Title:
Shotline Analysis of Ground Combat Vehicles using Target Geometry Modelling

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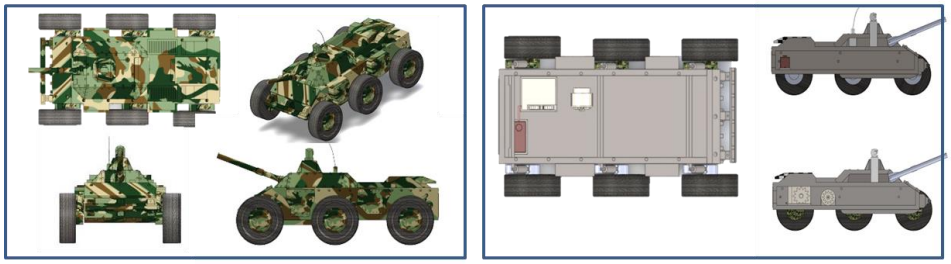
Introduction:
In the early stage of the design process of a ground combat vehicle (GCV), four major performance functions of GCV including mobility, fire power, vulnerability, and operability should be carefully designed and tested using the modelling and simulation (M&S) technology.

Fig. 1: The functions of the ground combat vehicle.

Among them, vulnerability assessment, which assesses the amount of damage when GCV is attached by enemy's weapon, is needed to develop more robust and highly survivable GCV. The first step for vulnerability assessment is to make a target geometry model using CAD system. In the previous research in vulnerability assessment, BRL CAD system which was developed at Ballistic Research Lab in USA has been widely used. However, it is not convenient to use it since it is not only hard to learn, but also models should be constructed using only CSG method. Thus, in order to use the target geometry model that is constructed easily using a commercial CAD system, a new vulnerability assessment system needs to be developed. This paper introduces the contents of the vulnerability analysis program including importing target geometry models made in a commercial CAD system and performing the shot line analysis.

Modelling the Target Geometry Model:
The target geometry model is modeled using a commercial CAD system. SolidWorks™ is used to build the model. Fig. 2 shows the external and the internal shape of the target geometry model (TGM) of GCV. Parts of the GCV are modeled and assembled into several subassemblies. The name of the subassembly should be carefully assigned according to the function of the GCV, which will be used to find the relationship between the damaged part and the disabled function of GCV in the shot line

analysis. Fig. 3 shows an example of the hierarchical tree of parts of GCV. The GCV has four major functions and parts and subassemblies are hierarchically organized. For example, if a wheel is damaged by the enemy's shot, it will affect the mobility of the GCV. However, since there are six wheels in the current model, the significance of the damage on the wheel will be restrictive.



(a) External shape of TGM using SolidWorks (b) Internal shape of TGM using SolidWorks

Fig. 2: External and internal shape of the TGM.

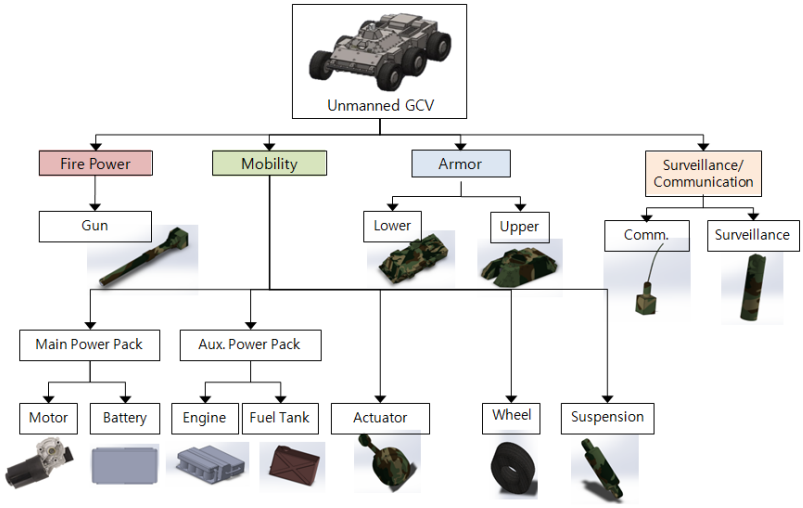
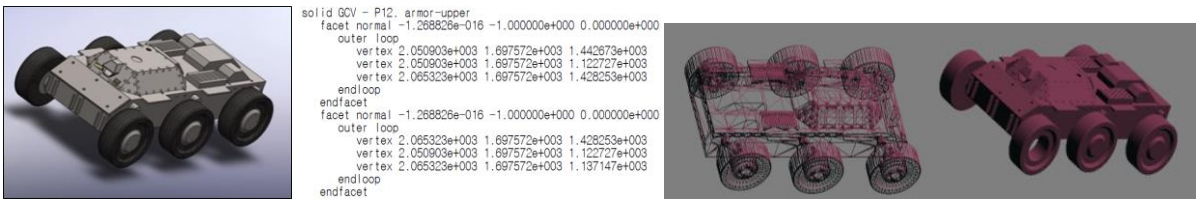


