IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

A Study on Wear Intensity in Gun Barrel

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ABSTRACT

A gun is fired, the metal temperature reaches a maximum temperature of 1100°C and reduces suddenly in a few seconds and again it is fired, and the temperature has been accumulated in it. These sudden heating and cooling temperature areas of zones are called the thermal-affected zone (TAZ)or heat-affected zones (HAZ). Atmospheric contaminants in the air can change the property of the gun and lead to a chemically affected zone and cause wear on the gun barrels. The silicon carbide material has been used to overcome all the defects on the gun and to avoid a catastrophic failure on the barrel. Various tests have been taken on the specimen to provide a suggestion on the material to be used to enhance the properties of from a previous material. The specimen has been cut into multiple pieces with the help of a wire cutting machine to provide accuracy in the specimen. The wear test was taken with a rig test wear intensity machine, the graph which shows a value of amount of wear has been initiated in the specimen and there is various other graph which shows an idea about the frictional factor, coefficient of friction and temperature with respect to the time. The load on the wear machine is 1kg and 2kg with a speed of 240rpm and duration of 6minutes. Creep is a time dependent process with an increase in temperature and constant load process, in this the graph shows a linear straight line for a 1 hour. The specimen has been given a temperature of 100 °C. and 200°C, with a duration of 1hour. With these graphs we can be able to provide a suggestion that when compared with a previous material with the silicon material, it is a good thermal resistant material, high in wear resisting rate and high in creep resisting rates. Most of the research focuses on the cook-temperature and few are on analysis on the barrels and no researchers in my analysis have given a viewpoint on recommended a material change to increase thermal efficiency to prevent material wear and fatigue.

Gun barrel, Silicon carbide, cook-off temperature, wear, and creep.

INTRODUCTION

The barrels are used in various pistols, snipers, and shotguns. The barrels are hollow-cylindrical shapes, which help to guide the bullet in a pre-defined path and the barrel has a swirl carved shape inside the barrel. This helps the bullet to swirl while exiting from the gun. The application of the gun is when firing once the head part moves back and returns to the ideal position. Bullets are casing metal that consists of high explosives inside, depending on the gun type the bullet intensity has been varied. A bullet consists of gun powder with a mixture of oxidizers. When a trigger is actuated, the pin hits the bullet's rear end, and the reaction takes place with the higher temperature it comes out from the barrel. There is no escape way to remove the hat from the barrel where the heat is trapped inside it and year after year due to this heating the material can be subjected to wear.

Thermal stresses are induced at the end of the barrel due to high heat developed in the barrel which causes cylindrical thermal failures **(5).** Carbon-based composites are being used in the defense sectors to increase thermal-resistance and light weight. With lightweight guns they could be able to travel for a longer distance by carrying the gun to various places. Due to carbon based they could be able to be a high strength and durability they provide the various results for the carbon-based components and could meet out the results **(6)**. The performance of the gun depends on thermal behavior, due to high heat induced in the bore, a cook-off temperature. Thermal failures can occur on the material due to high heat induced which is developed inside the barrels of a closed chamber, with which it provides a sudden failure on the materials or a fatigue failure. Cook-off temperature means that the temperature at which without pressing a trigger it automatically fires, which can cause collateral damage to the people. So, to reduce the cook-off temperature which has provided the carbon-based components which can with stand of a longer hours of firing, but it has failed to meet out the limits **(7)**. The process of changing the pistol took a long time. From swords to suitable high-range cannons, which took a lot of time to supply, numerous compositions of diverse materials have been developed, ranging from pure metal to ceramic-based composites.

Stainless steel and high carbon steel were once used to make gun barrels, but currently it is built of composite materials.

