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Complexities of Add-on Armour and Remedial Measures

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ABSTRACT

Armoured fighting vehicles are under constant threat against newly developed antitank ammunition having higher penetration capabilities. Enhancing protection levels of existing tanks is associated with increased weight and volume penalties, affecting tactical mobility of the tank. The complexities arising in designing add-on armour are described along with the remedial measures. It is observed that even optimum add-on design calls for minor compromise in the usage of a battle tank.

1. INTRODUCTION

Projectile-target interaction is a complex metallurgical phenomenon. The race between armour and penetrator is on, for stamping its superiority on the battlefield. The fast development of penetrator forces an armour designer to take stock of the existing protection levels to counter the increased threat. An optimised armour system is thus required to be re-evaluated against the threat caused by the development of superior ammunition. This ammunition can be either a kinetic energy or a shaped charge having higher penetration capabilities. The problem of increased threat can be tackled by discarding the existing armour system and going for the new one. However, economic constraints, especially in the developing countries, do not permit this approach, which is also a time consuming process. Due to these reasons, the existing armour design needs to be modified to meet the challenge within permissible limits of weight penalty, cost and time. This modification being an afterthought, it interferes with the overall design philosophy of the battle tank. Enhancing protection levels of existing tanks thus involves technical and tactical complexities.

The aim of this paper is to highlight major and minor complexities of adding armour on any battle tank and also to provide a considered viewpoint with regard to the inherent compromises that may have to be made in the usage of the tank.

2. PROTECTION MODES

Protection levels of existing tanks can be enhanced to counter increased threat by superior ammunition in the following modes:

- (a) Application of rolled homogeneous armour (RHA),
- (b) Application of light weight composite armour (LWCA),
- (c) Application of reactive armour (RA),
- (d) Application of active armour (AA), and
- (e) Application of insensitive energetic armour (IEA).

Type of mode to be selected will be dictated by threat perception, vintage of equipment, tactical scenario, cost and lead time. However, irrespective of the protection mode adopted, the add-on armour process is complex in nature and the complexities of add-on armour arise mainly out of weight and volume penalty in case of RHA and LWCA, respectively. While the AA system is likely to be quite expensive, it may not prove to be a complex process. Though RA may offer the least weight and volume penalties, it is also associated with some complexities. In the near future, probably, IEA mode of enhancing protection may prove to be the most effective method with the least complexities.

It is beyond the scope of this paper to deal in detail about the nature and quantum of complexities arising out of different modes of protection. What is intended here is to highlight important complexities due to

add-on light weight composite armour. Readers may note that the term complexity truly indicates the intricacies and complications involved in the design of add-on armour on a battle tank. These complications mainly arise out of weight and volume of the add-on armour as it might affect the basic characteristics of a fighting tank in a direct or indirect manner. What is acceptable or not acceptable is a compromise, in the real sense, keeping in mind the basic aim of enhancing protection levels of the tank.

3. MAJOR COMPLEXITIES

Mobility, protection and fire power are the three important requirements of a battle tank. While enhancing protection levels, there is bound to be an increase in the weight of the tank. However, with the application of light weight composite armour materials, presently used all over the world, weight penalty is minimised to a large extent in relation to the desired protection level of the tank. The term mobility, practically means the mobility of the tank and mobility of the turret. Mobility of the tank is linked with the horse power of the engine and it is not adversely affected with the additional weight of the composite armour required for enhancing the protection level of the tank. However, what is critical in the design of add-on armour is the weight penalty on the turret, affecting its mobility, especially during cross-country manoeuvring of the tank, involving ground slopes of 20-30°.

Some of the important complexities affecting the performance of the battle tank due to add-on armour are discussed here.

3.1 Turret Mobility

It is a basic requirement that turret be able to rotate 360° around its axis, but more importantly, acceleration of the turret is a major requirement due to tactical considerations, wherein it should be feasible to shift the gun from one position to the other in the shortest possible time. The rotation of turret is imparted by the gun control equipment (GCE), which is at its optimum level for an existing tank. Additional weight penalty on turret for enhancing protection level overloads GCE and limits the acceleration of the turret. In a design situation like this, the following options are open:

- (a) Replace GCE with new one,
- (b) Modify existing GCE, and
- (c) Retain existing GCE.

Option of retaining existing GCE will depend upon the mode of protection to a large extent. However, degradation in acceleration of the turret will not be acceptable to the crew. The question of replacing GCE with a new one is linked with the overall cost of the project and may not be acceptable due to budget restriction. The only option left is to modify the existing GCE within resources, with an acceptable compromise of protection mode, protection level and turret acceleration. This aspect needs micro level planning and experimentation, and it is feasible to strike a balance.

