finished, before abruptly rising. Under cryogenic cooling, tool wear and saw tooth development were all minimized [29]. [62] Using G X2CrNiMoCuN 26-6-3-3 cast SDSS, PVD coated cutting inserts, TiAlN, and TiAlSiN with constant cutting speed and feed rate, an experimental test was conducted. In the machining tests, extreme burrs and build-up edge forming were found, which ruined the tool edges, according to the source. Dry machining showed the most tool flank wear, and values improved as cutting pace increased [32]. The experimental work is carried out using a feed, cutting depth and cutting speed as input parameter using molded DSS. The shape of the insert and quality of the cutting tool and technical viables of the machining, flank wear and crater wear determined [63]. In cryogenic machining, chip breakage is high, which results in less resistance between the chip-tool interfaces [37]. The effect of LN2 cryogenic coolants delivered through holes on the flank and rake surface of tungsten carbide cutter tool material in SDSS - 2507 turning using a cryogenic configuration built in-house is the focus of this study. Under dry and cryogenically cutting prepared inserts, the temperature of the cutting instrument does not alter substantially. When the LN2 is provided by a specifically adjusted insert, though, there is a noticeable change in the temperature of the cutting instrument, which has resulted in the tool having a long service life. In dry cutting, abrasion and obedience governed the wear process, resulting in increased tool wear [64]. In contrast to dry cutting, flood machining and the MQL setting decreased edge accumulation and increased tool wear efficiency by 11.95 percent and 33.08 percent, respectively [39]. The existence of AlTiCrN and AlTiN coated instruments is 6 and 4 times that of uncoated tools, respectively [41].

3.3. Factors affecting Machinability

DSS are considered difficult to automate. During machining processes, built-up edges and rough wear show off often. As high-strength DSS are machined, the processing problems increase. Machinability is commonly related to the stainless steel counterpart of pitting corrosion resistance, which is a value that reflects the alloy material of the steel. Modern duplex stainless steel grades are difficult to machine due to higher austenite and nitrogen content, as well as growing alloy content [65]. Tests were conducted using a DSS - X2CrNiMo22-5 (2205). The authors suggest that by improving machinability characteristics, productivity improves proportionately [43]. To improve the strength of an LDSS, lowering its FN appears to be a good solution. It could be obtained by increasing the most austenitic elements (C, N, Ni, and Cu) and/or reducing the most ferritizing elements (Mo, Si, Cr) [66]. The authors discussed the effect of cutting parameters and conditions to calculate machinability index and effect of different tool materials is emphasized and concluded that tool wear mechanisms is the most responsible for tool failure [49], [67]. EN 1.4462 and super EN 1.4410 DSS are machined at a steady cutting pace to meet industrial requirements. The author emphasizes that reducing the cutting speed during dry cutting EN 1.4410 improves machinability. Wet cutting EN 1.4462 got a higher choice than equivalent dry cutting EN 1.4462 and wet cutting EN 1.4410 [11]. The chip forming process and machinability of two-phase materials is investigated using the wrought DSS- SAF 2205 and SAF 2507. Drilling tests were carried out on a CNC machining center with solid carbide twist drills coated with (TiAlN+TiN). The highest machinability for tool wear and cutting strength is SAF 2205 [68]. To boost machinability and reliability, the author [30] proposed that vegetable oil-based cutting fluids could be a safer alternative to mineral oil. The machinability indices for DSS-2205 under liquid nitrogen cryogenic cooling worked higher than dry cutting conditions, according to experimental findings [29]. Different cooling media, such as dry cutting, flood coolant, and MQL , were used to examine the SDSS's machinability and surface integrity conduct [39]. The machining reliability projections indicate that increasing the nose distance increases the total secure cutting depth below which unpredictable vibrations exist, according to the researcher [40]. This observation can be used to direct the selection of cutting parameters for SDSS machining to ensure high-performance and vibration-free results. However, according to the literature, DSS is not as machinable as ASS. For dry spinning, a cemented M35 grade unglazed carbide method was used. HiPIMS has been used to cover cemented carbide substrates with AlTiN and AlTiCrN. Cutting tempo, feed, and depth are all maintained at the same level. Benchmarking requirements included nose wear, tool life, and surface roughness. Because of its high heat reliability, the AlTiCrN coated tool had a tool life 5 times longer than non-coated tools and performed higher. Due to the higher wear rate of uncoated equipment, the surface unevenness of coated tools was observed to be 1.006 m compared to 3.14 m for uncoated tools [69].

3.4. Factors affecting Material Removal Rate (MRR)

The material removal rate (MRR) is the volume of material extracted every minute or second. It can also be calculated by dividing the amount of material separated by the machining period [70].

$$MRR = \pi . Davg. d. f. N \text{ in } mm^3/min \qquad (1)$$

where,
Davg - Average diameter of workpiece in mm
D - Cutting Depth in mm
f - Rate of Feed in mm/rev
N - Rotational speed of workpiece in rpm

The authors [71] identify the most important criteria for increasing efficiency thus maintaining target product output at a low cost and shorter lead time. The tests were carried out under dry and wet conditions using ANOVA and Taguchi's mixed orthogonal network L18 to process duplex alloy steel work pieces using a cemented carbide method. Taguchi's person method was used to find the best criteria for minimal surface roughness and optimal MRR. By integrating optimization problem into an equal target, the outcomes are comparable to those produced by GRA. The key aim of this experiment is to find the best process parameters for achieving high MRR and low surface unevenness. The author came to the conclusion that when the spindle speed is strong, the MRR is high, and vice versa [31]. Ra and Fc are reduced, and MRR is maximized, to obtain the output attributes. Relational research Taguchi-grey [34] using S/N ratio review, the author [36] estimated MRR. As a consequence, the cutting forces and material removal intensity are largely defined by the depth of break. The chip volume ratio is determined by the chip shape. [50] The equation for Chip volume ratio was derived. To estimate chip volume ratio, the author developed a new technique focused on Mamdani fuzzy intervention of chip shapes classified in chip split diagrams.

$$Qw = Vc. Ac = Vc. f. a_p \qquad (2)$$

$$Qsp = R. Qw \qquad (3)$$

Where,
Qw - Volume of the removed material
Ac - Chip with cross sectional area
Vc - Cutting Speed
F - Rate of Feed
a_p - Cutting Depth
R - Chip Volume ratio
Qsp - Volume of chips
R -Volume needed for randomly arranged metal chips, material volume of the same amount of metal removal

