Defence Science Journal, Vol 47, No 1, January 1997, pp. 89-96

Add-on Armour Repair – Concepts & Techniques

S.N. Dikshit
Defence Metallurgical Research Laboratory, Hyderabad 500 058

ABSTRACT

The nature of damage likely to occur to an add-on armour module due to the impact of incoming projectile is described. Observations are based on a series of ballistic trials at zero and oblique striking angles. Simple repair techniques have been suggested for restoring ballistic worth of the damaged composite armour on the battle tank.

1. INTRODUCTION

Reliability, maintainability and availability of components are major constituents of an effective engineering design. These are particularly of vital importance in case of battle tanks, wherein speed of action demands that the tank be always available to the troops. The concepts of meantime-to-failure and down-time-to repair are incorporated in the initial design stage. Accordingly, add-on armour modules while enhancing protection levels of vintage tanks should also conform to reliability, maintainability and availability standards. Since a battle tank is designed to protect its crew against antitank ammunitions, it is expected that add-on armour will get damaged by a variety of incoming projectiles. The type of damage caused to an add-on armour module will largely depend on the mass, velocity and obliquity of the projectile. Quick repair of a damaged tank is a morale-boosting factor for any commander in planning and executing the next course of action. Therefore, the issue here is related to the feasibility and the quickness with which armour modules (additional armour plates mounted on the tank surface at selected locations to provide immunity against antitank ammunition having higher penetrating capability) can be repaired so that maximum number of tanks are available on the battlefield.

Repairing of damaged armour of a tank and making it battle worthy had been attempted during various conflicts by the armies worldover. However, in all these situations, either cast or rolled homogeneous armour plates were used. Apprehensions with regard to feasibility of repairing armour, consisting of a variety of composite materials are being raised. Experience and information available in open literature suggest that the feasibility of repairing composite armour plate is a technological reality.

This paper is aimed to describe the nature of damage to the add-on module due to the impact of penetrating projectile. Further, the repair technique is suggested in detail along with essential precautions to be followed during defect rectification process.

2. REPAIRABILITY OF COMPOSITE STRUCTURES

Pioneered in the laboratories during the sixties and seventies, the advanced composite materials have now found application in the battle tanks for enhancing the protection levels. Therefore, it is important to address the basic question of 'repairability' of composite structures. Doubts

Received 16 August 1995, revised 11 July 1996

arise in the mind of end user due to the following facts:

(a) Simplified field repairs not adequately documented[1],

(b) Poor accessibility to a damaged part from both sides,

(c) Inadequate repair research and experience[2],

(d) Feasibility demonstrations for repair-solution not readily available[3], and

(e) Available non-destructive methods to check and assess effectiveness of repair-solution are inadequate.

3. DAMAGE PATTERN

Before describing actual repair techniques of a damaged add-on armour module, it would be pertinent to know the details regarding the type and extent of the damage due to the impact of a projectile. Experience based on a large number of ballistic trials shows that the following types of add-on module failures are expected, depending on the speed and obliquity of the projectile:

(a) Excessive bulging on backface of the tank surface,

(b) Multi-hit on small portion, rendering plate to be ineffective to absorb subsequent hits,

(c) Single, isolated crater formation on a large plate,

(d) Tearing/buckling of side plate of add-on module,

(e) Fractured gusset,

(f) Scab formation at the backface,

(g) Partial penetration of module,

(h) Projected lip on front surface,

(i) Delamination of composite material,

(j) Buckling and partial tearing of front plate,

(k) Single crack in front plate while all other inside materials remain intact,

(l) De-welding of front plate without any damage to subsequent layers of the stack, and

(m) Crack formation near the edge of top plate in between two gussets.