Concerning the various journals, the ideas below have not been mentioned. Our idea enhances thermal resistance and reduces the wear intensity, and weight. The recent composite material is **AISI 4140 ALLOY STEEL**, which provides high strength, durability, thermal resistance, shearing modulus, and melting point. But the composite alloys have started declining due to the induced heat inside the gun barrel. To overcome these demerits, we have proposed the **SILICON CARBIDE (SiC**). The property of the material is high in melting point, tensile strength, bulk modulus, and shear modulus. The thermal-affected zone (or) heat-affected zones **(13)** are created due to sudden rises in temperature and sudden cooling which causes the heat to be continuously get trapped in the area where lots of heat is accumulated, which can lead to an increase in the wear in the metal. Later, the metal could eventually fail. Another leading factor due to the heat-affected zones are chemically affected **(13)** area, it is the area of the zones where due to a sudden rise in the temperature atmospheric contaminants can penetrate the heat-affected zones, and can change the property of the metal, reducing the melting point temperature of the metal. Due to this behavior, the gun eventually cost a lot of maintenance and repair time.

LITERATURE REVIEW

The pistol is fired for the longer duration, there can be internal cracks and internal wear in the materials which causes the bore to expand and the lack of accuracy. The study used: – 9 mm Makarov pistols (PM) – 6 pcs, go gage and no-go gage caliber of 9 mm pistol PM Here they use the go no-go gauges to the gun barrel bore for the faster measurements in the previous dates. In the 9mm pistol the ammunition which has 7 or 9 bullets on the case to fire one round if it requires it takes again another due to the change in the ammunition on the case which creates wear on the inner sides of the gun case **(2).**

The ceramics are lighter weight and more erosion-resistant materials. The ceramic matrix composite barrel liners with lightweight metal matrix composite are being jacketed on the outer liner of the gun barrel. The main objective of the paper is to investigate ceramic matrix composite (CMC) lined metal matrix composite (MMC) hybrid barrels. Work on the CMC composites and MMC hybrids are being inner lined to the barrels. The CMC is a present development consisting of a composite Al2O3 fiber/SiC matrix formed by winding. Various experimental tests on the FEA are being made to compare with the other composites material to determine the strength and high thermal resistance to the newly developed composite materials **(3).**

Research on failure mechanism of prolonging of gun barrel lifetime. Damage characteristics of a machine gun barrel were characterized to check the reason for the mechanism's failure. Cr layer on the bore surface which softens the bore matrix. The long barrel has been split into a 6 division which is been named MG1-6. various machines are being used to test the character of the element.

The gun barrel frequently undergoes dynamic loading of gas pressure, mechanical stress and thermal stress when firing a round. Erosion, propellant combustion gas of elevated temperature. Fatigue, dynamic loading of high gas pressure, mechanical stress by barrel-projectile interaction and thermal stress produced by a large temperature gradient.

The following result has been concluded with which and been analyzed with the above materials s. Permanent bore expansion, brittle fracture and fatigue fracture were reproduced by laboratory simulations. The continued firing of guns must be stopped to prevent fatigue fracture **(5).**

If the Cook-off temperature is reached, the propellant will burn automatically and cause damage to persons 7.62 mm cartridge: - It was observed that the cook-off temperature of the double-base propellant was between 151.4 °C to 153.4 °C.

Additives can be used as propellant to minimize the heat transfer to the gun barrel bore surface. Outer Gun tubes were used to be coated with Tantalum (Ta), Tungsten (W), Cobalt (Co), Chromium (Cr), Molybdenum (Mo) and Satellite The 155 mm artillery gun can fire 56 rounds at a rate of 3 rounds per minute as modeling in ANSYS 17.2. The gun will cook off after 1132 seconds (about 19 minutes) **(7).**

Composite models were analyzed for 6 mm, 12 mm and 13 mm wound carbon fibers. Barrel of the older version of the 7.62×54R mm machine gun and already included the barrel for the 7.62×51 mm cartridge. Material with higher strength parameters compared to the older ones is used; however, the masses of both barrels are comparable **(8).**

The material is 30CrNi2MoV gun steel. During processing and production of the gun barrel, micro-defects and micro/nano cracks will also occur on the surface and inside, which will grow due to a high-temperature and high-pressure propellant gas cycle that results from normal operation.

