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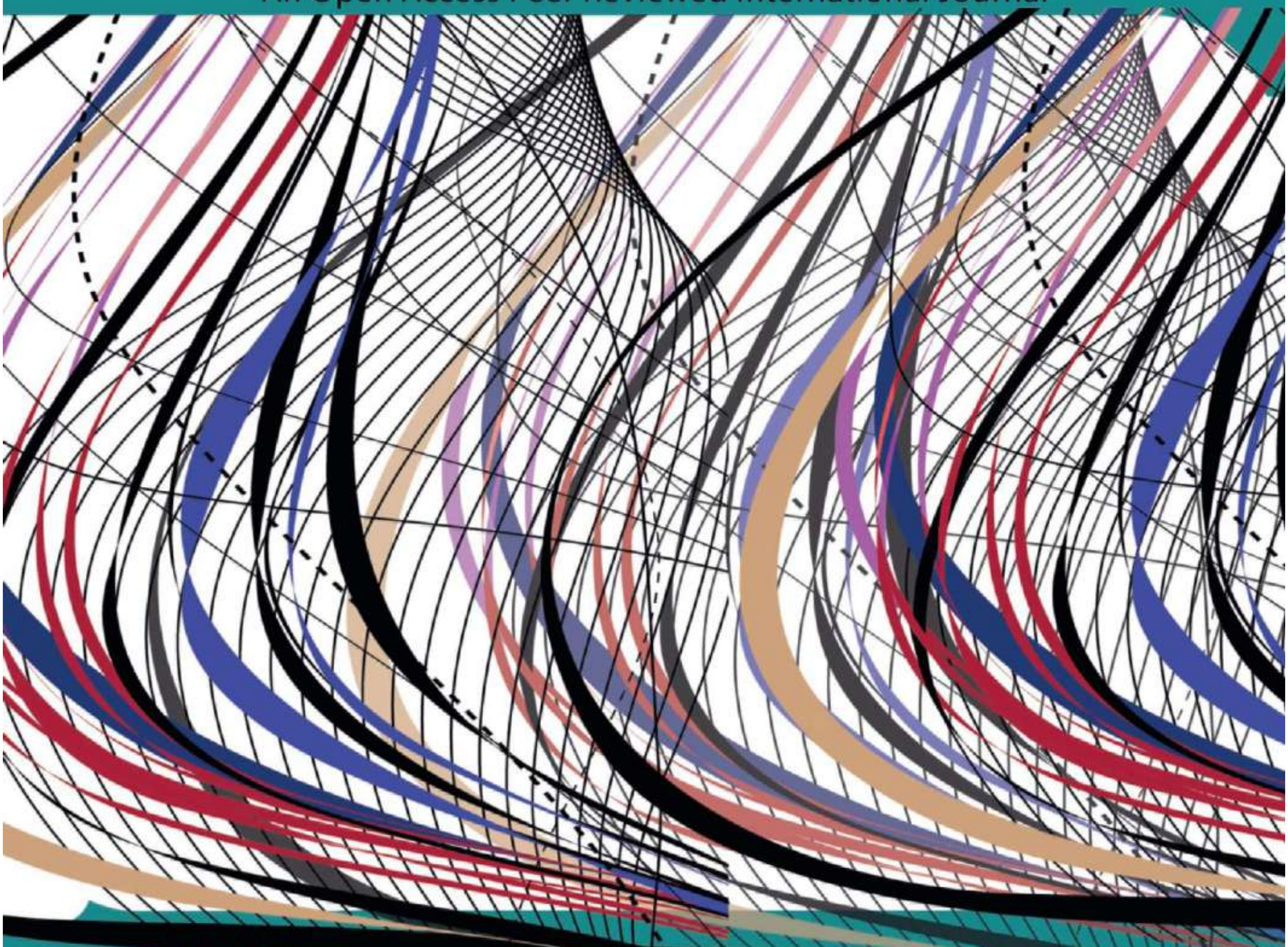

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FOREWORD

I am pleased to put into the hands of readers Volume-6; Issue-9: Sep, 2020 of **“International Journal of Advanced Engineering, Management and Science (IJAEMS) (ISSN: 2354-1311)” ,** an international journal which publishes peer reviewed quality research papers on a wide variety of topics related to Science, Technology, Management and Humanities. Looking to the keen interest shown by the authors and readers, the editorial board has decided to release print issue also, but this decision the journal issue will be available in various library also in print and online version. This will motivate authors for quick publication of their research papers. Even with these changes our objective remains the same, that is, to encourage young researchers and academicians to think innovatively and share their research findings with others for the betterment of mankind. This journal has DOI (Digital Object Identifier) also, this will improve citation of research papers.

I thank all the authors of the research papers for contributing their scholarly articles. Despite many challenges, the entire editorial board has worked tirelessly and helped me to bring out this issue of the journal well in time. They all deserve my heartfelt thanks.

Finally, I hope the readers will make good use of this valuable research material and continue to contribute their research finding for publication in this journal. Constructive comments and suggestions from our readers are welcome for further improvement of the quality and usefulness of the journal.

With warm regards.

Dr. Dinh Tran Ngoc Huy
Editor-in-Chief
Date: Oct, 2020

Editorial Board/ Reviewer Board

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Enhancing the Tribological Behavior of Hybrid Al6061 Metal Matrix Composites through the incorporation of Nickel and Chromium Nanoparticles

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***Abstract*— *In this work, the influence of addition of nickel and chromium micron/nano particles on the tribological behavior of developed Al6061 hybrid metal matrix composites has been identified. In the first category Al6061 based hybrid metal matrix composite reinforced with x wt.% of nickel (x=0, 0.9, 1.8 and 2.7) and same wt.% of chromium micron size particles were fabricated throughcost- effective stir casting technique. In the second category Al6061 based hybrid nano metal matrix composites reinforced with y wt.% of nickel(y=0, 0.6 and 1.2) and same wt.% of chromium nanoparticles developed through same technique. Graphite and magnesium micron/nano size particles added to improve self-lubrication property and wettability respectively. The wear rate of developed composites has been tested on pin-on-disc experimental set up at defined speed 500 RPM, sliding distance 1000 m and variable load 10N, 20N & 30N. The reduction of wear rate of Al6061/1.8Ni/1.8Cr hybrid metal matrix composite and Al6061/0.6Ni_{np}/0.6Cr_{np} hybrid nano metal matrix composite 37.1% and 76% w.r.to Al6061 alloy. The results revealed that there is significant improvement in wear resistance or decrement in wear rate of hybrid nano metal matrix compositesas compared to hybrid metal matrix composite and Al6061 alloy. An attempt made in this work to provide information for superior tribological behavior of hybrid nano metal matrix composites.*

***Keywords*— Al6061, hybrid metal matrix composites, nickel, chromium, nanoparticles, wear rate.**

I. INTRODUCTION

Aluminum (Al) alloy has many applications in industries due to its excellent strength, low strength to weight ratio, good thermal properties and resistance in corrosion. On the other hand, Al alloys have low resistance to wear. The desired properties of the Al alloy can be achieved through hybrid metal matrix composites reinforced with nano size particles. Reinforcement particles at micro or nano scale level can be placed inside it, creating a new aluminum based composite material. Introducing of two or more than two filler materials or reinforced particles developed a composite with superior properties as compared monolithic metal or alloy and single type particulate reinforced metal matric composites (Ramesh et al. 2009). Enhancement in tribological behavior of developed MMCs reinforced with single type particles have been reported by various investigators.

Sharifi and Karimzadeh (2011) studied the mechanical and tribological behavior of fabricated pure aluminum-based metal matrix composite reinforced with different weight percentage (5, 10 and 15) of B_4C nanoparticles by powder metallurgy technique. By increasing the weight percentage of B_4C nanoparticles the wear resistance increases continuously but optimum value observed at 15 wt. % of B_4C nanoparticles. By reduction in size of particle from micron to nano tendency of cracking of particles get reduced. Results revealed that micron size reinforced hybrid composites are inferior in wear properties w.r.to nano size reinforced hybrid composites.

Premnath et al. (2014) examined the influence of reinforced particles on the wear behavior of aluminum metal matrix composite. They fabricated Al6061 based composites reinforced with varying weight fraction (5%, 10% and 15%) of alumina and fixed weight fraction (5%) of graphite. Graphite is added to improve self-lubricating property hence it affects the wear behavior of developed composite. Results concluded that wear resistance increased with increasing weight percentage of silica and which is dominated by the load and followed by speed and composition of reinforcement.

Nassar and Nassar (2017) studied the mechanical properties of Al/TiO_2 nano composites. Uniform distribution of TiO_2 nano particles and absence of cluster formation observed. Wear resistance increased with increasing the volume percentage of reinforced nano particles.

Umanath et al. (2011) examined the wear behavior of Al6061 based composite reinforced with varying volume fraction (5-25%) in steps of 5% of Al_2O_3 and SiC particles. Wear test conducted at constant speed and distance 2.09m/s and 1884m respectively at loads 3kgf, 4kgf and 5kgf of developed composites on pin-on-disc apparatus. Authors reported that wear rate decreased with increasing volume fraction of reinforcement.

Mohapatra et al. (2015) compared the tribological behavior between developed Al6061 alloy-based metal matrix composite reinforced with micron and nano size aluminum oxide with fixed amount of titanium.MMCs reinforced with nano size particulate of aluminum oxide shows better wear resistance w.r.to MMCs reinforced with micron size particulate of aluminum oxide and base alloy i.e. Al6061.

Reddy et al. (2019) carried out an investigation on wear behavior of Al6061 based MMC reinforced with fixed wt.% 2 of SiC nano particles of size 50 nm and X wt. % of Gr particles of size 500 nm (X=0, 0.5, 1, 1.5, 2, 3). Wear rate decreased monotonically with addition of SiC particles and Gr particle up to 2 wt.% afterwards wear rate increases. Results revealed that maximum microhardness 91 HV for Al6061/2SiC nano composite and maximum reduction 73% in wear rate observed for Al6061/2SiC/2Gr nano hybrid composite as compared to Al6061 matrix.

It is observed that hybrid nano metal matrix composites are in better choice as compared to nano metal matrix composites, hybrid metal matrix composites and monolithic metals or alloys.Therefore, more attention is focused on cheap transition metals like nickel and chromium micron/nano size particles to enhance tribological properties. In the present study, the influence of nickel and chromium micron/nano size particles addition on the tribological properties of Al6061 developed by liquid casting technique were analyzed. Graphite/Graphene used to improve self-lubrication property whereas magnesium used to improve wettability of developed HMMCs and HNMMCs.

II. MATERIALS AND METHODS

For the current work Al6061 alloy was chosen as a base material or matrix because of its vast applications.Table 1 shows the chemical composition of Al6061.

Table 1. Chemical composition of Al 6061alloy

Element	Mg	Si	Fe	Cr	Zn	Pb	Cu	Mn	Ti	Ni	Sn	Al
Wt. %	0.81	0.45	0.39	0.25	0.25	0.24	0.24	0.14	0.15	0.05	0.001	Bal.

