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FRACTROGRAPHY OF S.E.N. SOFT SOLDERED COMPOSITE LAMINATES MADE FROM 0.8 % CARBON MANGANESE STEEL UNDER PLANE STRAIN CONDITIONS

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ABSTRACT:

An attempt has been made to discuss the design criterion of the composite materials at and during service conditions of engineering structures. The present work supports this and suggests a compromise between the properties of the materials such as strength and fracture toughness with pearlitic and martensic structures of composite laminates by using thin sheets of critical thickness in the form of laminate with crack divider geometry under plane strain conditions. This is supported by the load displacement graph by using an Instron testing machine at a strain rate of 0.05 cm/min and the fractography which supports the same modes of failure during fracture process. Thus suggesting the advanced materials for achieving the structure integrity of engineering structures.

KEY WORDS:

Composite laminates, crack controlling properties, delamination fracture and structural integrity.

INTRODUCTION:

A most serious problem now a days is to be able to build an Engineering structure which can resist the cracks or flaws present in it. Failure may take place in such structures below their yield or ultimate strengths. To over come this, composite materials, particularly laminates have been used, (Embury, (1), 1969). Such materials C not only resist crack propagation more (Sabayo, (2), 1981), than the homogenous materials but also have higher critical crack lengths giving a better chance of crack detention prior to failure and in some cases completely prevented through the thickness cracks (Sabayo, (3), 1982). This has drawn attention to the role of interfaces, their strength, delimitation during and after fracture, and the thickness of elements (layers) used in composite laminates.

Crack controlling properties and lamination have recently been applied in conventional metallurgy. Steel can be made more resistant to crack by cementing together thin sheets of it with soft solder. This laminated steel is of course a composite materials, (Kelley, (4) 1970). Such studies have shown that through proper control of mechanical properties of the bonds, joining the sheets, it is possible to introduce delimitation fracture that markedly improve the over-all toughness of composite and in some cases completely prevented through the thickness cracks, (Sabayo, (5), 1983).

In order to optimize the performance of the composite materials, it is necessary to gain some fundamental understanding of the nature of the components. Even for simple external composite loadings, the state of stress and strain at the interfaces between the components are complex and vary from place to place in the composite. This complexity of conditions at the interface is different from what might be expected from simple loading conditions. Although a precise description of the interface is beyond our present knowledge, and understanding of the role of the interface on composite behaviour and the ability to control the interface are important factors. (Sabayo, 5, 1991).

Strength and toughness are related but different properties. One is generally obtained at the expense of the other where as the lamination provides a means of increasing resistance to fracture that is independent of the structure variables of the materials very much required for achieving the structural integrity. (Sabyo, 6, 1997).

MATERIAL AND EXPERIMENTAL PROCEDURE:

The patented and cold worked pearlitic material with the following compsition and homogenous properties throughout its length in the form of coiled strip was supplied.

C: 0.8%, Si 0.18%, S 0.015%, P 0.007%, Mn 0.55%.

The same material was hardened at 790oC and tempered at 418oC for one hourt to give almost identical strength values corresponds to a hardness of 431 + 16 D.P.N. To make fracture toughness specimens, strips 84x19x1mm were polished down to 30 grade emery paper and then dpped into 70% pb & 30% Sn molten lead tin solder held in graphite crucible at a temperature of 232oC. In this way a uniform layer of solder was maintained on each strip. In order to get the required geometry for the fracture toughness specimens, eight such strips were riveted together and then hot pressed at a temperature of 250oC for one hour. A pressure of 635 MN/m2 was maintained until the temperature dropped to room temperature. The composite specimens were machined and then notched according to the specification. Fig. 1 shows the specimen geometry. For pre-cracking, a high frequency vibraphone was used. All conditions satisfied for pre-cracking were fulfilled, (Brown, 7, 1970).