The performance of artillery will decline and lead to catastrophic failure. Improve the efficiency and accuracy of the analysis. The stress analysis of pressure vessel, the gun barrel stress model is established, and the load intensity under different charge conditions is calculated according to the internal ballistic equation. Longitudinal initial crack is the main risk of gun barrel fatigue during firing **(9).**

Study on failure analysis of machine gun barrel. Due to the high temperature and pressure of the gunpowder gas, the chromium layer on the back of the barrel eroded.

Elliptical bullet hole ratio-based criterion (EBC). ratio of the major axis to the minor axis of the bullet hole on the target is greater than 1.25, it is considered as an elliptical bullet hole 20 rounds as a group, when the elliptical bullet. Three groups (20 rounds per group) are fired continuously on the ground target, and the average radius of the 50% projectile (R50) is taken. The dispersion intensity at the end of the barrel life is taken as the continuous three-target average, R50 300 mm. There is no obvious change in the falling point radius and dispersion intensity during the whole barrel life process. Therefore, the projectile dispersion does not accurately reflect the performance degradation of the test barrel **(10).**

Effects of various grain sizes (300–425, 425–500, 500–600, 600–710, 710–850 lm) and initial temperatures (60, 20, 0, 20, and 60 C) Experimental measurements of temperature readings where thermocouples are installed on the outer wall of the barrel were compared with the results of the thermo-mechanical model for the nodes corresponding to the experimental data collection points. The maximum pressure in the barrel is measured by using piezoelectric transducers, and strain gages were located at 24 points along the barrel which made it possible to determine the pressure distribution along the barrel **(11).**

Gun barrels are made from advanced materials to provide an increase in barrel life and a reduction in weight (for advanced ceramic materials) for small caliber systems. To be used as gun barrels that have rifle pattern in the inner diameter. The failure occurs as the chromium coating is cracks which allow the hot propellant gases to reach the Steel Substrate and resulting in the coating layer. The process of powder injection molding (PIM) is a modern technology used to produce parts on advanced materials. The changing in the material which produces the change in the results, a various advanced materials to generate a high strength to gun barrel and to resist to prevent from the elevated temperature and oxidation **(12).**

A gun fires the metal temperatures at the bore may reach 1100◦C in a few milliseconds, which does create a hard and brittle surface as the heat-affected zone. The diffusion of chemicals such as CO and N2 into the hot surface forms a chemically affected zone. Heat transfer may be 500 MW/m2, and the propellant gas pressure may reach 600 MPa.

Ni–Cr–Mo steel (British Standard 826M31, formerly EN25), which is like gun steel. Five different propellants were used in the creation of the gun barrels. The propellant gas diffuses in the gun surface forming a weak, cracked, chemically affected zone. The weakened material will be removed by the flow of high velocity gases on the inner surface. The muzzle flash suppressant reduced the erosive of the propellant without changing the heat transfer to the surface. Wear reducing additives used in guns which reduce the heat transfer because wear is overly sensitive to the maximum temperature **(13).**

When firing, substantial amounts of heat flow in the gun bore surfaces and result in wear and erosion of the gun bore. Moreover, the chamber surface temperature will reach the cook-off temperature of propellant during long firing, which can create accidents. During long-burst firing, heat accumulates and causes the barrel to reach an elevated temperature, limited by the cook-off temperature. Once the cookoff temperature is reached, propellant from a new round will self-ignite **(14).**

Vibration characteristics of gun under a action of moving profile. The amplitude of gun barrel decreases as the acceleration of the projectile in the gun bore increases. When the projectile has mass eccentricity, the vibration characteristics of the muzzle under the action of the centrifugal force, the amplitude of gun barrel significantly increases, and the vibration frequency of gun barrel is higher than the condition without mass eccentricity. This paper helps us understand and compare the vibration of the barrel and the sliding materials with the various theoretical data compared **(15).**

