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PAKISTAN ENGINEERING CONGRESS
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PAKISTAN ENGINEERING CONGRESS BUILDING

48th YEAR OF PUBLICATION

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ON OTHER PAGES

IN THIS ISSUE

NEWS

TECHNICAL VIEWS

PRESIDENT
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SECRETARY
Engr. Ch. Ghulam Hussain

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FOR MEMBERS ONLY

Pakistan Engineering Congress is a prestigious professional body established in 1912 dedicated, interalia to technical advancement of Science & Engineering in the country.

News

MEET THE NEW PRESIDENT

Engr. Husnain Ahmad the newly elected President was born at Pasrur, district Sialkot in 1963. He was primarily schooled at Lahore till his graduation from the University of Engineering & Technology (UET), Lahore. From UET Lahore, he acquired Bachelor and Master Degrees in Civil Engineering. During his stay at UET, he also held University Colour for representing the University in Rifle Shooting Competitions and remained student's representative throughout his tenure.

After graduation, he started his professional career by joining Communication and Works Department, Government of the Punjab in 1989 as Assistant Executive Engineer / Assistant Project Manager, yet, he continued improving his educational qualifications and earned many distinctions. He was also awarded the Britannia Chevening Scholarship. During his stay in UK he earned Master Degree in Business Administration from Cardiff Business School, University of Wales and acquired the fellowship of Institute of Professional Financial Managers, London. His continued endeavour for improving his academic excellence inspired him to have Master Degree in Computer Sciences. His research aptitude made him author of more than eight technical refereed publications. He has also been awarded the Congress medal for co-authoring a paper on the topic : "USE OF ENVIRONMENTAL FRIENDLY FINELY DIVIDED MATERIALS IN BRITTLE MATRIX COMPOSITES".

Besides rich scholastic credentials, he has a remarkable diversified experience of serving in various organizations. He supervised construction of various prestigious buildings such as Pediatric Hospital Lahore and highways projects, such as Saggian Ravi Bridge and construction of over 400 kilometers of roads. He also headed Information Technology Department (ITD) of City District Government Lahore (CDGL) where he remained instrumental in planning and developing a vision for IT department and contributed significantly in getting Lahore declared as one of the first e-districts of Pakistan. He was also the first Project Director of the University of Veterinary and Animal Sciences, Lahore where he helped in envisaging the developmental needs and initiating practical execution of construction activities for developing the needed facilities.

Apart from his brilliance in academics and professional persuits, he not only participated in social activities but also possess a unique honour of representing his equals as well as community at all levels. During his stay at University of Wales, his efforts for the promotion of multi racial culture and image building of Pakistan were widely acknowledged. He also had the honour of getting elected as President Pakistani Students Society, National Union of Students UK. He has a large number of features in his cap, such as Member Chartered Institute of Marketing, UK. Life member Pakistan Engineering Council, Member of Executive Council, Institute of Engineers, Pakistan. Elected Vice President Britannia Alumni Association of Pakistan (BAAP) and life Member Old Uetians Association.

Ever since Mr. Ahmad came into the fold of Congress in 1991, he actively participated and made untiring efforts in uplifting of and promotion of the Congress. He served Congress as Treasurer, Business Manager and contributed in its various committees, such as, Public Relations, Welfare of Engineers, Symposium Professional Activities, Library and Publications, Constitution and Bye-laws, Building and Fund Raising, apart from convening Membership, Administration and Finance Committees. He was also elected as Vice President of the Congress during the 70th Session. Last but not the least, Mr. Husnain Ahmad is the ever youngest President of the Congress during 94 years history since its creation.

A view of the section of Executive Council of PEC in Meeting

WELFARE OF ENGINEERS

In keeping with the objective of the Pakistan Engineering Congress of promoting science, profession and practice of engineering, the executive Council of this August Body has Instituted 60 Nos. Scholarships for Graduate Level Engineering studies and 16 Nos. for Post-Graduate studies at Rs. 2,000/- per month each for the whole study period as under. The unique feature is that the numbers of scholarships tabled below are being increased appreciably from year-to-year.

GRADUATE LEVEL

Sr. No.	Name of University / Institute	Number of Scholarships
1	University of Engineering and Technology, Lahore	9
2	University of Engineering and Technology, Taxila	9
3	Baha-ud-Din Zakria University Multan College of Engineering and Technology	3
4	**Punjab University** Institution of Chemical Engineering and Technology, Punjab University New Campus, Lahore	3
5	National University of Sciences and Technology (NUST) Military College of Signals, Rawalpindi	3
6	NED University of Engineering and Technology, Karachi	6
7	Mehran University of Engineering and Technology, Karachi	6
8	Sir Syed University of Engineering and Technology, Karachi	3
9	Quaid-e-Awam University of Engineering and Technology, Nawabshah	3
10	NWFP University of Engineering and Technology, Peshawar	6
11	GIK Institute of Science and Technology Topi (Swat)	3
12	Balochistan University of Engineering and Technology, Khuzdar	3
13	Ali Ahmad Shah University of Engineering and Technology, (Mirpur) AJK	3
	Grand Total	**60**

POST-GRADUATE LEVEL

Sr. No.	Name of University / Institute	Number of Scholarships
14	University of Engineering and Technology, Lahore	5
15	NWFP University of Engineering and Technology, Peshawar	2
16	University of Engineering and Technology, Taxila	4
17	NED University of Engineering and Technology, Karachi	2
18	Mehran University of Engineering and Technology, (Jamshoro)	2
19	Balochistan University of Engineering and Technology, Khuzdar	1
	Grand Total	**16**

- The Congress is also awarding Scholarships for the Education of the Children of deceased Engineers facing financial hardships. The amount of scholarship is Rs. 2,000/- per child capped at Rs. 5,000/- per month depending upon the pecuniary conditions of the families of departed Engineers.

- The Congress has given a donation of Rs. 5 Lac towards the fund for Liver Transplant in China of Engr. Capt (R) Latafat Qaseem Executive Engineer, of Irrigation and Power Department Govt. of the Punjab. He is suffering from Liver Cancer and Transplant Facility available in China is by far most economical.

- The Multi-purposes Mashhadi Hall (i.e. Auditorium) of the Congress located at 4th Floor of its Building named after Past President Engr. Syed Nazar Hussain Mashhadi in recognition of his services to the Engineering Congress is undergoing renovation / alternation to be able to cater for all its activities in it. It is being propely carpeted, Air Conditioned and equipped with multi-Media / LDC etc.

- The Congress has extensive Programme for holding Lectures on current issues concerning Engineers / Engineering Profession.

NATIONAL TRADE CORRIDOR IN THE REGIONAL AND GLOBAL CONTEXT

Dr. Engr. Asad Ali Shah, Member Infrastructure and Energy Planning Commission, Govt. of Pakistan delivered lecture on "National Trade Corridor in the Regional and Global Context" at Pakistan Engineering Congress Headquarter on February 17, 2007. The lecture was largely attended in the jam packed Multi-purpose Hall of the Congress.

The learned speaker eloquently spoke on the concept of National Trade Corridor / its objectives.

He said that performance of the transport system in Pakistan has not been up to the mark with economic losses from congestion and poor quality roads and mismatch between supply and demand for transport services and supporting infrastructure. The logistic constraints are impact competitiveness of the country's trade and industrial development. The conventional system, documentation clearance, movement facilitation and electronic data interchange has yet to be modernized to international levels. These inefficiencies are resulting in increasing the cost of business. Constraining economic growth, reducing export competitiveness, and hindering social development. It is estimated that these inefficiencies are imposing a cost to the economy in excess of Rs. 220 billion annually or 3.5% of the GDP.

He added that in order to cope with the situation, a major initiative namely the "National Trade Corridor (NTC)" has launched to address the entire logistics chain in a holistic manner and revamp transport sector including ports and shipping, roads, railway, trucking, aviation and trade facilitative measures. The NTC initiative is in line with Medium Term Development Framework (MTDF 2005) strategy, which includes establishment of a multi-modal transport system ; emphasis on as management with consolidation upgrading, rehabilitation and maintenance of the existing system enhanced private sector participation in sector development and institution capacity building research and development and use of modern technology, procedures and processes to increase efficiency. The strategy also incorporates measures for enhancing regional connectivity through road, aviation and shipping sub-sectors to improve North-South and East-West trade

Dr. Engr. Asad Ali Shah delivering the lecture

Section of the audience listening to Engr. Asad Ali Shah links with Central Asian States, Iran, Afghanistan, India and Europe and development of energy and industrial corridors with these countries.

Talking about the objectives of establishment of NTCMU and TTFU, he said that the objective of the Project is to provide overall technical leadership and coordination with line ministries and other organizations in undertaking measures / reforms project to improve the logistics system that would lead to reducing the cost to trade and business in the country. Focusing on improving the infrastructure sector, services and streamline procedures, the proposed NTC and TTF components will :

1. Enable institutions of the infrastructure sector conduct project and studies and project preparation activities in a timely manner and in line with international standards and best practices.

2. Ensure implementation readiness of the infrastructure projects.

3. Improve institutional capacities within the infrastructure agencies to meet business management and process changes as required by recent sector policies, reforms regulatory agencies.

4. Work with the private sector to improve in-house logistics.

He went on to say that the technical assistance will further enhance the internal capacity of infrastructure agencies develop a project program and implement identified projects successfully. The proposed steps will ultimately build intellectual leadership and also enhance the productivity of all those involved in Trade and Transport Facilitation.

He concluded that the crux of the talk was that with gigantic modernization of Ports, Roads, and Railway Net-Work Road and Freight Industry, State of Art Air-Terminals, Media and Communication expansion, under the "Trade and Transport Facilities Project" will usher in an economic revolution (in a period of 5 Years) in the country with "Gawadar" playing a pivotal Role. According to the speaker "Gawadar" will be one of the most advanced city of the World in a decade and a hub of economic development. A film on Gawadar was also shown.

The session was followed by questions from the audience which were elaborately answered by the speaker.

TARGETS SET FOR ACHIEVEMENT IN THE 2ND MEETING OF THE 71TH SESSION OF THE EXECUTIVE COUNCIL

President PEC, informed the House, that he would greatly appreciate the In-Put of the members of Executive Council in respect the cardinal goals that ought to be achieved in 71th Session to make the Congress a progressive and vibrant organization. Engr. Iftikhar-ul-Haq suggested that all members of the Congress may be invited to convey their proposals in this respect.

Elaborating his vision for 71th Session, the President outlined some of the major objectives i.e.

- Membership Committee should embark on a well-planned programme to visit Chief Engineers / Administrative Heads of various engineering departments / organizations and Faculty Members of Engineering Universities with the twin purpose of (a) introducing the congress and (b) increasing the Congress Membership.

- Building Committee may prepare a "Short Term" and a "Long Term" plan of maintenance / construction activities i.e. construction of Additional Block Cum Parking Lot in the existing premises (if feasible) or alternatively acquire additional Space / Building etc. for future use.

