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Fabrication and Characterization ofAluminum Metal Matrix Composite

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ABSTRACT
Metal matrix composite materials increasingly replace traditional materials used in building engineering, aeronautics, mechanical engineering and in many other domains. It is related to a possibility of obtaining practically any combination of beneficial properties of the material, e.g. high vibration damping coefficient, high abrasion resistance, and high value of the Young's modulus, low specific gravity and low coefficient of thermal expansion. In the present investigation, Al 6351/Al_2O_3 metal matrix composite was fabricated by stir casting technique. Microstructure characteristics wereobserved on metallurgical microscope to observe the distribution of reinforcement in matrix alloy. Uniform distribution was observed in all samples.

KEYWORDS: Aluminium alloy (6351), Alumina (Al_2O_3).

1.INTRODUCTION

Metal matrix composites (MMCs) usually consist of a low-density metal, such as aluminum or magnesium, reinforced with particulate or fibers of a ceramic material, such as silicon carbide or graphite. Compared with unreinforced metals, MMCs offer higher specific strength and stiffness, higher operating temperature, and greater wear resistance, as well as the opportunity to tailor these properties for a particular application. However, MMCs also have some disadvantages compared with metals. Chief among these are the higher cost of fabrication for high-performance MMCs, lower ductility and toughness. Presently, MMCs tend to cluster around two extreme types. One consists of very high performance composites reinforced with expensive continuous fibers and requiring expensive processing methods. The other consists of relatively low-cost and low-performance composites reinforced with relatively inexpensive particulate or fibers. The cost of the first type is too high for any but military or space applications, whereas the cost/benefit advantages of the second type over unreinforced metal alloys remain in doubt.The application of response surface methodology (RSM) and central composite design (CCD) for modeling, optimization, and an analysis of the influences of dominant machining parameters on thrust force, surface roughness and burr height in the drilling of hybrid metal matrix composites produced through stir casting route[1]. Many factors which influence the effect of viscosity during Al–SiC MMC production. Processing periods (up to 65 min), stirring speeds (50–500 rpm), and reinforcement sizes (13–100 µm) for two different viscosity levels (1 and 300 mPa-s) were investigated [2]. Particulate metal matrix composites (PMMCs) have attracted interest for application in numerous fields [3]. The wear rate of spray formed composites is significantly lower than the base alloy and stir cast composite under same sliding condition [4] .Comparing with the Newtonian case, the couple stress effects of fluids containing suspensions provide an enhancement in the load capacity, as well as a reduction in the attitude angle and the friction parameter. AA6063 aluminium matrix composite billets reinforced with SiC particles (Al/SiCp) were prepared by stir casting method for extrusion process. The results show that the die wear is affected differently by the SiC particle size[5].Optical microscopy of the conventional cast and stir cast hypereutectic alloy has shown that stir casting causes refinement of primary silicon particles and modification of eutectic silicon compared to conventional cast alloy[6].The formation of TiB_2 particles occurred via diffusion of Boron atoms through TiAl3 particles interface, thereby reacting to form fine TiB2 particles [7].The use of aluminium-based particulate reinforced MMCs for automotive components and aircraft structures have been shown to be highly advantageous over their unreinforced alloys, due to their high specific strength and stiffness and superior wear resistance in a wide temperature range. SEM analyses of the fracture surfaces of the tensile specimens showed substantially similar morphologies for the as-cast and forged composites, both at room and high temperature. The mechanism of damage was mainly decohesion at the matrix–particle interface [8]. Rheological properties of aqueous concentrated aluminium nitride (AlN) suspensions have been investigated in the presence of a sintering aid, deffloculant, binder and plasticizers, in order to screen the most suitable experimental conditions to obtain a good rheological behavior for tape casting thick and non-cracked tapes with good flexibility[9].The wear rate of all heat-treated specimens is less than that of the specimens in the as-cast condition. The main reason for this improvement is clearly related to the hardness enhancement after the aging treatment [10].The wear resistance of the as-cast Al–Si alloy and composites was decreased with increasing sliding distance, while the wear resistance of Al–Si alloy matrix composites has increased with increasing wt% of Al_2O_3 particles. This is due to higher load-carrying capacity of the hard reinforcement Al_2O_3 particles, which limits the amount ofplastic deformation of the matrix [11].Literature survey did not reveal any systematic study of Al 6351/Al_2O_3metal matrix composites. Objective of the present work Fabrication of Al 6351/Al_2O_3 metal matrix composites with different percentage of reinforcement by stir carting method.Microstructure observation of all fabricated samples to observe distribution of reinforcement. Investigation of mechanical properties of all samples.

2. EXPERIMENTATION

2.1 MATRIX MATERIAL

Most of the aerospace structures and its allied infrastructure are made of aluminum alloy. In this context considering Al 6351 which was used for making pressure vessel cylinders is now testing for aircraft structures. Al 6351 has high corrosion resistance and can be seen in forms of extruded rod bar and wire and extruded shapes. It is easily machinable and can have a wide variety of surface finishes. It also has good electrical and thermal conductivities and is highly reflective to heat and light. Due to the superior corrosion resistance, Al 6351 offers extremely low maintenance. The experimental results were found satisfactory to propose the alternative alloy for aircraft structures. The mechanical and physical properties of aluminum alloy (6351) have been reviewed from literature data for the purpose of characterizing the mechanical for manufacturing process in engineering application. Aluminum alloys are used in many applications in which the combination of high strength and low weight is attractive in air frame in which the low weight can be significant value. Al 6351 is known for its light weight (density = 2.7g/cm^3) and good corrosion resistance to air, water, oils and many chemicals. Thermal and electrical conductivity is four times greater than steels. The chemical composition of alloy is follows

Table 1: Properties of aluminum alloy (Al 6351) [12]

aluminum alloy	Cu	magnesium	Silicon	iron	Manganese	Others	Remaining
Al 6351	0.1 %	0.4-1.2%	0.6-1.3%	0.6%	0.4-1.0%	0.3%	Al

It has higher strength amongst the 6000 series alloys. Alloy Al 6351 is known as a structural alloy, in plate form. This alloy is most commonly used for machining.

2.2 REINFORCEMENT MATERIAL

Aluminum oxide (Al_2O_3) is widely used as the reinforcement in the metal matrix composites.The mechanical and physical properties of alumina (Al_2O_3) have been reviewed from literature data for the purpose of characterizing the mechanical properties of alumina for manufacturing process in engineering application.

Table 2: Mechanical properties of (Al_2O_3)

Alumina (Al_2O_3)	Grade	pH value	Mesh size
Neutral(1344-28-1)	Brockman 1 or 2	6.5-7.5	100

Metal–matrix composites (MMCs) are most promising in achieving enhanced mechanical properties such as: hardness, toughness and ultimate tensile strength due to the presence of micro-sized reinforcement particles into the matrix. Generally, regards to the mechanical properties, the reinforcements result in higher strength and hardness, often at the expense of some ductility. Aluminum-matrix composites (AMCs) reinforced with particles and whiskers are widely used for high performance applications such as in automotive, military, aerospace and electricity industries because of their improved physical and mechanical properties. In the composites relatively soft alloy like aluminum can be made highly resistant by introducing predominantly hard but brittle particles such as Al_2O_3 and SiC.