All these defects will not appear in a single plate, and only few will appear in an individual or combined form. A summary of the important types of damages to the add-on armour and the suggested repair techniques is provided in Table 1. However, the list is by no way exhaustive, since the nature of damage depends on the location of impact, mounting mode of the add-on armour and the projectile-plate related parameters, like strength, velocity and obliquity. As the ballistic performance of composite armour is affected by the presence of these defects[4], defect rectification thus assumes high importance in the case of battle tanks.

4. REPAIR OPERATIONS

Some of the following simple operations may have to be resorted to repair add-on armour panel for making it ballistically sound to protect the crew:

(a) De-welding

(b) Flame cutting

(c) Grinding

(d) Cutting of non-metallic materials in the affected zone

(e) Edge preparation

(f) Sizing and shaping of non-metallic materials

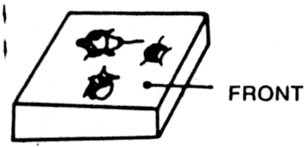
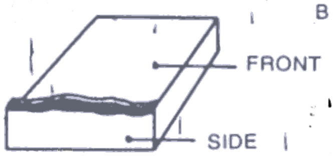
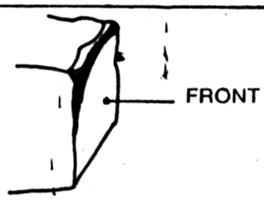
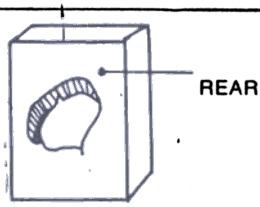
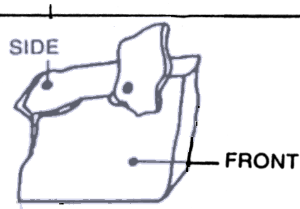
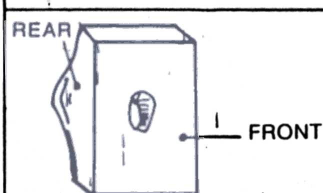
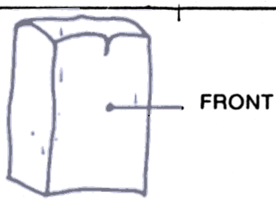
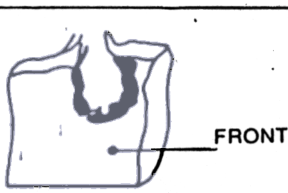
(g) Preparation ofsuitable sized plug, comprising affected materials and/or monolithic plug (Figs 1 & 2)

(h) Positioning of the prepared plug in the cavity, and

(i) Welding.

Table 1 provides likely damage pattern to the add-on armour module and also the steps to be taken in repairing such damages. It is clear that no sophisticated equipment or skill is needed in undertaking these repairs; however, there is a need to provide expert guidance to the repair team in the initial stages. For this purpose, a research and development agency has to conduct training

Table 1. Likely damage pattern and suggested repair techniques

DEFECTS	REPAIRS
A 	(a) DEWELD FRONT PLATE (b) REPLACE IT WITH NEW PLATE (c) WELD
B 	(a) GAP TO BE FILLED WITH FILLER MATERIAL AND REWELD IT FOR PROVIDING STRUCTURAL STABILITY
C 	(a) DEWELD FRONT & SIDE PLATES (b) REPLACE IT WITH NEW PLATE (c) WELD
D 	(a) SURFACE PREPARATION BY WAY OF GRINDING (b) PREPARE SUITABLE SIZE & SHAPED PLUG OF ARMOUR GRADE MATERIAL (c) WELD THE PLUG SO PREPARED
E 	(a) DEWELD FRONT PLATE (b) PREPARE NEW PLATES OF APPROPRIATE SIZES (c) WELD
F 	(a) SURFACE PREPARATION OF CRATER HOLE BY GRINDING (b) PREPARE PLUG OF ARMOUR MATERIAL (c) INSERT THE PLUG & WELD (d) NO REPAIRS REQUIRED ON REAR PLATE
G 	(a) NO REPAIRS REQUIRED
H 	(a) SURFACE PREPARATION BY GAS CUTTING & GRINDING (b) PREPARE A SUITABLE PLUG OF ARMOUR MATERIAL & INSERT IN THE CAVITY & WELD