HONORARIUM TO CONGRESS STAFF AS WELL AS OTHERS WHO WORKED DURING THE LAST ANNUAL SESSION WAS GRANTED AS UNDER IN RECOGNITION OF THEIR SERVICES TO THE PAKISTAN ENGINEERING CONGRESS

Congress Personnel	Rs. 69200
Computer College Personnel of PEC	Rs. 10000
Personnel of NDC (Regd.)	Rs. 22000
Others for Receiving Congress Subscription / Election Duty etc. during the Session	Rs. 23500

WELCOME TO NEW MEMBERS

The Executive Council of the Pakistan Engineering Congress approved Membership of the following new members in to the Congress fold. The Engineering News congratulates all of them and welcomes them to Pakistan Engineering Congress

Members admitted on 08-04-2006

1 Engr. Zia ul Hassan Khan
2 Engr. Muhammad Atif ur Rehman
3 Engr. Danish Rafique
4 Engr. Luqman Zaffar
5 Engr. Muhammad Shafqat Khalid
6 Engr. Mashood Ahmed
7 Engr Muhammad Riaz Zahid
8 Engr. Mian Nadir Qayyum
9 Engr. Hafiz Muhammad Ramzan
10 Engr. Intizar Ali
11 Engr. Irfan Ullah
12 Engr. Roshan Ali Bhatti
13 Engr. Khurshid Ahmad Mirza
14 Engr. Naveed Abbas

Members admitted on 20-05-2006

1 Engr. Muhammad Usman Rashid
2 Engr. Muhammad Shahzad
3 Engr. Shafiq Ahmad
4 Engr. Asif Hayat Bhatti
5 Engr. Zameer Hussain
6 Engr. Muhammad Tayyab Ahmad
7 Engr. Muhammad Akbar Nawaz
8 Engr. Muzaffar Abbas
9 Engr. Atiq Ullah
10 Engr. Ali Jawaid Ghuman
11 Engr. Najamuddin Sheikh

Members admitted on 29-07-2006

1 Engr. Arif Saeed
2 Engr. Mian Babar Qayum
3 Engr. Muhammad Saeed
4 Engr. Muhammad Hamid Mahmood
5 Engr. Shahzad Ahmad
6 Engr. Muhammad Asif
7 Engr. Naseer Ahmad Zia
8 Engr. Arshad Saeed Khan
9 Engr. Aamir Miandad
10 Engr. Nisar Ahmad
11 Engr. Muhammad Yasir Malik
12 Engr. Ch. Muhammad Nadeem
13 Engr. Muhammad Kashif Khan
14 Engr. Syed Abid Ali Abid
15 Engr. Qasim Haq
16 Engr. Muhammad Ashraf
17 Engr. Hafiz Waqas Haider Shah
18 Engr. Imran Ghani
19 Engr. Asrif Masood
20 Engr. Syed Fayyaz Hussain
21 Engr. Amir Nadeem
22 Engr. Muhammad Zaman Khan Dawer

Members admitted on 21-10-2006

1 Engr. Hafiz Faisal Hassan Abid
2 Engr. Abdul Qayyum
3 Engr. Syed Muhammad Zaier Abbass Zaidi
4 Engr. Muhammad Farooq Azam
5 Engr. Zeeshan Ali
6 Engr. Usman Arif
7 Engr. Aataf Ahmed
8 Engr. Babar Saeed Sehole
9 Engr. Muhammad Hafeez Khan
10 Engr. Tanveer Afzal
11 Engr. Syed Farrukh Ali Shah
12 Engr. Muhammad Asjad Ajfan
13 Engr. Muhammad Shahbaz
14 Engr. Faiz-ul-Hassan Sipra
15 Engr. Hassan Mohy-ud-Din

Members admitted on 20-01-2007 (71st Session)

1 Engr. Asif Mahmood
2 Engr. Muhammad Afzal Mughal
3 Engr. Jahanzeb Afridi
4 Engr. Bilal Ahmed
5 Engr. Muhammad Imran
6 Engr. Muhammad Aamir Iftikhar
7 Engr. Sh. Saeed Ahmad
8 Engr. Nabil Haider
9 Engr. Anzar Hussain Shah
10 Engr. Aun Muhammad
11 Engr. Ch. Rashid Majeed
12 Engr. Muhammad Saleem Shahid
13 Engr. Muhammad Zubair Asghar
14 Engr. Imran Sadiq Afridi
15 Engr. Muhammad Mudassar Ali
16 Engr. Abdul Qayyum
17 Engr. Muhammad Imran Malik
18 Engr. Imran Rashid
19 Engr. Faisal Shoukat
20 Engr. Shahid Mahmood
21 Engr. Muhammad Arshad
22 Engr. Kashif Nadeem
23 Engr. Zahid Majeed
24 Engr. Ijaz Ahmad Bhatti
25 Engr. Mahmood Ahmad
26 Engr. Aqil Inam
27 Engr. Aftab Ahmad Chaudhry
28 Engr. Syed Salman Mazhar
29 Engr. Hafiz Haider Ali
30 Engr. Syed Muhammad Sajjad Hashmi
31 Engr. Muhammad Afzal
32 Engr. Arshad Chaudhry
33 Engr. Abdul Majeed Naveed
34 Engr. Atif Ameen Awan
35 Engr. Muhammad Abu Bakr Khan Sherwani
36 Engr. Muhammad Umar Farooq
37 Engr. Muhammad Zaka Ullah Khan
38 Engr. Muhammad Akram
39 Engr. Muhammad Bilal Ahmad
40 Engr. Umar Karim
41 Engr. Muhammad Shahbaz Rasheed
42 Engr. Shoaib Ahmed Awan
43 Engr. Ali Mukhtar

OBITUARIES

May their souls rest in Peace

1. Engr. Khalid Latif Khawaja (Past President of the Congress) passed away on 2.12.2006.
2. Ch. Muhammad Aslam Khan Brother of Engr. Ch. Muhammad Rashid Khan Vice President and Past President of Congress.
3. Engr. Maqbool Ahmad Siddiq (R) Deputy Chief Engineer Railways passed away on 15.12.2006.
4. Mother of Engr. Atiqu-ur-Rehman Addl Director NAB and Member of Executive Council of Pakistan Engineering Congress.
5. Engr. Syed Munawar Ali.
6. Mr. Ghulam Ahmad Father of Engr. Ijaz Ahmad Cheema, Member of Executive Council.
7. Engr. Malik M. A. Ahad Khan passed away on 13.1.2007.
8. Engr. Javed Ahmad, Director WASA
9. Engr. Abdur Rashid Khan, XEN WASA

DEVELOPMENT OF ALUMINIUM MATRIX COMPOSITES USING CARBON FIBER

By

Dr. Liaqat Ali[1], Dr. Gul Hameed Awan[2], Dr. Khalid Mahmood Ghauri[3] and Engr. Zeeshan[4]

ABSTRACT

Aluminium matrix composites (AMCs) possess high temperature capability, high thermal conductivity, low coefficient of thermal expansion, and high specific stiffness and strength, AMCs are candidate materials for aerospace, automotive, [2]electronics and commercial/industrial applications. Continuous fiber reinforced aluminium composites have unique properties which make them suitable for use in critical space applications, for instance, satellite applications. Current applications include structural members in the space shuttle cargo bay, a multi-functional antenna mast/signal waveguide in the hubble space telescope and electronic packaging for communication satellites in low earth orbit.

A detailed study of production and evaluation of properties of carbon fiber reinforced aluminium composites has been carried out along with preliminary experiments and observations. In this regard two processing routes have been adopted which include sand casting and pressure die casting. AMCs developed have been evaluated in terms of mechanical, chemical and metallurgical characterization. Results obtained are discussed in the light of information available in the literature. Evaluation of the AMCs developed is in good agreement with the already published research wok.

Review articles scanned on AMCs have given indications for future research and development in areas such as bonding, interphase formation, surface treatment, and modeling and simulation.

INTRODUCTION

Aluminum matrix composites (AMCs) refer to the class of light weight high performance aluminum centric material systems. AMCs are type of metal matrix composites (MMCs) in which one of the constituent is aluminum/aluminum alloy which forms percolating network and is termed as matrix phase. The other constituent is embedded in aluminium/aluminium alloy and serves as reinforcement, which is usually non-metallic and commonly ceramic such as carbon, SiC and Al_2O_3. Properties of AMCs can be tailored by varying the nature of constituents and their volume fraction. Aluminium and its alloys are quite attractive for matrix material because of:

- Low density
- Capability to be strengthened by precipitation
- Good corrosion resistance
- High thermal and electrical conductivity
- Availability as per intended application.

Currently research interests on the use of carbon fiber as reinforcement in both MMCs and polymer matrix composites (PMCs) has been growing. Metal matrix composites (MMCs) are advanced engineering materials in which tailored properties are achieved. As current functional materials reach their performance limits, designers are looking towards MMCs to

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1, 2, 3 and 4 Department of Metallurgical & Materials Engineering, University of Engineering & Technology, Lahore.

provide extra strength, stiffness and higher temperature capabilities, required for advanced applications [1-4].

Aluminium carbon composites can be processed via casting routes due to compatibility of carbon with molten aluminium. The choice of process is dictated by the final product form. Casting processes enable the fabrication of relatively low-cost, high-performance composites when compared to metal matrix composites made by other methods such as diffusion bonding, physical vapour deposition, or chemical vapour deposition [5-6].

Criteria for Matrix Selection in Continuous Fiber AMCs

Traditionally fabrication of continuous fiber aluminium matrix composites has been carried out using high strength fibers and high strength matrices, often commercial alloys, with the goal of producing high strength composites. However the specific role of the choice of matrix alloy on composite properties has not been well established. One way to control composite tensile strength is to use coatings to introduce a low strength interface between fiber and matrix which tends to reduce the importance of the matrix selection, but unfortunately renders the transverse strength unacceptably low. Thus using a system with strong bonding between fiber and matrix is desirable. The key attributes are matrix constituent phases, alloy chemistry, alloy reactivity with the fiber, and matrix strength [7].

EXPERIMENTAL WORK

Materials:

The materials employed to carry out trial runs in order to qualitatively validate the findings in the present work on AMCs are summarized in Table-1. The fiber was delivered as 1K-tow and woven fabric.

Manufacturing techniques:

Two processing techniques, sand casting and pressure die casting were adopted to check the validity and compatibility of carbon fibers with aluminium. Unidirectional carbon fibers shown in Fig-1 were reinforced in aluminium. Melting of aluminium was carried out in pit furnace.

Pressure die casting is a quick and accurate and offers reliable, results and properties. Process parameter includes pressure of 250-300 Kg/cm^2, solidification time of 7-8 seconds and die temperature of 200°C. The carbon fiber was used as preform shown in Figure 2 and made to be unidirectional in array and in two dimensional.

Tensile test:

Tensile specimens were prepared from the unreinforced alloy and the composite with carbon fiber oriented parallel to the tensile axes direction and two dimensional woven fabric composite. The specimens were machined as according ASM D3039 specification as shown in the Figures 3 & 4. Tensile test were carried out using Shimadzu DCS testing machine with a 5 KN load cell at the cross-head speed of 2 mm/min at room temperature.

Metallography:

Optical and scanning electron microscope (SEM) were used to examine the micro structure of the AMCs specimens. Metallographic samples were prepared using standard techniques. Optical microscopy was used to reveal the micro structural features and the distribution of the carbon fibers. The SEM was employed to characterize fractured surfaces of the tensile test specimens.

RESULTS AND DISCUSSION

Development of AMCs: Development of the AMCs was carried out using two liquid metallurgy techniques i.e., sand casting and pressure die casting as given in Figures 5(a) & (b). The Figure captioned sand cast tensile specimens of carbon fiber-aluminium matrix composites revealed the information given below:

- There is an incomplete infiltration of aluminium into the fibers.
- There is no sign of melting of fibers with aluminium.
- From the figure it is clearly indicated that fibers are not properly embedded in aluminium matrix.

The results of AMCs obtained from pressure die casting are given in Figure-6 captioned as "Pressure die cast parts of woven and unidirectional carbon fiber reinforced aluminium (LM6) matrix composites (a,b), composite tensile specimen for mechanical test (c)".

Die cast specimens clearly exhibit complete infiltration or penetration of aluminium into the carbon fiber performs. Though woven fabric composite specimen was not sound but it exhibited that process adopted was adequate for the development of AMCs. The important parameter, which controls the infiltration i.e., pressure of die casting machine is the only parameter which not only helps in embedding but also helps in wetting the carbon fibers.