In case of hybrid metal matrix composites nickel and chromium micron size particles were used as reinforcement due to better strengthening effect and corrosion resistance respectively. Graphite and magnesium particles of micron size added in fixed weight fraction to improve self-lubrication property and wettability respectively. Table 2 shows the properties of micron size reinforced particles.

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Table 2. Properties of micron size reinforced particles

Case A: Al6061 Reinforced with Micron Size Particles				
Reinforcement	Nickel	Chromium	Graphite	Magnesium
Images				
Purity	99.16%	99.60%	99.50%	99.87%
Particle Size	44 µm	44 µm	37 µm	149 µm
Melting Point	1450°C	1900°C	3652°C	650°C

In case of hybrid nano metal matrix composite, nickel and chromium nano particles were used for reinforcement. Whereas, graphene and magnesium nanoparticles were added in fixed weight fraction. Table 3. Shows the properties on nano sized reinforced particles

Table 3. Properties of nano size reinforced particles

Case B: Al6061 Reinforced with Nano Size Particles				
Reinforcement	Nickel	Chromium	Graphite	Magnesium
Images				
Purity	>99 %	>99.9%	>99%	>99.9%
Particle Size	30-50 nm	30-50 nm	5-10 nm	30-50 nm
Melting Point	1453°C	1875°C	3550°C	2852°C

Table 4. Planning for fabrication of MMCs reinforced with micron size particles

Category (C)	**Sample No.**	**Al6061**		**Nickel (Ni)**		**Chromium (Cr)**		**Graphite (Gr)**		**Magnesium (Mg)**	
		gm	**%**	**gm**	**%**	**gm**	**%**	**gm**	**%**	**gm**	**%**
C1 (Different wt. % of Ni & Cr micron particles)	SM1	473	94.6	4.5	0.9	4.5	0.9	13.5	2.7	4.5	0.9
	SM2	464	92.8	9.0	1.8	9.0	1.8	13.5	2.7	4.5	0.9
	SM3	455	91.0	13.5	2.7	13.5	2.7	13.5	2.7	4.5	0.9

Table 5. Planning for fabrication of MMCs reinforced with nano size particles

Category (C)	**Sample No.**	**Al6061**		**Nickel (Ni)**		**Chromium (Cr)**		**Graphite (Gr)**		**Magnesium (Mg)**	
		gm	**%**	**gm**	**%**	**gm**	**%**	**gm**	**%**	**gm**	**%**
C2 (Different wt. % of Ni & Cr nanoparticle)	SN1	488.5	97.7	3	0.6	3	0.6	3	0.6	2.5	0.5
	SN2	485.5	97.1	3	0.6	6	1.2	3	0.6	2.5	0.5
	SN3	485.5	97.1	6	1.2	3	0.6	3	0.6	2.5	0.5
	SN4	482.5	96.5	6	1.2	6	1.2	3	0.6	2.5	0.5

Stir casting is a cost-effective technique for the development of Al6061 based HMMCs and NHMMCs as per table 4 and 5 at casting temperature 750˚C and stirring for 15-20 mins at 400 rpm through an automated stir casting set up. After solidification, specimens were prepared as per ASTM standards for wear test. The specimens for wear test were tested on pin-on-disc apparatus at: normal load 10 N, 20Nand30N, speed 500 RPM and sliding distance 1000 m.

III. RESULTS AND DISCUSSIONS

3.1. Wear Rate for Hybrid Metal Matrix Composites (HMMCs)

Table 6 shows the results obtained during wear test of developed HMMCs. Wear rate was calculated for different weight fraction of Ni and Cr reinforced micron size particles.

Table 6. Wear rate for developed MMCs reinforced with micron size particles

Category C	Sample No.	Composition Designation	Speed (RPM)	Distance (m)	Load (N)	Wear Rate (10^{-3} mm^3/Nm)
C0 Base alloy	SM0	Al6061	500	1000	10	0.52456
					20	0.5632
					30	0.63212
C1 Different weight % of Ni and Cr micron particles	SM1	Al6061/0.9Ni/0.9Cr	500	100	10	0.3853
					20	0.44221
					30	0.4983
	SM2	Al6061/1.8Ni/1.8Cr	500	1000	10	0.32994
					20	0.38734
					30	0.45423
	SM3	Al6061/2.7Ni/2.7Cr	500	1000	10	0.60452
					20	0.68354
					30	0.8868

Figure 1 shows that wear rate decreased by adding Ni and Cr from 0 wt.% to 1.8 wt.% as reinforced particle to Al6061. further addition of reinforced particles wear rate drastically increased even greater than casted Al6061. Wear resistance monotonically decreased by increasing the load. The optimum result observed for Al6061/1.8 Ni/1.8 Cr with wear rate 0.32994x$10^{-3}$$mm^3$/N.m at 10 N load. Similar behavior of results were obtained by Suresh and Moorthi (2013) when they performed tests on metal matrix comosites. HMMCs have better wear resistance than that of MMCs.

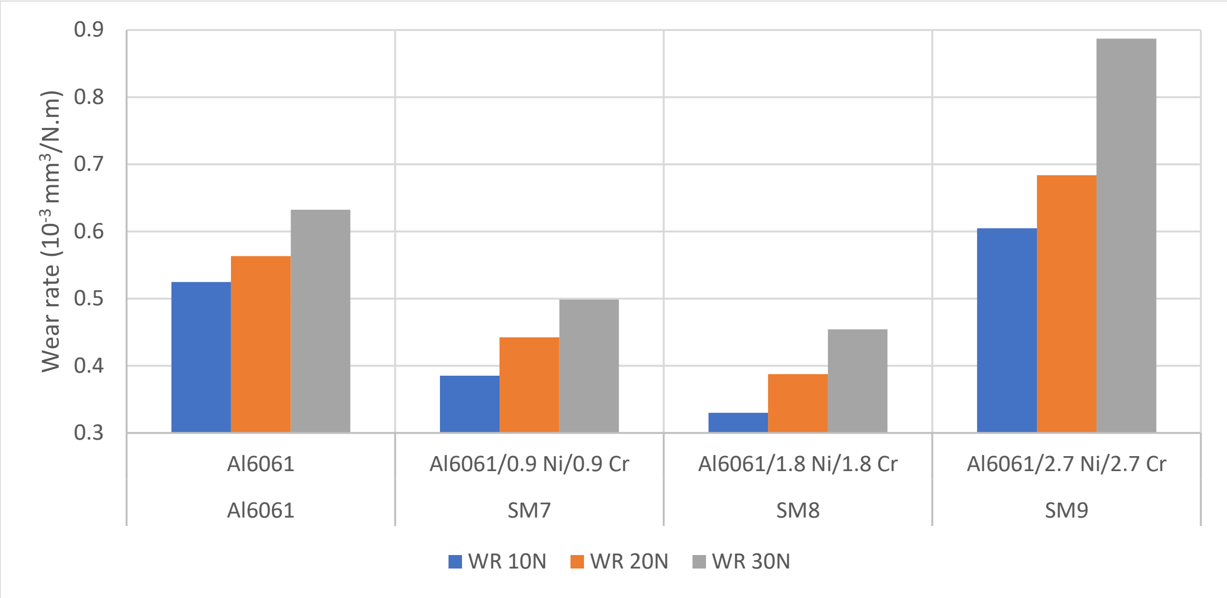

Fig.1: Variation in wear rate of Al6061 and Al6061/Ni/Cr HMMCs

The reinforcement of Ni and Cr particles strengthens the Al6061 matrix and improve the tribological behavior. Hard reinforced particles can be responsible to improve hardness hence reduction in wear rate The decrease in wear rate and enhancement in wear resistance due to uniform distribution of reinforced particles in Al6061, wettability is responsible for this. Mg addition in fixed weight percentage improve the surface wetting of MMC (kumar et al., 2011). Gr is added in fixed weight percentage to improve self lubricating property, which reduces the contact area b/w sliding pairs hence the wear rate decreases. Wear rate suddenly increased due to poor bonding between matrix and reinforced particles.

3.2. Wear Rate for Hybrid Nano Metal Matrix Composites (HNMMCs)

Table 7 shows the results obtained during wear test of developed HNMMCs. Wear rate was calculated for different weight fraction of Ni and Cr reinforced nano size particles.

Table 7. Wear rate for developed NMMCs reinforced with nano size particles

Category (C)	Sample No.	Composition Designation	Speed (RPM)	Distance (m)	Load (N)	Wear Rate (10^{-3} mm^3/Nm)
C2 Different wt.% of Ni and Cr nanoparticles	SN1	Al6061/0.6Ni_{np}/0.6Cr_{np}	500	1000	10	0.12600
					20	0.15632
					30	0.17162
	SN2	Al6061/0.6Ni_{np}/1.2Cr_{np}	500	1000	10	0.18064
					20	0.21367
					30	0.24378
	SN3	Al6061/1.2Ni_{np}/ 0.6Cr_{np}	500	1000	10	0.22430
					20	0.25267
					30	0.28276
	SN4	Al6061/1.2Ni_{np}/ 1.2Cr_{np}	500	1000	10	0.25432
					20	0.32340
					30	0.38453

Figure 2 shows the change of wear resistance and wear rate for casted Al6061, Al6061/1.8 Ni /1.8 Cr MMC and Al6061/Ni/Cr NMMCs w.r.to applied load and wt.% of reinforced nanoparticles. Wear rate reduced whereas wear resistance improved by adding minimal amount of Ni nanoparticles (0.6 wt.%) and Cr nanoparticles (0.6 wt.%) to Al6061.Wear resistance decreased by increasing the applied load. Wear rate increased if reinforced particle in developed composite higher than 0.6 wt.% but having lower value than that of casted Al6061, Al6061/1.8 Ni /1.8 Cr MMC. Graphene and MgO have better tribological properties so minimum wear rate 0.12600 x10^{-3} mm^3/N.m at 10 N load observed for Al6061/0.6Ni_{np}/0.6Cr_{np} NMMC. Muley et al. (2015) were observed similar effects of varying load at particular speed and sliding distance on NHMMCs.