The paper will describe our preliminary attempts at processing a rifled gun barrel tube made of alumina. Ceramic-lined gun tubes have excellent potential if they can be processed into complex shapes. This grinding process is not only expensive but also flaws in the ceramic (microcracks) that can be detrimental to the performance of the material as gun barrels. As the process of PIM is generic, and if PIM can successfully in rifled shape in alumina and maintain the shape after consolidation, the process can later be substituted for other expensive ceramics such as silicon nitride. The processing of longer rifled tubes as well as rifled tubes with larger diameters will be investigated in the future **(16).**

The barrel vibrations can affect the accuracy of firing guns due to the up and down on the barrel due to higher usage. The overall process for investigating the shock behavior of a demonstrated CTA gun has been presented by the shock response analysis with aids of numerical modal analysis and signal processing technique. The numerical modal analysis was compared with signal processing techniques such as FFT and STFT in finding mode frequencies for shock behavior. Various shock response test and analysis on the 3 different case modals with respect to muzzle and barrel tip with varying it we do get the various results and FEA are be done on each case, we compare their case and analyze to it **(17).**

Light cannon barrel from the collection of the Castle Museum in Malbork (Marien burg). The spot of sampling, a macroscopic image of the sample surface with spots of microscopic observations (1–2) and a schematic distribution of structural components and hardness tests (HV10) The matrix of the multiphase slag inclusions is composed of Fe, O, Si, Al, Ca, K, Mg, P, S and Tic

The various materials which are included in the and mixed with the various proportion to get the varied results and to get a derided strength and resistance to high temperature. Slag inclusion and oxidation temperature which is been present in the gun barrel and the various materials has been combined and formed a new structure **(18).**

The maximum difference among the numerical results, including the muzzle velocity, the width and depth of the bullet, and real experimental data, is only 2.56%, indicating that in the simulation. This simulation allows the collection of data for the whole shot travel, including movement, velocity, acceleration, rotation, stress, and strain.
Furthermore, bullet stress research is useful for projectile design and material selection. To simplify the numerical model and reduce computation time, this study neglects the heat effects **(19).**

The barrel has been constructed with the help of the 2 materials where the inner layer is low alloy steel, and the outer layer is wound with the SiC/Ti–24Al–11Nb composite. This study investigates a traditional low-alloy gun steel, a high temperature Sic/titanium-alloy metal matrix composite, as well as various hybrid combinations of these materials, for their ability to develop the necessary residual stress and inelastic strain states necessary for durability. In designs where the outer 25% of the cylinder radius is comprised of SiC/Ti–24Al–11Nb, a weight savings of 14% over a homogeneous cylinder is gained **(20).**

The pressure band model examines and analyzes the varying geometry using an available FE tool. A series of simulations are performed to properly evaluate the effects of firing width.

The material properties are affected because of the inner cracks and high temperature effect, and a more developed material model is required. A uniform variation is evaluated in this case, which can be altered with different variations in the front and rear parts for future consideration. The ramming effect is also disregarded in this case, but it can be incorporated by including newer techniques **(21).**

ANSYS 14.5 version was used to generate mathematical models and simulations. Due to factors affecting manufacturability, the extension of fins was halted at mid length, i.e., where the gas block attaches (in case of a gas operated weapon). Results may indeed vary with different lengths of fin extension **(22).**

In this research, cartridge house inner cavity ECM of a gun barrel, with three deep cavities, is analyzed. machine efficiency is more than 15 times less and with very high-surface quality. The process by passing an electric current through an electrolyte flowing within the inter-electrode gap between the tool (cathode) and the work piece (anode)