EVALUATION OF AMCS

Mechanical Evaluation of AMCs:

The findings of mechanical evaluation of AMCs are summarized in Table-2. The pictorial and graphical representation of the tested tensile specimens is given in Fig.6 and 7. From the graphs obtained it can clearly be seen that breaking strength of unidirectional composite is more than un-reinforced aluminium and woven fabric composite.

Micro-structural Analysis:

Figure 8 shows optical micrographs of the specimen containing Al-10 vol% carbon fiber (C_f) in longitudinal direction. It can clearly be observed that there is full infiltration of molten aluminium alloy. The fibers are evenly distributed with a volume fraction of 10 vol% in the aluminium matrix alloy and there is no sign of fiber clustering or residual porosity. The fiber matrix interface is smooth with no discontinuities observed even at higher magnification.

Fractography Analysis:

Figure 9(a) shows SEM micrographs of the fracture surface of the reinforced Al-matrix alloy (LM 6). The fracture surface exhibits a predominantly transgranular rupture with dimples and shear deformation. The specimen shows evidence of having plastic deformation during cracking consistent with high ductility [Fig.9 (b)]. However the composite exhibited limited ductility on a macroscopic scale with fracture essentially normal to the loading axis. Figure 9(c) is an overview of the C_f-Al composite fractured surface at low magnification. It can be clearly seen that the fractured surface is flat with evident pullout of carbon fibers. Figure 9(d) reveals a fiber-matrix interface debonding after tensile failure, but most of the fiber-matrix interfaces still remain bonded. Also matrix adherences to the fibers in some locations due to the high ductility of the matrix alloy can be noted. Figure 9(d) depicts that in the transverse direction fibers are well embedded and adhere to the matrix.

Three possible types of fracture behaviour in composites have been reported by Lloyd et al [8]. If the reinforcement-matrix interface is weak, the crack will initiate and then propagate through the interface. If the interface is strong, together with a strong matrix, the reinforcement will be loaded to their fracture stress and cracked. In the case that the matrix is weak relative to the interfacial and reinforcement strengths, the fracture will occur in the matrix by normal void nucleation and growth. However, in real composites, a complex fracture process may result. Based on the above, the fracture mechanism operative in the present composite can be suggested as shown in Figure 10. The fracture of composite started at the relatively weak aluminium alloy matrix, in comparison to the interfacial and fiber strengths, by normal void nucleation and growth Fig. 10(a). When the crack reaches the fiber-matrix interface due to the strong interfacial bonding, the fiber-matrix interface does not separate [Fig.10 (b)]. Therefore, a high concentration is formed at the interfaces; the carbon fibers were sheared after loading high strength and then the crack continues to propagate [Fig 10(c)].

CONCLUSIONS

Present research program was conducted to assess feasibility and compatibility of carbon fibers reinforced aluminum matrix composites (AMCs) in terms of manufacturing techniques, mechanical properties and micro structural analysis. The results are summarized as:

- Sand casting technique is not feasible for the production of carbon fiber reinforced aluminum composites because there is no pressure involved and no adequate wetting of carbon fibers with aluminum takes place.
- A pressure infiltration technique (pressure die casting) was used successfully to prepare a composite consisting of unidirectional and woven fabric carbon fibers in LM6 matrix.
- Compared to the unreinforced aluminum matrix, the composite exhibits significant increases in modulus and ultimate tensile strength, but the elongation to failure of the composite is considerably reduced.
- Properties of the composite may also be affected by the percentage and orientation of the carbon fiber in aluminum matrix.
- The microstructure of the composite produced exhibited a full infiltration of molten aluminum alloy and evenly distributed fibers. The fiber matrix interface is smooth with no evidence of discontinuities.

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	Carbon fiber	Pure aluminum	LM6
Type	Pitch	-	-
Filament count	1000	-	-
Yield mg/m	68	-	-
UTS (N/mm^2)	4700	55-110	280
Young's modulus (GPa)	235	62	71
Density (g/cm3)	1.80	2.7	2.65
Elongation %	2	-	2-5

*values of carbon fiber according to data sheet of supplier

Table-1: Constituent Properties

Properties (longitudinal)	**Sample#1 (unreinforced)**	**Sample#2 (unidirectional)**	**Sample#3 (woven fabric)**
Tensile strength (N/mm^2)	105	165	125
Modulus of elasticity (GPa)	71	102	80
Elongation (%)	5	2	3

Table-2: Results of the mechanical tests-as cast condition-carbon fiber Reinforced aluminum (LM6) composites