2.3 EXPERIMENTAL PROCEDURE

The materials used in the present work are aluminium alloy (Al 6351) and aluminium oxide (Al_2O_3 as reinforcement). These materials are chosen due to their easily mixable property and gives good mechanical properties. The aluminium alloy (Al 6351) is heated up to its melting temperature 600^0C in a mufflefurnace. Temperature measurement is done with help of K-type thermocouple. Preheatedaluminium oxide at 100^0Cis mixed slowly in molten aluminium alloy with the help of stirrer. The material is left for cool down in the crucible in which it was melted and mixed. There are three samples in different ratios which are prepared for testing mechanical properties. The ratios are shown below in the Table 3.

Table 3: Composition selection

Material	Sample 1	Sample 2	Sample 3
(Al 6351)	97.5%	95%	92.5%
(Al_2O_3)	2.5%	5.0%	7.5%

Figure 1 a. Muffle furnace   Figure 1 b. Preparation of sample by stir casting

Now the mixed composite after cooling and solidification is cut into desired shapes for testing mechanical properties on the band saw machine. The machine is an electrically driven machine which is used to cut the hard composites. The MMC samples prepared are shown in figures given below.

Figure 2: MMC (Al 6351+2.5% of Al_2O_3)

Figure 3: MMC (Al 6351+ 5% of Al_2O_3)

Figure 4: MMC (Al 6351+7.5% of Al_2O_3)

Figure 5: MMC sample prepared for hardness test

Figure 6: MMC sample for tensile test

Figure 7: MMC sample prepared for toughness test

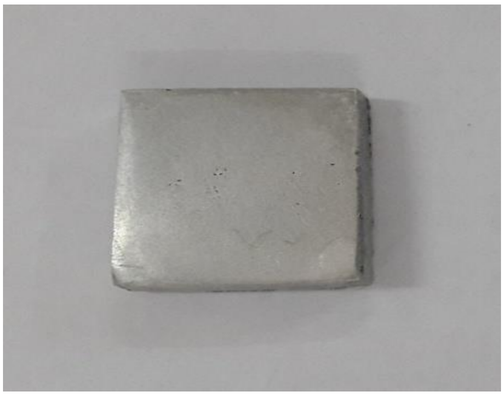


Figure 8: MMC sample prepared for microstructure

2.4 Grinding/polishing

The cut samples prepared above had an uneven surface. So, the cut samples were then taken for grinding/polishing operation. The sample was first held over a grinding machine with a moving belt to obtain a smooth surface. The grinding was done in such a way so that all the scratches are in the same direction and the grinded surface becomes flat. After this the samples were polished using different grits of emery papers. Because the samples being aluminium alloy composites it is rubbed over the emery paper for a small time. It was rubbed over an emery paper of 400, 600, 800, 1000 grit and then over a very fine emery paper of 1200, 1600,2000 grit for a considerable time in order to get a smooth and clear surface of the samples.

3. RESULTS AND DISCUSSION

3.1 Analysis of Microstructure

The microstructures of the MMC samples are seen using metallurgical microscope. The term 'microstructure' in metal matrix composites is used to describe the appearance of the reinforcement material. Microstructure shows that the Al_2O_3 reinforcement distributed uniformly throughout the casted component. Here Al_2O_3 distribution did not show any segregation.Uniform distribution was observed of all selected composition as shown in figure 9.

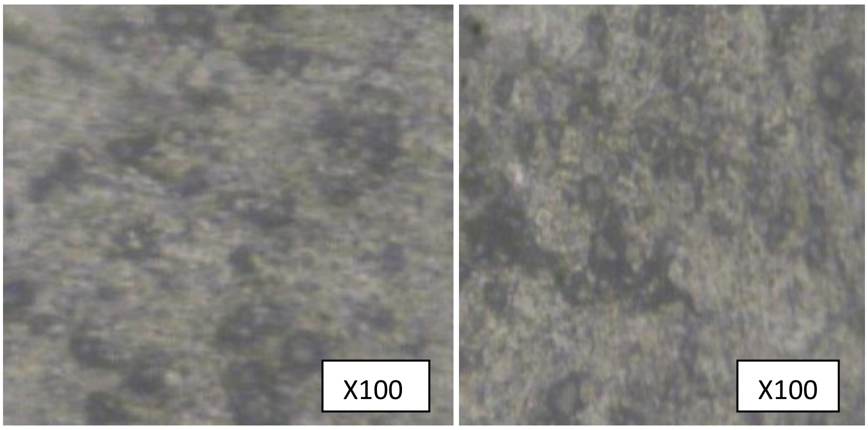
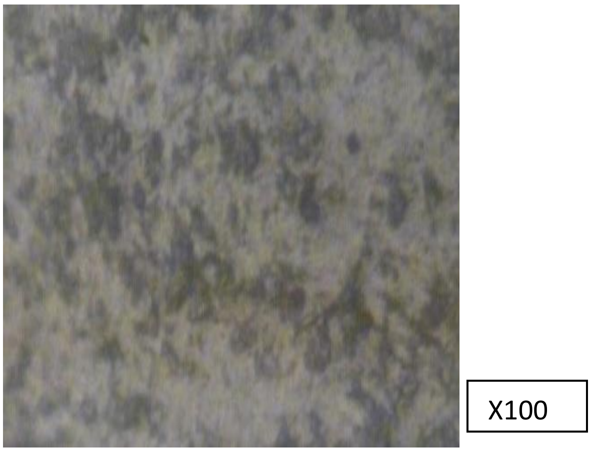


Figure 9: (a) Al 6351+2.5 % Al_2O_3 reinforcement (b) Al 6351+5 %Al_2O_3 reinforcement



(c) Al 6351+7.5 % Al_2O_3 reinforcement

3.2 Analyses of Tensile Strength

Tensile tests are used to determine the elastic limit, elongation, tensile strength, yield strength and reduction in area. Tensile tests were carried out at room temperature using computerized universal testing machine with a capacity of 40 KN. The specimens were tested according to ASTM E8M-01 standard. Specimens of sub sized sample are length of 100 mm, width of 6 mm and gauge length is 36 mm.The ultimate tensile strength, percentage elongation was calculated for each prepared sample.

Table 4: Tensile Test of Al 6351+Al_2O_3 MMC

Samples (of Al_2O_3)	Ultimate strength(N)	Elongation (mm)	Break load (N)	Break Elongation (mm)	True UTS (N/ sq mm)	Area (sq. mm)
2.5%	698.3	0.52	146.1	0.62	26	27.341
5.0%	642.5	0.51	209.9	0.69	21.4	24.453
7.5%	1531.1	2.42	1315	3.23	67.2	26

3.3 Analysis of Toughness Test

In these MMC specimens toughness is tested by breaking it with impact force of a hammer weighing 21 kg. The Hammer is leaved from 140 degree of angle with the initial energy of 300 J. According to ASTM E-23, standard specimen, sizes are 10 mm x 10 mm x 55 mm. for charpy impact test analysis. The table shows the results while testing as follows:

Table 5: Toughness of Al6351+Al_2O_3 MMC

Sample No.	Composite Sample Name	Trial			Average Energy (Joule) (A+B+C) / 3
		A	B	C	
1	Al6351+2.5 % Al_2O_3	14	16	18	16.00
2	Al6351+5 % Al_2O_3	12	14	14	12.66
3	Al6351+7.5 % Al_2O_3	10	10	12	10.66

3.4 ANALYSIS OF HARDNESS TEST

The hardness test was carried on Rockwell Hardness testing method. For hardness testing, the samples of Al6351/2.5, 5, 7.5% wt. Al_2O_3 composite were prepared as per dimension (10 mm x 10 mm x 25 mm) as ASTM E18-05, standard.