FRACTURE TOUGHNESS TESTING:

Fracture toughness tests were carried out on an Instron machine at a cross head-displacement rate of 0.05cm/min using the pre-cracked specimens and specimens were mounted in pin type grips loaded in tension. A 1000 ohm BISRA clip guage was located across the notch of the specimens using brass sadles glued on the X-Y recorder was subsequently used for analysis and measurement of fracture toughness. Fig 3 shows the load displacement records, which full-filled all conditions for valid K_{IC}. The results are shown in Table 1 and Table 2.

MICROSCOPY:

To study the modes of failure of the laminates electron fractography was carried out by using EM6G microscope and Cambridge Scanning Electron Microscope. Such details are shown in Fig. 3 (a, b, c) and Fig. 4 (a, b, c) for soft soldered composite laminates tested at a cross head displacement rate of 0.05cm/min, with pearlitic and martensitic and martensitic structures. This includes delamination in the region of slow crack growth, cracking of pearliest and inclusions in the region of fast fracture and ductile failure in the region of fast fracture in either case.

TABLE 1. FRACTURE TOUGHNESS TEST RESULTS OF S.E.N., SPECIMEN MADE FROM 0.8% CARBON MANGANESE STEEL WITH PATENTED AND COLD WORKED SOFT SOLDERED LAMINATES TESTED IN AIR.

Specimen No.	Displacement Rate.	Tagent Line (Degree)	P5 (A) P_{kg}	KQ M_{Nm}-3/2
1.	0.05	51	1530	140.75
2.	0.05	51	1530	140.75
3.	0.05	51	1530	140.75
Mean KQ = 140.75$MNm^{-3/2}$				

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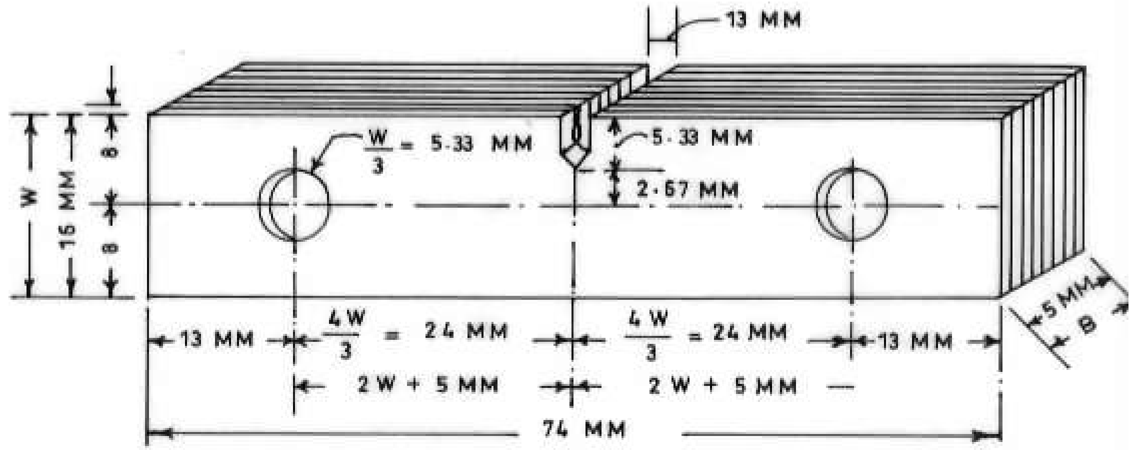