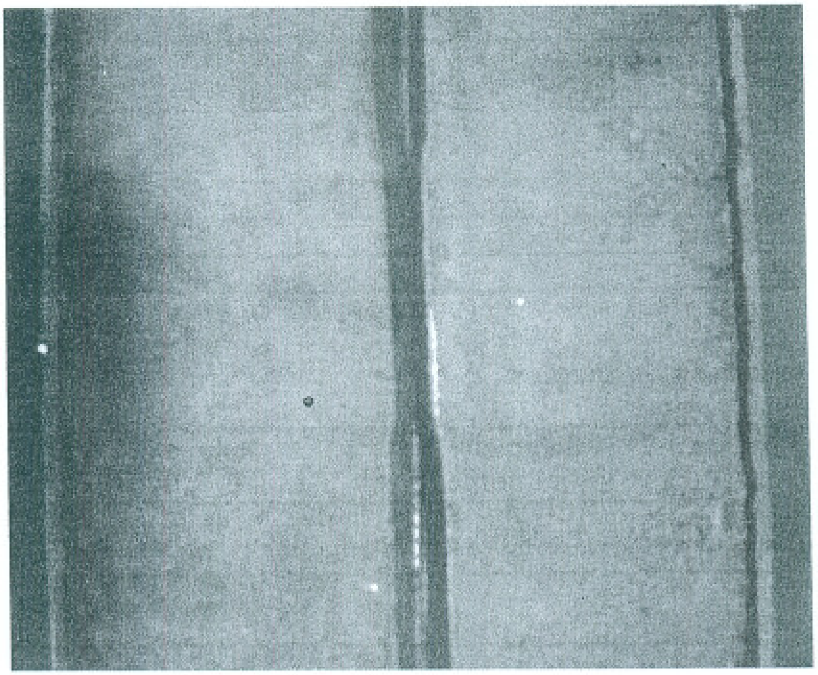


Fig-1: Holding of carbon fibers in the mold

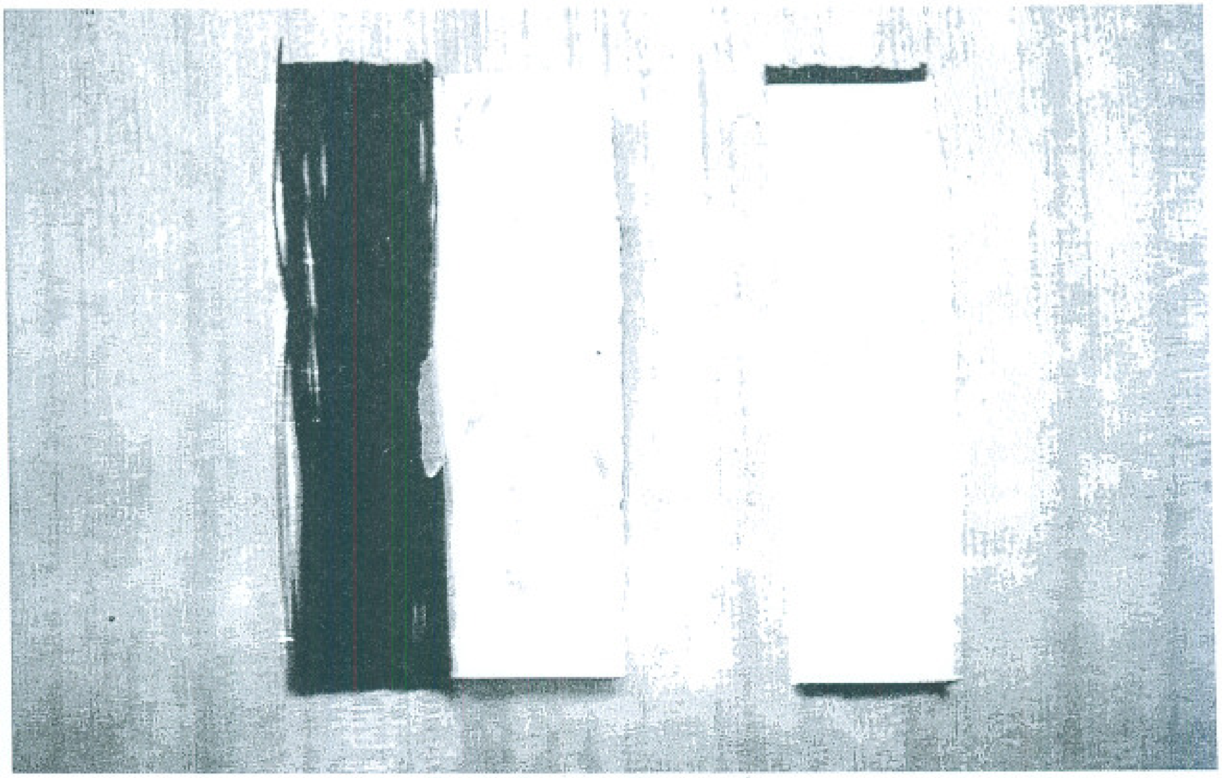


Fig-2: Carbon fiber perform

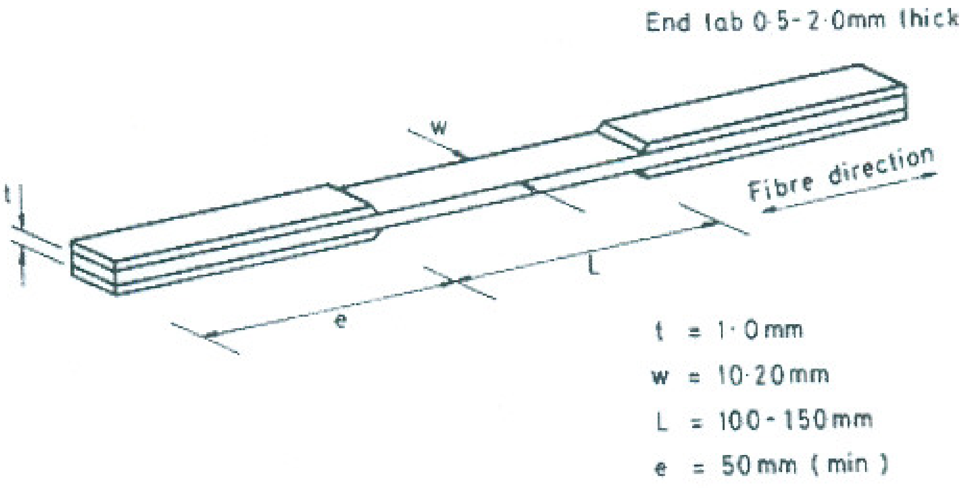


Fig-3: Typical tensile specimen used on tensile testing machine

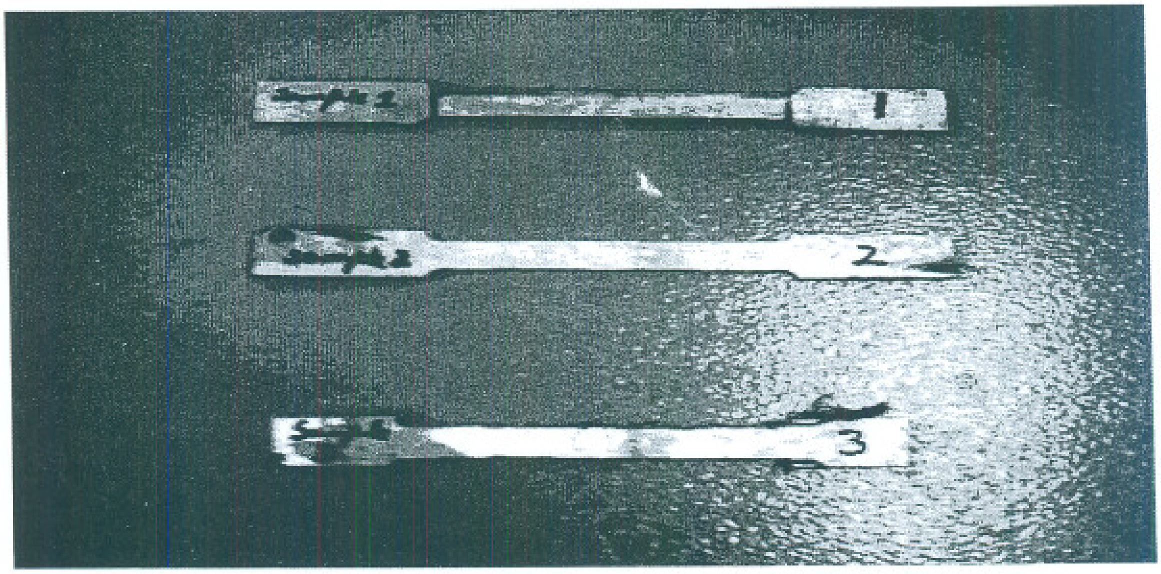
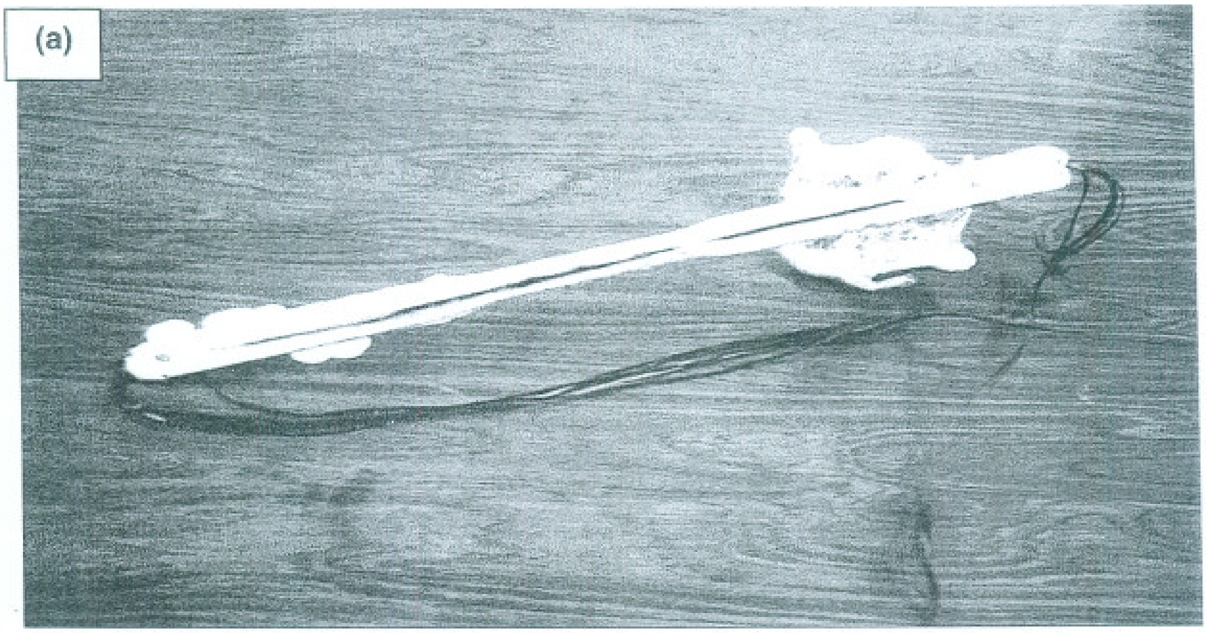


Fig-4: Machined samples for tensile testing



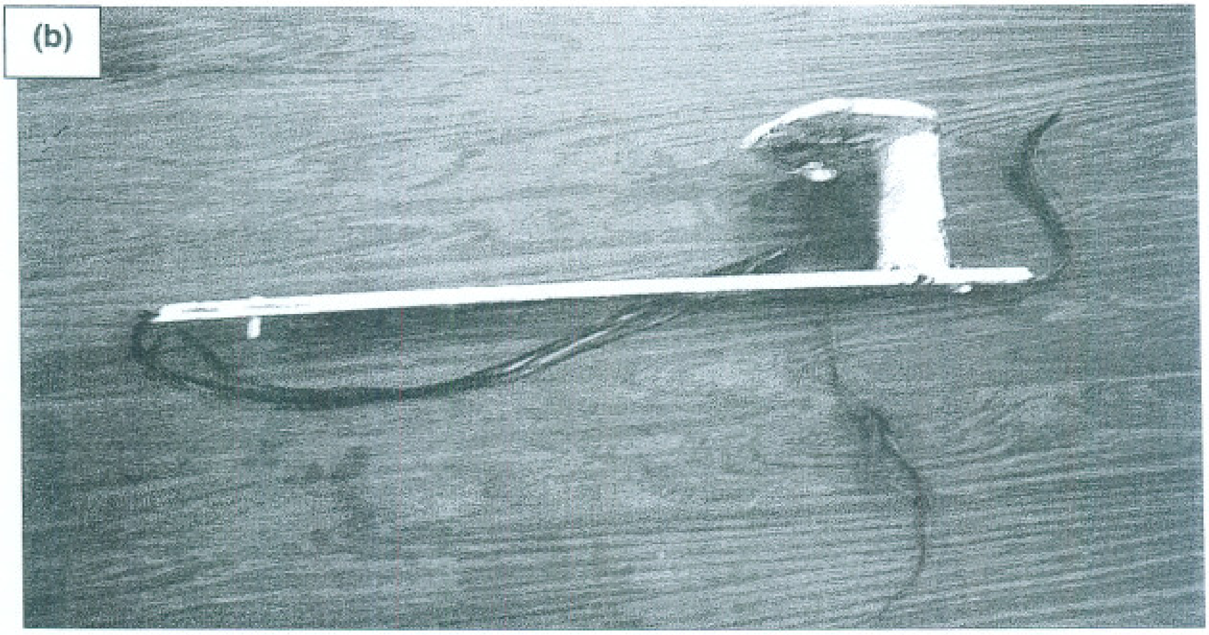


Fig-5: Sand cast tensile specimen of carbon fiber-aluminum matrix composites (a, b).

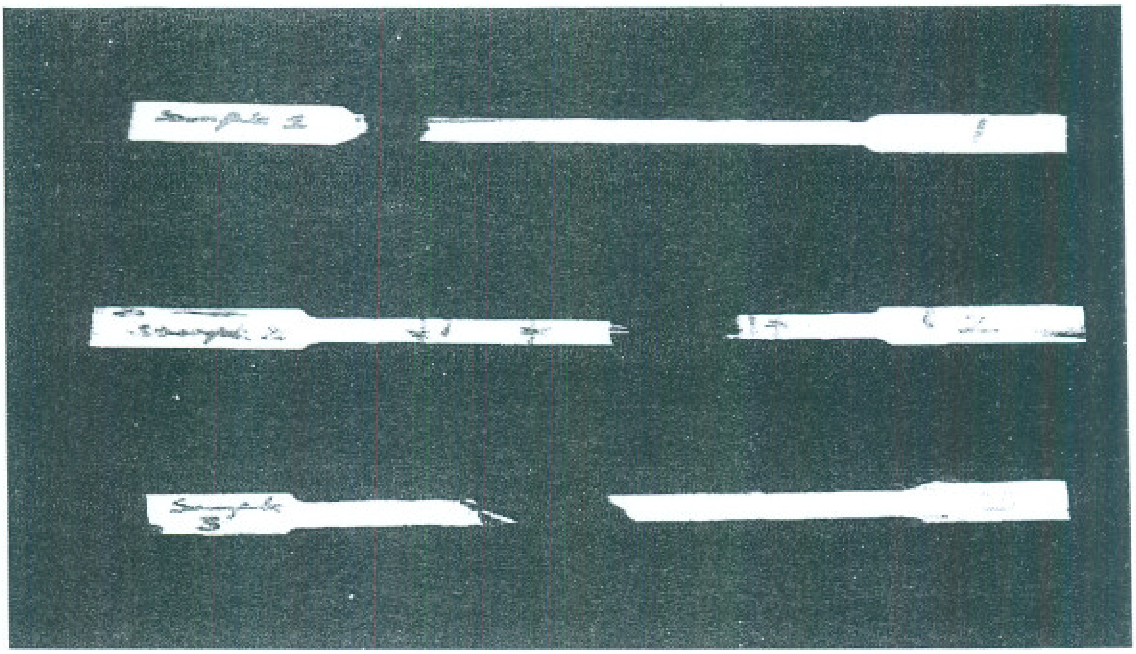


Fig-6: Tested tensile specimens (a) unreinforced aluminum (LM6), (b) unidirectional, and (c) woven fabric o carbon fiber reinforced aluminum matrix composite

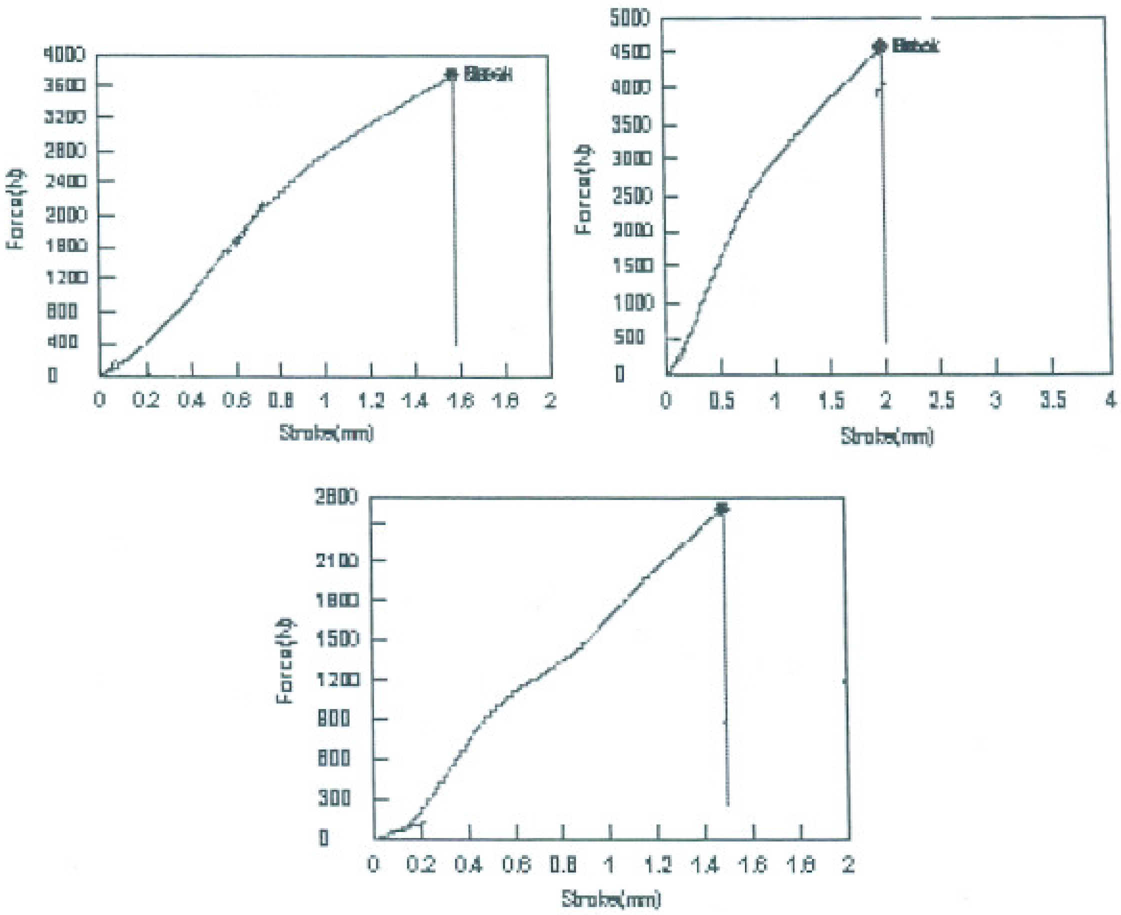


Fig-7: Force versus stroke curve of the tensile test of (a) un-reinforced aluminum; (b) unidirectional composite; (c) woven fabric composites.