Figure 10: MMC sample after indentation on hardness testing machine.

Table 6: Hardness of MMC

Sample No.	Composite Sample Name	Rockwell Hardness at (HRC) scale			Mean Hardness
		Trial 1	Trial 2	Trial 3	
1	Al6351+2.5 % Al_2O_3	42	45	51	46
2	Al6351+5 % Al_2O_3	50	51.5	53	51.5
3	Al6351+7.5 % Al_2O_3	57	58.4	60	58.4

3.0 CONCLUSION

The following conclusions are arrived based on the experimental investigation on the distribution of Al_2O_3 in themechanical stir casting and its effect on mechanical properties of the as cast MMCs at different weight fraction of Al_2O_3.

1. In the present investigation, it was observed that maximum mechanical properties were obtained for Al 6351/7.5% Al_2O_3.
2. The tensile strength of the as cast composites increases on increasing the weight fraction of Al_2O_3.
3. The hardness of the MMCs is higher than the unreinforced matrix metal and the hardness of the cast composites increases linearly with increasing the weight fraction of Al_2O_3.
4. Microstructural observation suggests that stirring action produces MMC with smaller grain size and there is a good particulate matrix interface bonding.
5. The increase in Al_2O_3 constituent toughness decreases with respect to base metal. This is due to increase in brittleness between the alloy Al6351 and Al_2O_3 interfaces.

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Investigations on mechanical peculiarity of Nano Titanium Oxide filled vinyl ester based Functionally Graded Materials

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Abstract— **Filler as reinforcing material plays a major role for the strength of composite materials. It is also depends on the fabrication methodology of the composite materials. The aim of this work is to find out the influence of nano Titanium Oxide (TiO_2) filler and fabrication technique on the mechanical properties of filler filled vinyl ester composites. TiO_2 filled vinyl ester based nano homogeneous composites (HNCs) and their functionally graded materials (FGMs) are fabricated using stirring and centrifugal casting technique, respectively. HNCs and FGMs are fabricated with the reinforcement of 5wt% and 10wt% of nano TiO_2 fillers respectively. Neat vinyl ester is also fabricated for the performance compression with HNC and FGMs. Result finding shows that nano TiO_2 filled FGMs performed better than HNCs. Mechanical properties neat vinyl ester is minimum among the all the fabricated composites.**

***Index Terms*—Nano TiO_2 filler, Vinyl ester resin, FGMs. Mechanical properties**

1. INTRODUCTION

In the present scenario, polymer composites are frequently employed as sliding elements in various industrial applications. In practice, special fillers are important for these purposes to improve the relatively poor load carrying capacity of neat polymers. One of the major benefits of nanocomposites is that it required low concentration of fillers as compared to micro composites and performed better. However, it is agglomerate very easily into polymer because of high percentage of atoms on the surface of nanoparticles, which are not enough for getting a homogeneous dispersion state of nanoparticles [1].

Titanium Oxide is representing with the chemical formula of TiO_2. It is the compound of nitrogen and boron having the property of heat and chemically resistant refractory material. TiO_2 is generally exists in the crystalline forms. It is frequently used in cosmetic products because of their structure is the most stable and soft. Nano fillers reinforced composites have superior wear resistance and mechanical properties [3, 4]. The inclusion of fillers into polymers affects the cost and stiffness of the composites [5, 6]. Patnaik et al. [7] fabricated the silicon carbide filler filled epoxy matrix composite and examine the erosion wear performance of fabricated composites. They found that SiC filled composite performed better as compared to unfilled composite. It is also observed that mechanical properties of fabricated composites are enhanced. Pravurum et al. [8] investigate the parametrical effect on the aluminium nitride and flass fiber filled epoxy composites. Result finding shows that impact angle has significant effect on the erosion wear whereas temperature has minimum effect on the performance of fabricated composites. N. Mohan et al. [9] use the vacuum assisted resin infusion (VARI) technique to fabricate the (WC) filled GF-epoxy composite. Remarkable improvement is observed in the toughness of fabricated composites with the incorporation of WC micro fillers. It is also observed that tensile strength and impact strength is also increase as compared to neat epoxy composite. The fracture energies of filler filled epoxy and polyester resin is examined by Karger et al. [10]. It has observed that crack growth increase initially for certain fraction of volume and then decreased. This phenomenon is observed for both matrix material based composites. FGMs come under the excellent class of materials group. Property of the FGMs is very from one end to other end of FGMs samples. Changes are occurred at the micro level in the FGMs. There are two types of FGMs. One is continuous graded FGMs and other is the step graded FGMs [11]. Various types of fillers have been used by investigators to manufacture FGMs [12-19]. Tribological behavior of ultra-high molecular weight polyethylene (UHMWPE) filled epoxy based FGM has been investigated by Chand et al. [20].

It has been observed from literature review that much work have been done on fillers filled vinyl ester based FGMs but from the author's observation, nano- TiO_2 filled vinyl ester based FGMs have not been developed so far. The focus of current work is to fabricate nano TiO_2 reinforced vinyl ester based HNC and FGMs and to examine their mechanical properties.

2. DETAILS OF THE EXPERIMENTAL WORK

2.1 SAMPLE FABRICATION

Detailed information about HNC and their FGMs is given in Table 1. HNC and FGMs is fabricated using weight percentage of 5 and 10 of nano TiO_2 fillers. Nano- TiO_2 filler is mixed with the vinyl ester matrix by stirring technique which is rotated at 1000 r/min for 30 min. After then, accelerator and hardener are put into the mixture of matrix and filler and stirred gently to avoid the air bubbles formation inside the fabricated specimens. The mixture of nano TiO_2 fillers and vinyl ester matrix are filled into test tubes having the length and diameter of 100 mm and 12 mm, respectively. Fabricated samples were retained at room temperature for one day for curing. Cured HNC specimens are take out from the test tubes. Nano- TiO_2 filler is provided by Intelligent Materials Pvt. Ltd., Chandigarh and vinyl ester matrix material is provided by Sakshi Chemicals, Delhi. FGM specimens are also manufactured with the same weight percentage of nano fillers as it is used to fabricate HNC. The mixture of vinyl ester matrix and nano filler in the test tube is rotated at 1000 rpm for 40 minutes with the help of customised setup to fabricate FGMs. After completing this process, specimens are kept at room temperature for one day for curing.

Table 1 Experimental and theoretical density of HNCs and FGMs

Composite Designation	Composite composition	Experimental density (ρ_e) g/cm^3	Theoretical density (ρ_t) g/cm^3	Void fraction (%)
NV	Neat vinyl ester	1.7943	1.8000	0.3151
VH5	Vinyl ester + 5wt % nano-TiO_2 filled HNC	1.7878	1.8735	4.5732
VH10	Vinyl ester + 10wt % nano-TiO_2filled HNC	1.7111	1.9163	10.6942
VF5	Vinyl ester + 5wt % nano-TiO_2 filled FGMs	1.8204	1.8735	2.8361
VF10	Vinyl ester + 10wt % nano- TiO_2 filled FGMs	1.8257	1.9163	4.7295

2.3 MECHANICAL CHARACTERIZATION

Agarwal and Broutman's formula is used to calculate the theoretical density of HNCs and FGMs [21]. However, experimental density of fabricated specimens is measured as per the ASTM D792 standard. The void content (%) of the fabricated samples is calculated with the help of theoretical and experimental densities as shown in Table 1. Universal testing machine is used for the tensile, flexural and compression test. Tensile and flexural tests are executed as per the ASTM D3039 and D2344 standards, respectively. However compression test is performed as per ASTM D695 standard. Plastic impact tester is used for the impact testing of fabricated composites. Impact test is performed as per ASTM D 256 standard. Rockwell hardness tester is used for hardness (HRL) measurement of HNC and FGMs.