A SEM was used to examine the chips produced during the process, which were optimized using three methods: dry, wet, and gaseous cooling machining. Dry machining produces constant and rippling chips, which curl inside the tool work attachment and must be withdrawn abruptly during machining. Since the chips produced in gas-cooled machining split at regular intervals and shape discontinuous chips, the tool's working interface is less affected [9]. The author [10] investigated the morphology of chips under different working conditions and came to the conclusion that gas-cooled machining is ideal for higher output ratio machining. The aim of this research was to develop a method for determining the minimum chip thickness. According to the author [72], a considerable amount of component content can only be bent on the machined surface or shape lateral flow and will not be withdrawn as a chip. An overview of soft computing techniques and optimization methods

Selecting optimal process parameters plays a significant role in ensuring quality of product, lowering manufacturing costs and increasing productivity, better surface unevenness, higher MRR and low wear in cutting tool. In the case of a turning process, the important variables to optimise are the cutting speed, rate of feed, cutting depth, spindle speed, nomenclature of tool etc. To optimize the machining process, modelling and optimization of process variable of any industrialized process is usually a difficult work. The author [73] in-process input-output and parameter optimization techniques are divided into traditional optimization algorithms, nontraditional optimization algorithms. The traditional and nontraditional technique used for optimization is show in figure 5.

4. The traditional optimization techniques are Modeling and Optimization Techniques

Statistical Regression method and ANOVA, Fuzzy Set Theory - Artificial Neural Networks, Gray Relational Analysis (GRA), Taguchi Robust Design Method, Taguchi Fuzzy-Based Approach, Factorial Design Method, Response Surface Methodology, Knowledge-Based Expert Systems, Principal Component Analysis (PCA).

Mathematical Iterative Search Methods:
Dynamic Programming, Goal Programming, Generalized reduced gradient Method (GRG), Geometric Programming, Quadratic Programming, Integer Linear Programming [74], [75].

The nontraditional optimization algorithms are Meta-Heuristics optimization techniques:
Genetic Algorithms, Simulated Annealing, Tabu Search, Particle Swarm Optimization, Ant Colony Optimization, Artificial Bee Colony Algorithm, Artificial Immune Algorithm, Shuffled Frog Leaping Algorithm, Harmony Search Algorithm.

Hybrid Algorithms: Genetic Simulated annealing algorithm (GSA), Hybrid immune algorithm (artificial immune algorithm and hill climbing local search algorithm), Memetic algorithm (GA is combined with the heavy local search), Hybrid approach (GA, SA, and tabu search), Heuristic algorithms such as SA, GA and hybrid algorithm(hybrid-GASA), Novel hybrid ant colony optimization approach, Adaptive network based fuzzy inference system (ANFIS) with the genetic learning algorithm, Hybrid Taguchi-genetic learning algorithm (HTGLA), Multi-objective optimization method based on adaptive simulated annealing genetic algorithm, Hybrid global best harmony search (hgHS) algorithm and hybrid modified global best harmony search (hmgHS) algorithm, Hybrid meta-heuristics with evolutionary algorithms, Hybrid harmony search (hHS) algorithm Apart from the optimization the author added some the optimization techniques that are used while conducting literature survey in Duplex stainless steel.

Modeling and Optimization Techniques: Dijkstra's optimization algorithm, MADM METHODS (Multiple Attribute Decision Making and Multiple Objective Decision Making).

Table 2. DSS Material used in Experimental Work

Generations of DSS	Grade/ Commercial Name- DSS	UNS Number - DSS	EN Nr.- DSS	Surface Roughness	Tool Wear	Machinability	MRR	Chip volume ratio
First generation duplex stainless steel	329	S32900	1.4460	-	-	-	-	-
	3RE60	S31500	1.4424	-	-	-	-	-
	324	S32404	-	-	-	-	-	-
Lean duplex stainless steel	A789	S32001	1.4482	-	-	-	-	-
	LDX 2101	S32101	1.4162	-	44		72	72
	A815	S32202	1.4062	-	-	-	-	-
	EDX 2304	S32304	1.4362	-	-	-	-	-
	ATI 2102	S82011	-	-	-	-	-	-
	FDX 25	S82012	1.4635	-	-	-	-	-
	NSSC 2120	S82122	-	-	-	-	-	-
	A815	S31803	1.4655	--	-	-	-	-
	-	-	1.4669	-	-	-	-	-
	316L	-	1.4404	11, 17	50	11	-	-
Molybdenum - containing Lean duplex stainless steel	A790	S32003	-	-	-	-	-	-
	A240	S81921	-	-	-	-	-	-
	FDX 27	S82031	1.4637	-	-	-	-	-
	A790	S82121	-	-	-	-	-	-
	LDX 2404	S82441	1.4662	-	-	-	-	-
Standard duplex stainless steel	2205	S31803	1.4462	-	-	-	-	-
	2205	S32205	1.4462	6, 7, 8, 11, 13, 14, 15, 16, 17, 19, 21, 23, 26, 27, 29, 30, 31, 33, 35, 38,41,71	15, 23, 29, 30, 41, 42, 43, 44, 47, 48, 49, 50, 52, 53, 54, 55, 60	11, 41, 43, 49, 68, 69	71, 72	72
	A473	S32950	-	-	-	-	-	-
	DP28W	S32808	-	-	-	-	-	-
Super duplex stainless steel	NAS 64	S32506	-	-	-	-	-	-
	F255	S32520	1.4507	-	-	-	-	-
	255	S32550	1.4507	-	-	-		-
	2507	S32750	1.4410	6, 9, 10, 11, 12, 15,16, 17, 18, 20, 22, 24, 25, 28, 32, 37 39, 40	12, 15, 24, 25, 32, 37, 39, 44, 46, 50, 51, 53, 57, 58, 59, 61, 64	11, 68	9, 10, 72	9, 10, 72
	F55	S32760	1.4501	34, 36		34, 36	-	-
	SAF 2906	S32906	1.4477	-	-	-	-	-
	A790	S39277	-	-	-	-	-	-
Hyper duplex stainless steel	SAF 3707 HD	S32707	-	-	-	-	-	-
	SAF 3207 HD	S33207	-	-	-	-	-	-