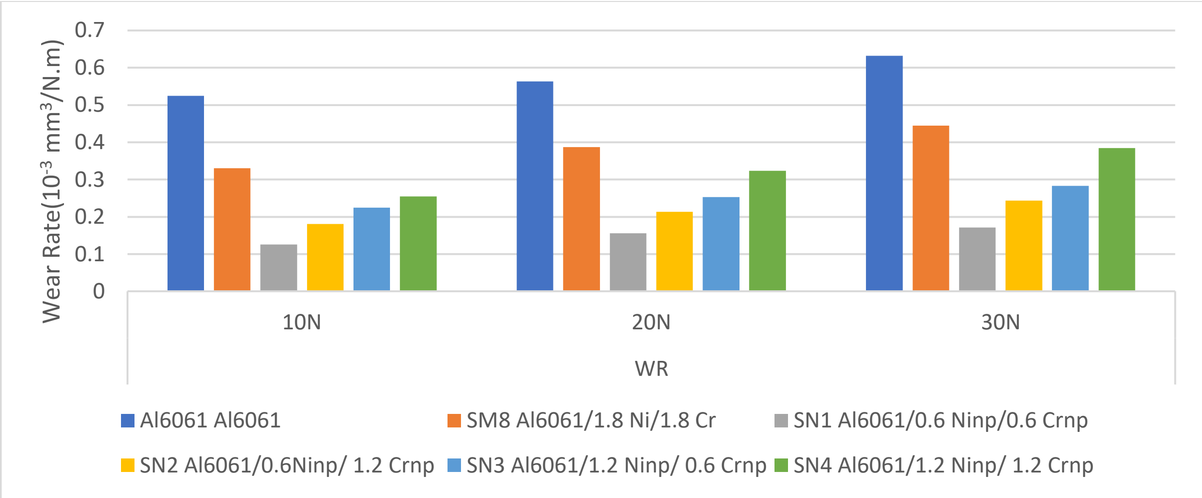

Fig.2: Variation in wear rate of Al6061, Al6061/1.8Ni/1.8Cr and Al6061/Ni_{np}/Cr_{np} HNMMCs

Addition of Ni and Cr nanoparticles positively affect the wear rate. It was observed that size of reinforced particle reduced from micron to nano the wear resistance improved due to enhancement in hardness and spacing between particles whereas cracking tendency of particle reduced by decrease in size of reinforced particles. The nano sized reinforced particles are more evenly distributed so less amount of cluster formation observed.Kumar and Xavior **(2017**) observed higher concentration of nano filler responsible for agglomeration, porosity and crack which leads to weakening of properties.Wear rate increased by increasing the weight percentage of reinforced particles in developed NMMCs due to increase in porosity and decrease in density (Muley et al., 2015).

IV. CONCLUSIONS

The reduction in wear rate of hybrid metal matrix composites and hybrid nano metal matrix composites for all applied loads observed from increasing the weight fraction up to 1.8% and 0.6% of micron and nano size reinforced particles respectively. The hybrid metal matrix composites exhibit lower wear rate at minimal concentration 0.6 wt.% of Ni and Cr nano particle and higher concentration of Ni and Cr micron size particles limited up to 1.8 wt.%. It was observed that wear rate increased by increasing the normal load. The reduction in wear rate HNMMCs and HMMCs 76% and 37.1% respectively at 10N. Al6061/0.6Ni_{np}/0.6Cr_{np} hybrid nano metal matrix composites exhibit superior tribological properties than Al6061/1.8Ni/1.8Cr hybrid metal matrix composites and monolithic Al6061 alloy. So nano hybrid metal matrix composites have better possibility to improve the tribological behavior.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Review of Gas Turbine Combustion Chamber Designs to Reduce Emissions

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***Abstract*— *Ensuring the environmental safety of aircraft engines is an important task for developers. This problem is becoming more urgent due to an increase in engine power, since an increase in power is achieved primarily by increasing the temperature in the combustion chamber, leading to an increase in NO_x emissions. In this study, the problem of emission in the aviation industry and ways to solve it were considered. Separately, the method of reducing emissions by changing the design of combustion chambers was considered in more detail.*

Keywords*— *emission, combustion chamber, swirler, atomizer, vortex, stabilizing.

I. INTRODUCTION

One of the main global problems of mankind is the restoration and improvement of its habitat. One of the main sources of environmental pollution are transport systems, in particular, aircraft gas turbine engines, so reducing emissions of harmful substances in exhaust gases is one of the main tasks at the stage of creation and environmental modernization of the gas turbine power plant combustion chambers. Pollutant emissions (nitrogen oxides (NO_x), carbon monoxide (CO), unburned hydrocarbons (UHC) and smoke) are normalized by the International Civil Aviation Organization (ICAO) requirements for the environmental performance of aircraft engines increase every year [1, 2]

Combustion chamber is the main component of the gas turbine engine, which determines its environmental characteristics. An important role in the combustion chamber is played by the combustion zone, which determines the burning rate of the fuel-air mixture, the range of stable operation, the thermal state of the flame tube elements, the emission and launchers characteristics of the chamber. The processes in this part of the combustion chamber largely depend on the design and operation mode of the base element of the frontal area - a vortex gas burner.

The main difficulties in creating a combustion chamber with low emissions of harmful substances are due to the fact that in order to reduce the output of CO and NO_x, it is necessary to carry out mutually opposite measures. The rational design of the combustion chamber should constitute a compromise between the requirements arising from the task of reducing the emissions of these two groups of pollutants (CO and NO_x). This can be achieved by improving the workflow of the primary zone [3], the intermediate and delution zones [4], the rational choice of the volume of the flame tube and the residence time in the combustion chamber [5]. The principle of operation of all low-emission combustion chambers is based on maintaining the temperature in the combustion zone(s) in a fairly narrow range in all engine operating conditions (Fig. 1).

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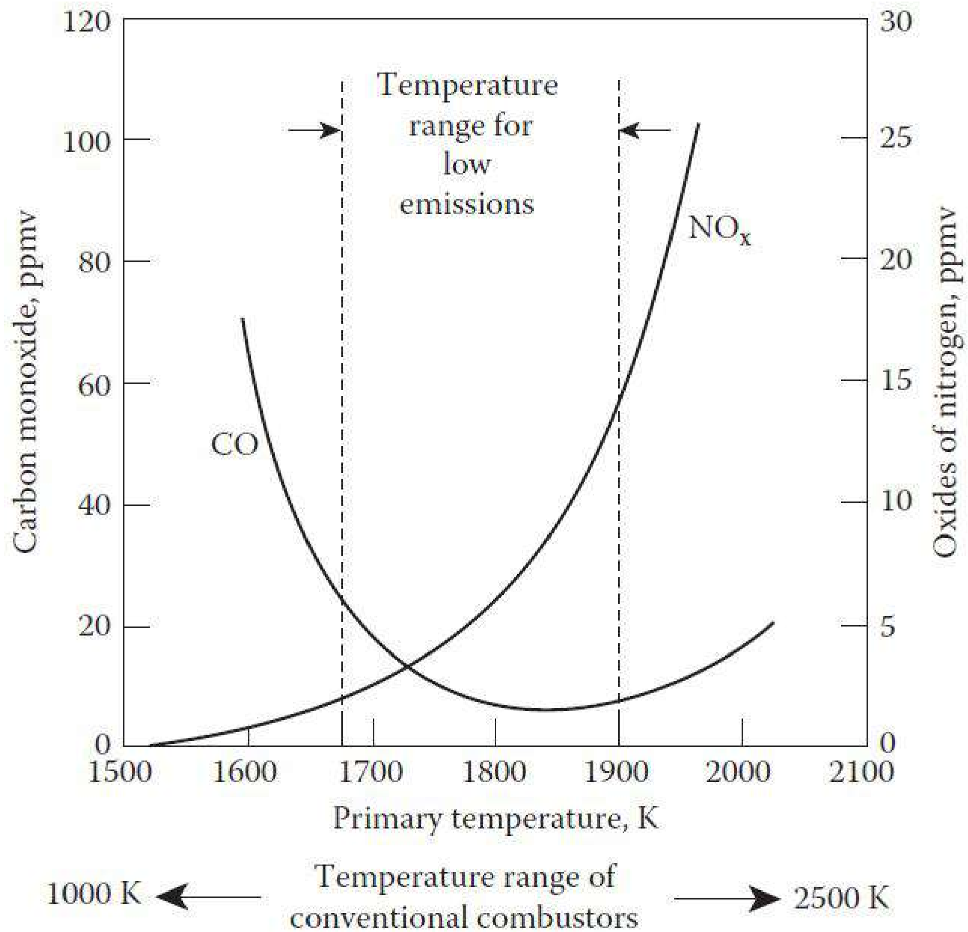

Fig. 1. Temperature range with low emissions of CO (p.p.m) and NOx (p.p.m), (p.p.m is a unit of concentration in parts per million) [4]

To reduce the emission of harmful substances by other methods, it is necessary to develop combustion chambers of complex construction with an increase in the combustion zones number, each of which is optimized for a particular mode of operation. At the same time, to ensure promising standards for the emission of harmful substances, it is necessary to create combustion chambers that would allow at the same time to reduce all types of harmful components.

II. THE MAIN CHARACTERISTICS OF THE DESIGN OF THE COMBUSTION CHAMBER

The development stages of the traditional combustion chamber scheme of the gas turbine engines can be represented from the diagrams presented in Fig. 2, illustrate the logical development of the principle of workflow organization in the combustion chamber of the most common scheme. There are respectively a large variants number of the basic scheme shown in Fig. 2, d. However, in the general case, the design of any gas turbine engine combustion chamber always has the following main elements: a housing, a diffuser, a flame tube and an atomizer.

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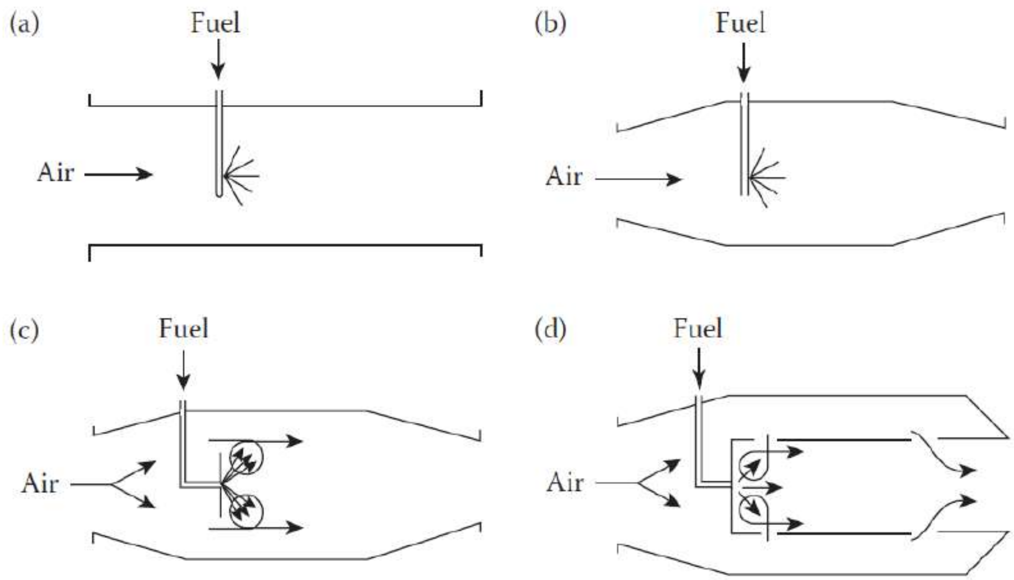

Fig.2: Stages of the development Schematic of the traditional combustion chamber of a gas turbine engine [3]

Further development and improvement of gas turbine engines required a significant change in the combustion chamber design. These changes affect the combustion chambers of engines used in aviation, in which high values of pressure and temperature are realized, with a longer resource, high reliability of work and minimum concentration of toxicity and smoke of exhaust products.

In fig. 2. a. there is no constant pressure in the combustion zone, part of the compression energy generated by the compressor is wasted, no complete combustion of the fuel, the pressure loss is proportional to the square of the speed of the air flow. In fig.2.b. braking zones have been created (air velocity is reduced along the inner surface of the combustion chamber), it is impossible to fully control the air velocity and prevent processes such as flame separation, which is necessary to maintain a steady burning process. In fig. 2. to achieve the required temperature, a ratio is required that its concentration may exceed the upper flammability limit (re-enriched fuel).