3. RESULTS AND DISCUSSION

3.1 VOID FRACTION OF HNC AND FGM

It is very difficult to fabricate voids free filler filled thermosetting based polymer composites. Probability of voids generation is increased with the nano filler reinforcement. Voids inside the nanocomposites affect their mechanical properties. Void content of fabricated nanocomposites is calculated with the help of theoretical and experimental density. Void fraction of neat vinyl ester, HNC and FGMs are shown in Table 1. FGMs have less void fraction as compared to unfilled vinyl ester and HNC. FGMs have less void fraction due to their fabrication technique. Bubbles are collapsed quickly towards the outer periphery of FGMs sample surface. Centrifugal action is the reason for this phenonmena . Therefore, void fraction decreases spontaneously.

3.2 HARDNESS OF HNC AND FGM

Hardness is an important parameter to select any material for specific applications. FGMs samples have the variation in hardness from inner to the surface periphery due to gradation of fillers. Density of filler and matrix play an important role for the gradation. The density of vinyl ester resin is less than nano- TiO_2 filler. Therefore, gradation of nano TiO_2 fillers take place from the center to periphery of the FGM samples under centrifugal casting. Hardness of FGMs samples is estimated in three dissimilar places as revealed in Fig. 1.

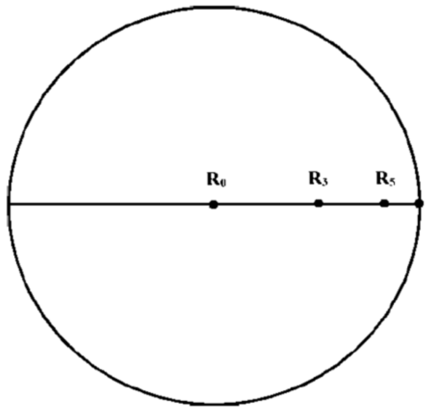

Fig. 1 Schematic representations of zones for micro-hardness measurement

The average value of hardness for three dissimilar places is engaged as the demonstrative hardness value of the FGMs. Average hardness value is 71 HRL and 85 HRL for PF5 and PF10, FGMs samples, respectively. HNCs have lower hardness than FGMs as evident from Fig. 2. The hardness of HNC and their FGMs upsurges with upsurge in the nano TiO_2 filler loading. Neat vinyl ester has less hardness as compared to filler filled nanocomposites.

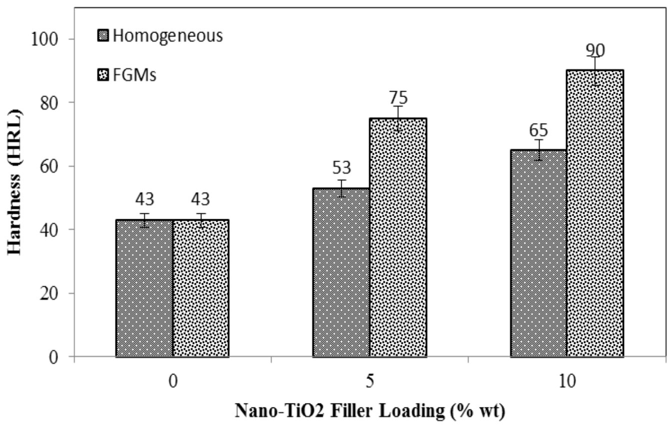

Fig.2 Hardness of HNC and FGM

3.3 TENSILE STRENGTH OF HNC AND FGM

This statement is notorious that the strength of composites material is very much depends on the strength of filler and their content in the composite material. Fig. 3 shows the tensile strength of HNC and FGMs. Unfilled vinyl ester has the tensile strength of 20 MPa. This is witnessed from Fig. 3 that tensile strength upsurges with the 5 weight percent of nano TiO_2 filler filling and it is further decreases for 10 weight percent of filler filling. This phenomenon is perceived for FGMs as well as HNC. Tensile strength decreases for 10 weight percent of filler filling due to increase the brittleness and void fraction of the fabricated composites. FGMs have high tensile strength at both weight percentages of filler filling as compared to HNC as observed in Table 1. Tensile strength of 5 weight percent of nano filler occupied FGM is remarkably extraordinary.

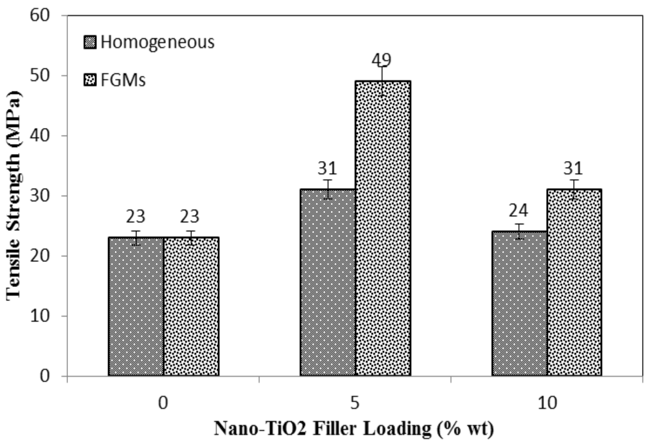

Fig. 3 Tensile strength of HNC and FGM

3.4 FLEXURAL STRENGTH OF HNC AND FGM

Fig. 4 shows the beading capability of HNC and FGMs. It is saw that flexural strength of fabricated composites upsurges with the corroboration of the fillers and also increases with the filler loading. FGMs performed better than HNC for both the weight the weight percentage. Flexural strength of neat vinyl ester is 40 MPa. Under flexure loading, voids and crack inside the nanocomposites is closed due to the perpendicular loading to the sample axis. However, loading is parallel to the sample axis under tensile loading causes opening the cracks and voids results in early failure of the samples. As compare to FGMs, nano TiO_2 filled HNCs, have 17% and 21% less flexural strength for 5 and 10 of weight percentage of nano- TiO_2 filler filling, respectively.

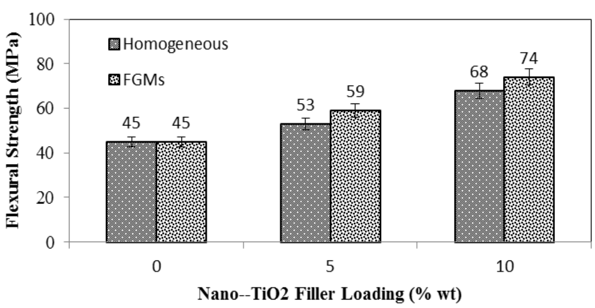

Fig. 4 Flexural strength of HNC and FGM

4.5 COMPRESSIVE STRENGTH OF HNC AND FGM

Compressive strength shows the structural ability of composite materials. Compressive strength capability of HNC and FGMs is given in Fig. 5. Unfilled vinyl ester has the compressive strength of 35 MPa. Compressive strength enhanced for HNC and FGMs with growing the charging of nano- TiO_2 filler. This is witnessed from Fig. 5 that compressive strength of HNC is higher than FGMs for both 5 and 10 weight percentage of nano filler filling. It may happen due to the resin rich reason of the core of FGMs causes less compressive strength.