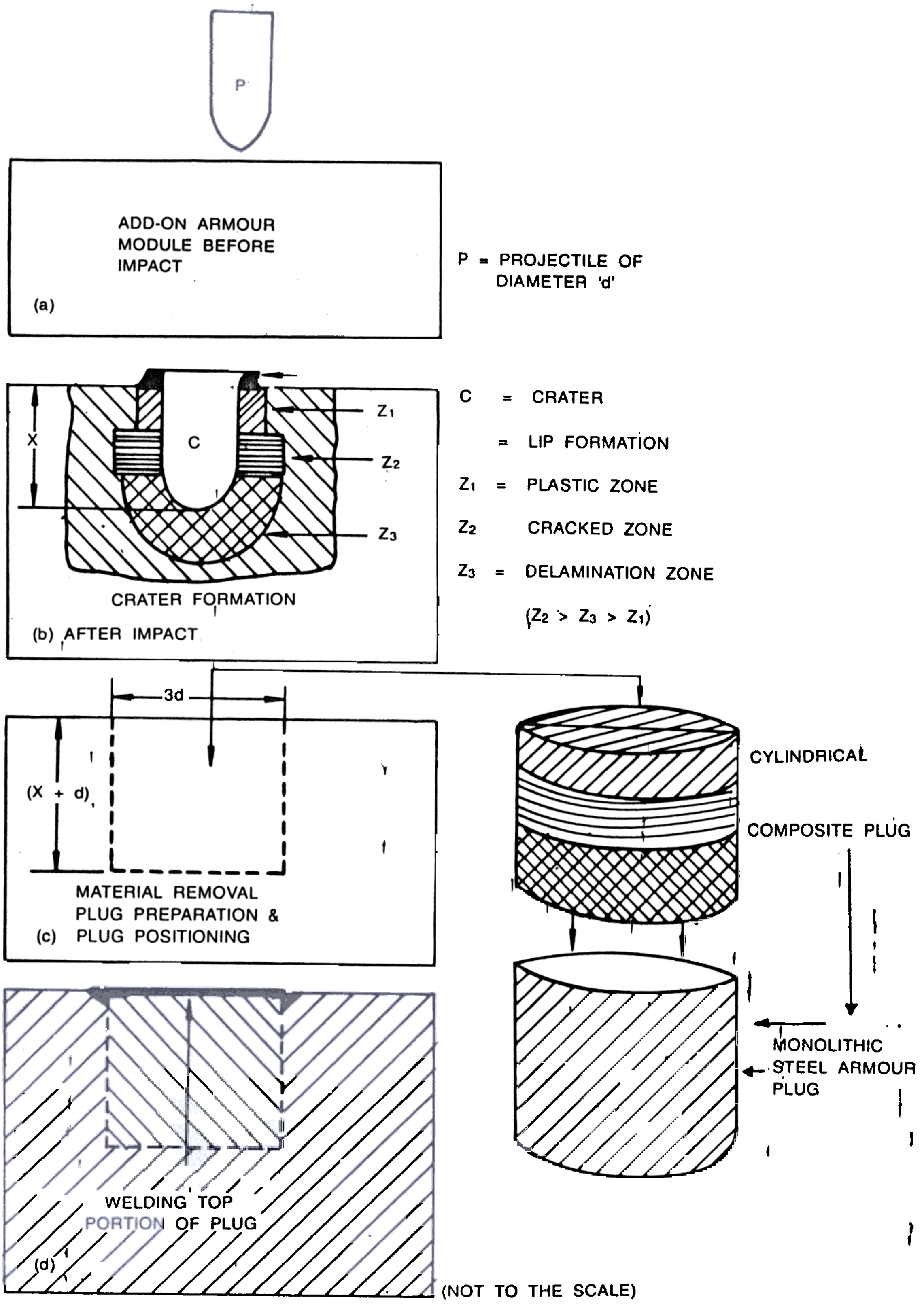


Figure 1. Crater formation at zero obliquity and its repair

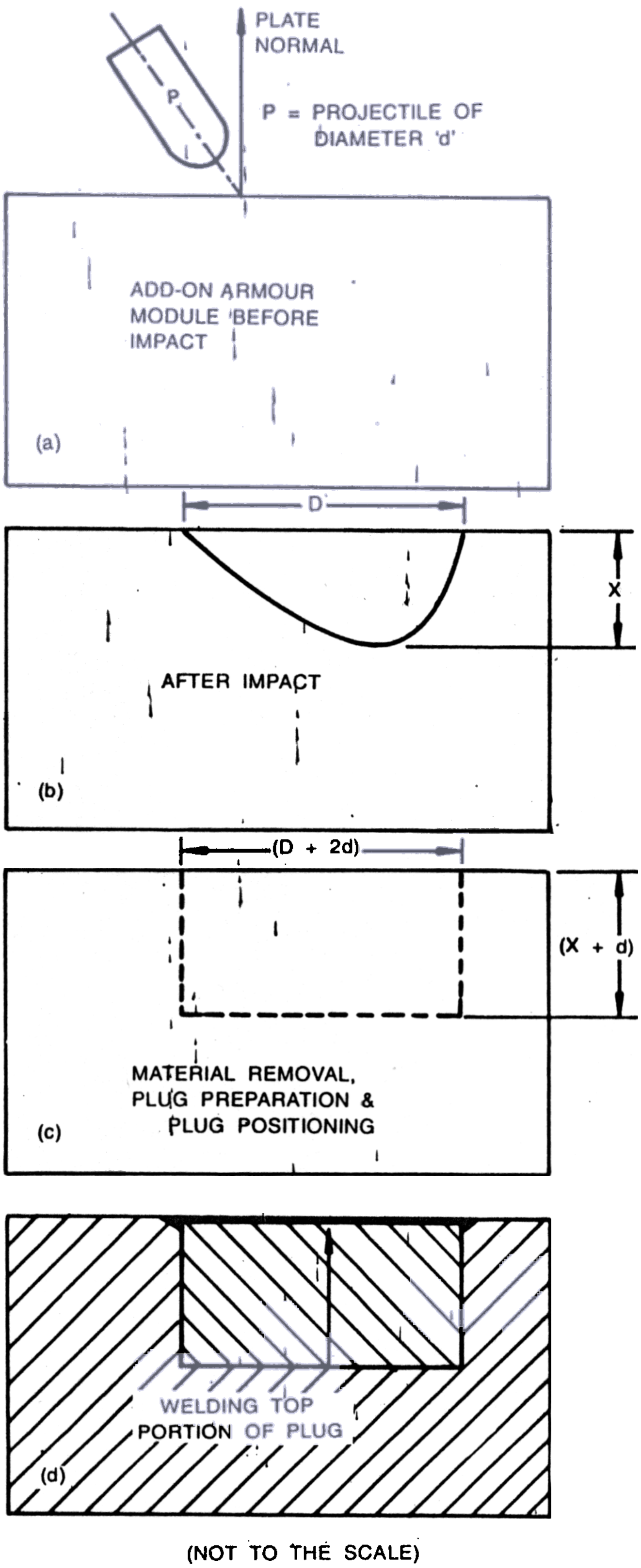


Figure 2. Crater formation at high obliquity and its repair

programmes for the concerned user representatives on the precautions and detailed repair techniques.