In this research, a high efficiency ECM method and device of inner cavity of gun barrel chamber is used. In this study, the inner cavity's machining accuracy was 0.06 mm prior to machining, 0.01 mm following machining, and surface finishing was 0.8 mm prior to machining, 0.2 mm following machining by ECM. This study demonstrates that the inside barrel chamber of a rifle may be machined by setting up ECM experimental settings. **(23).**

From the literature survey, most researchers are focused on bore temperature and cook off temperature. Few researchers focused on analysis of heat induced in barrels. Researchers have not given a viewpoint on the effects of changing the elements, but the results of the modified composition do not match those of the comparative composition. So recommended a material change to increase thermal efficiency to prevent material wear and fatigue. Moreover, to offer greater barley efficiency and require less maintenance. The silicon carbide, which offers greater overall efficiency than the materials already in use.

MATERIAL & METHODS: -

TABLE:1 CHEMICAL COMPOSITION

ELEMENTS	CHEMICAL COMPOSITION
Chromium,Ci	0.80-1.10
Manganese,Mn	0.75-1.0
Carbon,C	0.380-0.430
Silicon.Si	0.15-0.30

Molybdenum,Mb	0.15-0.25
Sulfur,S	0.040
Phosphorous,P	0.035
Iron,Fe	Balance

The table: 1 It displays information about silicon carbide's chemical make-up. These informational data reveal a material's compositional integration.

TABLE: 2 PROPERTIES

PROPERTIES	**Silicon Carbide (SiC)**
Melting point	3059.33°F
Tensile strength	1625 MPa
Bulk modulus	176 GPa
Density	4.84 Mg/m^3
Shear modulus	51 GPa
Elastic modulus	1245 MPa

The table: 2 demonstrates the mechanical characteristics of silicon carbides and offers information for use in data analysis and interpretation considering the findings.

FIG: 1 SILICON CARBIDE

Silicon carbide (SiC) is a compound made up of silicon and carbon atoms. It is a unique material with a combination of physical and electronic properties that make it useful in a variety of application, SiC has high thermal conductivity, making it useful for power electronic applications. It also has a wide bandgap, allowing it to operate at high temperature and high voltage without breaking down. SiC is used in semiconductors, high-temperature devices, and abrasive materials due to its excellent mechanical properties. The fig:1 shows the component of silicon carbide.

FIG: 2 INTENTATION CREEP TESTING MACHINE

Fg: 2 indentation creep testing machine is used to assess how materials creep under various loading scenarios. Creep, which is the time-dependent deformation of a material under a constant load, is a crucial characteristic for materials used in high-temperature applications, including those found in the aerospace, automotive, and power generation sectors.

The specimen holder, the loading system, and the measuring system make up the indentation creep testing apparatus in most cases. The specimen holder is manufactured generally of a high-temperature resistant material, such as metals or ceramics, and is intended to keep the test material in a specified form and size.

FIG: 3 PIN ON DISC WEAR FRCTION TEST RIG

The rig is often fitted with equipment and sensors that can gauge numerous quantities, including temperature, wear rate, and coefficient of friction. These data may be used to compare the tribological characteristics of various lubricants and materials and to enhance their performance in diverse applications.

The disc rotates at a predetermined speed while the pin is held motionless against it, applying a certain load. As a result, the two surfaces slide against one another, causing wear and friction.

The fig: 3 is utilized to test the specimen for wear and provides information about system wear. The machine requires a specimen that is 30mm long and 10mm in diameter.

WEAR

Silicon Carbide (SiC) rod of 300mm length and 14mm diameter. It has been cut into multiple pieces with the help of a wire cutting machine. The pieces are to be turned into 2sets of pieces for wear and creep. The measurement for wear is 10mm diameter and length of 30mm. For the creep it is 10mm diameter and length of 10mm length.

Pin on disc wear friction test rig machine has been used to test 4 samples of 240rpm with a constant load of 1 kg and 2kg.