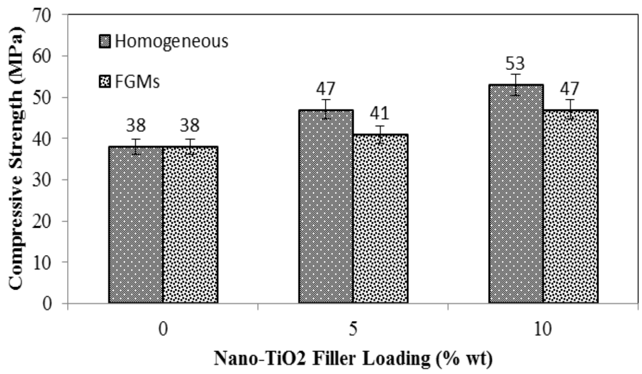

Fig. 5 Compressive strength of HNC and FGM

3.6 Impact strength of HNC and FGM

Impact strength of HNC and FGMs is revealed in Fig. 6. The extent of impact strength for unfilled vinyl ester is 0.33 J. The impact strength of HNC and FGMs upsurges with 5 weight percent of nano- TiO_2 filler filling, and it drops to 10 weight percent of filler filling. FGMs have great impact strength as compared to HNC at 5 and 10 weight percentage of filler filling, respectively. The extent of maximum impact strength is 0.78 J for FGMs at 10 weight percentage of nano-TiO_2 filler filling. FGMs have higher impact strength due to temperature-cure gradient effects.

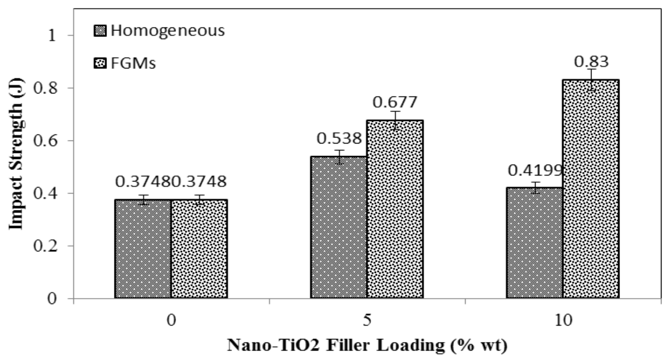

Fig. 6 Impact strength of HNC and FGM

Conclusion

1. Nano- TiO_2 filled vinyl ester based HNCs and FGMs fabricated successfully.
2. Hardness, flexural and compressive strength increases with increase in the filler loading of nano TiO_2 particulates.

3. Tensile strength of 5 weight percent of nano- TiO_2 filled FGMs and HNC are higher as compared 10 weight percent of nano- TiO_2 filled nano-composite materials.
4. Impact strength of HNC increases with 5 weight percent of filler filling and vice versa is perceived for 10 weight percent of nano TiO_2 filler filling. However, Impact strength of FGMs is upsurges with the upsurge in filler filling.
5. Unfilled vinyl ester has least mechanical properties in comparison to FGMs and HNCs.

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An Analysis on Monitoring and Control of Real Time Systems

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***Abstract*-Oneofthemost challenging scenarios facedintheprocess industry is the need of constant monitoring and controlling of parameters under hazardous conditions.In-depth analysis of various control techniques used for monitoring and controlling the real time parameters of Process Industries has been done in this paper.As the processesare highly critical so they need to be run at the appropriate temperature, humidity, pressure etc continuously. Various control methods are being explored and analyzed based on merits or demerit for their suitability. Microcontroller and PIC based Control system,PLC Controller, SCADA based Automation System,Fuzzy Controller etc are the various control methods which has been investigated in this paper.Our paper is presenting a review and analysis of various advanced controls and optimization solutions and in this study, we found that Arduino based control system is the most suitable approach for various process application.**

***Keywords*-Arduino, SCADA, PIC, PLC,Fuzzy.**

I. INTRODUCTION

The Access of Real-Time Data is quite a herculean task. With the advancement in technology, many methods have come up for obtaining these Real Time Data. There are pros and cons of every method which is used for finding thesedata.

The development of an efficient parameter monitoring system requires the use of adata acquisition system,the analysis of several parameters that are monitored (temperature, humidity, light etc) and a real-time notification system in case of condition failure.The objective is to develop a flexible and robust intelligent systemby keeping it as simple aspossible.

Now a day's control of parameter is used in industries and can be used in variety of applications available.The main of function of control action is to a maintain a particular parameter which changes due to some chemical reaction and environmental parameters [1-3].In this context, lot of research work has been explored and presented in next section.

II. LITERATUREREVIEW

Lots of research work has been done for monitoring the real time parameters and controlling strategies in process industries such asMicrocontroller and PIC based Control system, PLC Controller; SCADA based Automation System, Fuzzy Controller etc.

Microcontroller based system is one of the most popular among various techniques. Instead of usage of a separate microprocessor and other components separately, we can economically operate the device by using microcontroller. Md. BelayatHossain[4] has discussed the Queue Control in banks, retail stores etc. Unique numbers are assigned tocustomer and service is processed accordingly.Ahmed Salih[5] describesAutomatic Railway Gate and Crossing Control using microcontroller and magnetic sensor.

Rashidi[6] describes Car Monitoring using Bluetooth security system. In this the whole system under consideration can be accessed by the Bluetooth of the mobile phone.Zairi Ismael Rizman[7] has discussedAutomatic Temperature Control Systemfor Smart Electric Fan. Microcontroller based system has certain constraints. Its software development is much more expensive aswell as difficult to implement. Although it is economical as compared to the usage of a separate microprocessor but it had issues with software development and powerconsumption.

A Programmable Logic Controller (PLC) is a industrial computer control system used for monitoring the processes in industries, for e.gautomation of electromechanical processes, manufacturing lines oil industries etc.M.GIoannides [8] describes implementation of monitoring and control system for the induction motor basedPLC controller.PLC correlates the operational parameters to the speed requested by the user and monitors the system during normal operation and under trip conditions.Irmak[9]has discussed real time monitoring and controlling of an elevator based on PLC.MinggangZheng[10]formulated a control strategy to control the temperature of blast furnace by regulating water spray.D.V. PushpaLatha[11]has explained the measurement of temperature and is then controlled using Programmable Logic Controller (PLC).Advantage of using PLC control system is its ability to change and make the same copy of the operation while it communicates and collects the important information.However,PLC based control system poses certain limitations too. Extra effortis required to connect

Wires in assembly lines. It is a tedious task to find the error in PLC based control system as compared to other control systems.

Supervisory control and data acquisition(SCADA) is used todescribe a system where both data acquisition and supervisory control are performed. AdityaGoel[12] has formulated a control strategy to control temperature, pressure, humidity etc. for real time monitoring of remotely situated DAQ.EnginOzdemir[13]describes Mobile phone based SCADA for industrial automation.This paper explained that operator can visualize and modify the plantparameters using his mobile phone, without reaching the site. In this way maintenance costs are reduced andproductivity is increased.However, SCADA based system has certain restrictions. It is rather more expensive than other control techniques.It is difficult to install and maintain the SCADA based Control Technique. There is no systematic approach to acquiring data from the plant devices – if two operators require the same-data.