Table 1 also shows that some of the defects noticed on the surface of the add-on module, such as a minor crack near the edge of the plate (Table 1-G) do not really require any repair, as the presence of such a defect does not degrade ballistic worth of these panels. In fact, repairing of such superficial defect may introduce some kind of technical complexity. In some cases, the repair effort may only be of minor nature, use of filler material for structural stability (Table 1-B). One major task of this repair technique involves preparation of a suitable plug similar to the one shown in Fig. 1. Figure 1 shows crater formation at zero obliquity. Details of add-on armour module just before and after the impact of the projectile are shown in Figs 1(a) and 1(b), respectively. Repair steps are shown in Figs 1(c) and 1(d). Figure 1(c) provides details with regard to removal of the damaged material, plug preparation and its positioning in the cavity prepared in the base plate. Magnified view of cylindrical plug (composite and monolithic) is also presented. Figure 1(d) shows the final step of welding the top portion of the plug with that of the module. Such a plug is generally formed when a projectile hits the armour at zero obliquity. The add-on armour module before and after the impact of a projectile at higher obliquity is shown in Figs 2(a) and 2(b), respectively. Here, the path of the incoming projectile does not coincide with the normal to the plate, and it is for this reason that the shape and size of the crater (Fig. 2(b)), is quite different from that observed in Fig. 1(b). The repair steps are shown in Figs 2(c) and 2(d). What is important in both these cases is to ascertain the extent of partially damaged area (Z1, Z2 and Z3) around the crater formed on the armour plate (Fig. 1(b)). This information will be useful in deciding the area up to which the material is to be removed all around the crater and in the direction of motion of the projectile. The method of removing damaged material is a very vital issue confronting the repair team. For this, a portion of the top plate is to be removed by way of drilling, and subsequent layers of the composite materials are to be removed with the help of a portable, diamond-coated abrasive cutter. However, for the removal of layered materials the use of trepanning tool is observed to be more effective and less time-consuming. In case such equipment are not presently authorised in field and advance base repair workshops, these can be procured from the market.

The question whether this kind of repair and maintenance work is to be carried out by Armoured Workshop Coy (AWC), Armoured static workshop or advance base repair workshop will be dictated by the damage level and the location of the damage. If the repair equipment is available in AWC and there being a single hit damage, such repairs can be undertaken by AWC. In the event of large number of hits, the repairs have to be undertaken by the advance base repair workshop, as it may need more time. However, if the battle tank needs other mechanical defect rectifications in the advance base repair workshop, armour-related repairs should obviously be carried out in the advance base repair workshop even if the nature of damage is not of serious type.

The repair technique suggested in this investigation is applicable to battle tanks under any classification, wherein composite materials have been used by the armour designers in the hull glacis and also in the turret.

Equipment and technicians already available in a field repair worksho and advance base repair workshops can thus complete the repairjob with prior training on these repair techniques. Technicians, however, will have to adhere to some simple precautions during the conduct of these repair operations.

5. PRECAUTIONS

Important precautions to be taken in cutting, de-welding, grinding and welding operations are:

(a) Use diamond-coated abrasive cutters for cutting and shaping of non-metallic materials,

(b) Avoid undesired lamination and cracking while cutting non-metallic material,

(c) Use proper coolants during water jet cutting at high speed.

(d) Employ specified grade of electrodes in welding/de-welding operation,

(e) Maintain preheating at specified temperature and duration,

(f) Before welding, prepare good surface by reducing surface contamination to improve the quality of weld,

(g) Give root passes with 2-3 mm diameter electrodes depending on the type of joint,

(h) Remove damaged material about three times the diameter of the crater,

(i) Remove cracked tiles, if any, without fail,

(j) Prepare good joint preparation while dealing with different thicknesses for better weld property, and reduced distortion,

(k) Avoid excessive heat input during flame cutting/welding to minimise microstructural variations in heat-affected zones,

(l) Avoid weld contamination to minimise cracking in weld metal,

(m) Preheat the electrodes to avoid moisture pickup causing hydrogen cracking,

(n) Adopt back stepping and skip welding techniques to minimise distortions,

(o) Use proper heat input for correct penetration to minimise thermal constraint on weld joint,

(p) Carry out welding from fixed end to free end,

(q) Avoid inconsistent arc length as it leads to arc voltage variations[5],

(r) Plan carefully to deal with *in situ* repair demanding deviation from standard procedures, and

(s) Protect the damaged area against moisture absorption as it leads to the degradation of adhesive bond strength[6].