FIG_1 SEN FRACTURE TOUGHNESS TESTING COMPOSITE LAMINATES

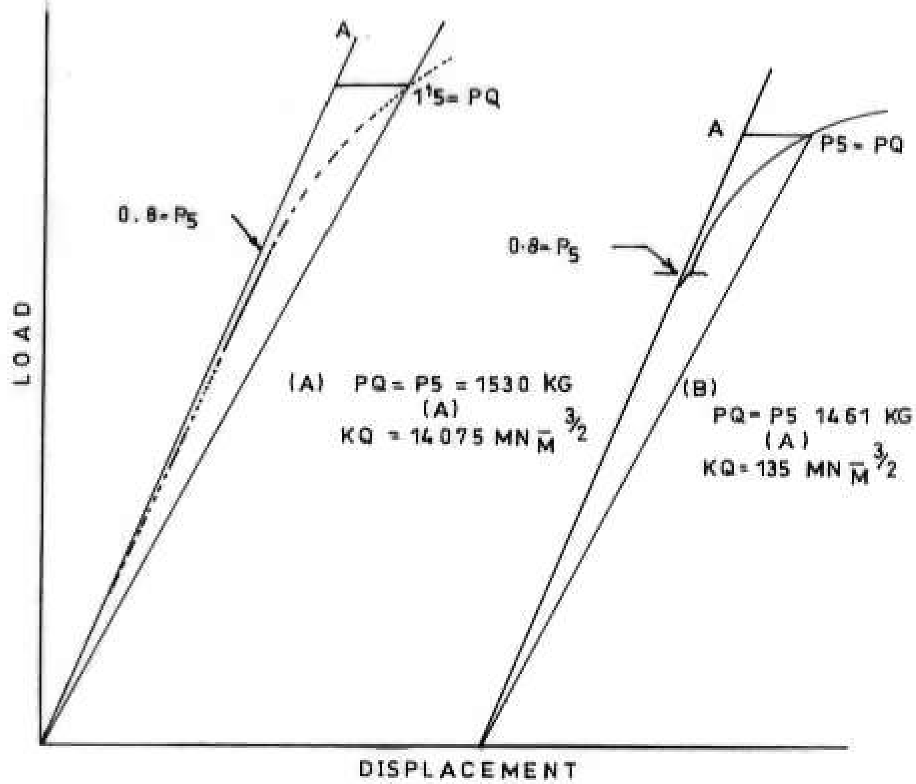

FIG_2 LOAD DISPLACEMENT GRAPH FOR SOFT SOLDERED COMPOSITE LAMINATES WITH (A) PEARLICTIC AND (B) MARTENSITIC STRUCTURES

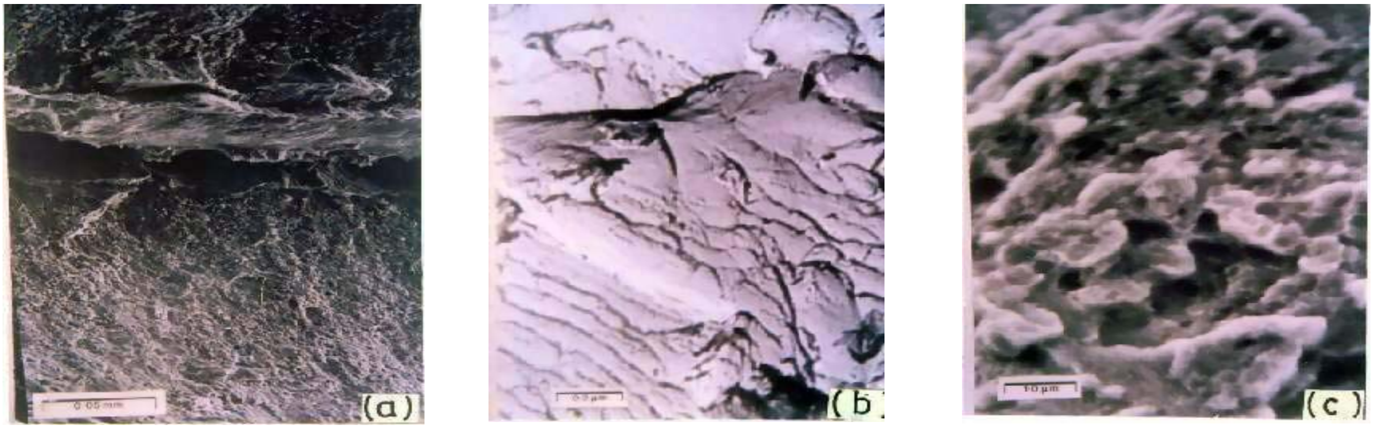

Fig. 3 (a, b, c) Electron fractography for SEN soft soldered composite laminates made from 0.8C% manganese steel with pearlatic structure tested in air at 0.05cm/min

a) Delamination in one layer in the region of slow crack growth.
b) Cracking of pearlites in the region of fast fracture.
C) Ductile failure in the region of fast fracture.