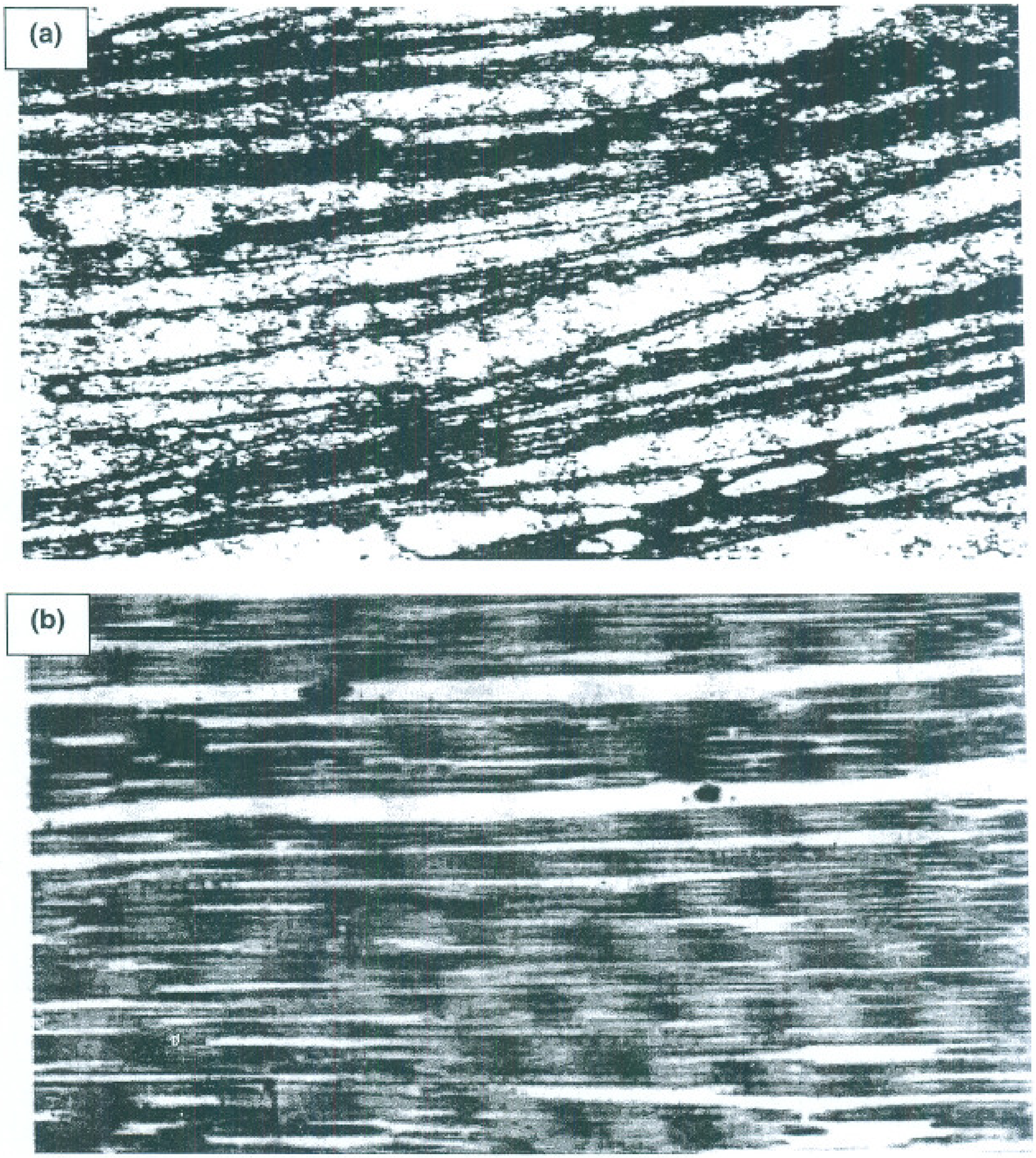
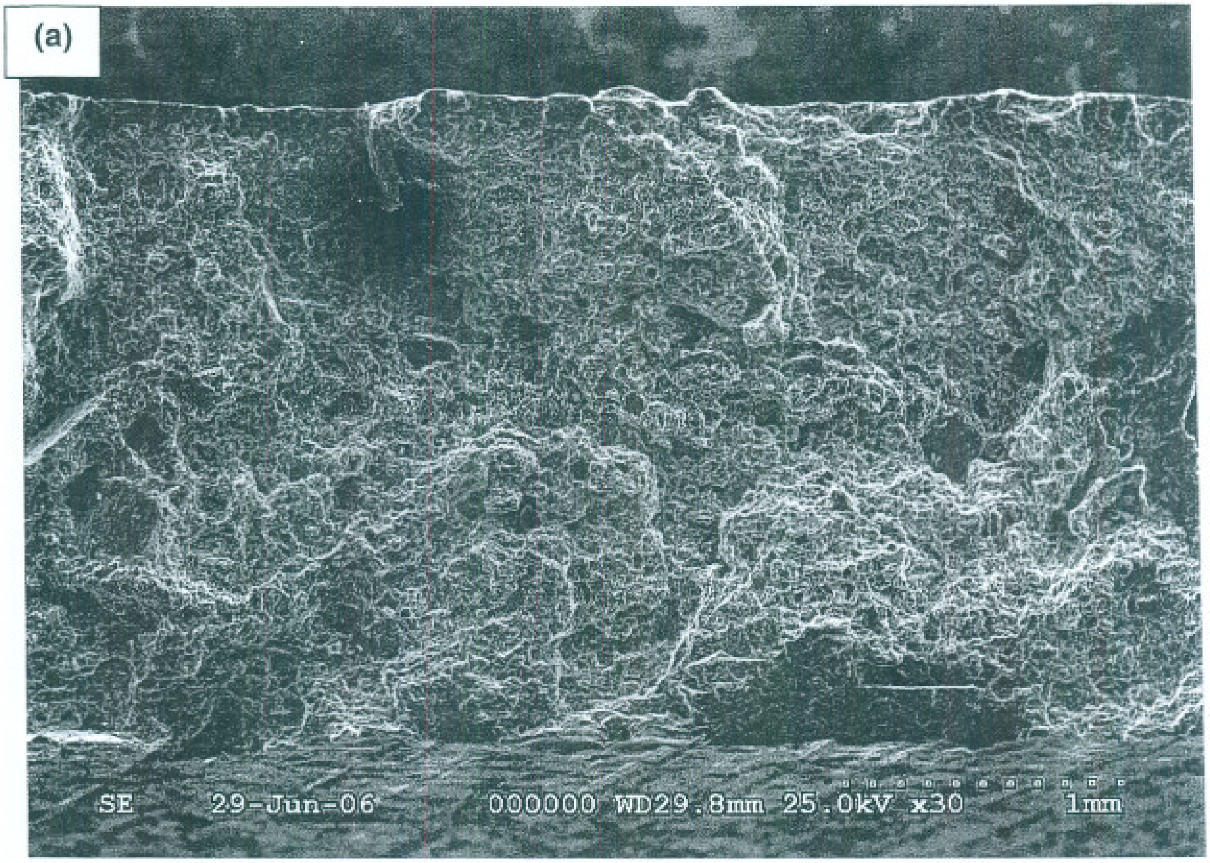
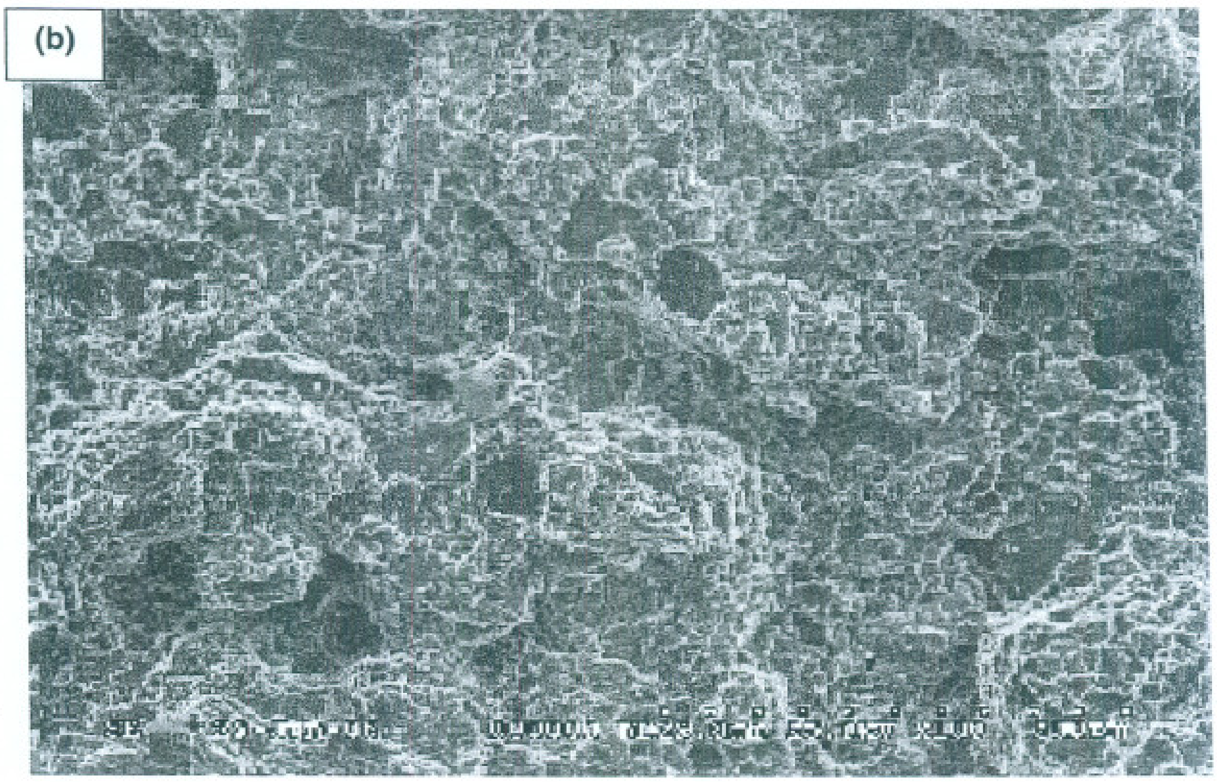


Fig-8: Optical micrographs of the microstructure of Al-10 vol% carbon fiber longitudinal direction (a,b)