III. LOW EMISSION COMBUSTION CHAMBERS

The combustion chamber shown in fig. 3 is an example of an unusual and ingenious design. Even more significant design changes may be required in order to satisfy the very stringent restrictions now imposed on emissions of harmful substances. The main problem with the development of combustion chambers has been and remains to obtain good starting characteristics, a wide range of stable combustion, high combustion efficiency, minimum soot formation, which must be ensured by a volume-limited combustion zone, in one of which fuel is injected. Since some of the listed requirements are contradictory, the resulting characteristics are inevitably the result of a compromise. Recently, this situation has been complicated by the requirements to reduce emissions of harmful substances; However, reducing emissions of carbon monoxide and unburned hydrocarbons is achieved at the cost of increasing the opacity and the content of nitrogen oxides in exhaust gases. With this in mind, the urgent need for radical changes in the design of the combustion chamber becomes obvious.

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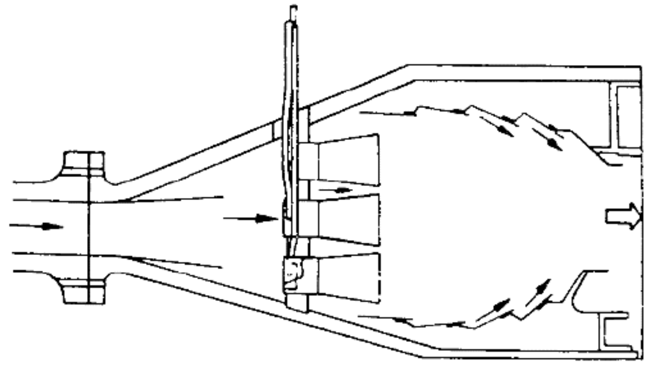

Fig.3: The design of the combustion chamber with a system of vortex burners of modules [6]

One of the possible approaches is to use in one form or another "variable geometry", i.e., to regulate the flow areas and, therefore, the amount of air entering the primary combustion zone. At high pressures to reduce to a minimum the formation of smoke and nitrogen oxides air is supplied in large quantities. At low pressures, the primary air is throttled, as a result of which the fuel/air ratio increases and the velocity of the air flow in the primary zone decreases. This increases the completeness of combustion of fuel (as well as reduces emissions of carbon monoxide and unburned hydrocarbons) in the idle mode and improves start-up characteristics [7].

Another approach involves the use of two separate combustion zones, each of which is optimized for operation, respectively, on low and high power modes. A typical dual-zone combustion chamber should have a weakly forced primary combustion zone, which, with an excess fuel ratio of $\varphi \approx 0.8$, would ensure high combustion efficiency and low emissions of carbon monoxide and unburned hydrocarbons. Such a primary zone should provide an increase in the gas temperature sufficient for low power regimes and serve as a source of hot gas for a downstream main combustion zone into which a fully mixed mixture of fuel and air could be fed. When operating at full power, the fuel should be supplied to both zones, and the value of φ in them should be maintained at a sufficiently low level, close to 0.6, which minimizes the emission of nitrogen oxides and smoke. [8]

By using twelve flameholder designs the emissions of NOx, CO and unburned hydrocarbons (UHC) are reported for a lean premixed propane-air system at 800K and 1MPa inlet conditions. The flameholders approved six design concepts with two values of blockage for each concept. The principal determinant of emissions performance is pressure drop of the flameholder. Designs producing larger pressure drops and less NO_X, CO and UHC emissions. For all designs, the lean stability limit equivalence ratio is approximately 0.35. Flashback velocities is ranged from 30 mls to 40 mls. The flameholder with a perforated plate was operated with a velocity of 23 mls through perforations at equivalence ratio 0.7 without producing flashback. [9]

In fig. 4. A schematic view shows of the vorbix represents a new approach to a gas turbine combustor design. To increase the mixing and combustion rates, the Rayleigh instability of swirling flows was exploited. Two-stage fuel system combination with a piloted combustor leads to high rate technique for fuel preuaporization within the combustor proper. The results show that this combustor has uncommon performance characteristics that include perfect stability and high combustion efficiency over wide excursions in operating fuel air ratios in addition to substantially reduced emission levels during high power operation. [10]

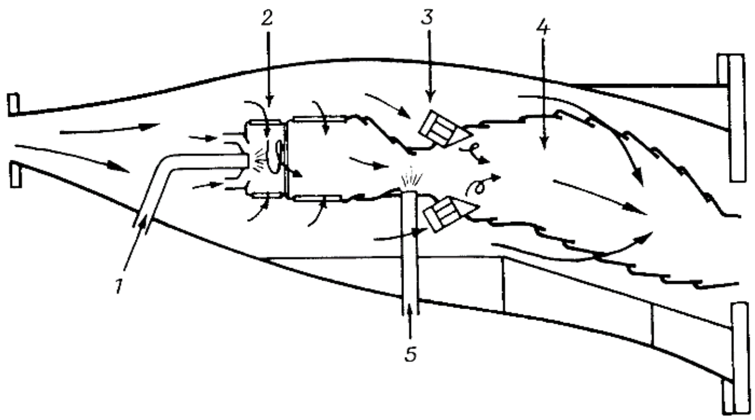

Fig. 4: The vorbix burner (acronym for Vortex Burning and Mixing) [10]

1 – pilot gas injection; 2 – pilot tubular zone of combustion; 3 – swirlers: 4 – main annular zone of combustion; 5 – main gas injection.

Vorbix, designed by Pratt-Whitney under a contract with NASA. The first stage is a traditional design of an annular combustion chamber with 30 swirlers and centrifugal atomizer that feed fuel to the combustion zone. Air, necessary for complete combustion with a small value of φ, is supplied to the main combustion zone of the chamber through 60 vortex burners located on both sides of the flame tube. The high level of turbulence generated by these vortex burners provides intensive mixing of the fuel with hot combustion products coming from the primary zone and the rapid completion of the combustion process. [11]

To determine how equivalence ratio and residence time effect on exhaust emissions with premixed, prevaporized propane fuel, a flame-tube study was performed. Nitrogen oxides emissions of 0.3 g NO2/kg fuel were measured with more than 99 percent combustion efficiency at inlet temperature of 800 K and an equivalence ratio of 0.4. By burning very lean with relatively long residence times it was obtained constant combustion efficiency, lower nitrogen oxides emissions. [12]

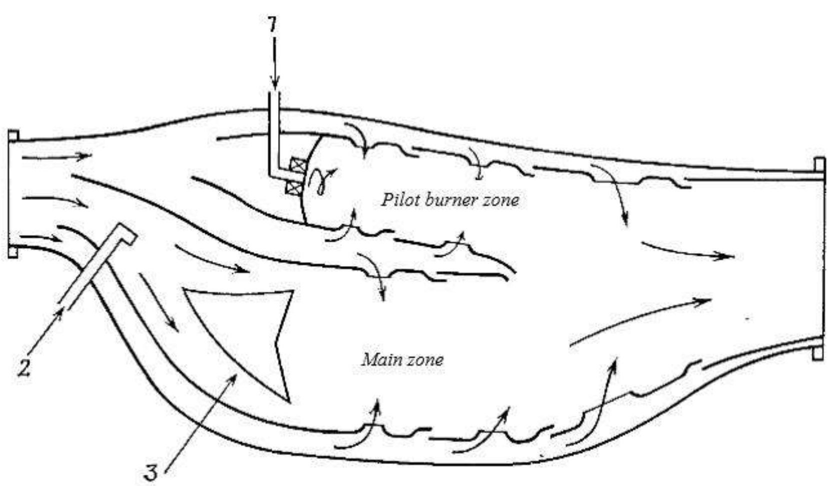

Fig. 5: Two-stage annular combustion chamber [12]

1 – pilot gas injection; 2 – main gas injection; 3 – pre-mixing channel.

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In Fig.5. a schematic of a two-zone, two-tier annular combustion chamber developed by General Electric, also for NASA. This combustion chamber has two annular combustion zones. The outer zone – the stage of low gas – is designed to operate under conditions typical of the low gas mode. This stage serves simultaneously as a pilot zone of combustion for the inner main zone, which is used in all other engine operating modes [13].

Also led the developers to the technology of the organization of the combustion process of the air-fuel mixture using a large number of atomizers to solve the environmental safety of the combustion chamber. There are publications that present the results of the development and research of the combustion chamber operation with the number of atomizers from 100 to 600 [14, 15, 16]. The main advantage of this technology is high controllability of the combustion process.

The multi-discharge low-emission combustion chamber of the engines of OAO Kuznetsov (Samara, Russian Federation) [17]. It was shown that the proposed layout of the multi-burner combustion chamber allows to ensure environmental safety and high reliability of the engine operation in various operating modes.

Currently, studies are underway to reduce emissions of nitrogen oxides in such combustion chambers. These studies have shown that the use of multifocal burning in the combustion chamber of a traditional scheme makes it possible to reduce the level of NO_x emission by 10 ... 15%. In this regard, it was proposed to divide the combustion zone into 2 areas – a pilot one and a main one. To implement such a scheme, a complex and expensive automatic fuel control system was introduced. This ensured the reduction of nitrogen oxide emissions by 30 ... 35%. However, as can be seen, this is not enough to achieve the promising regulatory requirements described above. Therefore, research and development in this direction continues. These developments use an integrated approach that includes the following areas:

- improvement of the working process in the combustion chamber;

- determination of the optimal parameters of the thermodynamic cycle of the gas turbine engine as a whole;

- increase the efficiency of individual engine components;

- Determination of the optimal degree of bypass gas turbine engine;

- improvement and cheapening of the fuel supply system;

- transition to alternative types of fuel: liquefied natural gas, hydrogen [18, 19].

In the design of the frontal area of the serial annular combustion chamber, vortex gas burners (Fig. 6) are installed evenly around the circumference between the inner and outer walls of the flame tube [20].

The fuel supplied by the gas atomizers 1 along the axis of each burners is mixed in the mixing chamber 3 with the air flow swirling in the swirler 2.

As a result, in the primary zone of the combustion chamber behind the nozzle extension 4 of each vortex burners, flows of the fuel-air mixture are formed, which have axial circulation areas. The presence of such areas ensures the circulation of hot combustion products and active centers from the combustion zone to the torch root of the fresh mixture, which creates conditions for stable ignition and flame stabilization.