Fuzzy logic based control systems are also gaining popularity now-a-days. The quality and performance can be improved using fuzzy logic Control Strategy due to well-known merits of soft computing techniques. The fuzzy logic is a soft computing method; whichcan help in many complex control techniques.Pekka [14] introduces a fuzzy logic controller for temperature control of the superheated steam. This paper describes the usefulness of self-tuningmethods that modifies the scaling factor of FLC output as well as the membership functions of fuzzy rule set. Malki A Heider [15] describes a fuzzy PI controller and its application in the control for boilers.It is very popular in automation based control system.A. Hossain[16] has formulated a strategy for monitoring and controlling of a real-time industrial process using dynamic model control technology.A dynamic model could provide early signal to detect deterioration ofcertain equipment,animated control of an industrial process, and tuning of certain control devices under real-time process dynamics.J.W Shin [17] has discussed a patient monitoring system using fuzzy information. This paperoffers not only the real-time monitoring information but also the references of a patient’s ECG waveform and a past recorded data.Thistype of control system is very close to the way human thinks and approaches than traditional logical system.Basically it provides an approximate picture of the real world.Hence, the basic part of Fuzzy logic controller is set of basic rules, which have a dual concept of fuzzy implication, and compositional rules of inference. It converts the control strategy, which is based on the knowledge of expert into an automation based control solutions. However, it poses certain limitations too. It is difficult to estimate membership functions and there are several ways of interpretingrules.

In the recent years, the technological advancements have given us many new control techniques.This paper investigates an alternative approach through Arduinosystem for parameters analysis and monitoring.Georgitzikis[18] expanded the Arduino capabilities by adding an 802.15.4 wireless module, in order to expose its functionality as a Web of Things node.There is a description of the necessary steps to make a heterogeneous network interoperate and the implementation of a network stack for the 4 most representative hardware platforms, as used by the relevant research community (Arduino, SunSPOT, TelosB, iSense).These types of control systems have certain unique advantages.Arduino is open source hardware. Hence, we can develop any applications according to our requirement.The Arduino hardware platform has the power and reset circuitry setup as well as circuitry to program with the microcontroller over USB. In this context, lot of proposed work has been explored and presented in next section.

III. PROPOSEDWORK

In this paper, the main emphasis is given on real time parameter monitoring and controlling. The data acquisition is obtained through the MATLAB, simply through programming, without using of the tool box and Simulink. Hence this would be more user friendly and would be cheaper way of obtaining real time data acquisition.

Arduino system consists of an ARDUINO board and PC. It has a user interface realized under the MATLAB and a Microsoft OUTLOOK.The real-time alert is sent to the decision making factorsvia Internet.

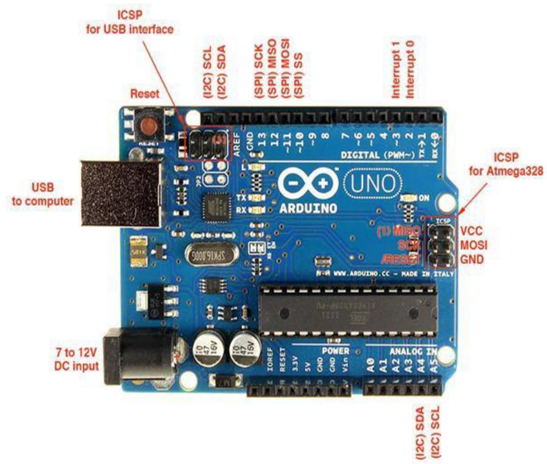

Fig 1.Arduino Board

The Arduino Uno which has been used in this project, is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which we can use 6 pins as PWM outputs), 6 analog inputs, a ceramic resonator of 16MHz, a USB connection, a power jack, and a reset button. In our project we have use ARDUINO UNO because, it has an advantage of being open source, because of which any user can debug it easily. It has an easy USB interface. This board is cheap and easy to find so if any fault arises in thisboard.

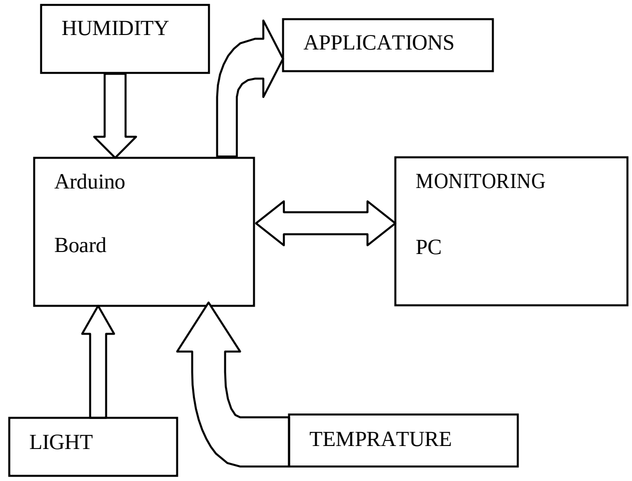

Fig 2.Block diagram of Monitoring and controlling

On the other hand the automation is obtained with the help of Arduino Uno and MATLAB, by interfacing the HR202 (humidity sensor) and LM35 (temperature sensor), LDR (light sensor) with the Arduino.

Fig 3. Temperature Sensor(LM35)

Fig 4. Humidity Sensor(HR202)

Fig .5 Light Dependent Resistor

In this proposed work, sensors used are shown in fig. 3, 4, 5. Results of these sensors are appealing. Hence, real time data time data can be extracted and monitored in a very efficient manner.

IV. CONCLUSION

In this paper rigorous analysis and review on various control techniques such as Microcontroller, PIC, PLC, SCADA, Fuzzy etc. has been done.The attempted work thus, presents that Arduino based controller is the best and optimal solution for controlling the parameters of a control room in process industry. Several researchers have implemented Arduinologic on robotics but it has not yet been implemented in controlling the parameters of a control room in industry. Practical implementation of Arduino controller for control unit in a typical industry can have certain bottlenecks. However, it seems it is the best possible method as compared to conventional methods.Arduinoboards are relatively inexpensive compared to other microcontroller platforms. It is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well.

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An ab initio study of electronic Structure and properties of guanosine

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***Abstract*— Ground state geometries of the two tautomeric forms of guanosine (rG) of anti-conformations of keto-N9R and keto-N7R, R=sugar moiety in rG were optimized using the ab initio at B3LYP6-31G** level. These calculations were also extended to hydrogen-bonded complex of two water molecules with each of the keto-N9R (rG9-2W) and keto-N7R (rG7-2W) forms of rG. Relative stabilities of the two above mentioned tautomers of rG as well as those of rG-2W (keto-N9R) and rG-2W (keto-N7R) complexes in the ground state in the gas phase were studied employing the MP2 correlation correction. It appears that both the keto-N9R and keto-N7R forms of rG would be present in the ground state, particularly near the aqueous solution-air interface.**

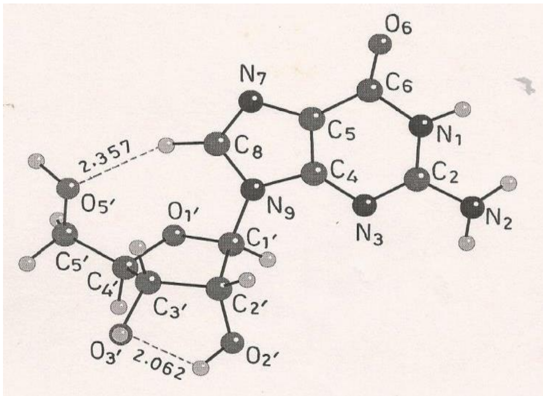
Keywords: Guanosine (rG); Ab initio study; Tautomerism