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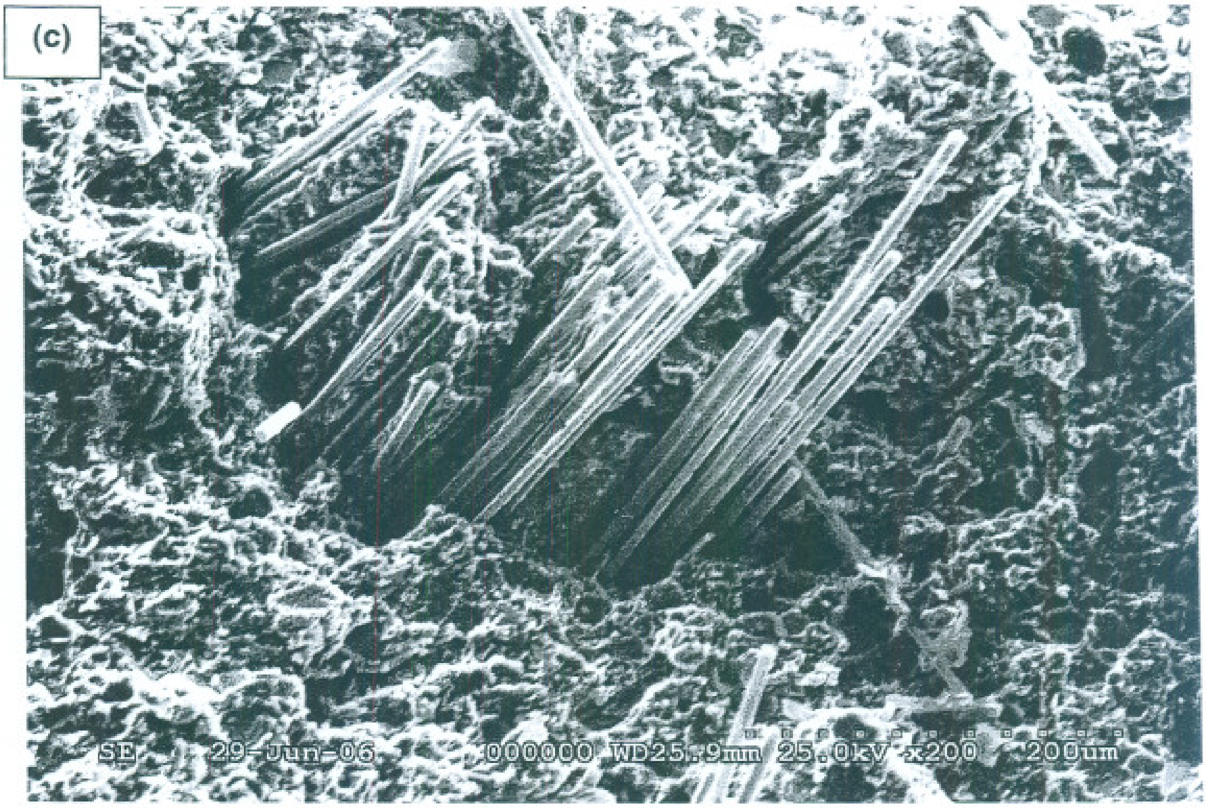

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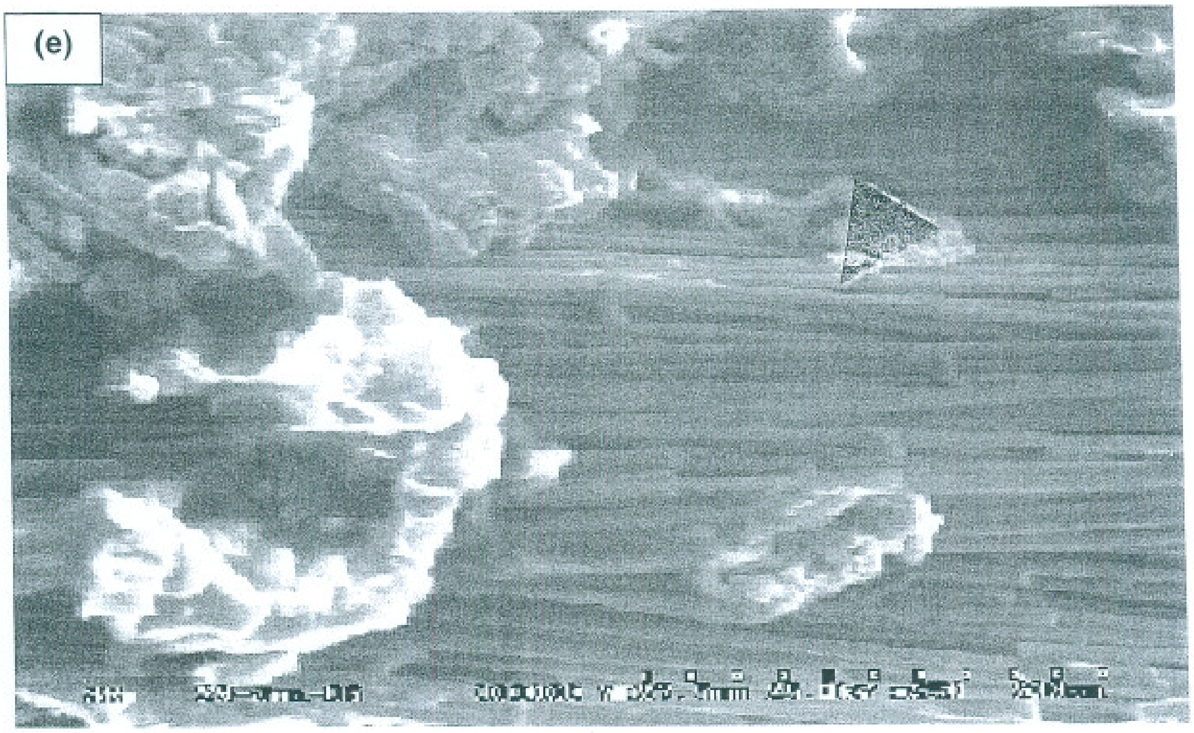

Fig-9: SEM micrographs of the fracture surface (d) of Al alloy (LM6) (a,b), and Al-10 vol% C_f composite (c,d),Al-10 vol% carbon fiber in transverse direction (e)

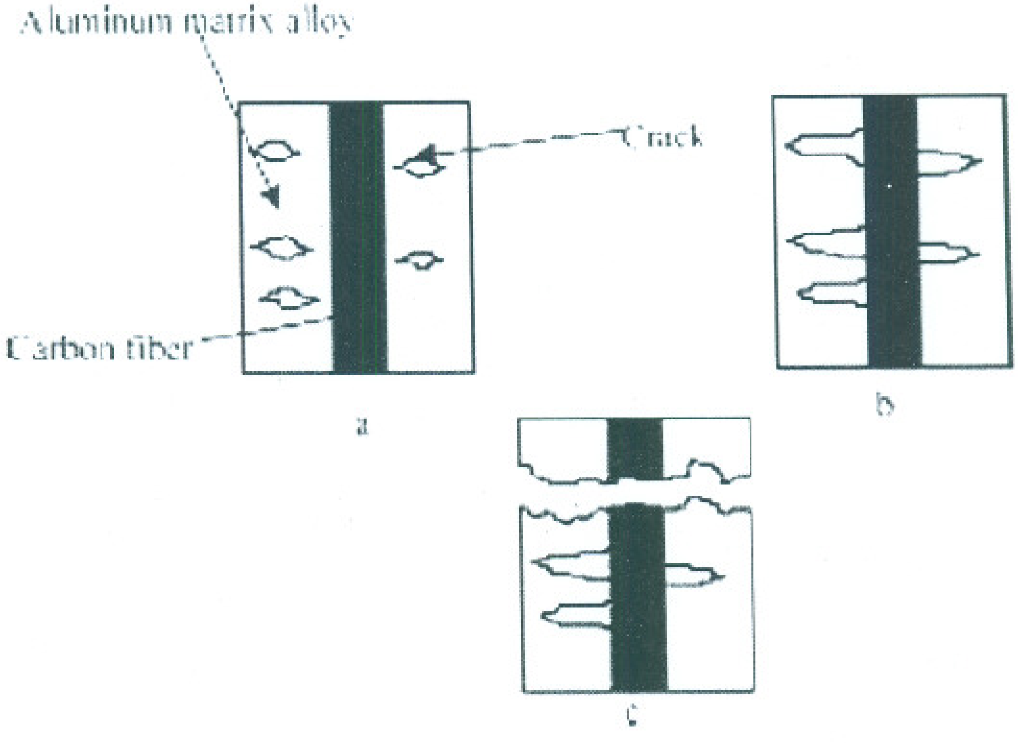

Fig-10: Schematic illustration showing the crack propagation in the composite: (a) crack initiation at the aluminum matrix alloy, (b) crack propagation into the aluminum matrix and interface and (c) Fracture of the fiber through the carbon fibre.

APPLICATIONS AND PROCESS TECHNOLOGY FOR THE FABRICATION OF CERAMICS

By

Dr. Khalid Mahmood Ghauri[1], Dr. Gul Hameed Awan[2] and Dr. Liaqat Ali[3]

Abstract

Present article discusses the applications and process technology for the fabrication of ceramics. To some people the term ceramics means dishes, porcelain figurines, and the like. For current review the term engineering ceramics will be used for the ceramics that were in use or being researched for industrial applications in 1994 and onwards.

Introduction

A ceramic can be defined as a combination of one or more metals with a non-metallic element. What really distinguishes a ceramic from other engineering materials, however, is the nature of the bond between atoms. Ceramics can be strengthened by adding elements, but the effect is usually not pronounced. They usually cannot be strengthened by cold working or precipitation hardening. Some ceramics can be strengthened by changes in crystal structure; for example hexagonal boron nitride is very soft and cubic boron nitride is very hard, but such cases are the exception rather than the rule. One of the latest strengthening practices for ceramics is the use of fiber reinforcement, that is, ceramic fibers (like silicon carbide) in a ceramic matrix [1-2].

Material selection is based on properties. The major categories to be considered in material selection are shown in Fig.1 [5]. Bricks and clay products are often madefrom natural clays. Clays are mostly composed of SiO_2 and Al_2O_3 ($Al_2O_3.4SiO_2.2H_2O$) and the bonding mechanism is usually week vander walls forces, an electrostatic attraction between neutral atoms in close proximity. The ceramics with the highest strength, the highest moduli, and the best toughness such as ZrO_2, Al_2O_3, SiC and Si_3N_4, have strong ionic or covalent bonds. In the 1980s these materials were sometimes called structural ceramics, engineering ceramics or advanced ceramics [3]. In the late 1980s, the Japanese made a national effort in this area, and they called ceramics used in engineering applications, fine ceramics [4]. In 1990, the ASTM Committee on Ceramics (C-28) advocated use of the term advanced ceramics. Their definition of this class of materials is "a highly engineered, high performance, predominantly non-metallic, inorganic, high value added object having unique or superior functional attributes". The spectrum of the things that can be construed to be ceramics is shown in Fig.2 [5]. The term engineering ceramics can be used for the ceramics that were in use or being researched and considered for industrial applications in 1994 [6]. As shown in Fig.3 [7], the fracture toughness of ceramics can be from one to two orders of magnitude lower than that of metals. Typical ceramics recommended for engineering design are summarized in Table-1 [7]. They can be classified as shown in the table as oxides, carbides, sulfides, nitrides, metalloids or intermetallics.