Table 3. Various factors and Optimization used in Experimental work

Author	Material used & Tools used	Quantative insight (Input & Output Responses)	Optimization Methods used	Outcomes & Critical evaluation
Philip and Chandramohan (2013) [6]	**Material:** ASTMGradeA-995, ASTMGrade-4A and ASTM Grade A-995 ASTMGrade-5A **Tools:** TiCN Coated and TiC Coated Cemented Carbide	**Input-** V_c (80,100,120,140 and160m/min), a_p (0.04,0.08 and 0.12mm/rev), Constant f_z (0.5mm/rev) **Output -** Surface Roughness	Statistical regression technique, Texture analysis(Bulk)	ASTM A 995 Grade5A leads to better surface finish. Texture analysis only carried out, recent optimization methods are not used for prediction.
Krolczyk et al. (2013) [7]	**Material:** 1.4462 (DIN EN 10088-1) DSS & **Tools:** Duplex coated carbide tools (T1 MM 2025) (T2 CTC 1135)	**Input-** Vc(50,100,150m/min), a_p(2 mm), f_z(0.3mm/rev) **Output -** Surface Roughness	Statistical regression technique	Increase of Vc (from 50 m/min to 150m/min) tends to increase of surface hardness. Work is done to perform the hardness using different grade of tools
Krolczyk et al. [8]	**Material:** 1.4462 (DIN EN 10088-1) DSS & **Tools:** TNMG 160408(Coatings: Ti(C,N)-(2µm)(top layer), Al2O3-(1.5 µm) (middle layer), TiN-(2 µm) (bottom layer) Coating technique:CVD.	**Input-** Vc (50and150m/min), a_p (2mm), f_z (0.2and0.4 mm) **Output -** Surface Roughness	Statistical regression technique	f_z was main factor influences surface roughness. The ranges is not specified by author to get optimum cutting conditions
Senthil Kumar et al. (2013) [9]	**Material:** SAF 2507 DSS **Tools:** Uncoated cemented carbide cutting tool inserts - CNMG 120408-QM, grade H13A	**Input-** Vc (100and120 m/min), f_z (0.6,0.8 and1.00mm/rev) , a_p (0.5,0.75 and 1.00 mm) **Output -** Surface Roughness and S/N ratio	ANOVA and Taguchi method	Vc -100 m/min, f_z - 0.06 mm/rev, and Depth of cut - 0.75 mm. Feed rate was main factor influences on surface roughness
Senthil Kumar and SenthilKumaar (2014) [10]	**Material:** SAF 2507 DSS **Tools:** Uncoated cemented carbide cutting tool inserts - CNMG 120408-QM, grade H13A	**Input-** Vc (80,100and120m/min), f_z (0.6,0.8and1.00mm) , a_p (0.5,0.75and 1.00mm) **Output -** Surface Roughness and Flank wear	ANOVA and Taguchi method	Using liquid CO_2 as coolant the surface roughness and the flank wear was reduced.
Rastee et al.	**Material:** EN 1.4404 austenitic, EN	**Input-** Vc (50,100,150,200), a_p	Taguchi method,	The ANOVA result emphasizes that feed flow is