I. INTRODUCTION

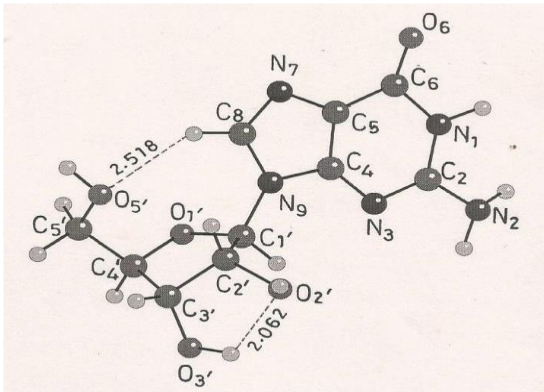
Guanosine (rG) is a purine nucleoside comprising guanine attached to ribose ring and an important building block for supramolecular gels owing to the unique self-assembly property that results from the unique hydrogen-bond acceptors and donor groups [1]. Mutation of biological systems and carcinogenesis are complex phenomena involving genetic changes at the molecular level which are not yet properly understood. Incorporation of enol and imine tautomers of the bases in the nucleic acids in place of normal keto and amino forms respectively is considered to be one of the different possible causes of mutation [2,3]. However, theoretical studies suggest that the enol and imine tautomers of the bases may not occur abundantly enough to be important for mutation [4,5]. A bottleneck in the study of tautomers is the fact that these species are normally not crystallized. However, in this context, spectroscopic and theoretical methods appear to be quite useful [4-7]. Electronic absorption, fluorescence and ab initio quantum theoretical calculations have shown that the guanine base of the nucleic acids mainly in the keto-N9H form inside bulk water while it occurs in the keto-N7H form at the water-air interface [5]. In an experiment study using hole burning spectroscopy [8], beside the keto-N9H and keto-N7H forms, an enol tautomer of guanine was also found to occur. These results give rise to important questions as what would be the relative stabilities of the keto-N9R and keto-N7R tautomeric forms of rG, where R stands for the sugar moiety, in bulk water and at the water-air interface. However, to the best of our information, the possibility of occurrence of the keto-N7R form of rG in gas phase and aqueous media has not yet been studied.

II. METHOD OF CALCULATIONS

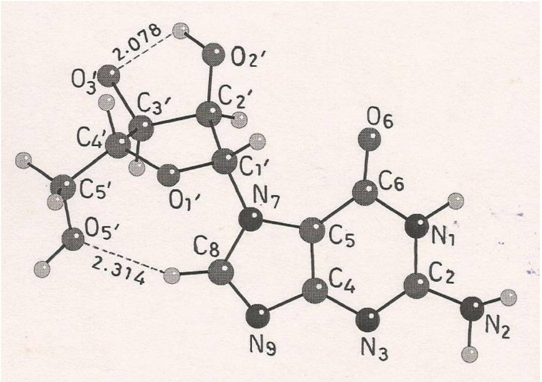
Molecular geometries of the anti-conformation of the two tautomeric forms of rG (keto-N9R and keto-N7R, R=sugar moiety in rG) and anti-conformations of keto-N9R and keto-N7R forms of rG-2W (Figs. 1, 2) were optimized using the ab initio at B3LYP/6-31G** level [5]. Due to a large size of the molecule and as a detailed investigation of its two tautomeric forms in both gas phase and aqueous media was undertaken, a more sophisticated basis set could not be employed. All these calculations were performed using Windows version of Gaussian 94 (G94W) (Revision E.3) program [9].



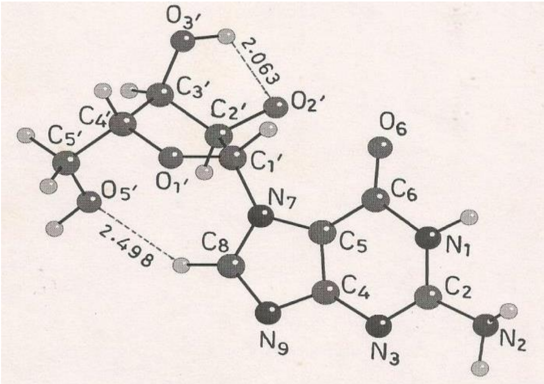
(a) C3′-endo (keto-N9R)



(b) C2′-endo (keto-N9R)

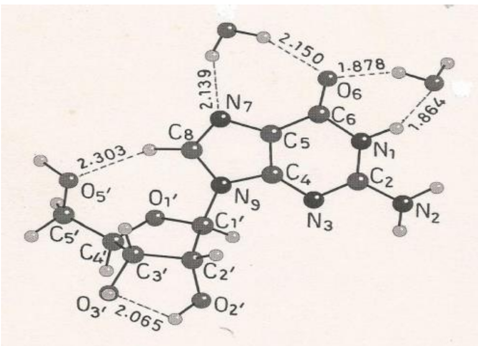


(c) C3$^{/}$-endo (keto-N7R)

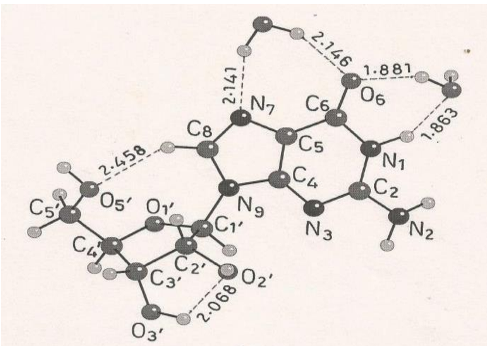


(d) C2$^{/}$-endo (keto-N7R)

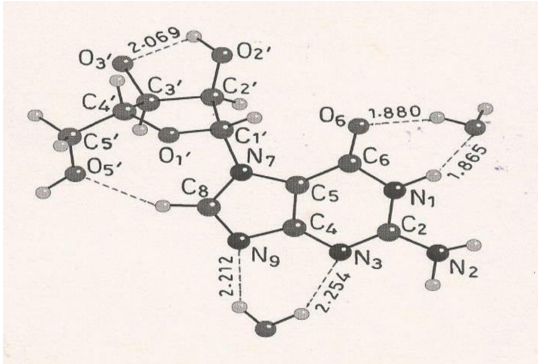
Fig. 1. (a-d) Molecular structures of the anti-conformations of the keto forms of rG



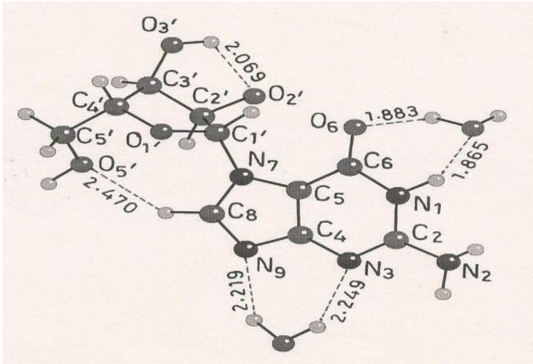
(a) C3$^{/}$-endo (keto-N9R)-2W



(b) C2$^{/}$-endo (keto-N9R)-2W



(c) C3$^{/}$-endo (keto-N7R)-2W



(d) C2$^{/}$-endo (keto-N7R)-2W

Fig. 2. (a-d) Hydrogen-bonded complexes of the anti-conformations of rG with two water molecules each

III. RESULTS AND DISCUSSION

The relative total energies of the different keto tautomers of the anti-conformations of rG and the corresponding energies of the complexes with two water molecules each in gas phase and aqueous media obtained at the B3LYP/6-31G** levels are presented in Table 1. Further, this table includes the relative total energies of each of the above mentioned systems for C2$^{/}$-endo and C3$^{/}$-endo conformations of sugar moiety.