Fig. 3: Hierarchical tree of parts of GCV which is arranged for the shot line analysis.

Importing the Target Geometry Model:

When the target geometry model of GCV is imported to the shot line analysis program, the STL file format is used since the STL format can express complex shapes with simple triangular elements. Fig. 4 shows (a) TGM of SolidWorks™, (b) STL file format, and (c) TGM of the shot line analysis program after import.



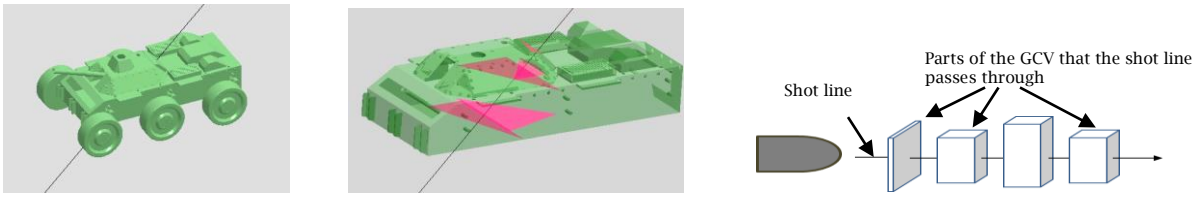
(a) SolidWork™ model (b) STL file (c) Imported model

Fig. 4: Importing the target geometry model to the shot line analysis program using STL file.

After the whole TGM of GCV is assembled with multiple subassemblies and parts, it needs to be converted into STL file format. SolidWorks™ generates a separate STL file of each and every part of TGM while it automatically assigns the name of each STL file based on the hierarchy of the assembly. For example, as shown in Fig. 4 (b), the name of "solid GCV- P12, armor-upper" is automatically assigned to the STL file of the upper armor (12th part) of GCV model (See Fig. 3). By analyzing the name of the STL file, the hierarch tree can be reconstructed after importing.

Shot Line Analysis Program:

Shot line analysis is to calculate the penetrated parts along given path of the bullet (shot line). For the shot line analysis, after defining the location and orientation of the shot line, all the parts that the shot line passes should be calculated. Shot line analysis program consists of the following steps: 1) input the direction and the position of the shot line, 2) find all the triangles ID that the shot line meets and calculate the coordinates of penetration points, 3) retrieve the information of the part that each penetrated triangle belongs to such as part ID, material properties, attach angle, thickness, etc. , 4) calculate the penetration depth for each part and find the damaged parts, 4) find the functions of GCV that are damaged because of failure of parts. Fig. 5 shows an example of shot line analysis: for the given shot line of Fig. 5(a), triangles that are penetrated by the shot line are identified and the accurate penetration position and the attach angle are calculated (Fig. 5(b)). After sorting the parts along shot line based on the nearest distance (Fig. 5(c)), the penetration depth is successively calculated for each part. When the penetration depth is deeper than the thickness of the part, the bullet penetrates the part and the exit velocity of the bullet is calculated, which becomes the entrance velocity to the next part.



(a) Input the shot line (b) penetrated triangles (c) calculation of the penetration depth to check how many parts are penetrated

Fig. 5: Example of the shot line analysis.

Conclusions:

The shot line analysis program that has the following characteristics was developed: a) it can import the target geometry model that were modeled in the commercial CAD system, b) by calculating the penetration point, the triangle ID and the part ID can be identified, which the properties of the part can be retrieved from, c) the penetration depth of each part is calculated and it can be determined which part is damaged and what function of GCV is damaged. In order to do this analysis, TGM should be carefully modeled and named in hierarchical order.

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