(2014) [11]	1.4462 Std DSS and EN 1.4410 SDSS **Tools:** Coated carbide inserts - CNMG 120408-MM 2025	(0.5,1.5,2.5, 3.5), f_z (0.1,0.25,0.4,0.55) **Output** - Surface Roughness	MADM, AHP-TOPSIS FMADM	the most important factor affecting surface quality. The machining of austenitic stainless steel EN 1.4404 was considered easier to machine.
De Oliveira Junior et al. (2014) [12]	**Material:** Super duplex stainless steel UNS S32750 **Tools:** Cemented carbide grade - ISO M25 grade PVD multi-coated with TiAlN and TiN layers	**Input-** Vc (110and130m/min), f_z (0.15mm/rev), a_p (1mm), low and high fluid pressure cooling conditions **Output** - Surface Roughness, Tool wear, Corrosion resistance	SEM analysis with EDS.	Cooling pressure and cutting speed and their effect on tool life, roughness of part surface . PVD-coated inserts results long tool life
Krolczyk and Legutko (2014) [13]	**Material:** 1.4462 (DIN EN 10088-1) **Tools:** Cutting tool inserts - TNMG 160408	Input- Vc (50-150m/min), a_p (1-3mm), f_z (0.2-0.4mm/rev) Output - Surface Roughness, Tool wear	SRT, Surface texture analysis- IFM method	The f_z is the main parameter which affects the surface roughness.
Thiyagu and Arunkumar (2014) [14]	**Material:** UNS 31803 (2205) DSS & **Tools:** CNMG 120408 SM grade 1115 Sandvik Coromant make with PVD multi-layer coating (TiAlN + Chromium Oxide)	**Input-**Vc (21,49,77m/min), f_z (0.4,0.8,1.2mm/rev), a_p (0.051,0.128,0.205 mm), Nose radius (0.4,0.8,1.2) **Output** - Surface Roughness and Cutting force	ANOVA, RSM	The f_z and Vc were the main parameter which affects the surface roughness.
Philip et al. (2014) [15]	**Material:** Cast DSS ASTM A 995 grade 5A and grade 4A **Tools:** TiC and TiCN coated carbide cutting tool	**Input-** Vc (80,100,120m/min), a_p (0.5mm), f_z (0.04,0.08and 0.12mm/rev) **Output** - Surface Roughness and Cutting force	TRDM, ANOVA signal to noise ratio	The f_z is the main parameter which affects the surface roughness. The Vc was the influencing the tool wear.
Koyee et al (2014) [16]	**Material:** Standard duplex EN 1.4462 and super duplex EN 1.4410 stainless steel rods **Tools:** Coated carbide inserts with ISO code of CNMG120408-QM 2025	**Input-** Vc-200 m/min, a_p-1.5mm, f_z-0.25 mm/rev,Length of cut - 12mm process condition **Output** - Surface Roughness, radial cutting force , effective cutting power, maximum tool flank wear and chip volume ratio	ANOVA, RSM, AHP-TOPSIS, CSNNS	Vc and f_z is the most influencing parameters
Ali. 2015 [17]	**Material:** Austenitic EN 1.4404, standard duplex EN 1.4462 and super duplex EN 1.4410 **Tools:** Coated carbide inserts - CNMG 120408-MM 2025 and CNMG 120408-QM 2025.	**Input-** Vc – (100,180 m/min), a_p (1mm), f_z (0.15, 0.2, 0.25, 0.3, 0.35, 0.4 mm/rev), Cooling medium - Dry, Wet **Output** - Cutting Power, Surface Roughness, Chip volume ratio, Tool wear, Temperature	SRT, Fuzzy Set Theory, GRA, RSM, AHP-TOPSIS, FANNS	The f_z is the main parameter which affects the surface roughness.
Ramadhan et al. (2015) [18]	**Material:** Super duplex stainless steel SAF 2507 **Tools:** TiC insert	Input- Vc (12.5, 22.5m/min, a_p (0.25 mm), f_z (0.06,0.08,0.1,0.12 and 0.14 mm/rev) **Output** - Surface roughness	Comparison between heat, non-heat treated DSS material	The higher Vc and lower f_z is the main parameter which affects the surface roughness.
Krolczyk et al. (2016) [19]	**Material:** Duplex stainless steel 1.4462 (DIN EN 10088-1) **Tools:** TNMG 160408	**Input-** Vc (100m/min), ap (2mm), fz (0.3mm/rev), Dry and wet cooling conditions **Output** - Surface roughness, Tool wear	Comparison between dry and wet cooling conditions	Low f_z and high of cutting speed results minimum surface roughness.
Rohit et al. (2016) [20]	**Material:** SAF2507 DSS & **Tools:** PVD coated carbide inserts - TiAlSiN, AlTiN (3 µm) and AlTiN (7 µm)	**Input-** Vc (60-360m/min), ap (0.5-2mm), fz (0.05-0.35mm/rev) **Output** - Surface Roughness, machinability cutting force, tool wear	Comparison between tools	At higher Vc, surface quality get damage due to chip gets adhere to the machined surface.
Krolczyk et al .(2016 b) [21]	**Material:** 1.4462 (DIN EN 10088-1) DSS **Tools:** Coated carbide inserts with ISO code of TNMG 160408 – GC 2025	**Input-** Vc (50m/min), fz (0.05mm/rev) **Output** - Surface Roughness	Dry and MQCL cutting technology	If an increase of Vc has a positive effect on surface quality.
Mario and Jozić (2017) [22]	**Material:** EN 1.4410 **Tools:** TiC insert	**Input-** Vc, fz, ap **Output** - Machinability, Surface roughness	ANOVA, RSM, GA.	The f_z is the main parameter which affects the surface roughness.
Liew et al. (2017) [23]	**Material:** 2205 DSS & **Tools:** TiAlN coated carbide	**Input-** Vc (210m/min), fz (0.10mm/rev), ap (1.00mm) **Output** - Surface Roughness, Tool wear	Comparison between dry and wet cooling conditions	The surface roughness is low when the temperature of chilled air coolant decreases. The tool wear is lower when using conventional coolant method.
Kadam et al. (2017) [24]	**Material:** Super DSS -2507 **Tools:** TiAlSiN PVD coated tool (3.3µm), AlTiN (3 µm) and AlTiN (7µm).	**Input-** Vc (60-360m/min), fz (0.05-0.35mm/rev)and ap (0.5-2mm) **Output** - Surface Roughness, Tool wear	Comparison between tools	Higher Vc the temperature of the Continuous chips effects the machined surface and the increase of the Vc effect the tool wear.
Gamarra et al. (2018) [25]	**Material:** Super duplex stainless steel-SAF 2507 **Tools:** Carbide inserts - CNMG120408MM-GC 1115 and index able wiper inserts CNMG120408WF-GC 1115	**Input-** Vc (150m/min), Ap (0.5mm), Tool geometries, coolant **Output** - Surface Roughness, Tool wear	Comparison between tools	For long tool life and low surface roughness the f_z value should be maintain very less
Pawan and Misra (2018) [26]	**Material:** DSS (2205) **Tools:** WC-Co cutting inserts, TNMG 160404 FM TN8135	**Input-** Vc (550,930,1210m/min), fz (0.05,0.20,0.36mm/rev) and approach angle (60,75,90mm) **Output** - Surface Roughness	ANOVA, TRDM	f_z is the most influential parameter reduces surface roughness
Philip. (2018) [27]	**Material:** ASTM A 995 Grade 5A **Tools:** Carbide inserts coated with TiC and TiCN with a specification of SNMG 120408 MT TT5100	**Input-** Vc (80,100,120m/min), fz (0.04,0.08,0.12mm/rev), Ap (0.4, 0.8, 1.2mm) **Output** -Surface Roughness	ANOVA, TRDM	f_z is the most influential parameter reduces surface roughness
Auteur Mario Veić et al. (2018) [28]	**Material:** EN 1.4410 super DSS **Tools:** C5-CSRNR/L-27060-12-4	**Input-** Vc (0.063, 0.063m/min), fz (28,45and ap(1,2mm) **Output** - Surface Roughness	ANOVA, RSM, ANFIS	f_z is the most influential parameter reduces surface roughness
Dhananchezian et al. (2018) [29]	**Material:** AISI 2205 DSS **Tools:** PVD coated Nano-multilayer TiAlN cutting tool insert	**Input-** Vc (72,119,197m/min), fz (0.111mm/rev), ap (1mm),cryogenic cooling **Output** -Surface Roughness, Tool wear, machinability	Dry and Wet Cooling conditions	liquid nitrogen decreased the Surface Roughness, Tool wear, machinability
Ghatge et al. (2018) [30]	**Material:** AISI 2205 DSS **Tools:** Multi-layer coated carbide insert (TiN/Al2O3/TICN/TiN)	**Input-** Vc (100,150,200m/min), fz (0.1, 0.2, 0.3mm/rev), ap (0.4,0.8,1.2mm), cutting fluid. **Output** - Surface roughness, Tool wear and Tool temperature	TRDM	Lower tool wear is observed at low Vc and high f_z and by using mineral oil to improving machinability
Vijayan et al. (2019) [31]	**Material:** Duplex 2205 **Tools:** Tungsten carbide	**Input-** Spindle speed, fz and ap **Output** - M.R.R, surface roughness, feed force, thrust force and Cutting force	ANOVA, RSM	High Surface roughness is attained when spindle speed and DOC is high and high spindle speed the MRR is high
Subhash et al.	**Material:** SDSS SAF 2507	**Input-** Vc (40, 60, 80, 100, and	ANOVA, RSM,	f_z is the most significant parameter which effects