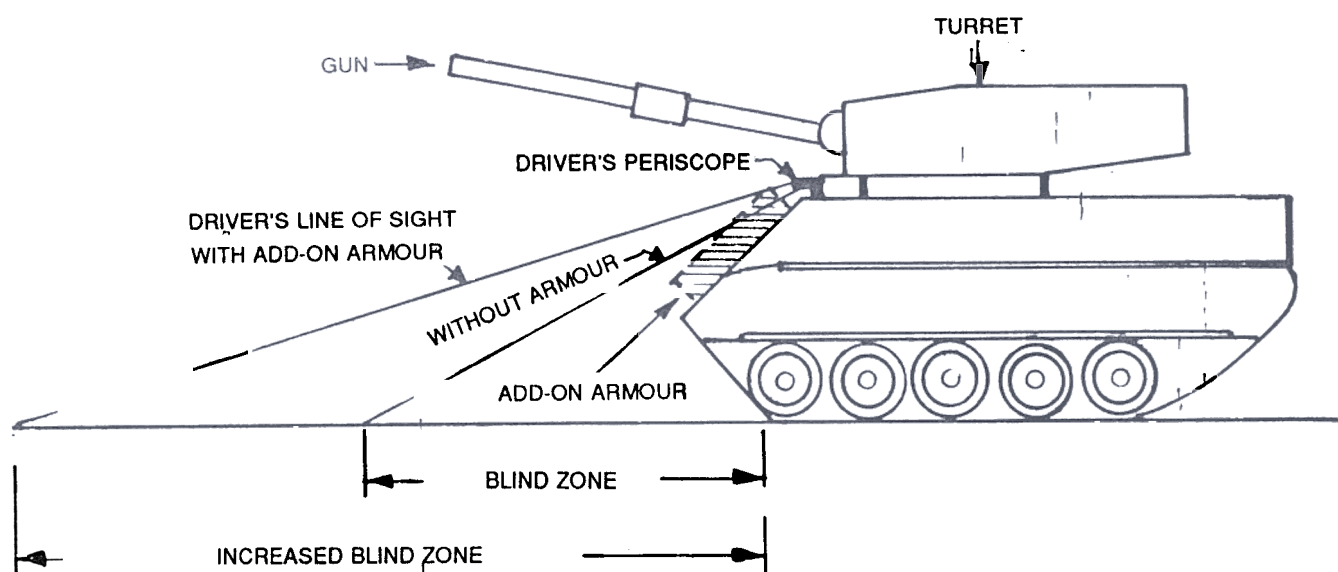


Figure 1. Additional armour and its effect on driver's vision and blind zone.

3.2 Vision Problems

Vision devices are provided in the tank at appropriate places for the driver to see the foreground so as to comfortably manoeuvre the tank, for the commander to observe the battlefield to locate enemy targets and direct the gunner to fire on the enemy tank. Addition of armour on hull glacis affects the driver's vision while the add-on armour on the turret and turret glacis affects the vision of commander and gunner in the three-men crew tank. However, the vision of loader will also be affected in a tank of four-men crew, provided additional armour is also located in an area of the turret which affects loader vision device.

Hull glacis of the tanks are inclined to get full advantage of the slope of the armour. In doing so, a definite blind zone is perforce created for the driver. For the purpose of providing full protection on hull glacis, additional armour will further widen the blind zone (Fig. 1). Two possible solutions emerge to solve this complexity of design;

- (a) Provide a double slope at hull glacis, and
- (b) Raise the height of the driver's vision device.

Raising the height of vision device would call for redesigning of the driver's cupola, which will not be a cost-effective way of solving blind zone. Also, raising the vision device amounts to raising driver's seat which, in turn, is related to the position of the steering linkages with respect to the existing seat of the driver. Thus, the only solution left is to provide necessary slope on the add-on armour on hull glacis on the upper edge in the driver's cupola zone. Also, enhancing protection in this region can be undertaken through innovative design consideration, involving the use of costlier materials. While striking balance between blind zone and

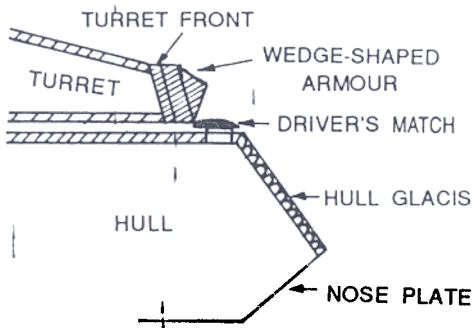


Figure 2. Wedge-shaped turret front armour.

