PRODUCTION OF SILICON CARBIDE WITH IMPROVED TOUGHNESS USING AGRICULTURAL WASTES

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Abstract : ***Silicon Carbide is a rarely found mineral. Hence various techniques are used to produce it but produced SiC lacks fracture toughness. This Qualitative research study has been undertaken to produce toughened SiC from Agricultural Wastes (peanut shells, rice husks, sugarcane extracts and corn cob) using Pyrolysis process and adding whiskers (ZrB_2) to the produced SiC. Pyrolysis is the thermal Decomposition of biomass at elevated temperatures in an inert atmosphere. This process has been carried out in Industrial Microwave oven and Argon gas is used to provide inert atmosphere.***

IndexTerms – Introduction, Current Status of Research, Conclusions, Problem Formulation, Proposed Methodology, Expected Outcomes, References

1. Introduction

1.1 About Agricultural Wastes

Agricultural wastes have various properties like large volume, high humidity and high organic composition. Past studies showed that, peanut shells, rice husks, sugarcane extracts and corn cob have high silicon content. Thus, these wastes are used to produce useful fuels and chemicals by thermo chemical biomass conversion process. Thermochemical biomass conversion does include a number of possible roots to produce from the initial biomass feedstock useful fuels and chemicals. The base of thermochemical conversion is the pyrolysis process, which include all chemical changes occurring when heat is applied to a material in the absence of oxygen. The products of biomass pyrolysis include water, charcoal (or more correctly a carbonaceous solid), oils or tars, and permanent gases including methane, hydrogen, carbon monoxide, and carbon dioxide. The process be carried out as slow or fast pyrolysis. The progression of traditional slow pyrolysis of a hardwood in a retort that collects the liquids and gases from the process is the following. Starting with 100% solid material at ambient temperature, by 250℃ the solid mass is at 88%, less than 10% liquid, and only a few percent gas. Between 300℃ and 350℃ the char mass rapidly decreases to less than 60%, the liquids are 20% to 30%, and the gases are between 15% and 25%. The char at this stage contains some amount of both oxygen and hydrogen. Further heating of the char to 750℃ will decrease the mass of the char, and while its composition moves closer to pure carbon, the yield of gas increases and that of liquids decreases. Typically the slow pyrolysis is conducted for hours to a maximum temperature of 400℃ - 500℃ . The charcoal yield is 35% to 40% by weight. The goal of fast pyrolysis is to produce liquid fuel from lignocellulosic biomass that can substitute for fuel oil in any application. The liquid can also be used to produce a range of specialty and commodity chemicals. The essential features of a fast pyrolysis process are very high heating and heat transfer rates, which often require a finely ground biomass feed.

1.1.1 Rice Husk

Rice hulls (or rice husks) are the hard protecting coverings of grains of rice. In addition to protecting rice during the growing season, rice hulls can be put to use as building material, fertilizer, insulation material, or fuel. Rice milling generates a by product know as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice , broken rice and bran .Rest 22 % of the weight of paddy is received as husk . This husk is used as fuel in the rice mills to generate steam for the parboiling process . This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process , is known as rice husk. This RHA in turn contains around 85 % - 90 % silica.So for every 1000 kgs of paddy milled , about 220 kgs (22 %) of husk is produced , and when this husk is burnt in the boilers , about 55 kgs (25 %) of RHA is generated.

1.1.2 Sugarcane Extracts (Bagasse)

Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is dry pulpy residue left after the extraction of juice from sugar cane. Bagasse is used as a biofuel and in the manufacture of pulp and building materials.Sugarcane bagasse ash (SCBA) consist the highest of the silica (96.93%) content. In India, sugarcane bagasse (SCB) has not yet been widely explored it application but several studies have been conducted on producing silica gel as adsorbent, raw material for ceramic, concrete additives, catalyst, cosmetics, paint and etc. due to its characteristics. The amount of the silica content in bagasse is varied depending on the surrounding environment, nature of soil, period of harvesting and process involve.