(2019) [32]	**Tools:** Carbide tool insert of ISO CNMG 120408TF IC6015	120m/min), fz (0.05, 0.1, and 0.15mm/rev) and ap (0.5mm), dry and wet machining **Output -** Temperature, Surface Roughness	ANN,GA	on surface finish, Tool flank wear is observed more in dry cutting condition, and increased with increasing Vc.
Sonawane and Sargade (2019) [33]	**Material:** DSS 2205 **Tools:** AlTiCrN and AlTiN with 4 μm thickness	**Input-** Vc (100, 40,180m/min), constant fz (0.18mm/rev) and ap (0.8mm) **Output -** Surface Roughness, Cutting Temperatures, Compressive Residual Stresses	RSM, PVD High Pulse Impulse Magnetron Sputtering (HiPIMS) technique.	Increase in Vc, results better surface roughness
Dinde and Dhende (2020) [34]	**Material:** Super-DSS UNS S32760 **Tools:** Nano-coated MEGACOAT carbide inserts	**Input-** Vc (110,120,130m/min), fz (0.20, 0.22, 0.25mm/rev) and ap(1.8, 2.0, 2.3mm) **Output -** Cutting force, Surface roughness, MRR	ANOVA,TRDM, GRA	Optimal cutting conditions are to minimum surface roughness are Vc = 120 m/min, fz = 0.20 mm/rev, ap = 2.0 mm and For MRR is optimum value is attained at 48 cc/min
Kumar and (2020) [35]	**Material:** DSS 2205 & **Tools**: WC-Co coated carbide inserts	**Input-** Vc (43.18, 73.0, 94.99 m/min), fz (0.05,0.20,0.36mm/rev), approach angle(60, 75. 90degree) **Output -** Surface roughness, MRR	ANOVA, TRDM	Feed rate is most influencing factor affecting each machining characteristics
Dinde and Dhende (2020) [36]	**Material:** Super-DSS UNS S32760 **Tools:** Nano-coated MEGACOAT carbide insert	**Input-** Vc (110, 120, 130m/min), fz (0.20, 0.22, 0.25mm/rev) and ap (1.8, 2.0, 2.3mm) **Output -** Surface roughness, Cutting force, and MRR	ANOVA, TRDM, S/N ratio analysis	For Least surface roughness the Vc : 120 m/min, f_z :0.20 mm/rev, depth of cut 2.0 mm should be maintained., highest MRR is attained at Vc = 130 m/min, f_z = 0.25 mm/rev, and ap = 2.3 mm
Narayanan et al. (2020) [37]	**Material:** Super DSS – 2507 **Tools:** PVD-coated tungsten carbide inserts (CNMG 120408MT12)	**Input-** Constant Vc (113m/min) , fz (0.35,0.26, 0.21mm/rev) , ap (1.2, 1.6, 2.0mm) **Output -** Surface roughness, MRR	Dry machining, Cryogenic machining	f_z has more influencing parameter that affect surface roughness and tool life
Mavi. (2020) [38].	**Material:** DSS – 2205 **Tools:** TiN and TiAlN coated carbide drills	**Input-** Vc (15,20,25m/min), , fz (0.05, 0.75, 0.1mm/rev), , Cutting tool types **Output -** Cutting force (Fc) and surface roughness (Ra)	Gray relational analysis,, ANOVA	f_z most significant factor that affect surface roughness
Rajaguru and Arunachalam (2020) [39]	**Material:** Super DSS – 2507 & **Tools:** Tungsten carbide inserts (KCM15)	**Input-** Dry, Flood, MQL, Vc (140 m/min) , ap (1 mm), Five different fz (0.05, 0.10, 0.15, 0.20 and 0.25 mm/rev) **Output -** Tool wear, cutting force, surface Roughness, morphology of chips and residual stress	SEM Analysis	Poor surface finish is obtained at dry cutting conditions, Machining under flood and MQL reduces tool wear and Machinability.
Subhash et al. (2020) [40]	**Material:** Hot forged SDSS 2507 (ASTM A240 – UNS S32750) **Tools:** CCMT120408MR type with a grade of GC2220	**Input-** Vc (160,175,190,205m/min), fz (0.15; 0.175; 0.2; 0.225mm/rev)and ap (1.5mm) **Output -** Cutting forces, Surface roughness	Frequency response functions (FRFs)	The optimal speed reduces the surface roughness and increases Machinability
Sonawane and Sargade (2020) [41]	**Material:** DSS2205 **Tools:** M35 grade Indexable Carbide tool - CNMG120408	**Input-** Vc (100, 140 and 180m/min), fz (0.12, 0.15, 0.18mm/rev) and constant ap (0.8mm) **Output -** Tool wear, Surface Roughness, Machinability	Regression Analysis, High Power Impulse Magnetron Sputtering technique,	Combination of high Vc (180 m/min) and low f_z (0.12 mm/rev) resulted in least surface finish. AlTiCrN and AlTiN coated tools show respectively 6-times more tool life than uncoated tools
Jiang et al. (1996) [42]	**Material:** HIP austenitic steel (PM 316L), HIP DSS (PM 2205) **Tools:** TiN - coated cemented Carbide	**Input-** Vc (15,35,45,55m/min), fz (0.15 mm/rev) and constant ap (1.0 mm) **Output -** Cutting force, surface Roughness, Tool wear	SEM and EDS analysis	Vc should be below 35m/min to achieve less tool wear
Bouchnak et al.(2010) [43]	**Material:** Duplex stainless steel, X2CrNiMo22-5 **Tools:** HPWJAT tool	**Input-** Vc (350, 450 $m.min^{-1}$), fz (0.15 $mm.tr^{-1}$.) , ap (0.5mm) **Output -** Surface Roughness, Tool wear	High pressure water jet assisted turning (HPWJAT)	The improvement of tool life by using high pressure water jet assistance
Schultheiss et al.(2011) [44]	**Material:** SAF 2507, SAF 2205 and LDX 2101 **Tools:** Coated carbide tools	**Input-** Vc, fz , ap **Output -** Tool wear	ANOVA	f_z is the most influencing parameter - tool wear
Ahmadi et al. (2012) [45]	**Material:** Austenitic ferritic (Duplex) stainless steel (330HRC) **Tools:** Ceramic cutting tool with Alumina base (aluminium oxide)	**Input-** Vc (120, 170, 220 and 270m/min), fz (0.12mm/rev) , ap (0.5mm) **Output -** Tool wear	Multi-regression analysis (MRA), (ANOVA).	Alumina-based ceramic cutting tools the flank wear has a considerable effect
Kumar and Senthilkumaar (2013) [46]	**Material:** Super DSS - SAF 2507 **Tools:** Uncoated Cemented carbide cutting tool inserts(CNMG 120408-QM, grade H13A)	**Input-** Vc (100,120m/min), fz (0.06,0.08,1.0mm/rev), ap (0.5,0.75,1mm) **Output -** Tool wear	Regression analysis, TRDM, SEM analysis	Tool wear is low in gas cooled machining
Królczyk et al. (2013) [47]	**Material:** 1.4462 (DIN EN 10088-1) steel **Tools:** Cutting tool inserts of TNMG 160408	**Input-** Vc (50,150m/min), fz (0.3mm/rev) , ap(2mm) **Output -** Tool wear	SEM analysis	Wear of tool is due to Increase of the Vc
Królczyk et al.(2013b) [48]	**Material:** 1.4462 (DIN EN 10088-1) steel **Tools:** Cutting tool inserts of TNMG 160408	**Input-** Vc (50, 150m/min), fz (0,2,0,4mm/rev) , ap (1, 3mm) **Output -** Tool wear, surface Roughness	Factorial Design Method, Metallographic microscopy analysis	Wear of tool is due to Increase of the Vc. The CVD - Ti(C, N)/Al2O3/TiN coated carbide tools has greater resistance to abrasive wear
Krolczyk et al.(2013 c) [49]	**Material:** 1.4462 (DIN EN 10088-1) steel **Tools:** Cutting tool inserts of TNMG 160408	**Input-** Vc (50, 150 m/min), fz (0,2,0,4 mm/rev) , ap (1, 3 mm) **Output -** Tool wear	Factorial Design Method	Wear of tool is due to Increase of the Vc
Rastee et al. (2013) [50]	**Material:** Super DSS EN 1.4410, standard DSS EN 1.4462 and austenitic EN, 1.4404 stainless steels **Tools:** Coated carbide inserts (CNMG 120408-MM 2025)	**Input-** fz (0.1, 0.175, 0.25, 0.325, 0.4mm/rev) , ap (0.5, 1, 1.5, 2, 2.5, 3, 3.5mm) **Output -** Tool wear	TOPSIS, GRA, VIKOR method, Utility Analysis (UA), MADM, MOO	Dominant at lower f_z the tool wear is high
Kumar et al. (2014) [51]	**Material:** Super DSS SAF 2507 **Tools:** Uncoated cemented carbide cutting tool inserts(CNMG 120408-QM, grade H13A)	**Input-** Vc (100,120m/min), fz (0.06,0.08, 0.10mm/rev), ap (0.50, 0.75 1.0mm) **Output -** Tool wear	Dry, wet, gas cooled Machining, SEM analysis	Gas cooled machining increases tool life
Krolczyk et al. (2015) [52]	**Material:** Duplex stainless steel 1.4462 (DIN EN 10088-1) **Tools:** Cutting tool inserts of TNMG 160408	**Input-** Vc (50,100,150m/min, fz (0.2,0.3,0.4mm/rev, ap (1,2, 3mm) **Output -** Tool wear	Factorial Design Method, Dry and Wet cutting condition, Tool comparison	Vc Increases tool wear also increases