Process Technology for the Fabrication of Ceramics

Most of the shapes illustrated in Fig.2 require some type of high temperature firing in their fabrication [6]. Fig.4 [7] shows some abbreviated schematics of the manufacturing processes

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that are used for some of the materials which are covered in the scope of the present article [7]. The starting material for most ceramics and similar materials is some type of powder that must some how be glued together to make a solid. Some powders can be joined into a useful solid by simply fusing powder particles together by high temperature diffusion which is called sintering [8-9]. Other ceramic materials are made by glueing the powders together with glasses, which is known as vitrification. The first illustration in Fig.4 shows concrete products and finally the sol-gel process which is used to form a solid material gelation of one or more liquids and subsequently hardening of the gel [7]. The gel can then be fired to form ceramic shapes. This is an emerging technology, and in 1994 many industries were experimenting with these materials but with little successes. The scientific community will hear more of this technology for couple of more years [10,6].

There are illustrated two of the most important ceramic fabrication processes in Fig.5 [5]. Vitrification is most widely used in the making of abrasive wheels and other shapes. It is also used to make a machinable ceramics. The most widely used ceramic fabrication process is compaction and sintering. Many processes exist to form ceramics into shapes. Tubes, cylinders, long and simple shapes can be made by extrusion of a ceramic-binder mixture [8,9].

Small, intricate shapes can be made by injection molding of ceramic powders mixed with plastic binders. The binders are removed by thermal treatments. Dry processing of powders by single or double acting process is a low cost method for making simple shapes. Isostatic processing is used for large, complicated shapes [8-10].

Cemented carbide cermets are made by compaction techniques. The starting material for the carbide portion of the composite is usually fine tungsten powder. This is converted into tungsten carbide by controlled carburization. The tungsten carbide powder is ball milled with the cobalt or other binder metal to reduce the carbide particle size and to coat the carbide powder with the binder. The coated powder is then classified to the desired particle size range and it is hydrostatically compressed into billets or press compacted into parts. The compacted material is vacuum or hydrogen sintered into the cemented carbide composite. The steps involved in the fabrication of most cemented carbides are shown in Fig.6 [6].

Sialons and Ca-ceramics are candidate materials for many applications but for the refining of high nitrogen alloyed steels, they are the important systems to be investigated [11]. Research on Ca-ceramics has been patented by numerous researchers in United States and Europe and the same well be reviewed and published in a different articles in due course [12,15]. Nitrogen ceramics, such as these in the Si-O-N and Si-Al-O-N systems have been considered possessing significant potential as low and high temperature ceramics. In principle, any phase or combination of phases can be formed by nitriding process or carbothermal reduction as has been demonstrated by a number of workers [12-15]. The very same theme has been discussed by Thomson and Hendry in one of the articles on the formation of β'-sialon by carbothermal reduction of aluminosilicate [15]. Undoubtedly, any combination of minerals such as given in Table 2 and 3, can be used to produce sialon phases [16]. An example of this is seen in the reduction of mineral containing calcium and is shown in Fig.7 [15]. The phases which are at equilibrium at the completion of equilibration reaction can be predicted from the phase diagrams and are therefore stable phase combinations. Consideration of the overall scheme of reaction concerns the Si-Al-O-N-C system drawn as a Janecke Prism, and is shown in Fig.8 [15], which acts as guideline for the fabrication of sialons and Ca-ceramics [15,16]. All those fabrication processes reviewed earlier are applicable to sialon powders in order to manufacture them into different shapes.

Summary

There aré many ways of making ceramic types of materials, but the authors have reviewed the most common ones. Engineering ceramics that are made by these processes can be classified into oxides, carbides, sulfides, nitrides, metalloids, or intermetallics. Itermetallic compounds are compounds that are formed by the combination of two metals which will be reviewed elsewhere.

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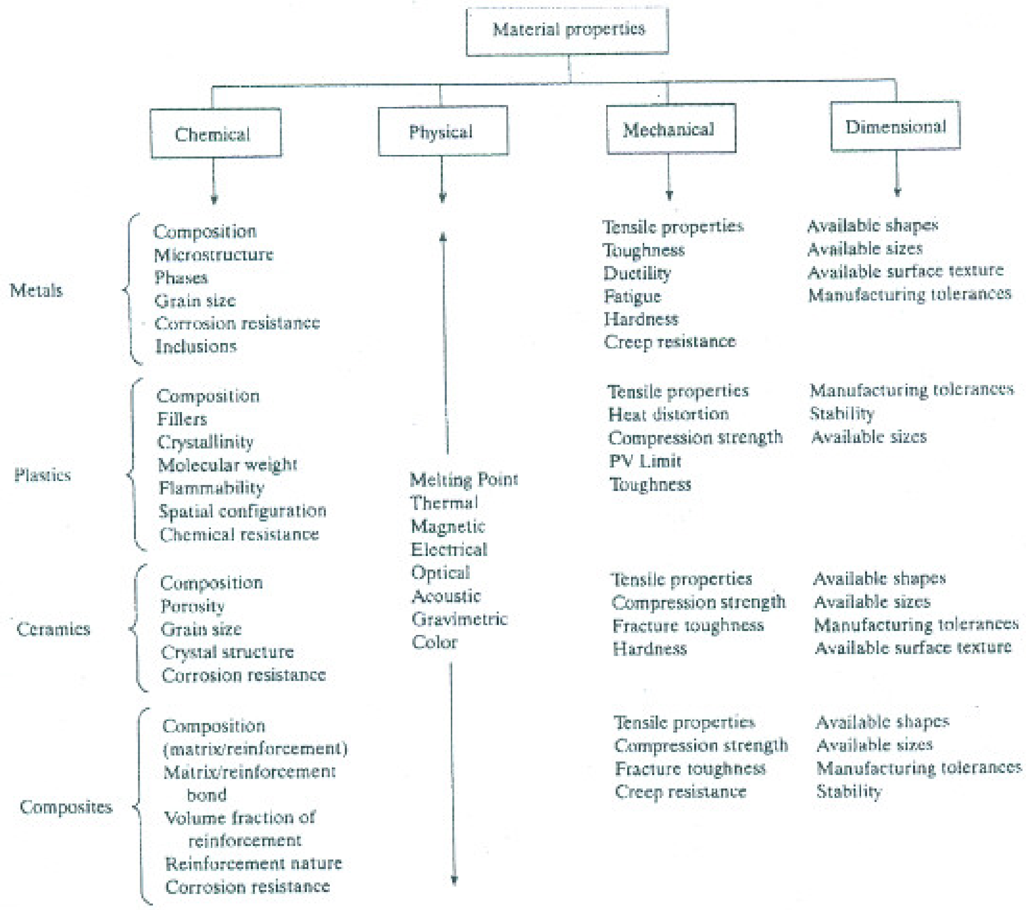

Fig-1: Spectrum of material properties and how they apply to various material systems (physical properties apply equally to all systems) [5]

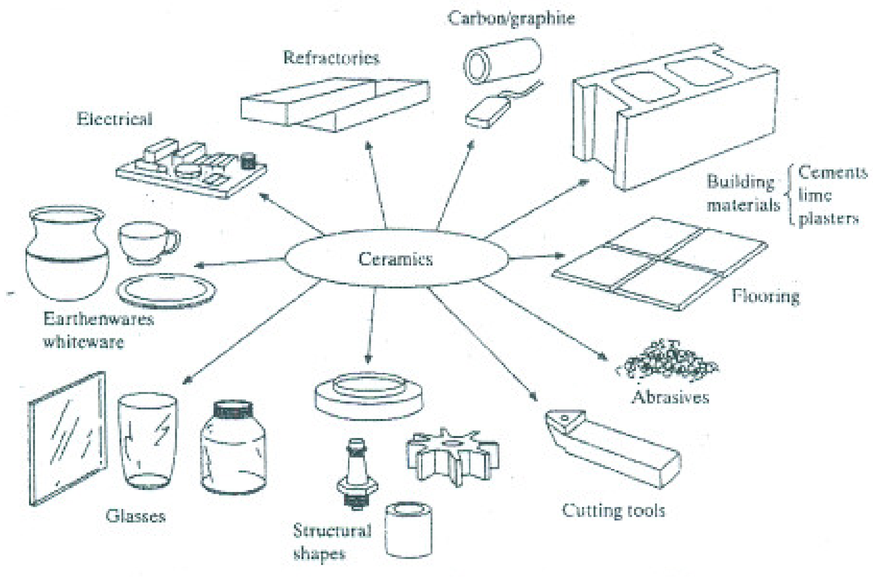

Fig-2: Spectrum of ceramic uses [6]

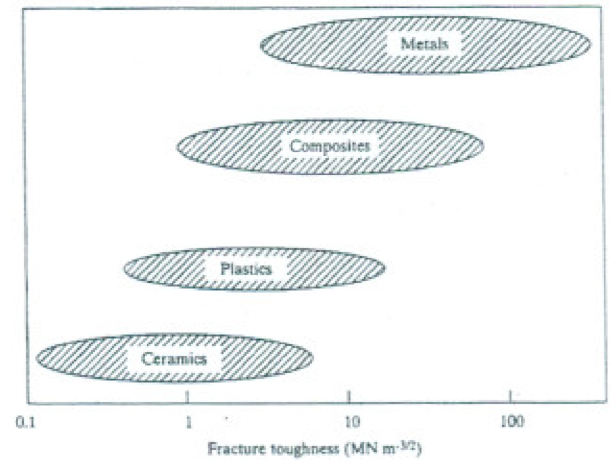

Fig-3: Relative fracture toughness of engineering materials [7]

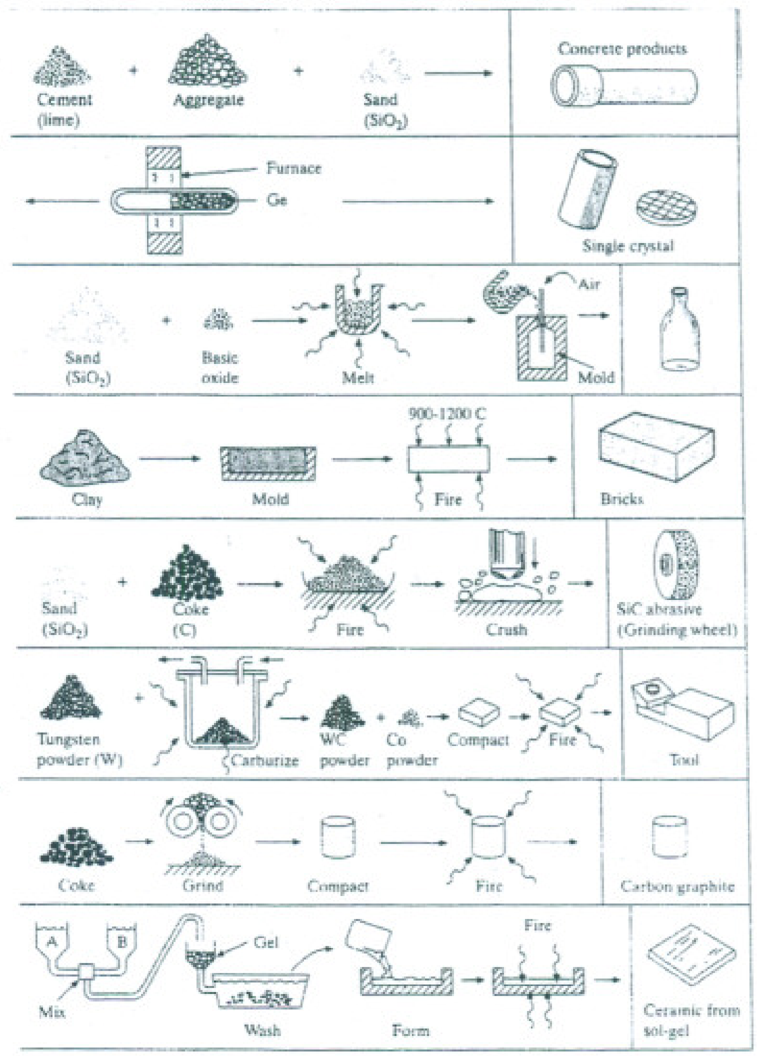

Fig-4: Some ceramic fabrication processes [7]