TABLE 2. FRACTURE TOUGHNESS TEST RESULTS OF S.E.N., SPECIMEN MADE FROM 0.8% CARBON MANGANESE STEEL WITH HARDENED AND TEMPERED SOFT SOLDERED LAMINATES TESTED IN AIR.

Specimen No.	**Displacement Rate.**	**Tagent Line (Degree)**	**P5 (A) P_{kg}**	**KQ M_{Nm}-3/2**
1.	0.05	55	1461	135
2.	0.05	55	1461	135
3.	0.05	55	1461	135
Mean KQ = 135MNm$^{-3/2}$				

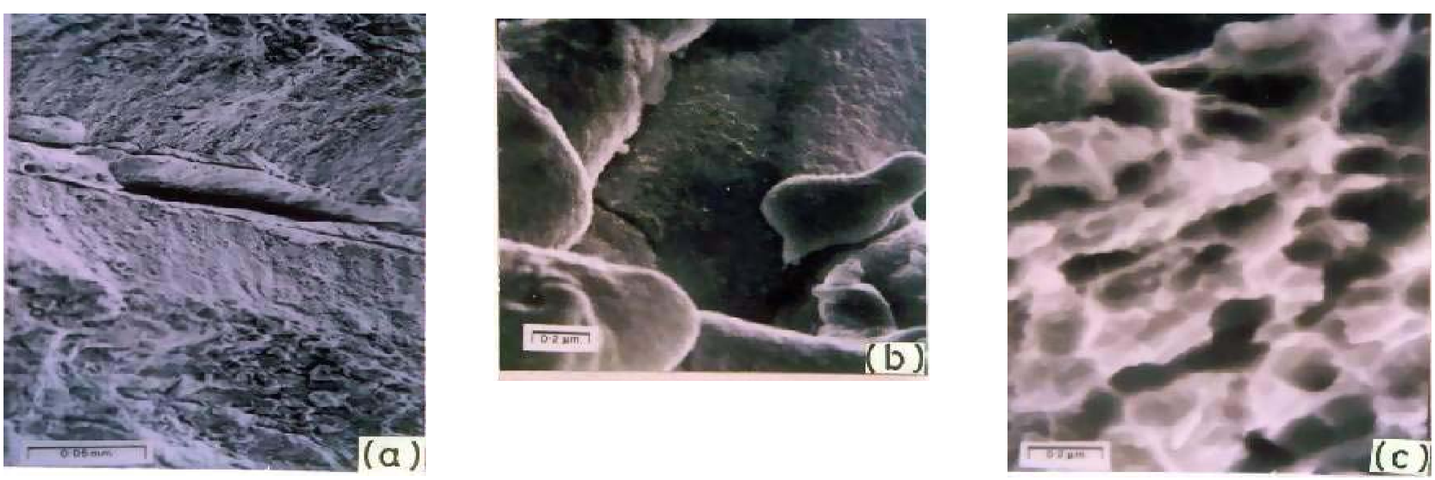

Fig. 4 (a, b, c) Electron fractography for SEN soft soldered composite laminates made from 0.8C% manganese steel with martensitic structure tested in air at 0.02cm/min

a) Delamination in one layer with region of slow crack.
b) Cracking along the inclusions in the region of fast fracture.
c) Ductile failure in the region of fast fracture.

DISCUSSION:

A laminated is a composite in which two or more sheets are bonded together, where crack growth can occur under either stress or plane strain conditions. Interfacial strength plays an important role in laminates. Usually too high an interfacial strength gives no benefits since the material then behaves as a homogenous solid. Similarly a material with negligible strength results if the adhesion is too weak. Even for simple external composite loading, the state of stress and strain at the interfaces between the components are complex and vary from place to place in the composite (Sabayo, 8, 1991).