Rastee et al. (2014) [53]	**Material:** Standard DSS EN1.4462 and Super DSS EN 1.4410 **Tools:** carbide inserts (CNMG 120408-MM 2025)	**Input-** Vc (100, 180m/min), fz (0.15, 0.2, 0.25, 0.3, 0.35, 0.4mm/rev) , ap (1mm) Dry and Wet cutting condition, **Output -** Tool wear	MOBA, ANOVA	At low Vc is the most dominant parameter for tool wear
Krolczyk Grzegorz et al. (2015) [54]	**Material:** DSS- 1.4462 (DIN EN 10088-1) **Tools:** TiCN / Al2O3 / TiN about 5.5 µm thickness (T1) and TiN / Ti(C,N) / Ti(N,B) / TiN / Ti(C,N) / Ti(C,N) about 12 µm thickness (T2).	**Input-** Vc(50 100 150m/min), fz (0.2 0.3 0.4mm/rev) , **Output -** Tool wear	ANOVA, TRDM, Signal-to-noise Ratio	Vc and f_z were affecting the life of the tool
Metelski Andrzej et al. (2016) [55]	**Material:** DSS 1.4462 (DIN EN 10088-1), **Tools:** Coated carbide inserts with ISO code of TNMG 160408: GC 2025 and CTC 1135	**Input-** Vc (50,100,150m/min), fz { 0.2 0.3 0.4mm/rev) **Output -** Tool wear	ANOVA, Dijkstra's algorithm	Vc and f_z were affecting the tool life
Diniz et al. (2016) [56]	**Material:** S41000 martensitic and S41426, super martensitic stainless steels **Tools:** Coated cemented carbide tools	**Input-** Tool material, the cutting conditions, and the cooling/lubrication system **Output -** Tool wear	SEM analysis with EDS device	Depth of cut is the most important parameter that affect the life of the tool
Rajaguru and Arunachalam (2017) [57]	**Material:** SDSS - S32750 **Tools:** Tungsten carbide cutting insert with geometry of TNMG 160408	**Input-** Variable speed from 150- 5600 rpm with the power rating of 10 kW, Vc (120 m/min), feed(0.3mm/rev) depth of cut (1mm) **Output -** Tool wear, cutting force and surface integrity	SEM, EDS, X-ray diffraction (XRD) technique	The tool wear [MT-TiCN]- Al2O3 coated tool provided good wear resistance
De Paiva et al. (2017) [58]	**Material:** Super DSS (UNS32750) **Tools:** chemical vapor deposited (CVD) TiCN + Al2O3as well as physical vapor deposited (PVD) TiCN and AlTiN coatings	**Input-** Back rake angle, clearance angle, cutting edge angle, rake angle, side cutting edge angle, and nose radius. **Output -** Tool wear	XPS analysis	AlTiN-coated tool have the longest tool life
Ahmed et al. (2017) [59]	**Material:** Super DSS—Grade UNS S32750 **Tools:** Cemented carbide inserts coated with PVD AlTiN and CVD TiCN + Al2O3	**Input-** Back rake angle, clearance angle, wedge edge radius angle, and nose radius. **Output -** Tool wear, Chip characteristics	(SEM) equipped with energy EDS, X-ray Photoelectron Spectroscopy (XPS).	Tool life is the twice that of the CVD TiCN + Al2O3 coated insert
Nomani et al. (2017) [60]	**Material:** Duplex SAF 2205 **Tools:** WNMG-TF solid carbide inserts	Input- Vc (94m/min), fz (0.15mm/rev) , Output - Tool wear	SEM and electron backscatter diffraction (EBSD)	Tool wear is dominated by built-up edge
Ahmed and Veldhuis (2017) [61]	**Material:** Super DSS - S32750 **Tools:** PVD deposited TiAlN coating on a carbide insert	**Input-** Point angle of 80°, negative geometry, nose radius of 0.8 mm **Output -** Tool wear, Tribological performance, Chip microstructure	(SEM) with energy dispersive spectroscopy (EDS)	AlTiN insert Longest tool life
Nagy et al.(2019) [62]	Material: G X2CrNiMoCuN 26-6-3-3 casted super duplex steel Tools: Coated with TiAlN and other with TiAlSiN	**Input-** Vc (70m/min) and feed (f = 0.15mm), **Output -** Tool wear-burr and built-up edge formation	Stereo microscope image analysis	Vc is the dominant parameter that effects the tool.
Dyl (2019) [63]	**Material:** Duplex cast stainless steel type GX2CrNiMoCuN25-6-3-3 **Tools:** 2025 grade - CCMT 09T308-MM , CCMT 09T308-UM , CCMT 09T304-UM	**Input-** Vc (70m/min), fz (0.2mm/rev), ap (0.5mm), Nose Radius, Flank Angle, Rake Angle **Output -** Surface roughness, flank wear (VB, mm) and crater wear (KB, mm)	Arithmetical mean deviation and the maximum height of profile	At lowest tool wear occurred at f_z - 0.1 mm/rev, Vc - 70 m/min, depth of cut -0.5 mm
Narayanan and Jagadeesha (2020) [64]	**Material:** Super DSS – 2507 **Tools:** PVD-coated tungsten carbide inserts (CNMG 120408MT12)	**Input-** Vc (113 m/min), fz (0.35,0.26,0.21 mm/rev), ap (1.2,1.6,2.0 mm) **Output -** Cutting Temperature, Tool Wear	SEM analysis	The coolant reduces the amount of flank wear up to 77.19 percentage as compared to dry machining
Nomani et al. (2015) [68]	**Material:** Wrought duplex stainless steel alloys SAF 2205 and SAF 2507. **Tools:** TiAIN+ TiN coated solid carbide twist drill	**Input-** Vc (60 m/min) , fz (0.15 mm/rev), ap (30 mm) **Output -** Tool wear, Machinability	SEM and optical microscopic analysis	SAF 2205 holds the better machinability in terms of tool wear
Sonawane et al. (2020) [69].	**Material:** DSS 2205 **Tools:** AlTiN and AlTiCrN on cemented carbide	**Input-** Vc (100 to 180m/min), , fz (0.12 to 0.18mm/rev), , ap -0.8 mm constant **Output -** Nose wear, tool life and surface roughness	BUE formation method	For maximum tool life an machinability - the parameter should be maintained at low cutting speed and feed rate
Dinesh et al.(2016) [71]	**Material:** Duplex alloy steel **Tools:** Cemented carbide tool	**Input-** Vc, fz , ap and tool nose radii **Output -** MRR and Surface roughness	ANOVA, TRDM, GRA	Vc, f_z is the most influential parameter for surface roughness and MRR
Schultheiss et al. (2019) [72]	**Material:** DSS- LDX 2101, SAF 2205, SAF 2507 **Tools:** Ti(C,N) and Al2O3-coated cemented carbide CNMG120412 cutting tools.	**Input-** Vc (125 m/min), fz (0.06, 0.10, 0.15, 0.20mm/rev), ap (3mm) and tool nose radii (0.4, 0.8, 1.2, 1.6mm), **Output -** Minimum chip thickness	Finite element simulation	Decreasing size of the tool nose radius leads to increased minimum chip thickness