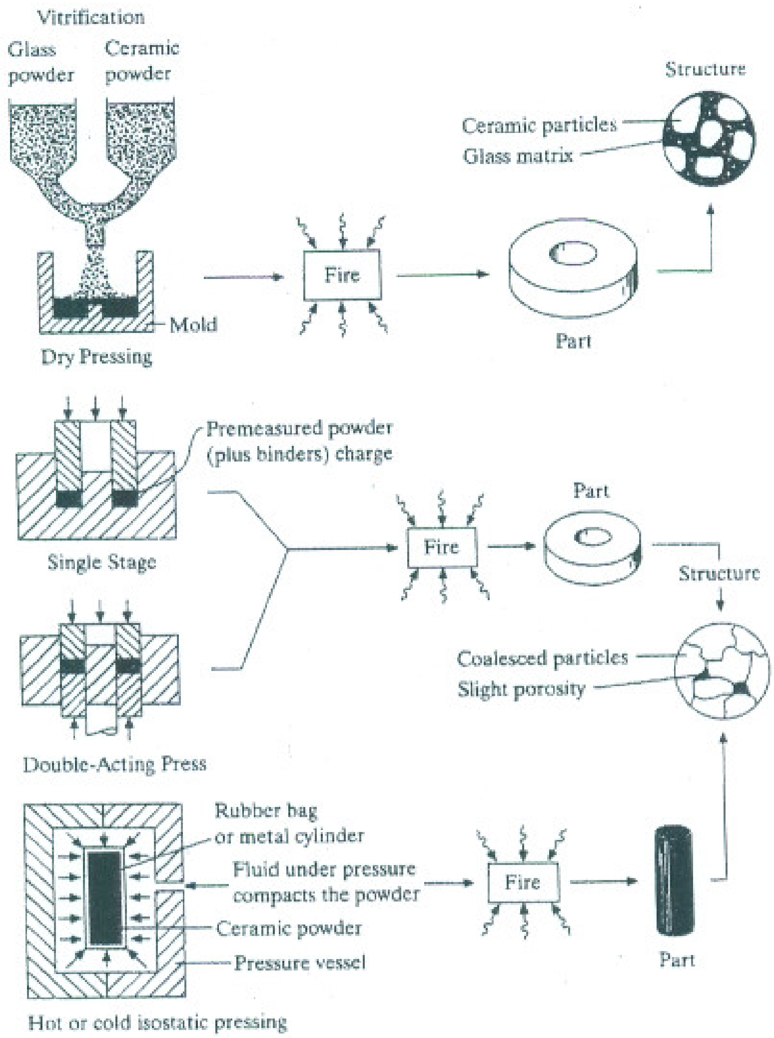

Fig-5: Fabrication of ceramic shapes [5]

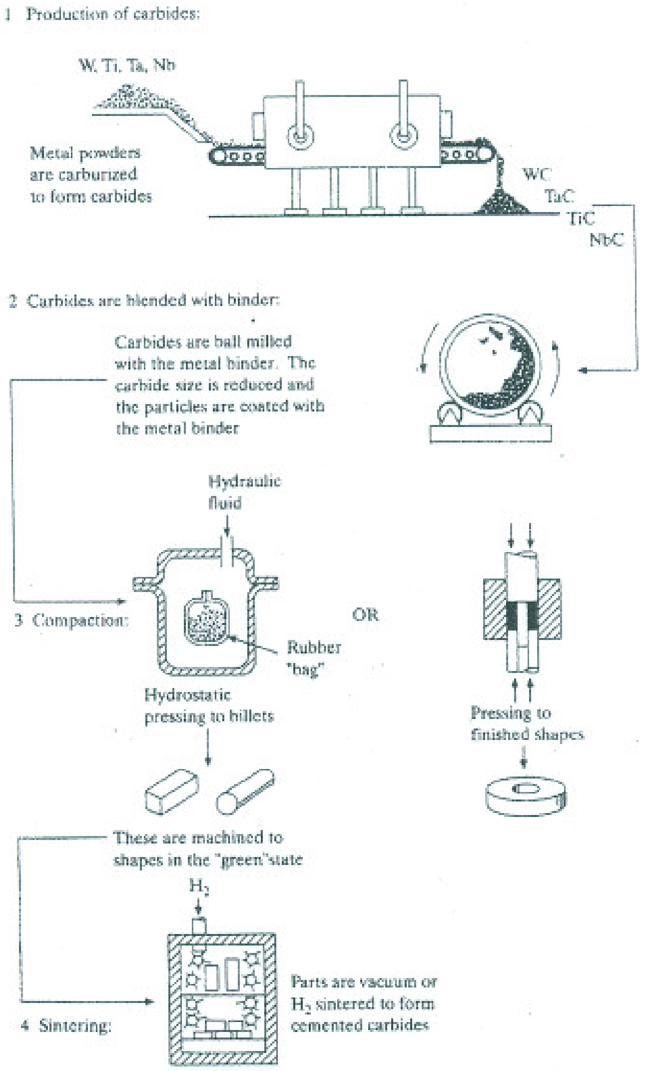

Fig-6: Making of cemented carbide shapes [6]

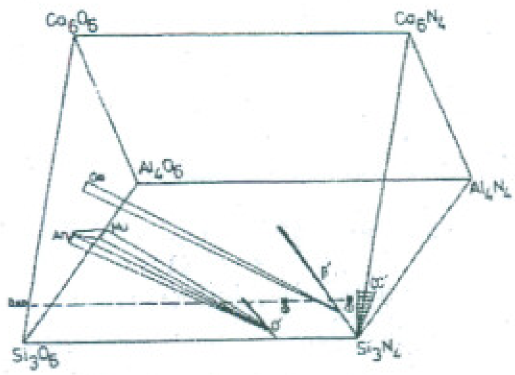

Fig-7: Si-Ali-O-N phase diagram [Ref] [15]

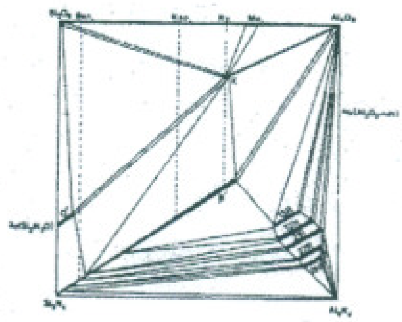

Fig-8: Ca-Si-Al-O-N phase diagram after Higgins [ref] [15]

Class	Examples	Uses
Single oxides	Alumina (Al_2O_3)	Electrical insulators (Figure 7–1)
	Chromium oxide (Cr_2O_3)	Wear coatings
	Zirconia (ZrO_2)	Thermal insulation
	Titania (TiO_2)	Pigment
	Magnesium oxide (MgO)	Wear parts
	Silica (SiO_2)	Abrasive, glass
Mixed oxides	Kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$)	Clay products
Carbides	Vanadium carbide (VC)	Wear-resistant materials
	Tantalum carbide (TaC)	Wear-resistant materials
	Tungsten carbide (WC)	Cutting tools
	Titanium carbide (TiC)	Wear-resistant materials
	Silicon carbide (SiC)	Abrasives
	Chromium carbide (Cr_3C_2)	Wear coatings
	Boron carbide (B_4C)	Abrasives
Sulfides	Molybdenum disulfide (MoS_2)	Lubricant
	Tungsten disulfide (WS_2)	Lubricant
Nitrides	Boron nitride (BN)	Insulator
	Silicon nitride (Si_3N_4)	Wear parts
Metalloid elements	Germanium (Ge)	Electronic devices
	Silicon (Si)	Electronic devices
Intermetallics	Nickel aluminide (NiAl)	Wear coatings

Table-1: Typical ceramics for engineering design [7]

Design	Experimental Comp	Predicted Phase
K_1	$10CaO-30Al_2O_3-60SiO_2$	M/A
K_1	$20CaO-33Al_2O_3-47SiO_2$	A/W/S
K_2	$40CaO-34Al_2O_3-26SiO_2$	G/A/W
K_3	$36CaO-37Al_2O_3-27SiO_2$	G/A
K_4	$40CaO-23Al_2O_3-32SiO_2$	G/A/W
K_5	$25CaO-22Al_2O_3-53SiO_2$	A/W/S
K_6	$50CaO-30Al_2O_3-20SiO_2$	$G/20CaO.SiO_2/Ca0.7Al_2O_3$
K_7	$60CaO-30Al_2O_3-10SiO_2$	$2CaO.SiO_2/3CaO.Al_2O_3/12\ Ca\ 0.7Al_2O_3$

Table-2: Experimental Composition and Predicted phases in Lime-Alumina-silica ternary system (unreacted master compositions) [11]

Design.	Predicted Phases	Identified Phases
K_1t_1	M(3A2S) / A(CAS2)	M (3A2S), A (CAS2), Ox
K_1t_1	A (CAS2)/ W (CS) / S	A (CAS2), W(CS), S, Ox
K_2t_1	G (C2AS) / A (CAS2) / W (CS)	G (C2AS) / A (CAS2) / W(CS), Ox + β
K_3t_1	G (C2AS) / A (CAS2)	G (C2AS), A (CAS2), Ox+β
K_4t_1	G (C2AS) / A (CAS2) / W (CS)	G(C2AS), A (CAS2), W(CS), Ox +α
K_5t_1	A (C2AS2) / W (CS) / S	A (C2AS2), W(CS), S, Ox
K_6t_1	G (C2AS) / C2S / CA	G (C2AS), C2S, CA, β/Ox
K_7t_1	C2S / C3A / C12A7	C2S, C3A, C12A7, α/Ox

Table-3: Predicted and identified Phase in $CaO-Al_2O_3-SiO_2$ System [12]

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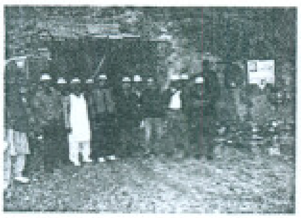


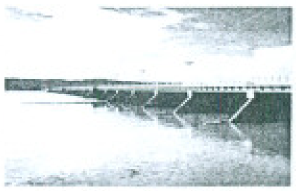
A Group Photo on the inauguration of Diamer Basha Dam Project

Sukkur Barrage Rehabilitation Project Completed Upstream Coffer Dam

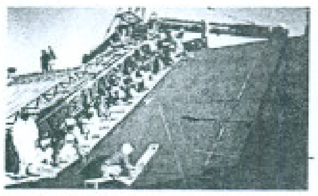
A view of Concrete lined Canal under the Revamping /Rehabilitation of Irrigation and Drainage Systems in Sindh Project

Drilling for Geo-technical Investigations in Progress with Rotary Rig in the Extension of Pat Feeder Canal Project Extension Area.

A view of Irrigation Channel under Merowe Irrigation and Dam Project in Sudan

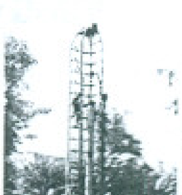


A view of Taunsa Barrage Project

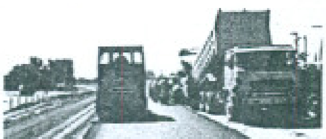


A view of Concrete lining with machine in Chashma Right Bank Irrigation Project Stage-III in Progress

A view of Lined Watercourse in Balochistan



WASA Project -Tubewell boring in Progress



Laying and Compaction of Asphaltic Base Course at KM 18+1300 to KM 18+400 Package A at D.G. Khan Rajanpur Road Section

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