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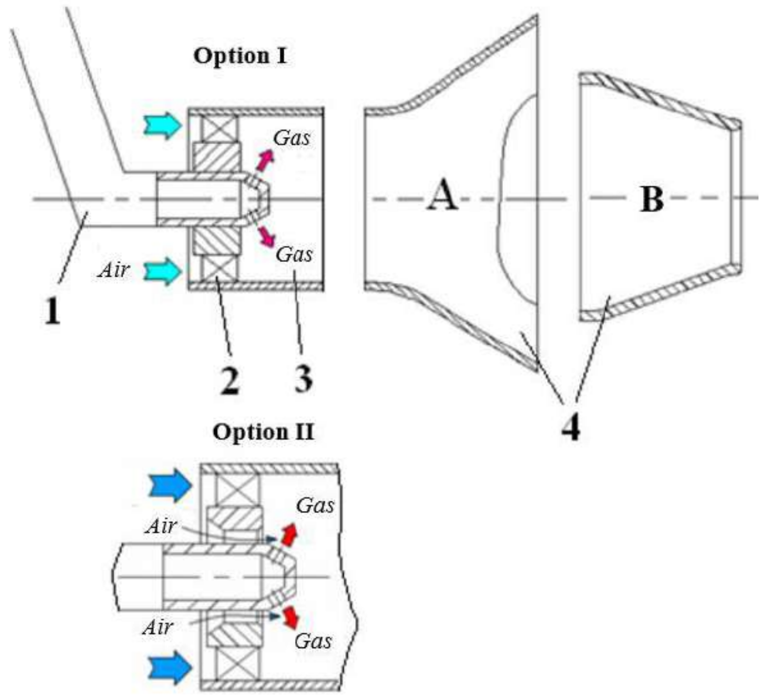

Fig.6: Schematic of burner circuit: [20]

1– simplex atomizer, 2– swirler, 3– mixing chamber, 4– nozzle extension

In fig. 7. A low-emission gas turbine combustion chamber operating predominantly on compressed gas with low emissions of nitrogen oxides and carbon oxides is presented. It contains frontal area and a cylindrical flame tube with air holes located around the circumference of the flame tube. The frontal area consists of at least two modules with cavities pre-mixing the fuel with air. The ratio of the distance between the axes of adjacent modules to the internal diameter of the flame tube is 0.4–0.5. The ratio of the length of the pre-mixing cavity of each module to the diameter of its output nozzle is 0-6 - 0.8. The flame tube includes the combustion cavity of the air-fuel mixture and the mixing cavity of hot gases with air. The flame tube contains a continuous inner wall and an outer perforated shell, an annular channel between which is made with the possibility of supplying cooling air into the mixing cavity. The ratio of the combustion cavity length to the internal diameter of the flame tube is 09–11. Holes for air supply are made in the mixing cavity. The invention reduces the emission of harmful substances due to the organization of "rich and poor" combustion of fuel through the implementation of pre-mixing of fuel with air in the frontal area and eliminating the supply of cooling air into the combustion zone [21].

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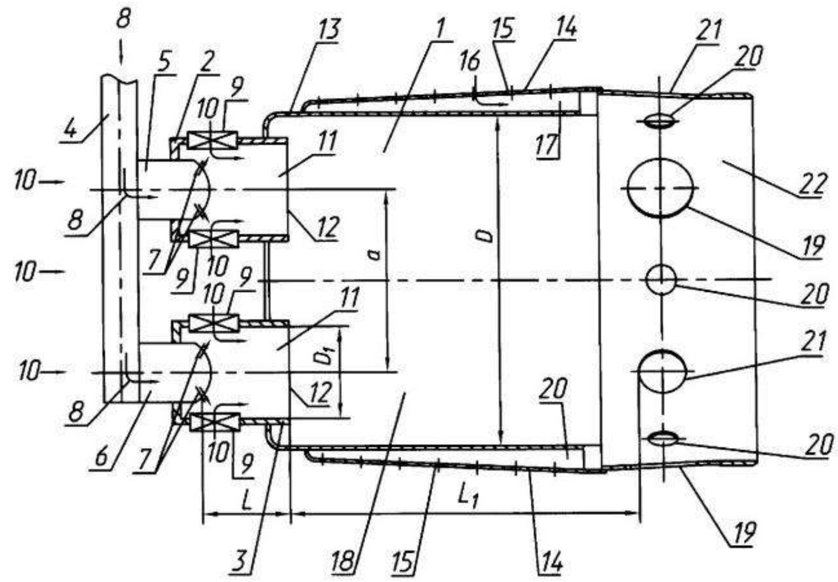

Fig.7: Low-emission combustion chamber of a gas turbine [22]

The gas turbine combustion system includes a combustion chamber having an end section and a pre-combustion section extending from the end section, a swirler, an optional pilot burner device, and a light-emitting device. Primary fuel is injected by the swirler into an inner volume of the pre-combustion section. The main flame is formed in the inner volume. The pilot burner device is installed in the end section of the combustion chamber and an pilot flame using the pilot fuel can be obtained inside the inner volume to stabilize the main flame. The light-emitting device emits electromagnetic radiation into the inner volume to stabilize the pilot and / or main flame. [23].

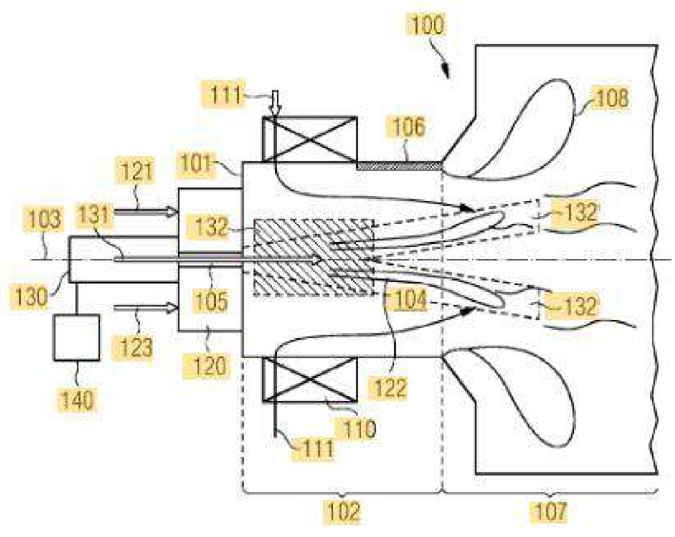

Fig.8: Schematic of Supplementary laser firing for combustion stability [24].

The fuel is introduced into the combustion system and its subsequent mixing with air by a critical aspect of the gas turbine engine performance. [25]. Premixing of fuel - air before burning in a DLE system can format "hot-spot" regions in the main combustion zone and increase the formation of thermal oxides of nitrogen (NO_x) [25].

A multipoint ignition technique with a single-shot laser is proposed and its feasibility has been experimentally tested with the mixture of hydrogen and air. On the walls of the combustion chamber there are two conical cavities combined with a laser. The first cavity has a hole near the apex. Part of the incident laser energy was passed through the opening and irradiates into the second resonator by directing unfocused laser beam into the first resonator. At the same time two-point ignition is achieved at each cavity. The method of simultaneous three-point ignition is based on the direction of a focused laser beam into a two-resonator device, which produces additional ignition in the center of the chamber by means of a laser-induced spark ignition. [26]

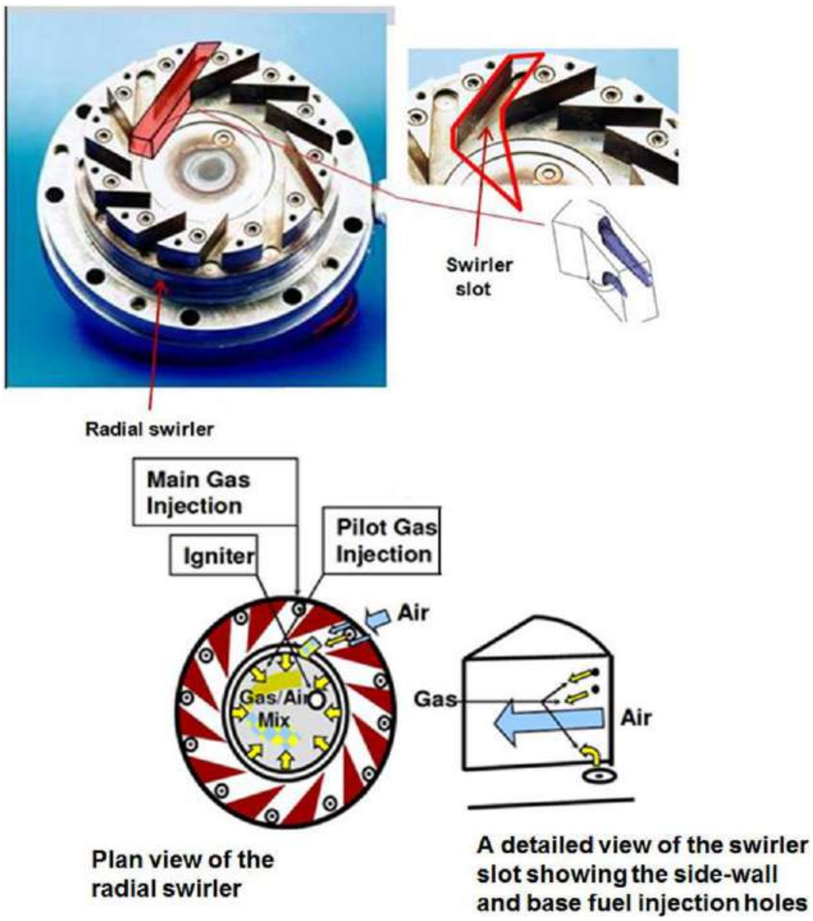

Fig.9: The radial swirler showing a rectangular slot.

Recently, a study was published in which the process of mixing fuel / air in a single slot in a radial swirler of a low-emission combustion system (DLE). fig. 9. [28]. It was shown that mixing in a swirler can be significantly improved by using the aerodynamic characteristics of the flow inside the slot.. [27, 40].

IV. CONCLUSIONS

Reducing the emission of harmful substances in the combustion chamber is a very difficult task, as mentioned above there are different ways to solve this problem, while changing the design is an effective solution. The most optimal design showed the lowest emission concentrations of a modular low-emission combustion chamber where good fuel-air mixing takes place and forming a more uniform mixture (fuel and air), provides high-combustion efficiency which forms low emissions of smoke and gaseous pollutant species.

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BPSO&1-NN algorithm-based variable selection for power system stability identification

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Abstract**—** *Due to the very high nonlinearity of the power system, traditional analytical methods take a lot of time to solve, causing delay in decision-making. Therefore, quickly detecting power system instability helps the control system to make timely decisions become the key factor to ensure stable operation of the power system. Power system stability identification encounters large data set size problem. The need is to select representative variables as input variables for the identifier. This paper proposes to apply wrapper method to select variables. In which, Binary Particle Swarm Optimization (BPSO) algorithm combines with K-NN (K=1) identifier to search for good set of variables. It is named BPSO&1-NN. Test results on IEEE 39-bus diagram show that the proposed method achieves the goal of reducing variables with high accuracy.*

Keywords**— *Identification, Power system, BPSO, Variable selection, K-NN.***

I. INTRODUCTION

Modern power systems suffer from operating pressure very close to a stable boundary limit, while power systems are always faced with abnormal agitation that can easily cause instability (Makarov, Reshetov, Stroev, & Voropai, 2005). Due to the very high nonlinearity of the power system, traditional analytical methods take a lot of time to solve, causing delay in decision-making. Therefore, quickly detecting power system instability helps the control system to make timely decisions become the key factor to ensure stable operation of the power system.