Meta-Heuristics optimization techniques: Multi objective bat algorithm (MOBA).

Hybrid Algorithms: Hybrid global best harmony search (hgHS) algorithm, Taguchi coupled Fuzzy Multi Attribute Decision Making (FMADM), Analytical Hierarchy process - Technique for Order Preference by Similarity to Ideal Solution (AHP-TOPSIS), Taguchi-VIKOR coupled with Firefly Algorithm Neural Network System (FANNS).

Comparsion methods: Tool Comparison, dry and wet (cooling / lubricating conditions).

The literature review on surface roughness, tool wear, machinability, chip volume report, material removal rate is presented in Table 2, shows that there is a limited research is available in the field of conducting the experiment using duplex stainless steel. The traditional and non-traditional technique used for DSS optimization is shown in Table 4. It also shows that there are numerous algorithms that can be used to optimize DSS materials.

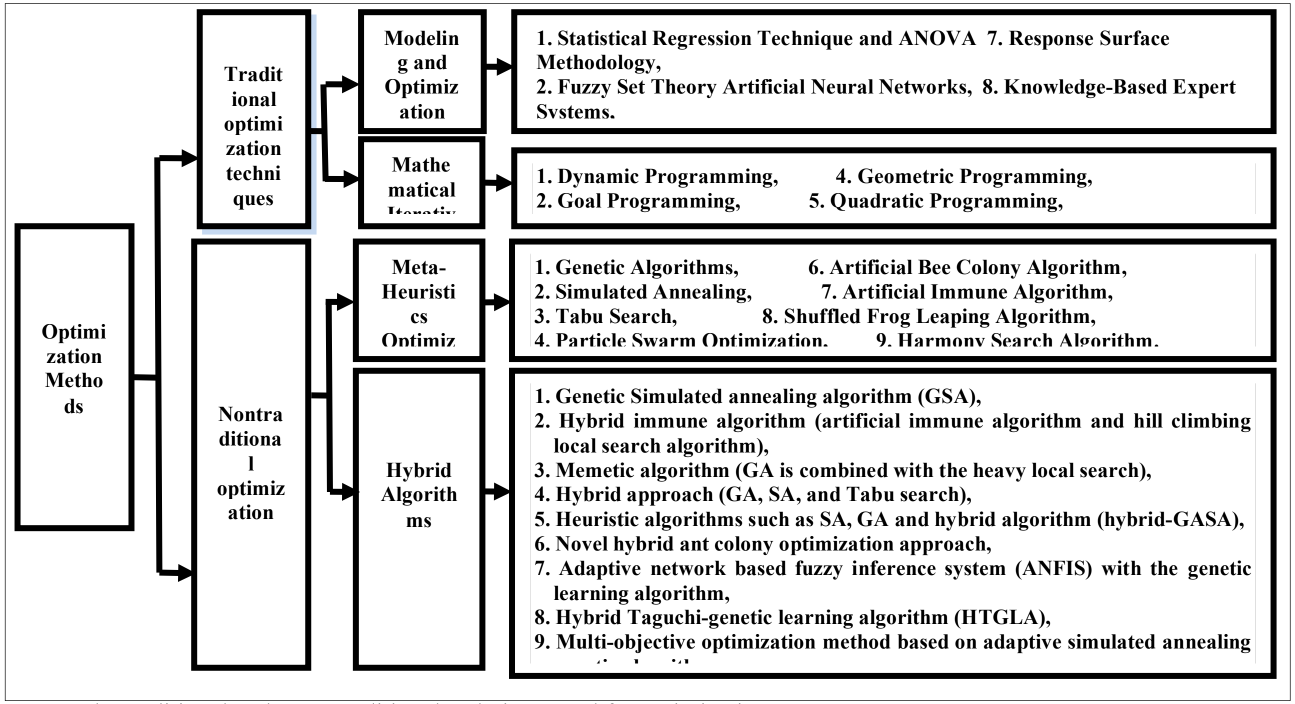

Fig. 5. The traditional and non - traditional technique used for optimization

Table 4. Optimization methods used in Turning of DSS

Modelling& Optimization Methods	Optimization methods used in turning of DSS - Reference in Numbers: 2010& Before	2012		2013				2014				2015			2016				2017			2018			2019				2020			
	Ra	V_B	K_M	Ra	V_B	K_M	MRR	Ra	V_B	K_M	MRR	Ra	V_B	K_M	Ra	V_B	K_M	MRR	Ra	V_B	K_M	Ra	V_B	K_M	Ra	V_B	K_M	MRR	Ra	V_B	K_M	MRR
Modelling Technique																																
Statistical Regression Technique & ANOVA		45		6,7,8,9	46		9	10, 13, 14, 15, 16	15,16, 53		10	17,18	54			55		71	22			26,27, 28			31, 32	32			34, 35, 36, 38, 41	41	41	34,35, 36
Fuzzy Set Theory												17																				
Artificial Neural Networks								16																	32	32						
Gray Relational Analysis (GRA)					50							17						71											34, 38			34
Taguchi Robust Design Method				9	46		9	10,11, 15	16		10		54					71				26,27, 30	30	30					34, 35,			34,35, 36

																													36		
Taguchi Fuzzy-Based Approach																						**26,27**									
Factorial Design Method					**48,49**	**49**		**13,52**	**13, 52**																						
Response Surface Methodology				**8**	**46**			**14,16**	**16**			**17**							**22**			**28**			**31, 32**	**32, 33**		**31**			
Dijkstra's optimization algorithm																**55**															
MADM Methods					**50**			**11**																							
Meta-Heuristics																															
Genetic Algorithms																			**22**						**32**	**32**					
Multi objective bat algorithm (MOBA)									**53**																						
Hybrid Algorithms																															
Adaptive network based fuzzy inference system (ANFIS)																						**28**									
Taguchi coupled Fuzzy Multi Attribute Decision Making (FMADM)								**11**																							
Analytical Hierarchy process -Technique for Order Preference by Similarity to Ideal Solution (AHP-TOPSIS)					**50**			**11, 16**	**16**			**17**																			
Taguchi-VIKOR coupled with Firefly Algorithm Neural Network System (FANNS)					**50**							**17**																			
Cuckoo search neural network systems (CSNNS)								**16**																							
Tool Comparison	**42**	**45**			**47**				**52**				**68**	**68**	**20**	**20**		**24**	**24, 69**	**24,57, 58,59, 61,69**	**69**	**25**	**25**		**33**	**63**			**37**	**37, 64**	
Dry and Wet (Cooling / Lubricating)	**43**	**45**						**11**	**11,51, 52**						**19, 21**	**19,56**			**23**	**23**		**29**	**29**	**29**					**37, 39**	**39, 64**	**39**