6. DISCUSSION

As the primary aim of these repairs is to restore ballistic worth of the add-on panel, the repair agency will have to ensure that the damaged material layers are removed from the impact site. As a thumb rule, an area equal to three times the diameter of the crater[7] is to be removed and filled with new material in that sequence. In an emergency repair situation where all kinds of materials are not readily available, armour grade material available as rolled homogeneous armour plate can be utilised to fill the damaged portion of the panel, both in the zero and non- zero angles of attack. It is observed that a monolithic cylindrical plug meets the ballistic requirement and one should not hesitate to use such a plug under field conditions.

A large number of experiments have been conducted to obtain information with regard to the size of the plastic zone (Z1) in the rolled-homogeneous armour steels at zero obliquity[7]. However, more studies are required for assessing the size of cracked zone (Z2) and delamination zone (Z3) in different composite materials at different obliquities and at different mass/velocity of the impacting projectiles. This information will help in the preparation of detailed repair specifications.

Repair-solution thus presented offers mission reliability and is a technological reality. However, repair research has to be a continuous process till an optimised and cost-effective procedure, acceptable to the end user, is established.

7. CONCLUSION

Add-on armour modules on a battle tank are expected to get damaged in a variety of ways by a striking projectile; and it is very much feasible to quickly restore the ballistic worth of this add-on armour module by adopting simple repair techniques even in the field conditions.

ACKNOWLEDGEMENTS

The author expresses his gratitude to Shri S.L.N. Acharyulu, Director, Defence Metallurgical Research Laboratory (DMRL), Hyderabad, for granting permission to publish this paper. Acknowledgement is also due to Dr M.C. Pandey, Sci F, DMRL, for his valuable suggestions.

REFERENCES

1 Stone, R.H. Filed level repair for composite structures. NADC Lockheed-California Co., 1980. Contract N 62269-80-C-0283.

2. Myhre, S.H. Advanced composite repair-recent developments and some problems. *SAMPE,* 1981, **26**, 716-27.

3. Sanders, A.L., Jr. Advanced structural repairs for lower cost. *SAMPE*, 1981, **26**, 804-15.

4 Bishop, Sarah M. The significance of defects on the failure of fibre composites. 1992, *Tech. Memo.*, MAT 394, BR 63660, 107p.

5 Lancaster J.F., (Ed.). The electric arc welding, *In* the physics of welding, Ed.1. Pergamon Press, London, 1984. p.138.

6. Boutilier, Joseph; Huges, Edward J. & Rutherford, John L. Moisture effects in epoxy adhesives. *SAMPE,* 1981, **26**, 781-86.

7. Dikshit, S.N. & Sundararajan, G. The penetration of thick steel armour plates by ogive-shaped projectiles-experiment and analysis. *Int. J. Impact Engg.*, 1992, **12**(13), 392-408.

Contributor

Col. (Dr) S.N. Dikshit obtained his BE (Metallurgy) from REC, Warangal, in 1970, ME (Mechanical) from Indian Institute of Science, Bangalore in 1982 and PhD from Banaras Hindu University in 1994. His research work includes armour materials. Currently, he is working at Defence Metallurgical Research Laboratory, Hyderabad, where he is actively engaged in the design and development of light weight 'Kanchan' composite armour and 'Explosive Reactive Armour' for the protection of MBT Arjun, Vijayanta and Ajeya tanks. He has published several papers in international and national journals. He is the life member of Indian Institute of Metals.