1.1.3 Peanut Shells

The peanut, also known as the groundnut is a legume crop grown mainly for its edible seeds. It is widely grown in the tropics and subtropics, being important to both small and large commercial producers. The inedible outer covering, in contact with dirties called as Peanut shells containing 56.4% of Silica content.

1.1.4 Corn Cob

A corncob, also called cob of corn, is the central core of an ear of maize . It is the part of the ear on which the kernels grow. The ear is also considered a "cob" or "pole" but it is not fully a "pole" until the ear is shucked, or removed from the plant material around the

ear.Young ears, also called baby corn, can be consumed raw, but as the plant matures the cob becomes tougher until only the kernels are edible.When harvesting corn, the corncob may be collected as part of the ear (necessary for corn on the cob), or instead may be left as part of the corn stover in the field. The innermost part of the cob is white and has a consistency similar to foam plastic. From the literature, it was reported that corn cob composes of cellulose and lignin and consists of significant elements such as silicon (Si, 0.133 wt%), calcium (Ca, 0.022 wt%) and aluminium (Al, 0.052 wt%). Relatively high content of silicon was found in corn cobs which could be converted into silica (SiO_2) in form CCA. Purified CCA silica (96.6%) can be obtained from burning corn cobs in air followed by extraction with alkaline or acid solutions.

1.2 Pyrolysis Process

Pyrolysis is the fundamental chemical reaction process that is the precursor of both the gasification and combustion of solid fuels, and is simply defined as the chemical changes occurring when heat is applied to a material in the absence of oxygen. The products of biomass pyrolysis include water, charcoal (or more correctly a carbonaceous solid), oils or tars, and permanent gases including methane, hydrogen, carbon monoxide, and carbon dioxide. The nature of the changes in pyrolysis depend on the material being pyrolyzed, the final temperature of the pyrolysis process and the rate at which it is heated up. As typical lignocellulosic biomass materials such as wood, straws, and stalks are poor heat conductors, management of the rate of heating requires that the size of the particles being heated be quite small. Otherwise, in massive materials such as logs, the heating rate is very slow, and this determines the yield of pyrolysis products. Depending on the thermal environment and the final temperature, pyrolysis will yield mainly char at low temperatures, less than 450℃, when the heating rate is quite slow, and mainly gases at high temperatures, greater than 800℃, with rapid heating rates. At an intermediate temperature and under relatively high heating rates, the main product is a liquid bio-oil, a relatively recent discovery, which is just being turned to commercial applications. However, the bulk of commercial and technical pyrolysis processes are applied to the production of charcoal from biomass - a solid biofuel, which is then used as a reducing agent in metallurgy, as activated charcoal in absorption applications after chemical processing, and in domestic cooking in urban areas of the developing world.

1.2.1 Pyrolysis Fundamentals

The pyrolysis process consumes energy and, in chemists terms, is described as an endothermic reaction. It is, however, only mildly endothermic; and a factor of much more importance, in terms of energy demand in pyrolysis, is the water content of the starting biomass. The heat of vaporization of pure water is 2.26 kJ g^{-1} at 100℃, while the chemical energy content of wood is only about 18.6 kJ g^{-1}. If there is a high moisture content to begin with, the net energy yield of the pyrolysis process will be very low because the energy necessary for the pyrolysis and gasification processes comes mainly from combustion of one or more of the products of pyrolysis (e.g., char, oil/tar, or combustible gases). Since most biomass is hygroscopic, the removal of water is even more endothermic because of the energy required to overcome the absorption energy. The behavior of solid biomass during heating is a complex interaction between the removal of water and the pyrolysis process. This is further compounded by the occurrence of reactions between the pyrolysis products and the char.