Silicon carbide has been fitted into the machine with measurements of 10mm diameter and 30mm length. This material is subjected to a constant load of 1kg with respect to a speed of 240 rpm. The work piece has been kept on the jaw which is present in the machine, and it is tightened with the bolts.

Once the material is fit into the respective area the machine is ready to start its function, the switches are on once the console is kept ready to provide the speeds it's been given with a gradual uplift of speed. If the material is attained the higher speed and starts to grain the area of the contact. Machine is kept running of 6min for the material. Till the duration of the time the machine disc rotates at 240rpm with a constant load of on the material.

Again, the material is removed now a new set of components has been fit into the machine now the load is 2kg of 240rpm. In both the areas of the difference got a different result.

TABLE :3 WEAR for (1kg)

S.NO	TIME	WEAR INTENSITY (MICRONS)
1	0-60	349.75
2	60-120	552.71
3	120-180	575.87
4	180-240	368.72
5	240-300	531.42
6	300-360	757.14

S.NO	TIME	WEAR INTENSITY (MICRONS)
1	0-60	324.62
2	60-120	520.97
3	120-180	543.97
4	180-240	390.25

5	240-300	546.71
6	300-360	824.51

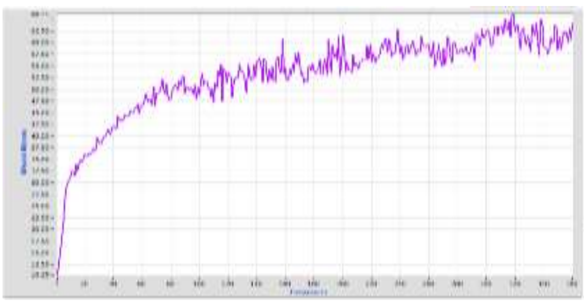
Fig:4 RESULT OF PIN ON DISC WEAR AND FRICTION TEST RIG

The result graph shows a rise and fall of point it is plotted for the time v/s wear in microns. With the understanding of this graph, we can be able to analyze the material that is been subjected to gradual increase in wear.

The graph shows in the fig:4 is of 1kg constant load with a speed of 240rpm.The wear rate on the material was 0.0001564(mm3/Nm), sliding velocity 2.51327(m/s) and coefficient of friction 0.678502. The sliding on the material produces a high heat on the material but the silicon carbide is a high thermal resistant material which can withstand a high heat.

TABLE :4 WEAR for (2kg)

S.NO	TIME	WEAR INTENSITY (MICRONS)
1	0-60	349.75
2	60-120	552.71
3	120-180	575.87
4	180-240	358.84
5	240-300	527.1
6	300-360	747.75



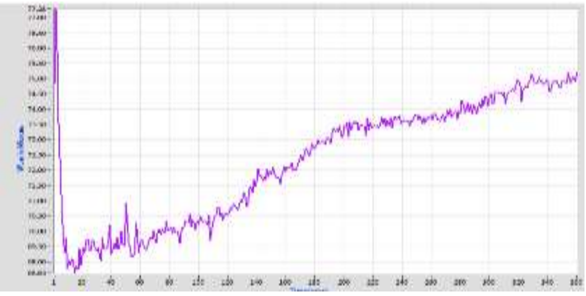


Fig:5 RESULT OF PIN ON DISC WEAR AND FRICTION TEST RIG

The result shows a graph for the time v/s wear in microns, with a load of 2kg and 240rpm in the Fig:5. This provides a gradual rise in the value of a wear with a time of 6min. There was a step in the graph where no down slope of a curve on the material.

S.NO	TIME	WEAR INTENSITY(MICRONS)
1	0-60	355.6
2	60-120	560.82
3	120-180	530.87
4	180-240	325.9
5	240-300	536.82
6	300-360	814.23

Time v/s frictional force is predominant when the specimen is running at a higher speed. It helps to provide the idea of the friction is uniform on throughout the specimen and no variation in the values.

Time v/s coefficient of friction is a graph which is the same as the frictional force graph. It is a straight exponential with a shorter duration of time and a linear graph throughout the running time of the specimen.