TABLE I. Relative total energies (kcal/mole) of the different keto tautomers of the anti-conformation of rG and its complexes with two water molecules each in gas phase obtained by geometry optimization at the B3LYP/6-31G* level. Each column (B3LYP or MP2) for each conformation has its own reference. R stands for the sugar moiety in rG. In the parenthesis, the values obtained [10] at B3LYP/6-31G* basis set level.

Molecule/Tautomer	B3LYP	MP2
rG		
keto-N9R (R=C3$^{/}$-endo)	0.0[a]	0.0[a]
keto-N9R (R=C2$^{/}$-endo)	+0.12 (+0.08)	+0.38
keto-N7R (R=C3$^{/}$-endo)	-0.14	-0.24
keto-N7R (R=C2$^{/}$-endo)	+0.19	+0.50
rG+2H$_2$O		
keto-N9R+2H$_2$O (R=C3$^{/}$-endo)	0.0[a]	0.0[a]
keto-N9R+2H$_2$O (R=C2$^{/}$-endo)	+0.21	+0.58
keto-N7R+2H$_2$O (R=C3$^{/}$-endo)	-0.08	-0.17
keto-N7R+2H$_2$O (R=C2$^{/}$-endo)	+1.81	+1.91

[a]Present work

Thus the anti-conformation of keto-N7R form of rG is appreciably more stable than the same conformation of keto-N9R form of the nucleoside in both gas phase and aqueous media at B3LYP and MP2 levels for C3′-endo conformation of the sugar ring.

Hydrogen-bonded complexes of rG with water molecules would be important since they may occur at the water-air interface, and this complexation would correspond to the microscopic solvent effect. For this reason, the geometries of anti-conformations of keto-N9R and keto-N7R forms of rG-2W were optimized in gas phase and subsequently, using these optimized geometries, the species solvated in bulk water. The gas phase geometries of these hydrogen bonded complexes are shown in Fig. 2 where the hydrogen bonding distances are also indicated.

The relative total energies obtained at B3LYP and MP2 levels presented in Table 1 show that the anti-conformations of keto-N7R form of rG and rG-2W with C3′-endo conformation of the sugar rings are more stable in aqueous media than the corresponding forms of the nucleoside where the sugar ring has C2′-endo conformation.

IV. MOLECULAR GEOMETRY

The gas phase optimized structures of anti-conformations of the C3′-endo (keto-N9R), C2′-endo (keto-N9R), C3′-endo (keto-N7R) and C3′-endo (N7R) forms of rG are shown in Figs. 1 (a − d) while the corresponding structures of hydrogen bonded complexes of the anti-conformations of rG with two water molecules each of C3′-endo (keto-N9R), C2′-endo (keto-N9R), C3′-endo (keto-N7R) and C3′-endo (N7R) are shown in Figs. 2 (a− d) respectively. Details of optimized molecular geometries of the keto-N9R and keto-N7R forms of rG for both the C2′-endo and C3′-endo conformations of the sugar ring for the ant-conformation of the nucleoside and hydrogen-bonded complexes of the anti-conformations of rG with two water molecules each of C3′-endo (keto-N9R), C2′-endo (keto-N9R), C3′-endo (keto-N7R) and C3′-endo (N7R) are presented in Tables 2 & 3 respectively. Only some hydrogen-bond parameters data are available [10,11]. Usually the agreement between the gas phase optimized and available data [10,11] was found to be quite good.

a.

TABLE II. The observed and calculated values of some sugar bond lengths (Å), bond angles (deg.) and dihedral angles (deg.) of the different keto tautomers of the anti-conformations of rG each in gas phase obtained by geometry optimization at the B3LYP/6-31G** level. For each bond length, bond angle and dihedral angle, the values are given in two lines, out of which the upper line corresponds to C3′-endo while the lower line corresponds to C2′-endo conformations of the sugar ring in rG.

b.

c.

d.

Geometrical Variables (Bonds/ angles)	Calculated[a] keto-N9R	Calculated[a] keto-N7R	Observed[b,c]
Bond lengths			
C1′ C2′	1.541	1.540	1.529[b]
	1.541	1.541	
O1′ C4′	1.433	1.435	
	1.441	1.441	
C2′ C3′	1.542	1.542	
	1.540	1.540	
C3′ O3′	1.426	1.426	1.417[b]
	1.415	1.415	
Bond angles			
C1′ C2′ C3′	102.3	102.0	101.3[b]
	102.2	102.2	101.5[b]
O1′ C1′ C2′	106.7	106.7	107.6[b]
	106.0	105.9	
C2′ C3′ C4′	101.8	101.5	
	102.4	102.3	102.6[b]
C3′ C4′ C5′	115.2	115.6	
	114.8	114.9	115.2[b]
Dihedral angles			
C1′ O1′ C4′ C3′	19.0	18.6	15.3[c]
	-7.1	-6.5	
C1′ C2′ C3′ C4′	33.9	35.4	33.8[c]
	-33.4	-33.7	
O1′ C1′ C2′ C3′	-24.0	-25.8	-25.0[c]
	30.4	31.0	

[a]Present work

[b]Ref. [10]

[c]Ref. [11]

TABLE III. Intramolecular hydrogen bond parameters[a] of the different keto tautomers of the anti-conformations of rG each in gas phase obtained by geometry optimization at the B3LYP/6-31G** level. R stands for the sugar moiety in rG. In the parenthesis, the value obtained at B3LYP/6-31G* basis set level [10].

Molecule/ Tautomer	C−H…O hydrogen bond parameters d(H…O(5′))	d(C…O(5′))	θ(C−H…O(5′))
keto-N9R (R=C(3′)-endo)	2.357 (2.356)	3.377(3.375)	156.8 (156)
keto-N9R (R=C(2′)-endo)	2.518 (2.542)	3.449 (3.470)	143.7 (143)
keto-N7R (R=C(3′)-endo)	2.314	3.320	153.9
keto-N7R (R=C(2′)-endo)	2.498	3.436	144.5

[a]d(H…O(5′)) (Å), d(C…O(5′)) (Å) and θ(C−H…O(5′)) (deg.) represent the hydrogen-acceptor distance, donor-distance and donor-hydrogen-acceptor angle respectively. H and C refer to H(8) and C(8) for rG, respectively.

The present optimized gas phase geometrical parameters of the sugar ring of the anti-conformation of keto-N9R form of rG, including the C2′-endo and C3′-endo conformations of the sugar ring, differ, on the average, from the results reported earlier [10,11] as follows:

(a) The present bond lengths differ from those obtained earlier by about 0.01Å.

(b) The present bond angles differ from those obtained at earlier by about 1 deg.

(c) The present value of the dihedral angles differ from that obtained earlier by about 1.5 deg.

(d) The present value of the (C8H8…O5′) hydrogen bond length differs from those obtained earlier by about 0.025 Å.

The above comparison shows that the B3LYP/6-31G** basis set approach a satisfactory gas phase molecular geometry.

We arrive at this conclusion from this study that the nucleoside rG or its complex rG-2W would occur in both the keto-N9R and keto-N7R forms at the solution-air interface. This result suggests that mutation may be induced when the nucleoside comes in contact with dissolved oxygen in biological systems.

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