1.3 Silicon Carbide

SiC also known as carborundum is a semiconductor containing silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Synthetic silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide such as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite

1.3.1 General Production of Silicon Carbide

Since natural moissanite is extremely scarce, most silicon carbide is synthetic. Silicon carbide is used as an abrasive, as well as a semiconductor and diamond simulant of gem quality. The simplest process to manufacture silicon carbide is to combine silica sand and carbon in an Acheson graphite electric resistance furnace at a high temperature, between 1,600 °C (2,910 °F) and 2,500 °C (4,530 °F). Fine SiO_2 particles in plant material (e.g. rice husks) can be converted to SiC by heating in the excess carbon from the organic material. Agricultural wastes have various properties like large volume, high humidity and high organic composition. Past studies showed that, peanut shells, rice husks, sugarcane extracts and corn cob have high silicon content. Thus, these wastes are used to produce useful fuels and chemicals by thermo chemical biomass conversion process. Colorless, pale yellow and green crystals have the highest purity and are found closest to the resistor. The color changes to blue and black at greater distance from the resistor, and these darker crystals are less pure. Nitrogen and aluminium are common impurities, and they affect the electrical conductivity of SiC.

Pure silicon carbide can be made by the so-called Lely process, in which SiC powder is sublimated into high-temperature species of silicon, carbon, silicon dicarbide, and disilicon carbide in an argon gas ambient at 2500 °C and redeposited into flake-like single crystals, sized up to 2×2 cm, at a slightly colder substrate. This process yields high-quality single crystals, mostly of 6H-SiC phase (because of high growth temperature).

Fig. 1.3.1(a) Synthetic SiC crystals ~3 mm in diameter

Fig. 1.3.1(b) Synthetic SiC Lely crystals

A modified Lely process involving induction heating in graphite crucibles yields even larger single crystals of 4 inches (10 cm) in diameter, having a section 81 times larger compared to the conventional Lely process. Cubic SiC is usually grown by the more expensive process of Chemical Vapor Deposition (CVD).. Relative to the CVD process, the pyrolysis method is advantageous because the polymer can be formed into various shapes prior to thermalization into the ceramic.

1.3.2 Production of Silicon Carbide in this Project

This Project concerns a method of making silicon carbide involving adding rice husk material, peanuts shell, Sugarcane extracts and Corn cob in powder form to a container, creating a vacuum or an inert atmosphere inside the container to perform pyrolysis process, applying microwave heating, heating rapidly, and reacting the material and forming silicon carbide (SiC). . Since pyrolysis conversion proved to be very economical , efficient and eco friendly so various researches are going on in order to improve its properties and enhance this conversion process. pyrolysis process include all chemical changes occurring when heat is applied to a material in the absence of oxygen. The products of biomass pyrolysis include water, biochar (or more correctly a carbonaceous solid), oils or tars, and permanent gases including methane, hydrogen, carbon monoxide, and carbon dioxide. Biochar has varied applications in almost all fields like mechanical, electronics , aviation, machinery etc. Further heating of biochar produced more effective product known as Silicon Carbide . SiC ceramics have aroused a great deal of concerns because of their great mechanical strength, high hardness, high thermal conductivity, lower physical density, and low coefficient of thermal expansion. However, the applications of SiC ceramics are restricted by low bending strength and fracture toughness.

1.3.3 Characteristics of Silicon Carbide

Typical silicon carbide characteristics include:

- ✓ Low density
- ✓ High strength
- ✓ Low Toughness
- ✓ Good high temperature strength (Reaction bonded)
- ✓ Oxidation resistance (Reaction bonded)
- ✓ Excellent thermal shock resistance
- ✓ High hardness and wear resistance
- ✓ Excellent chemical resistance
- ✓ Low thermal expansion and high thermal conductivity

1.3.4 Applications of Silicon Carbide

Typical silicon carbide applications include:

- ✓ Fixed and moving turbine components
- ✓ Seals, bearings, pump vanes
- ✓ Abrasives
- ✓ Ball valve parts
- ✓ Wear plates
- ✓ Heat exchanger

1.4 Toughness

In materials science and metallurgy, toughness is the ability of a material to absorb energy and plastically deform without fracturing. One definition of material toughness is the amount of energy per unit volume that a material can absorb before rupturing. It is also defined as a material's resistance to fracture when stressed.