SEM , IFM, XPS , Stereo microscope image analysis					**47,48**			**12,14**	**12,14**							**56**				**57,58, 59,60, 61**						**62**				**64, 68**	

5. Future Studies

New duplex grades have been added to the market in recent years, with the primary aim of improving tolerance to reducing acids, pitting, and crevice corrosion.

However, the duplex is also far from achieving its maximum capacity.

The study, which started in 2010 and based on metal cutting utilizing the turning operation, indicates that there is a lack of analysis and literature in the DSS families.

Past studies have focused on 2205, 2507, and Zeron 100 products, with the primary goal of reducing surface roughness, tool wear, machinability, chip volume ratio, and material removal rate. As a result, there are many study opportunities in other duplex households.

With the aid of meta-heuristics and hybrid optimization methods, there are various study opportunities to maximize and forecast performance responses.

6. Conclusion

Because of their higher hardness, duplex steels are more complex to machine than traditional austenitic stainless steels. The application of DSS is high due to its physical and chemical properties. Nowadays the growth of machining process is glowing improved. The highly developed optimization that means computational techniques by using hybrid algorithms places a virtual role in the field of research. The computational techniques are very easy to optimize, precision accuracy, time saving, reliable and efficient way to solve any type of completed problems. The DSS have high strength, superior pitting corrosion resistance, work hardening, two times the tensile strength of other austenitic alloys, outstanding pitting and crevice corrosion. This review concludes that there is a reach possibilities in the field of turning of DSS and heuristic methods used for optimization. The elaborated research is required in the field of DSS families considering different parameters and cooling conditions. The Duplex grade is the alternative to austenitic grade for their excellent corrosion resistance. Today, the growth of new duplex stainless steel grades is tremendously energetic with a high possibility of success in several new markets.

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Nomenclature

v_c Cutting speed in mm/min
f_z Feed per tooth in mm/tooth
a_p Depth of cut in mm
n Spindle speed in r/min
r_n Nose radius in mm
P Cutting power in W
Ra Machined surface roughness in µm
V_B Tool Wear in mm
K_M Machinability of a material
F Cutting force in N
MRR Material Removal Rate in mm^3/min
R_S Residual stress
M_i Machinability index
z Number of cutting teeth
SRT Statistical Regression Technique
ANOVA Analysis of Variance
BBD Box–Behnken Design
ANN Artificial Neural Network
GRA Gray Relational Analysis
TRDM Taguchi Robust Design Method
TFBA Taguchi Fuzzy-Based Approach
GTMA Graph theory and matrix approach
FDM Factorial Design Method
RSM Response Surface Methodology
DOA Dijkstra's Optimization Algorithm
MADM Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM)
GA Genetic Algorithm
MOBA Multi objective bat algorithm
ANFIS Adaptive network based fuzzy inference system
FMADM Taguchi coupled Fuzzy Multi Attribute Decision Making
AHP-TOPSIS Analytical Hierarchy process - Technique for Order Preference by Similarity to Ideal Solution
IFM Infinite Focus Measurement Machine
MSQCI Multi-Surface Quality Characteristics Index
FANNS Taguchi - VIKOR coupled with Firefly Algorithm Neural Network System
CSNNS Cuckoo search Neural Network Systems
HiPiMS High Power Impulse Magnetron Sputtering
UA Utility Analysis
SEMI Scanning Electron Microscope Image