In recent years, the identification method has been applied as an alternative to solving difficult problems that traditional methods of analysis cannot solve in terms of computational (Dong, Rui, & Xu, 2012; Mitra, Benidris, Nguyen, & Deb, 2017; Oliveira, Vieira, Bezerra, Martins, & Rodrigues, 2017; Zhang, Xu, Dong, Meng, & Xu, 2011). By learning the database, the nonlinear input/output relationship between the electrical system operating parameters and stability can be quickly calculated. However, if the identifier works fast, the number of input variables must be characteristic variables. Therefore, the selected variables must be characteristic, eliminate redundant variables and cause noise.

The selection of variables of previously published works mainly applies the filter method that has to go through many stages (Dong et al., 2012; Kalyani & Swarup, 2013; Swarup, 2008). With this method, the first is based on the statistical criteria to filter out the good variables first, then ask the identifier to evaluate the accuracy to find the appropriate set of variables. This article recommends a wrapper method to select variables. In which, BPSO (Binary Particle Swarm Optimization) algorithm combined with K-NN (K=1) identifier to perform the process of searching for good set of variables. It is named BPSO&1-NN. This helps to reduce the step of finding the variable set compared to the filter method and improves the automation of the process of finding the variable set. Test results on IEEE 39-bus diagram show that the proposed method achieves the goal of variable reduction with high accuracy.

II. VARIABLE SELECTION

In the design stages of a stable diagnostic model of the power system using the identification method, the selection of characteristic variables is very important because it directly affects the diagnostic accuracy of the model. This also helps to reduce the number of measurement sensors, reducing computation time for the model. This step defines a specific set of variables that represent the database for training. These initial characteristic variables are the input variable representing the operating parameters of the power system and covering the operating status of the power system. The characteristic variable of the power system in transient mode or dynamic mode is the change in generator

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capacity, change of load capacity, change of power on transmission lines, voltage drop at nodes, ... right at the time of the incident. The output variable is labeled binary. ‘0’ is unstable and ‘1’ is stable.

Filter method:

The Filter method applies the search algorithm with the statistical standard function such as Fisher, Divergence, ... to guide the search strategy for the best set of variables to achieve the target value (J) (Dong et al., 2012; Kalyani & Swarup, 2013; Swarup, 2008). The process of searching for the set of variables by the filter method is presented as Figure 1. This method shows that the result is a set of variables meeting statistical standards but does not show the identification accuracy and the number of necessary variables. Therefore, the filter method needs to add an identification accuracy assessment to select the last set of variables.

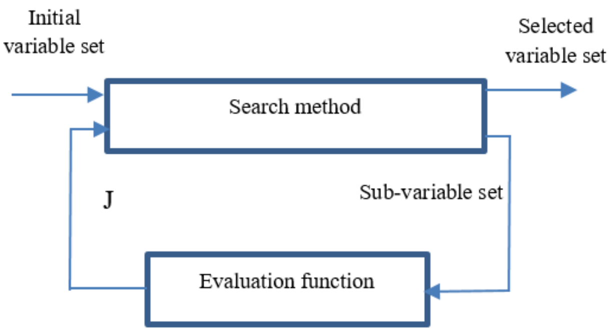

Fig. 1: Diagram of Filter method

Wrapper method:

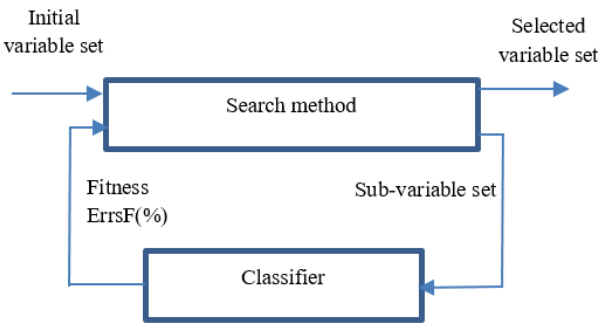

Fig. 2: Diagram of Wrapper method

The Wrapper method is presented as in Figure 2. However, this method differs from the Filter method in that the target function considering the identity accuracy. Thus, this method results in a set of variables to be selected with a specific identification accuracy.

The fitness function for selecting variables is presented in formulas (1), (2), and (3).

$$Fitness = \frac{ErrsF}{TotalF - sF} \quad (1)$$

$$AccsF(\%) = \frac{AccSample}{TotalSample}(\%) \quad (2)$$

$$ErrsF(\%) = 1 - AccsF \quad (3)$$

where:

Finess is the objective function.

AccsF is the identification accuracy of the selected set of variables.

AccSample is the number of the correct identifier. TotalSample is the total number of samples.

TotalF: the total number of variables in the data set.

sF is the number of selected variables.

ErrsF is the identification error of the selected variable.

III. BPSO ALGORITHM IN VARIABLE SELECTION

PSO (Particle Swarm Optimization) is the optimal search algorithm proposed by Kennedy and Eberhart (Kennedy & Eberhart, 1995). In the PSO, each candidate answer of the problem is encoded as an instance that moves through the search space. The whole herd seeks the optimal solution by updating the position of each individual based on their own experience and on neighboring individuals.

Generally, the vector $x_i = (x_{i1}, x_{i2}, ..., x_{iD})$ used in the PSO represents the position of the i th instance. The vector $v_i = (v_{i1}, v_{i2}, \dots, v_{iD})$ is used in the PSO to represent the velocity of the i th instance. D is the size of the search space. During the search, the best position for each previous individual was recorded as pbest. The best location of the herd is the gbest. The herd was randomly generated from the population. Finding the best solution by updating the velocity and position of each individual according to equations (4) and (5).

$$x_{id}^{t+1} = x_{id}^{t} + v_{id}^{t+1} \quad (4)$$

$$v_{id}^{t+1} = w * v_{id}^{t} + c_1 r_{1i} * (p_{id} - x_{id}^{t}) + + c_2 r_{2i} * (p_{gd} - x_{id}^{t}) \quad (5)$$

Where: t is the t th iteration of the search process. d is the size in the search space, d∈D. c_1, c_2 are acceleration constants. r_{1i}, r_{2i} are random values, valid in the range [0,1]. p_{id} and p_{gd} represent pbest and gbest particles of size

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d. w is the inertial weight. is the velocity, limited to the maximum velocity vmax, $v_{id}^{t} \in$[-vmax, vmax].

The original PSO algorithm applied to the problem of continuity. Kennedy and Eberhart developed the BPSO algorithm for the discrete problem (Kennedy & Eberhart, 1997). The velocity in BPSO represents the element that can take the value 1. Equation (4) is still used to update the velocity while x_{id}, p_{id} get the value 0 or 1. The function sigmoid $s(v_{id})$ is used to convert the value of v_{id} into a range of values (0,1). The BPSO updates each instance's position using equations (6) and (7).

$$x_{id} = \begin{cases} 1, \text{if } rand() < s(v_{id}) \\ 0, \quad otherwise \end{cases} \tag{6}$$

$$s(v_{id}) = \frac{1}{1+e^{-v_{id}}} \tag{7}$$

The function rand() is a random function whose value is distributed in (0,1).

BPSO

Begin

Data set, kfold; D: dimensionality of search space
N : the population size; T : maximum iterations;
c_1, c_2, v_{max}, w
Randomly initialise the position and velocity of each particle;

while $t \leq T$
evaluate fitness of each particle according to Equation (1);
for *i=1* **to** N
update the *pbest* of particle *i*;
update the *gbest* of particle *i*;
end
for *i=1* **to** *N*
for *d=1* **to** *D*
update the velocity of particle *i* according to Equation (4);
update the position of particle *i* according to Equations (6) and (7).
end
end
end
calculate the classification error of the selected feature subset;
return the position of *gbest* (the selected feature subset);
return the classification error of the selected feature subset;
end

IV. RESULTS

Features and samples:

The study was tested on the IEEE 39-bus scheme. It includes 39 buses, 19 loads, 10 generators. The diagram IEEE 39-bus scheme is shown as Fig. 2. It was used in many published works. The off-line simulation was implemented to collect data for training. Load levels are (20,30,…,120)% normal load. The setting fault clearing time (FCT) is 50ms (Glover, Sarma, & Overbye, 2012). In this paper, all kinds of faults such as single phase to ground, double phase to ground, three phases to ground and phase-to-phase short-circuit are considered. Faults are tested in any buses and in each of 5% distances of long transmission lines of the test systems. For each of the considered load samples, the generator samples have been got accordingly by running optimal power flow (OPF) tool of Power-World software.

The input and output feature are x{delV$_{bus}$,delP$_{Load}$,delP$_{flow}$} and y{1,0}. Total of input features is 104, x{104(39+19+46)}. The number of output feature is one, y{1,0}. From simulating results, there are 1167 samples that include 834 S samples and 783 U samples. The K-NN (K=1) is used as a classifier for evaluating accurate classification because of its simplicity. Assessment of classification error is a cross-assessment method. It is a 10-fold cross-validation.

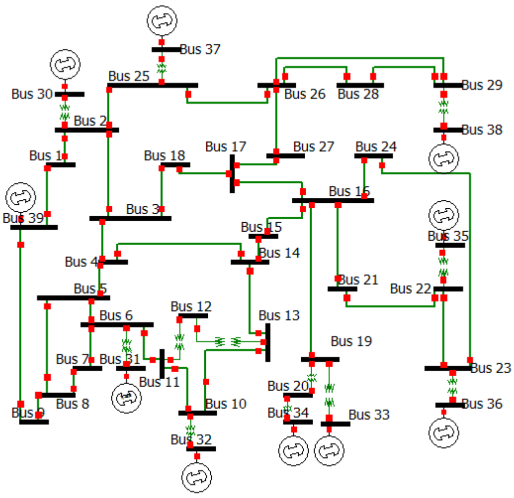

Fig. 2: The IEEE 39-bus diagram

Feature selection results:

The BPSO&1-NN algorithm works with different N values, namely 10, 20, 30, 40, and 50. The values of w are

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0.4, 0.5, 0.6, 0.7, 0.8, and 0.9. The number of iterations is 100 for the program executions, T=100. The values of c_1 and c_2 are selected unchanged during program execution, c_1=2, c_2=2. The program is also executed on Matlab 2018a software. Identification tool, 1-NN, is supported from this software.

The convergence characteristics of BPSO&1-NN variable selection algorithm are shown as Fig. 3 to Fig. 8. The results of the selected number of variables, the value of the best fitness function and the test error are presented in Table 1.

Table 1. Best results during the implementation of BPSO program with w = 0.9, N = 50, the number of variables in the set of variables is 23, the identification error is 5.07%. Thus, the algorithm BPSO&1-1NN has reduced the number of variables from 104 to 23 variables. The number of variables is reduced by 78% while test accuracy reaches 94.93%. This is the accepted result in previously published (Abdelaziz & El-Dessouki, 2013; Amjady & Majedi, 2007; Dong et al., 2012; Haidar, Mustafa, Ibrahim, & Ahmed, 2011; Kalyani & Swarup, 2013; Karami & Esmaili, 2013).