Toughness requires a balance of strength and ductility

1.4.1 Improving toughness of Silicon Carbide

As structural materials, SiC ceramics have aroused a great deal of concerns in the mechanical, electronics, machinery, and aviation industries because of their great mechanical strength, high hardness, high thermal conductivity, lower physical density, and low coefficient of thermal expansion. SiC ceramics possess superior antioxidation properties due to the self-sealing performance of SiO_2 during the oxidation process of SiC.However, the applications of SiC ceramics are restricted by low bending strength and fracture toughness. Moreover, the most intractable issue is the appropriate method to obtain a dense sample. The problem of the low fracture toughness can be overcome through designing and preparing composites reinforced with fibers, whiskers, or particles. The fracture toughness and bending strength of SiC are obviously increased with the addition of ZnB_2 particles and whiskers. Short fibers reinforced ceramics have some advantages, such as lower costs and easy of production. In the present study, ZrO_2 short fibers were doped into the SiC matrix to improve the mechanical properties of the composites.

ZrO2 fibers were considered due to their high melting point (2600°C), high temperature resistance (2200°C), strong oxidation resistance, good anti-corrosion, and low thermal conductivity

1.4.5 Process and Testing

SiC powders and ZrO2 short fibers with various proportions were distributed by ethyl alcohol as the dispersion medium in a ball mill operated for 2h at 159 rps. The homogeneous mixtures were dried at 60°C in a drying oven and then mingled with moderate polyvinyl alcohol (PVA) to obtain uniform powders, which were selected by a 40 mesh screen size griddle. The prepared mixture powders were placed for 24h after pelleting to allow for uniform diffusion and then were packaged into a graphite die. Finally, the graphite die containing the powders were placed into a hot press furnace with the air pressure reduced before heating. The heating produce involved a heating rate of 10°C/min below 1200°C and 5°C/min between 1200-1800°C. A pressure of 50 MPa was maintained for 60min at 1800°C. The cooling procedure was set to 10°C/min from 1800°C to room temperature, and the load was not removed until the die temperature reduced to below 500°C. Sintered samples were cut into several strips with the shape size of 35mm , 4mm, 3mm and chamfer of 0.3mm. The bending strength was tested by electronic universal testing machine with a crosshead speed of 0.5mm/min and span of 30mm. The density and porosity of the sintered compacts were identified from the Archimedean principle with distilled water as medium. The theoretical density of the composites was calculated through rule of mixtures. The polished surface and fracture surface of specimens were characterized by X-ray diffraction (XRD) with CuKa radiation to observe the phase compositions of the composites. The morphology of the composites were studied by scanning electron microscope.

2. Current Status of Research

Studies have been carried out on the conversion of biomass into useful fuels and chemicals using various processes like thermochemical conversion , gasification ,pyrolysis etc. Since pyrolysis conversion proved to be very economical , efficient and eco friendly so various researches are going on in order to improve its properties and enhance this conversion process. pyrolysis process include all chemical changes occurring when heat is applied to a material in the absence of oxygen. The products of biomass pyrolysis include water, biochar (or more correctly a carbonaceous solid), oils or tars, and permanent gases including methane, hydrogen, carbon monoxide, and carbon dioxide. Biochar has varied applications in almost all fields like mechanical, electronics, aviation, machinery etc. Further heating of biochar produced more effective product known as Silicon Carbide . SiC ceramics have aroused a great deal of concerns because of their great mechanical strength, high hardness, high thermal conductivity, lower physical density, and low coefficient of thermal expansion. However, the applications of SiC ceramics are restricted by low bending strength and fracture toughness.

Overend [6] investigated the use of thermochemical processes, based on pyrolysis and gasification of biomass to produce solid, liquid, and gaseous fuels is an area of considerable development, offering high efficiency and good environmental performance characteristics. Advanced pyrolysis processes are already commercial and can be used to manufacture chemical intermediates as well as a fuel to replace oil in combustion systems. Gasification at both large and small scales is being adopted for electricity and heat generation. Gasification is also the base to liquid fuels and ultimately to address the severe transportation fuel supply challenge.