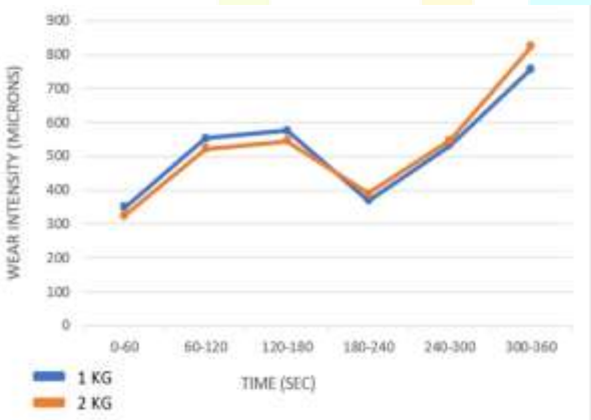


Fig:6- COMPRASSION GRAPH

CREEP

Creep is a time dependent process with a constant load at a higher rpm for a longer period of time. If the test temperature is <0.3tm it is a load influencing factor, if the temperature is >0.3tm it is both load and temperature influencing factor. Silicon carbide has been fit with a dimension of 10mm diameter and 10mm length into the creep machine.

TABLE :5 CREEP for (1kg)

TIME (MIN)	DEFORMATION (mm)	LOAD (KgS)
10	0.0935	1
10	2.6189	1
10	3.5783	1
10	0.0019	1
10	4.3524	1
10	2.4413	1

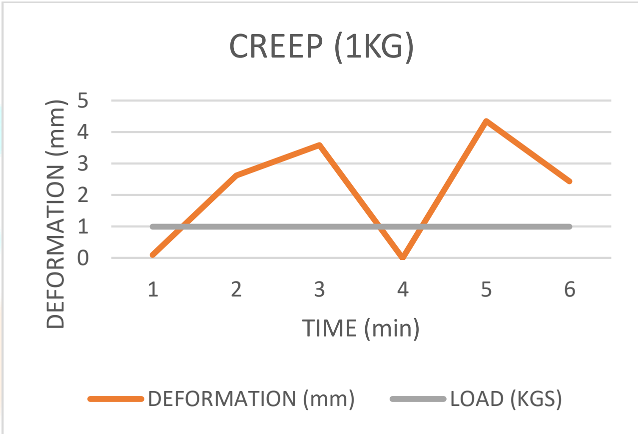


Fig:7 RESULT ON CREEP

The graph on fig:7 which shows a linear movement of a line for a deformation on the specimen measurements are 10mm diameter and 10mm length. The machine is kept running for a constant of 1kg of a duration of 1hour. There was a slight gradual rise in graph with respect to the material subject to a heat of 100°C.

Initially the specimen is kept in the work area, now from the ambient temperature it is been initiated to 100°C. by a gradual heating on the material. Once after heating and reaching the required temperature now the process has been started where the graph starts to plots. The duration of the specimen is of 1hour. Change in deformation with respect to time are being mentioned in the graph.

TABLE :6 CREEP for (2kg)