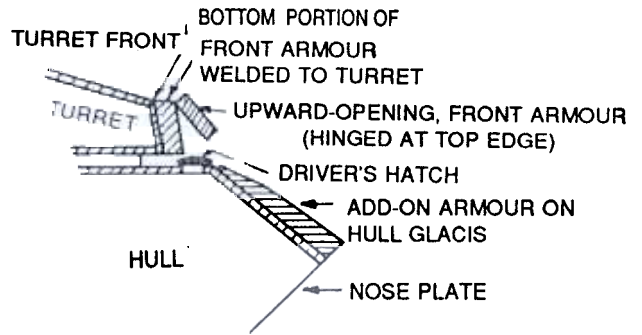


Figure 3. Upward-opening, front armour to facilitate driver's exit.

protection, it has to be understood that complexity of blind zone assumes vital importance with regard to loading/unloading of the tank on tank transporters and during crossing of any ditch-cum-bund on the steel bridge in the hours of darkness.

Similar complexity arises while designing add-on armour on turret glacis. A cut in the add-on armour is to be created in such a way that vision is not adversely affected in the entire range of field of view of the vision device.

In doing so, it is quite likely that the ballistic worth of the armour in that location is reduced to a large extent. It should also be appreciated that in such locations of the turret overall permissible add-on thickness is of very small order in comparison to other locations. Under these design constraints, it will be a difficult task for the designer to offer required protection without affecting vision of the crew. However, a solution is feasible by examining varieties of sloping cuts in the armour, fully supported by ballistic trial results in each design situation. This design exercise thus calls for a large number of ballistic trials for an optimised solution of maximum protection with minimum loss of crew vision.

3.3 Driver's Exit

Each one of the crew members in the tank is provided with a separate exit, so that they can get out of the tank in an emergency situation. By adding extra armour on the turret front, driver's exit gets blocked in certain positions of the gun. It may look quite simple but is a serious drawback in designing add-on armour as no driver would like to get trapped inside the tank, in case of explosion/fire in the fighting compartment. One way of solving this complexity is to reduce the thickness of armour in front of the turret. However, it

should be borne in mind that turret front is vulnerable to the enemy attack (60 per cent). Keeping in view the hit probability of turret front, reduction in armour thickness will seriously affect its protection level and hence no such compromise can be accepted. The following methods offer desired protection without seriously affecting driver's exit:

- (a) Wedge-shaped armour on turret front (Fig. 2), and
- (b) Hinged armour on turret front (Fig. 3).

In both the cases mentioned above, add-on armour is to be designed in two parts. The first part is to be made integral with the existing turret surface and the other part can be in the hinged or wedged shape. Hinged armour can be made out of light weight composite materials and it is likely to be better than the wedge-shaped armour. However, careful considerations are required while designing hinged armour as it is likely to create problems during cross-country movement. A simple holding mechanism is to be designed which can be operated by the driver with ease and without any loss of time.

3.4 Engine Removal

It is essential to remove the main and auxiliary engine of the tank from the engine compartment for maintenance and repair purposes. By increasing the thickness of the add-on armour on turret front and sides, the opening of the engine cover plate and hence removal of the engine gets restricted. Complexity of engine removal is to be solved by armour designer with full knowledge of the engine removal procedure. This problem can be tackled by designing add-on armour in two parts. The upper portion of add-on armour of appropriate thickness can be made detachable for removing the engine. Another way of solving this complexity is to design thick armour as a single unit and modify the engine removal procedure. From protection point of view add-on armour should be designed as a thick single plate.

3.5 Mantlet Removal

Add-on armour on front of the turret will adversely affect mantlet removal on some of the tanks. This problem can be solved by having detachable add-on armour on turret front, which might have a bearing on the protection levels especially in the front of the turret. In a simple way, size of the add-on armour on turret

front can be reduced in the vicinity of the mantlet, on either side of the barrel to facilitate unscrewing of the mantlet bolts and disengaging the mantlet bolt from the turret sliding block. This solution of having reduced size of add-on armour in a location of the turret having maximum hit probability is not advisable from the protection point of view and thus is not acceptable. Without affecting protection level, mantlet removal procedure can be altered by carrying out a minor modification in the mountings of the mantlet.