Salema et al. [17] discussed that the Pyrolysis of corn stalk biomass briquettes was carried out for the first time in a developed microwave (MW) reactor supplied with 2.45 GHz frequency using 3kW power generator. The quantity (yield) of biochar, bio-oil, and gas greatly depended on the process condition (MW power and biomass loading). Based on its heating value and elemental composition, biochar is suitable for energy applications, whereas bio-oil produced from CS in this study is neither good for energy application nor for chemical production.This work may open new dimension towards development of large-scale MW pyrolysis technology.Further research work is needed in terms of reactor design and biomass loading to prove the feasibility of system at large-scale production.

Mohamed et al. [16] concluded that K_3PO_4, clinoptilolite and bentonite showed good catalytic activities in microwave-assisted pyrolysis, resulting in reduced yield, acidity, viscosity and water content of bio-oil product. Catalyst loading and combination of different catalysts are important in controlling average heating rate and product quality. Mixing 10 wt.% K_3PO_4 with 10 wt.% clinoptilolite considerably reduced the water content of bio-oil by 39.5%; while pH of bio-oil increased by 43% compared to 10 wt.% clinoptilolite only, demonstrating a potential synergistic effect of catalyst mixtures. In addition to catalytic effect, those results are partly attributed to the increased heating rate and the internal-heating of biomass particles in the microwave reactor. Introducing catalysts showed a great potential for accelerating microwave heating and improving bio-oil and biochar qualities.

Hanwu et al.[7] investigated microwave pyrolysis of corn stover and demonstrated the influence of three main pyrolysis variables on the production and surface functionality of biochar. Two production models were satisfactorily developed to describe the total amount of surface carbonyl groups and basic groups respectively. The particle size was found to be a less significant parameter to the biochar surface functionality. The amount of basic groups was decreased with the increase of the reaction temperature. For carbonyl groups, the change of its amount was more complicated due to the biomass decomposition and vapour reforming reactions under different temperatures.

Liu [15] examined a sequential two-step fast microwave-assisted pyrolysis for high quality bio-oil production. Effects of pyrolysis temperature, catalyst loading,and catalyst bed temperature on the product distribution were investigated. The optimal pyrolysis and catalyst bed temperature were 550 °C and 425°C respectively.

Huang et al.[14] concluded that the influence of microwave power levels on maximum temperatures and heating rates was substantial.Microwave pyrolysis would need less input energy and processing time, and it would provide higher thermochemical decomposition of biomass feedstocks. Kinetic parameters of microwave pyrolysis at lower and higher microwave power levels were different. Compared with conventional pyrolysis, the rate constant of microwave pyrolysis was much higher, and its activation energy and pre-exponential factor were much lower.

Dai et al. [5] performed production of bio-oil and biochar from soapstock via microwave assisted co-catalytic fast pyrolysis combining the advantages of in-situ and ex-situ catalysis. They also investigated the effects of catalyst and pyrolysis temperature on product fractional yields and bio-oil chemical compositions. the use of bentonite increased the bio-oil yield. From the perspective of bio-oil yield, 550 °C was the optimal pyrolysis temperature.The proportion of hydrocarbons in the co-catalytic process was 17.07 wt.% higher than that in the non-catalytic process. Furthermore, the proportions of oxygenates and N containing compounds significantly decreased in the co-existence of bentonite and HZSM-5. The addition of bentonite improved the porous structure of bio-chars.

Antunes et al. [13] examined the impact of pyrolysis temperature between 300 °C and 800° C on the chemical and physical properties of biochar obtained from biosolids via MWAP. Preliminary phosphorus adsorption tests were carried out with the biochar produced from biosolids. This research demonstrated that pyrolysis temperature affects biochar specific surface area, ash and volatiles content, but does not impact heavily on the pH, chemical composition and crystalline phases of the resultant biochar. Biochar yield decreases as the pyrolysis

temperature increases. Phosphorus adsorption capacity of biochar was approximately around 15 mg/g of biochar. Biochar resulting from MWAP is a potential candidate for land application with an important role in water and nutrient retention, due to the high surface area.