TIME (MIN(S))	DEFORMATION (mm)	LOAD (KgS)
10	0.0753	2
10	2.1579	2
10	3.0024	2
10	0.017	2
10	4.0003	2
10	1.789	2

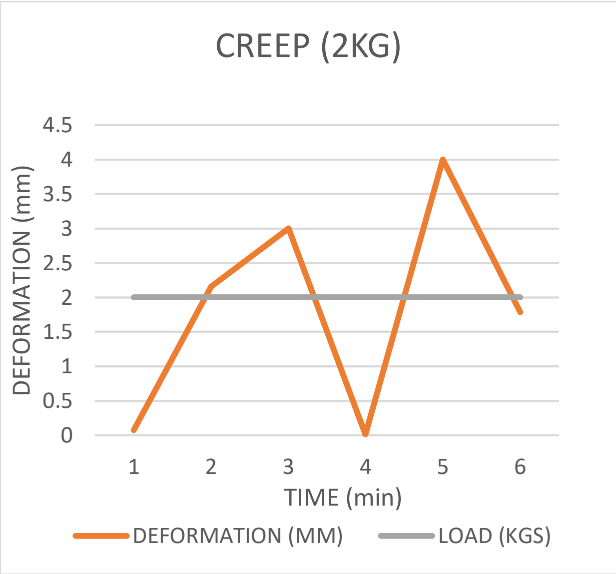


Fig: 8 RESULTS ON CREEP

In this Fig:8 which shows the graph on creep intensity with respect to time. In a linear pattern as that of the mentioned in the previous 1kg load, but it is formed even the same pattern for a 2 kg load. The temperature is kept at 100°C. Once after heating and reaching the required temperature now the process has been started where the graph starts to plot. The duration of the specimen is of 1hour. Deformation provides a value with respect to the change in time.

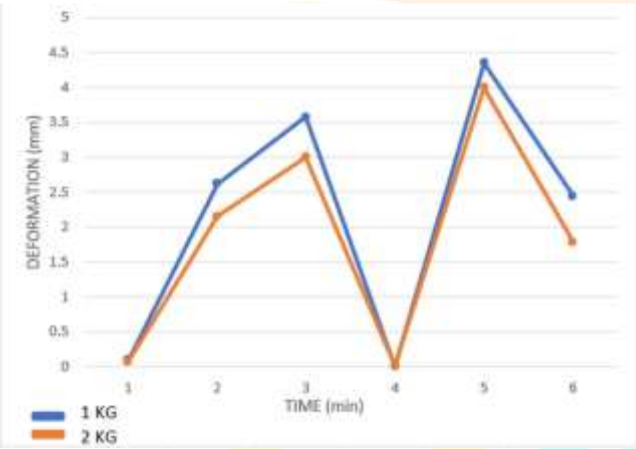


FIG:9 COMPRASSION GRAPH

CONCLUSION: -

According to the study, silicon carbide is a prominent material for making gun barrels which may result in more durable and dependable weapons. This is because silicon carbide can lessen fouling and erosion while also having a stronger resilience to wear and thermal stress.

In the experimental work, the damage characteristics of a machine gun barrel is investigated.

The silicon carbide material properties which enhance in various properties like thermal resistance, improve in wear intensity rates, and to withstand high creep rates. As the material function which provides a resisting approach on the real time applications. The result on creep and wear are determined with the graphs and the table shows the idea about the values.

The results on Wear provide an idea of wearing rates of material. The graph shows the pictorial representation of the exponential varying graph on the material with a different load. The loads used in the wear test were 1kg and 2kg, time for the system was 6minutes. The values which are proportionate to the expected results, which were increased gradually of wear with respect to increasing time, the above suggested for 1kg. But for the 2kg, the graph had changed its position to a varying of data on the graph. Initially the graph had undergone a straight down steep with a reduced time. But from which it has started to a gradual increase with respect to the time and wear intensity rates.

In the wear test there are various another graph which show different values on a different aspect. The time v/s temperature is a graph need to predominant because it shows a fluctuating value, this provides an idea how much heat has been induced in the specimen due to the high rotational forces. Time v/s frictional force is predominant when the specimen is running at a higher speed. It helps to provide the idea of the friction is uniform on throughout the specimen and no variation in the values. Time v/s coefficient of friction is a graph which is the same as the frictional force graph. It is a straight exponential with a shorter duration of time and a linear graph throughout the running time of the specimen.

Creep is a time dependence process for a longer period with a higher temperature and a constant load. In the creep the graph which shows a linear moment for a longer period of time. As the specimen is given a load of 1kg and 2kg with a temperature of 100°C and 200°C, the graph shows linear values of time v/s creep rates.

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