Table 1. Results of BPSO algorithm

w	N	f	Best Fitness	ErrsF(%)
0.4	10	32	7.3868e-04	5,07
	20	32	7.2150e-04	5,07
	30	33	7.3166e-04	5,01
	40	30	6.7693e-04	5,13
	50	37	7.1073e-04	5,01
0.5	10	33	7.1424e-04	5,19
	20	32	6.9573e-04	5,26
	30	33	7.0553e-04	5,07
	40	34	7.2445e-04	5,07
	50	31	7.3703e-04	5,26
0.6	10	33	7.2295e-04	4,95
	20	32	7.2150e-04	5,19
	30	36	7.3666e-04	5,01
	40	33	6.5327e-04	4,89
	50	36	6.9119e-04	5,13
0.7	10	31	7.0315e-04	5,13
	20	35	7.1702e-04	5,26
	30	30	6.9364e-04	5,26
	40	29	7.0089e-04	5,13
	50	26	6.6600e-04	4,95
0.8	10	32	6.6138e-04	5,07
	20	30	6.6021e-04	4,89
	30	33	6.5327e-04	5,26
	40	30	6.6857e-04	5,07
	50	27	6.1843e-04	5,26
0.9	10	32	6.6996e-04	5,44
	20	27	6.2646e-04	5,38
	30	27	6.1040e-04	5,13
	40	23	5.9552e-04	5,13
	50	23	6.1079e-04	5,07

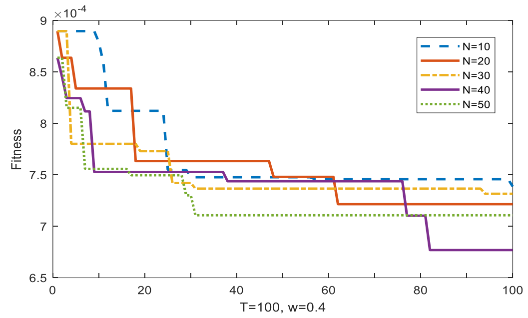

Fig. 3: Convergence characteristics of BPSO&1-NN, w=0,4

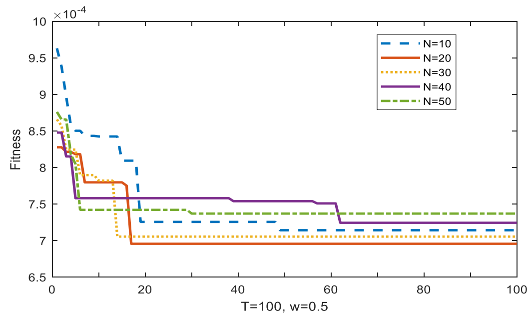

Fig. 4: Convergence characteristics of BPSO&1-NN, w=0,5

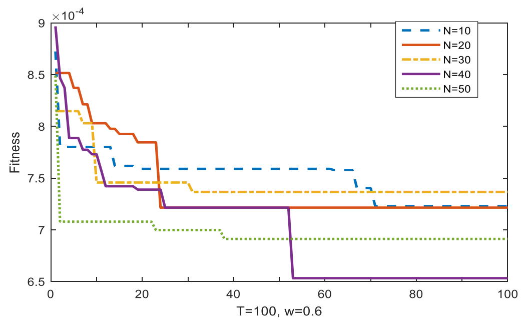

Fig. 5: Convergence characteristics of BPSO&1-NN, w=0,6

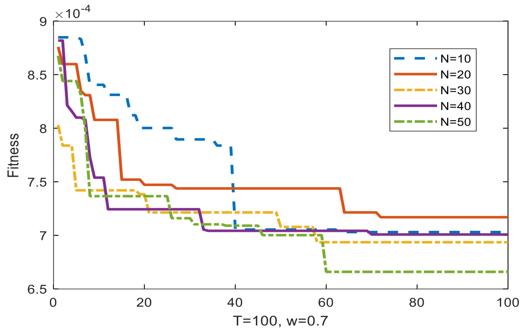

Fig. 6: Convergence characteristics of BPSO&1-NN, w=0,7

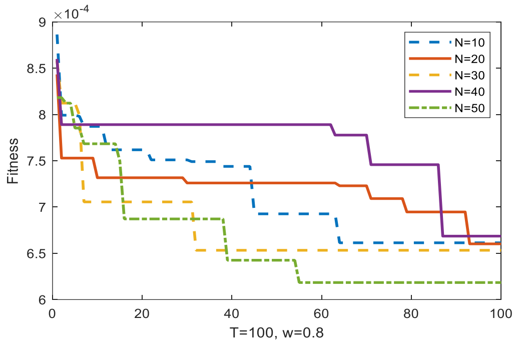

Fig. 7: Convergence characteristics of BPSO&1-NN, w=0,8

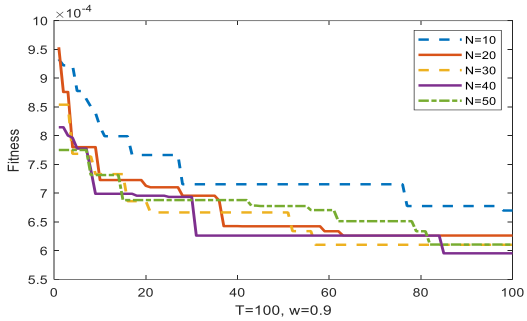

Fig. 8: Convergence characteristics of BPSO&1-NN, w=0,9

V. CONCLUSION

The paper successfully applied BPSO algorithm combined with 1-NN identifier in the variable selection approach to the problem of identifying stability of power system. Test results on IEEE-39 bus diagram showed that the number of variables decreased significantly, but the test accuracy still met expectations. This achieved result will be the driving force for the research and application of evolutionary algorithms to select variables for the problem of identifying stability of power systems.

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Review of the Chemical Separation

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Abstract**—** *The chemical separation is used to reduce the quantity of potentially toxic or hazardous materials discharged to the environment. In addition, separations that lead to recycle, recovery, or reuse of materials also prevent discharge. It is can assists in resolving some of the environmental challenges, so it became more important for researchers, in particular, environmental specialists. Hence, this article aimed to collection information about the chemical separation to help the researchers to resolve the environmental problems. Overall, it can concluded that the extraction is the first step to separate the desired substance from the raw materials and there are various methods for extraction such as sublimation, distillation method and solvent extraction. Correspondently, there are many types of separation processes, the most widely used method is the chromatography method.*

Keywords**—** ***chemical separation, gas chromatography, separation methods, solvent extraction, environment.***

I. INTRODUCTION

Separation processes, or processes that use physical, chemical, or electrical forces to isolate or concentrate selected constituents of a mixture, are essential to the chemical, petroleum refining, and materials processing industries (NRC, 1998). Chemical separations are of central importance in many areas of environmental science, whether it is the clean-up of polluted water or soil, the treatment of discharge streams from chemical processes, or modification of a specific process to decrease its environmental impact (Noble and Terry, 2004). Hence, this report will supply the reader with principle information about separation processes; functions, and methods of separation, more detail about extraction and chromatography methods, in particular, gas chromatography; classification, fundamentals and advantages and disadvantages of gas chromatography.

II. THE FUNCTIONS OF SEPARATION PROCESSES

Separation processes are used for three primary functions: purification, concentration, and fractionation. Purification is the removal of undesired components in a feed mixture from the desired species. For example, acid gases, such as sulfur dioxide and nitrogen oxides, must be removed from power plant combustion gas effluents before being discharged into the atmosphere. Concentration is performed to obtain a higher proportion of desired components that are initially dilute in a feed stream. An example is the concentration of metals present in an electroplating process by removal of water. This separation allows one to recycle the metals back to the electroplating process rather than discharge them to the environment. Lastly, in fractionation, a feed stream of two or more components is segregated into product streams of different components, typically relatively pure streams of each component. The separation of radioactive waste with short half-lives from that having much longer half-lives facilitates proper handling and storage (Noble and Terry, 2004).

III. SEPARATION METHODS

There are many different separation techniques which may be broadly classified into processes of mechanical separation and separation by diffusion or others, include various types of separation processes (Taulbee and Maroto-Valer, 2000; Moskvin, 2016 and Ibrahim, 2018), for example: extraction, chromatography, crystallization, filtration, Decantation and Sublimation. We will discuss extraction and chromatography, because they are widely used.

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3.1. Extraction:

Extraction is the first step to separate the desired substance from the raw materials. There are many methods for extraction such as solvent extraction, distillation method, pressing and sublimation. However, the most widely used method is solvent extraction (Zhang *et al*., 2018). These methods were summarized in (Table 1.). Soxhlet extraction and distillation method will be discussed as sample for extraction methods.

Table 1: A brief summary of various extraction methods for natural products (Zhang, et al., 2018).

Method	**Solvent**	**Temperature**	**Pressure**	**Time**	**Volume of organic solvent consumed**	**Polarity of natural products extracted**
Maceration	Water, aqueous and non-aqueous solvents	Room temperature	Atmospheric	Long	Large	Dependent on extracting solvent
Percolation	Water, aqueous and non-aqueous solvents	Room temperature, occasionally under heat	Atmospheric	Long	Large	Dependent on extracting solvent
Decoction	Water	Under heat	Atmospheric	Moderate	None	Polar compounds
Reflux extraction	Aqueous and non-aqueous solvents	Under heat	Atmospheric	Moderate	Moderate	Dependent on extracting solvent
Soxhlet	extraction Organic solvents	Under heat	Atmospheric	Long	Moderate	Dependent on extracting solvent
Pressurized liquid extraction	Water, aqueous and non-aqueous solvents	Under heat	High	Short	Small	Dependent on extracting solvent
Supercritical fluid extraction	Supercritical fluid (usually S-CO2), sometimes with modifier	Near room temperature	High	Short	None or small	Dependent on extracting solvent
Ultrasound assisted extraction	Water, aqueous and non-aqueous solvents	Room temperature, or under heat	Atmospheric	Short	Moderate	Dependent on extracting solvent
Microwave assisted extraction	Water, aqueous and non-aqueous solvents	Room temperature	Atmospheric	Short	None or moderate	Dependent on extracting Solvent
Pulsed electric field	Water, aqueous and non-aqueous	Room temperature, or	Atmospheric	Short	Moderate	Dependent on extracting Solvent

extraction	solvents	under heat				
Enzyme assisted extraction	Water, aqueous and non-aqueous solvents	Room temperature, or heated after enzyme treatment	Atmospheric	Moderate	Moderate	Dependent on extracting Solvent
Hydro distillation and steam distillation	Water	Under heat	Atmospheric	Long	None	Essential oil (usually non-polar)

3.1.1. Soxhlet extraction:

The extraction of organic compounds, including pesticides, polycyclic aromatic hydrocarbons and phenols from matrices (soils, sewage sludges, vegetables, plants), has historically been carried out by using Soxhlet extraction. The mode of operation of the extraction system is that organic solvent under the influence of heat (and pressure) will desorb, solvate and diffuse the organic compounds from the sample matrix allowing them to transfer into the bulk (organic) solvent (Dean, 2009).