Hossain et al.[12] used Response surface methodology (RSM) based on central composite design (CCD) to investigate the optimized experimental conditions for maximum H2 and biochar yields from microwave pyrolysis of OPF.Input parameters (temperature, microwave power and N_2 flow rate) have been coded which suggest a complete summary of experimental design with a set of experiment for the two responses of H_2 and biochar.Quadratic model has been found fit for the optimization. This method significantly reduces the number of the experiments (Full factorial experiments). Actual vs. predicted plots clearly imply that experimental values are well in agreement with the predicted values for both H_2 and biochar yield.The perturbation plots indicate that H_2 and biochar yields are more sensitive for N_2 flow rate and temperature respectively. The software suggested three optimized experimental conditions for maximum H_2 yield, maximum biochar yield and for both maximum H_2 and biochar yields together.

Chang et al.[10] has given in his paper "Production of Silicon Carbide Liquid Fertilizer by Hydrothermal Carbonization Processes from Silicon Containing Agricultural Waste Biomass" describe the process of Hydrothermal Carbonization Processes to produce Silicon Carbide liquid fertilizer from Agricultural waste.

Abderrazak et al.[11] found that the simplest manufacturing process of SiC is to combine silica sand and carbon in an Acheson graphite electric resistance furnace at temperatures higher than 2500 °C. The poor quality of the obtained product has limited its use for abrasive. Sol-gel process has proved to be a unique method for synthesis of nanopowder, having several outstanding features such as high purity, high chemical activity besides improvement of powder sinterability. On the other hand, mechanical alloying is a solid state process capable to obtain nanocrystalline silicon carbide . Liquid phase sintering technique, for instance, is an effective way to lower the sinterability temperature of SiC by adding adequate additives in the appropriate amount.

Sijo et al.[18] studied about Aluminium Silicon Carbide metal matrix composites and their properties. Earlier studies revealed that as the percentage of Silicon Carbide is increased the properties get increased up to a limit and fracture toughness gets reduced beyond that .Different percentage of SiC is added and fracture toughness is analyzed in terms of Stress intensity factor since fracture toughness cannot be calculated directly. Both software simulation and experimental methods has been done to find out the best percentage composition.

FERDOUS [19] examined the toughening mechanism of ceramic materials without sacrificing significantly other mechanical properties.Also investigated computational design of novel ceramic materials by nano-scale micro structure engineering and proposed several potential models to achieve target.

ZHANG et al.[8] studied that ZrO2/SiC composites were successfully fabricated via vacuum hot pressing at 1800°C for 60 min under a pressure of 50 MPa with 0, 5, 10, 15, and 20% of ZrO2 short fibers in volume. The fracture toughness and bending strength increased with the addition of fibres up to 20% ZrO2 fibres, in contrast to the change of the relative density with the addition of fibres.

Embong et al.[38] attempts to abridge a review of current literature on the extensive studies that have been undertaken to explore suitable method and pre-treatment to increase the level of silica extraction from SCB with Eco-Friendly approach. Conventional extraction and incineration process of sugarcane bagasse to extract its reactive silica content has confronted several critical issues, particularly in terms of the amount of reactive silica extracted, energy efficiency, and safety precautions. Based on this evaluation, pretreatment of sugarcane bagasse using acid solution is beneficial, particularly in the removal of alkali metals and increasing the amount of reactive SiO2. Amorphous SiO2 from the ashes by the hydration product of calcium hydrate (C-S-H) is completely beneficial in improving performance and durability of concrete.

3. Conclusions

After going through all the papers mentioned above, some very important conclusions are drawn which are given below:

i. The use of thermochemical processes, based on pyrolysis and gasification of biomass can be used to produce solid, liquid, and gaseous fuels.
ii. Research work is needed in terms of reactor design and biomass loading to prove the feasibility of system at large-scale production.
iii. K_3PO_4 , clinoptilolite and bentonite showed good catalytic activities in microwave-assisted pyrolysis, resulting in reduced yield, acidity, viscosity and water content of bio-oil product.
iv. Introducing catalysts showed a great potential for accelerating microwave heating and improving bio-oil and biochar qualities.
v. The optimal pyrolysis and catalyst bed temperature were 550 °C and 425°C° respectively.
vi. Compared with conventional pyrolysis, the rate constant of microwave pyrolysis was much higher, and its activation energy and pre-exponential factor were much lower.
vii. Pyrolysis temperature affects biochar specific surface area, ash and volatiles content, but does not impact heavily on the pH, chemical composition and crystalline phases of the resultant biocha.
viii. The process of Hydrothermal Carbonization was used to produce Silicon Carbide liquid fertilizer from Agricultural waste.
ix. Different percentage of SiC is added and fracture toughness is analyzed in terms of Stress intensity factor since fracture toughness cannot be calculated directly.
x. The fracture toughness and bending strength increased with the addition of fibres (up to 20% ZrO_2 fibres).
xi. Suitable method and pre-treatment were expolred to increase the level of silica extraction from SCB with Eco-Friendly approach.

4. Problem Formulation

Researchers found that Silicon carbide is not available as natural mineral. Hence excessive furnace techniques are needed to produce the compound from Si. There is difficulty in doping of SiC fabrication due to its chemical inertness, physical strength and low diffusion coefficient of other impurities.

4.1 Problem Identification

Different types of material defects are produced in SiC substrates with the present manufacturing processes. Silicon Carbide has low fracture toughness. This low toughness property causes difficulty to control dimensional tolerance while processing and it becomes more prone to cracks thus breaks very quickly. Researchers are trying to overcome this problem by enhancing the fracture toughness property of ceramic materials in several ways.

4.2 Objectives of the Proposed Study

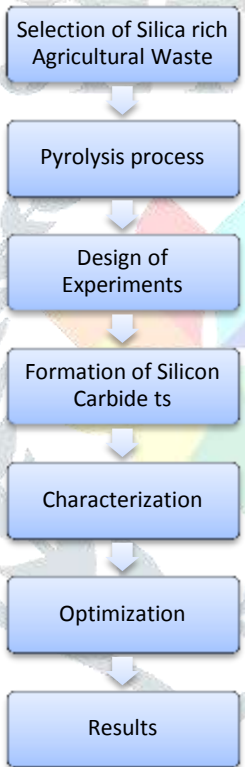
The following are the objectives of the proposed study:-

i. To use Agricultural waste such as Sugarcane extracts, Peanuts shells, Rice husks and corn cob for producing SiC.
ii. To use Microwave oven for pyrolysis process and make this project economical as compared to other processes.
iii. To use Argon gas in microwave oven to make the chamber, Oxygen free.
iv. To Improve the toughness of Silicon Carbide, whiskers or fibres like ZrB_2 are added to it.

5. Proposed Methodology

There are two parts of this work. First coversion of Agricultural wastes into biochar to make Silicon Carbide and Second to improve toughness of Silicon carbide by adding whispers or fibers:-

- ✓ **Selection of Silica rich Agricultural Waste :** In this research, Agricultural wastes such as Sugarcane extracts, Peanuts shells, Corn cob and Rice husks will be used for producing Silicon Carbide by Pyrolysis Process.
- ✓ **Pyrolysis Process:** Industrial Microwave Oven will be used to perform pyrolysis process, for which Argon gas will be used to create inert condition.
- ✓ **Design of Experiments:** Experiments will be conducted by varying three input parameters viz. Heating temperature, Heating time and Quantity of waste. Techniques like Taguchi Design or Central Composite Design will be used for the Design of Experiments.
- ✓ **Characterization:** The toughness of the obtained composite will be studied so that improvement can be made by adding fibres or whiskers like Zirconium di bromide.
- ✓ **Optimization:** The quantity and the size of the nano powder will be optimized for obtaining improved toughness of Silicon Carbide.



6. Expected Outcomes

One of the most important motive of every industry is to optimize the production, quality and cost of the product. In this thesi following outcome is expected:

- The Pyrolysis process has been reported to be used for producing Bio- fuels from Agricultural wastes. In the present work the feasibility of producing Silicon Carbide from Agricultural wastes by Pyrolysis process will be established.
- Obtain composite (SiC) will be experimentally measured and its toughness will be improved by adding nano particle of Zirconium Dibromide.
- An economical method of producing toughened Silicon Carbide will be established.

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