3.6 Turret Balancing

Turret is well-balanced to be able to rotate smoothly around its axis even while the tank is negotiating slopes in the cross-country movement. Add-on armour, especially in front of the turret, introduces out-of-balance moments, affecting smooth rotation of the turret. Out-of-balance moment of turret adversely affects turret rotation while the tank is negotiating a slope. If the slope of the ground is more than $20-25^\circ$, the problem is quite serious and it may even damage GCE if tried for longer duration. The main cause of the out-of-balance moment of turret is due to add-on armour which alters the centre of gravity (c.g.) of the turret. Since the main threat pertains to the front of the turret, maximum armour is added in this location, which shifts the c.g. of the turret towards the front portion of the turret. While designing add-on armour, it should be kept in mind that shift in the c.g. of the turret be as small as possible and it can be achieved by proper selection of armour materials and their location in the composite armour. Add-on armour on the sides of the turret does not create major out-of-balance moment of the turret. This is because of the fact that the shift of the c.g. caused by add-on armour is very small, as the armour mounted on two sides of the turret just tries to balance the turret.

To solve the problem of out-of-balance moment of turret, sufficient counter weight is to be added on to the turret in its rear portion. The unbalancing can be minimised in two ways. First, by using light weight armour materials in the front of the turret. Secondly, by avoiding putting dead weight in the rear of the turret. Instead, it is advisable to create a big tool box in the rear of the turret and place all heavier items of the tool boxes in it. These items are available from the tool boxes which are otherwise removed from the side of the

turret. Relocating the tool box might cause some inconvenience to the crew initially, but it is unavoidable.

4. MINOR COMPLEXITIES

There can be some more complexities of add-on armour, which can be resolved without affecting protection level of the tank.

4.1 Gun Balancing

In all such cases where add-on armour is mounted on the mantlet, balancing of the gun gets affected as the gun is mounted on the trunnion block for smooth operation while elevating and depressing the gun. To counter this unbalancing problem of the gun, a counterweight is to be added near the breech end of the gun. Limited space available between roof of the turret and breech does not accommodate the counterweight. This minor complexity can be resolved by casting the required counterweight in such a way that it can be located in the cradle guard assembly without creating any problem to the gunner in loading and unloading of the gun. The counterweight is to be cast from a material of very high density so that maximum weight can be created in the available space in the cradle guard.

4.2 Relocating Gun Pullback Hooks

Existing hooks can be removed and remounted on the add-on armour in such a way that mechanical advantage is not lost. It should be ensured, by proper location of these hooks, that crew fatigue is avoided.

4.3 Relocating Stowages

Careful consideration leads to need for relocation of stowages in different locations of the hull. Relocating stowages on the turret is to be avoided to ensure trouble-free functioning of GCE. Relocating stowages on hull will always be resisted by the crew as it will be inconvenient to them. However, by changing the tactical drill, it is a definite feasibility.

4.4 Relocating IR Devices/Head Lights

Due to add-on armour on the hull glacis, existing infrared devices and headlights are to be removed. These can be mounted on the add-on armour by suitably redesigning the mounting brackets, and ensuring that it does not create any additional vision problem to the driver.

4.5 Relocating Towing Hooks

It is feasible to mount towing hooks on nose plate in such a manner that it does not affect mounting of the mine ploughs. Towing hooks should not be mounted on the add-on armour. Redesigning towing hooks to suit the available space may offer better solution in some cases.

4.6 Mine Plough Mounting

Antitank mines are laid on expected routes to cause delay in the movement of tanks. For obvious reasons, these antitank mines are to be removed without affecting speed of action. It is for this reason, that mine clearing system should be available on tanks. A number of mounting brackets are thus required to be accommodated on the add-on armour module on hull glacis and nose plate for mounting the mine ploughs. Such an exercise would lead to reshaping of add-on armour on hull glacis near the nose plate, thereby affecting protection level to some extent. The loss of protection in this area of hull glacis can be reduced by shaping the add-on armour in such a manner that it does not have deep cut in it, either for the purpose of mine plough or for accommodating the towing hooks.

5. CONCLUSION

Add-on armour on hull glacis and turret introduces some technical and tactical restrictions on the usage of a battle tank. However, major and minor complexities arising out of add-on exercise can be resolved to a large extent by the armour designer with close interaction with the crew. The crew is to be made aware of the design complexities and offered, in depth, advantages and disadvantages of each solution for assessing the impact of optimum solution on tactical functioning of the equipment. Finally, add-on exercise may call for minor unavoidable 'compromises' in the usage of the tank and it should be acceptable to the crew, keeping in mind the 'gains' of the increased protection levels of vintage tanks.

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