This all is supported by the load displacement graph plotted by using Instron testing machine under plane strain condition and the fractography which shows similar modes of failures in each case during fracture process. This includes the delamination in the region of slow crack growth, cracking of pearlites / along the inclusions in the region of fast fracture and ductile failure in the region of fast fracture.

The average K_Q values for patented and cold worked were 141 $MNm^{-3/2}$ while hardened and tempered laminates gave an average value of $135MN3^{-/2}$. This showed that patented and cold worked composite laminates were tougher than the hardened and tampered laminates under plane conditions for identical strength values corresponds to hardness values of $431\pm$ 16DPN.

The work demonstrates that good combination of strength and toughness can be obtained in crack divider laminates of both pearlitic and martenstic structures under plane strength conditions provided the width of the strip is increased. Unfortunately the maximum width of the material that is obtainable not more than 19mm hence before it is impossible to get K_{IC} so far as specification (Brown, 5, 1971) is concerned. Although each element fails by slant fracture at approximately 45^o to the tension of axis Fig. 4 confirms that the individual element making up the laminates were of the thickness t critical corresponding to K_C maximum. It is however interesting to note that the results obtained with a low cost plain carbon steel are at least as good those reported by (Zakay, 9, 1970). Thus encouraging manufacturing technology sectors more to produce the advanced material for achieving the high structural integrity of the structures (Sabayo, 6) 1997.

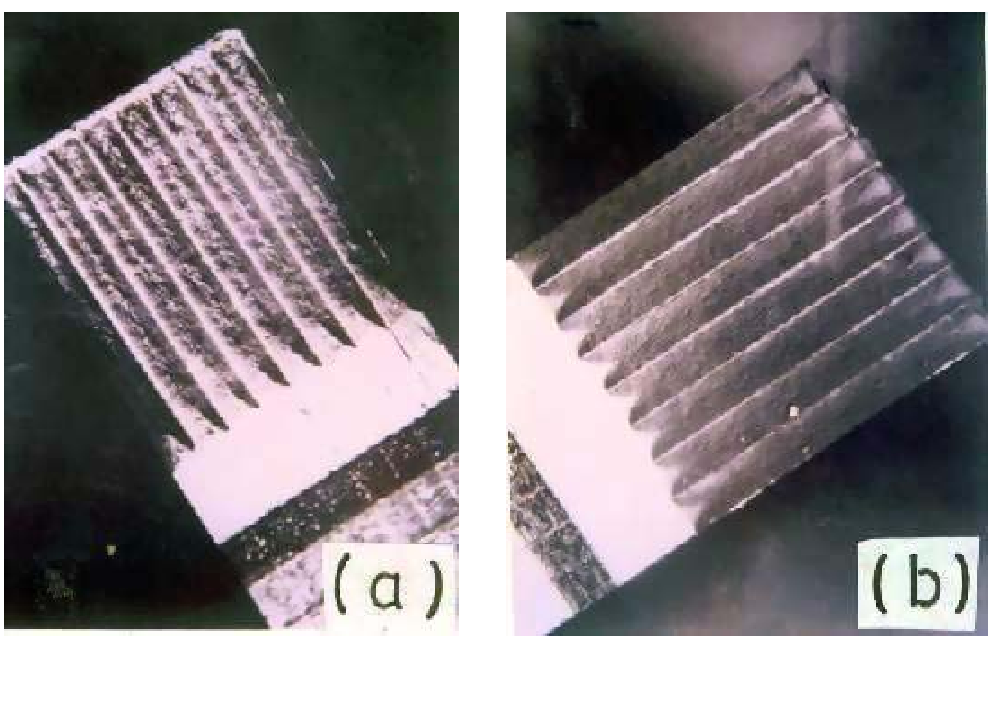

Fig. 4 General view of fracture surface typical of (a) patented and cold worked laminates and (b) hardened and tempered laminates where each elements fails by slant fracture at approximately 45^o to the tension axis.

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