The Soxhlet apparatus consists of a solvent reservoir, extractor body, an electric heat source and a water-cooled reflux condenser.

In the practice, the solid sample is loaded on the Soxhlet thimble and placed in the inner tube of the extractor body. The extractor body is then fitted to a round bottomed flask containing the chosen organic solvent and to a reflux condenser, then turn on heat source. The samples take few hours to extract, the process is repeated many times with new samples to get the required quantity (Dean, 2009; Elamin and Satti, 2012). Soxhlet extraction uses a range of organic solvents to remove organic compounds from samples, but solvent properties are very important to the extraction process (Prado *et al*., 2015 and Dean, 2009).

3.1.2. Hydrodistillation:

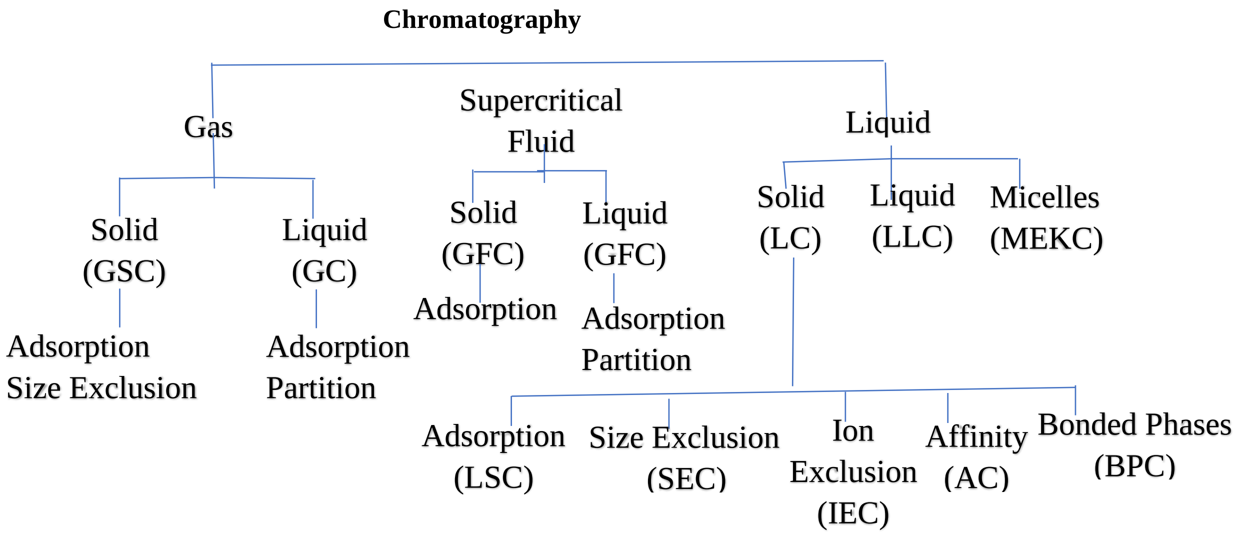
Hydrodistillation is a commonly used method of extracting essential oils from plant samples. This method is divided into the subcategories of steam distillation, water distillation, and a combination of water and steam distillation (Dilworth *et al*., 2017). The distillation apparatus consists of a vessel for plant material and water together (water distillation) or two vessels, one for plant material and other for water (water and steam distillation) or a vessel for plant material with steam inlet (steam distillation), a condenser to cool and condense the vapour produced and a method of collection, or 'receiver'. The sample for extraction is placed in the distillation vessel. This is then heated to boiling point and the steam (water vapour) carries out the volatile oils (Clarke, 2008).

3.2. Chromatography:

Chromatography is one of the most important analytical techniques. It allows the separation and subsequently the qualitative and quantitative analysis of complex mixtures, as long as the samples are volatile or soluble in a suitable solvent (Meyer, 2013). Chromatography has been defined by Irving *et al*. (1978) as "a method used primarily for separation of the components of a sample in which the components are distributed between two phases, one of which is stationary while the other moves. The stationary phase may be a solid, or a liquid supported on a solid, or a gel. The stationary phase may be packed in a column, spread as a layer, or distributed as a film, etc.; in these definitions Chromatographic bed is used as a general term to denote any of the different forms in which the stationary phase may be used. The mobile phase may be gaseous or liquid".

3.2.1. Classification of chromatography:

There are many forms of chromatography based on the different mobile phases, stationary phases, and supports that can be used in this method, which has led to a wide range of applications for this technique, they are summarized in the figure, then are explained as follow (Irving *et al*. 1978 and Moskvin, 2016).



The figure. Family tree of Chromatographic methods.

Source: Poole, C. F. (2000). Chromatography. In: Wilson, I. D.; K. Cooke, M. and Poole, C. F. (Ed.), Encyclopedia of Separation Science. Academic Press.

3.2.1.1. Classification according to phases used:

In this classification the first word specifies the mobile phase and the second the stationary phase. A liquid stationary phase is supported on a solid.

3.2.1.1.1. Gas Chromatography (GC), we will reach it in detail later.

3.2.1.1.1.1. Gas-liquid chromatography (GLC)

3.2.1.1.1.2 *Gas-solid chromatography* (GSC)

3.2.1.1.2. Liquid Chromatography (LC):

3.2.1.1.2.1. Liquid-liquid chromatography (LLC)

3.2.1.1.2.2. Liquid-solid chromatography (LSC)

3.2.1.1.2.3. Liquid-gel chromatography (LGC)

Liquid-gel chromatography includes gel-permeation and ion-exchange chromatography.

3.2.1.2. Classification According to Mechanisms:

Main types of liquid chromatography based on their separation mechanisms include:

3.2.1.2.1. Adsorption chromatography

3.2.1.2.2. Partition chromatography

3.2.1.2.3. Ion-exchange chromatography (IEC)

3.2.1.2.4. Size-exclusion chromatography (SEC)

3.2.1.2.5. Affinity chromatography.

In addition to LC and GC, and the use of columns or open tubular supports, there are a variety of other chromatographic methods that can be used for chemical separation and analysis. Some important examples are supercritical fluid chromatography (SFC) and planar chromatography.

3.2.1.3. Classification according to techniques used:

3.2.1.3.1 Column chromatography (cc)

3.2.1.3.2 Open-tube chromatography

3.2.1.3.3 Paper chromatography (pc)

3.2.1.3.4. Thin-layer chromatography

Chromatography carried out in a layer of adsorbent spread on a support, e.g. a glass plate.

3.5 filament chromatography

3.2.1.3.2.2. Gas chromatography:

Gas chromatography comprises all chromatographic methods in which the moving phase is a gas.

The word chromatography itself implies that a stationary phase is present in addition to the moving phase, Includes:

A. **Gas-liquid chromatography** comprises all gas-chromatographic methods in which the stationary phase is a liquid distributed on a solid support. Separation is achieved by partition of the components of a sample between the phases.
B. **Gas-solid chromatography** comprises all gas chromatographic methods in which the stationary phase is an active solid (e.g. charcoal, molecular sieves). Separation is achieved by adsorption of the components of a sample.

3.2.1.3.2.2.1. Fundamentals of gas chromatograph:

A typical gas chromatograph consists of an injection port, a column, carrier gas flow control equipment, ovens and heaters for maintaining temperatures of the injection port and the column, an integrator chart recorder and a detector (Halord and Miller, 1998; AGC, 2002; Stauffer, 2008 and Qian *et al*., 2017).

3.2.1.3.2.2.1.1. Injection port:

A sample port is necessary for introducing the sample at the head of the column. Modern injection techniques often employ the use of heated sample ports through which the sample can be injected and vaporized in a near simultaneous fashion. A calibrated micro-syringe is used to deliver a sample volume in the range of a few microliters through a rubber septum and into the vaporization chamber.

3.2.1.3.2.2.1.2. Carrier Gas:

The carrier gas plays an important role, and varies in the GC used. Carrier gas must be dry, free of oxygen and chemically inert mobile-phase employed in gas chromatography, Helium is most commonly used.

3.2.1.3.2.2.1.2. Detection Systems:

The detector is the device located at the end of the column which provides a quantitative measurement of the components of the mixture as they elute in combination with the carrier gas. These detection properties fall into two categories: bulk properties and specific properties. Bulk properties, which are also known as general properties, are properties that both the carrier gas and analytic possess but to different degrees. Specific properties, such as detectors that measure nitrogen-phosphorous content, have limited applications but compensate for this by their increased sensitivity. There are many detectors, but Mass Spectrometry Detectors detector are most powerful of all gas chromatography detectors (Table 2.).

Table 2: Typical gas chromatography detectors and their detection limits (Skoog, et al., 2007).

Type of Detector	**Applicable Samples**	**Detection Limit**
Mass Spectrometer (MS)	Tunable for any sample	0.25 to 100 pg
Flame Ionization (FID)	Hydrocarbons	1 pg/s
Thermal Conductivity (TCD)	Universal Detector	500 pg/ml
Electron-Capture (ECD)	Halogenated hydrocarbons	5 fg/s
Atomic Emission (AED)	Element-selective	1 pg
Chemiluminescence (CS)	Oxidizing reagent	Dark current of PMT
Photoionization (PID)	Vapor and gaseous Compounds	0.002 to 0.02 µg/L

3.2.1.3.2.2.1.3. Column Oven

The oven controls the temperature of the column. In GC, one takes advantage of both an interaction of the analyte with the stationary phase and the boiling point for separation of compounds. Oven temperature program rates can range from as little as 0.1 °C/min to the maximum temperature heating rate that the GC can provide. A rate of 2–10 °C/ min is most common.

3.2.1.3.2.2.1.4. Open Tubular Columns and Packed Columns

Open tubular columns, which are also known as capillary columns, come in two basic forms. The first is a wall-coated open tubular (WCOT) column and the second type is a support-coated open tubular (SCOT) column (Table 3.).

Table 3: Properties of gas chromatography columns (Thet and Woo, 2019).

Type of Column				
Property	**Fused-silica wall-coated (FSWC)**	**wall-coated open tubular (WCOT)**	**support-coated open tubular (SCOT)**	**Packed**
Length	10 to 1000 m	10 to 1000 m	10 to 100 m	1 to 6 m
Inner Diameter	0.1 to 03 mm	0.25 to 0.75 mm	0.5 mm	2 to 4 mm

Efficiency (plates/m)	2000 to 4000	1000 to 4000	600 to 1200	500 to 1000
Sample Size	10 to 75 ng	10 to 1000 ng	10 to 1000 ng	10 to 10^6 ng
Pressure	Low	Low	Low	High
Speed	Fast	Fast	Fast	Slow
Flexibility	Yes	No	No	No
Inertness	Best	Good	fair	Poor

IV. CONCLUSION

Solvent extraction is widely used among the extraction methods. Chromatography is one of the most important analytical techniques. It is classified based on three types classification according to phases used includes gas chromatography (GC) and liquid chromatography (LC); according to mechanisms includes adsorption chromatography, partition chromatography, ion-exchange chromatography (IEC), size-exclusion chromatography (SEC), and affinity chromatography and according to techniques used includes column chromatography (CC), open-tube chromatography, paper chromatography (PC) and thin-layer chromatography.

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