Defence Science Journal, Vol 45, No 2, April 1995, pp 141-146

Method for Improving the Performance of Electric Drive of the Tank Turret

Zang Kemao and Ma Xiaojun

Beijing Vehicle Engineering Institute, Beijing, China-100 072

ABSTRACT

A method for improving the performance of the electric drive of the tank turret device is developed, using an electronic circuit in place of the polarizing relay. This system is designed according to the theory of electronic optimal regulation. Tests proved the improvement to be quite effective. The volume of the sample product employed in this method is smaller and its price is lower.

1. INTRODUCTION

At present, the electric turret drives of a multitude of tanks are still the amplidyne-motor control systems. To heighten the maximum laying speed, lower the minimum laying speed and increase the speed range, the control windings of the amplidyne are controlled by a polarizing relay, i.e., the control windings of the amplidyne are closed/opened due to the vibration of the armature iron of the polarizing relay. The motor speed can be regulated by changing the closed/opened duration of the control windings of the amplidyne with a controller.

Because the vibration frequency of the armature iron cannot be increased further, the minimum laying speed also cannot be lowered further. Thus the requirements for improving the tactical and technical performance of the electric drive cannot be satisfied.

In this paper, a method is recommended by which the polarizing relay is replaced by an electronic circuit. The closed/opened frequency of the control windings of the amplidyne can be increased considerably, and therefore the performance of the electric turret drive can be heightened greatly. A sample product, made and mounted in a Type-A tank, has been proved to be effective by test.

2. MAIN CIRCUIT OF THE ELECTRIC TURRET DRIVE IN TYPE-A TANK

The main circuit on the amplidyne of the electric turret drive in Type-A tank is shown in Fig. 1. In Fig. 1, JJ is the polarizing relay, its core is wound with two coils–a main coil ZX and an auxiliary coil FX ; K_1, K_2 are the control windings of the amplidyne. When the controller turns clockwise or counterclockwise, the armature iron of the polarizing relay touches the contact 1 or 2, and the exciting current flows through the winding K_1 or K_2, producing the exciting flux resulting in generating the emf in the amplidyne which is fed to turret motor. Consequently, the turret is made to rotate.

The directions of the exciting flux are just opposite when the exciting current flows through K_1 and K_2, so the directions of the emf of the amplidyne and the rotation of the turret too are just opposite. When the control potentiometer of the controller is rotated, the control voltage exerting on the main coil ZX of the polarizing relay is changed. Therefore the duration that the armature iron of the polarizing relay stays in touch with the contact 1 or 2 is lengthened or shortened. Then the average current flowing through the control winding

Received 06 January 1993, revised 02 May 1994

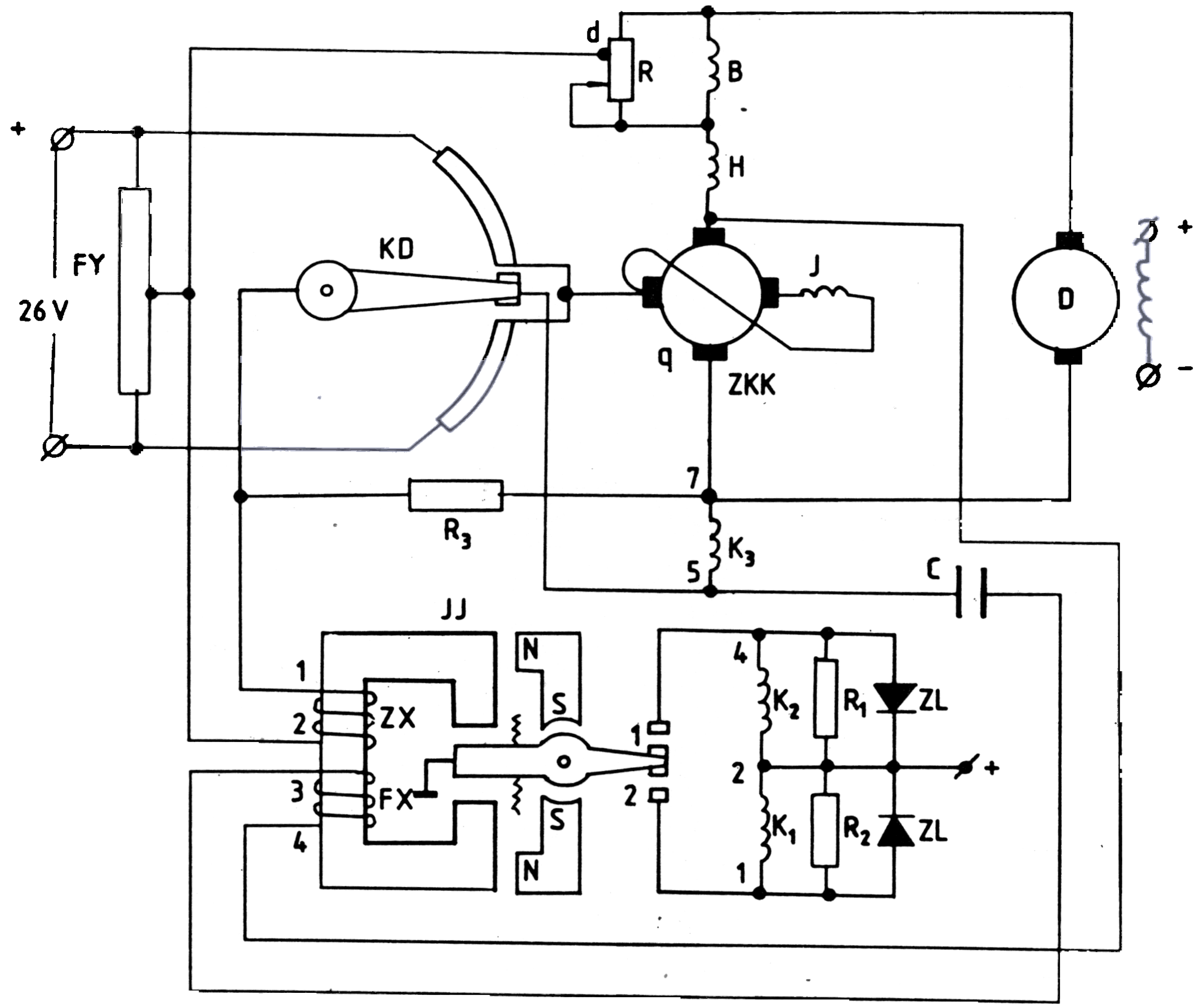

Figure 1 Main circuit on the amplidyne of the electric turret drive in Type-A tank.

K_1 or K_2 of the amplidyne is enhanced or reduced and the emf generated by amplidyne changes. As a result, the rotating speed can be changed. When only a main winding ZX is wound around the core of the polarizing relay, the vibration frequency of the armature iron is very low (about 10 Hz). Obviously, the terminal voltage generated by amplidyne, as well as the armature current of the turret motor, pulses. The rotating speed of the turret motor too pulses. Thus the accuracy of the gun laying must be lower considerably. When the variation of the armature current is assumed to be linear the magnitude of speed pulsation can be found, as illustrated in Fig. 2, by the relation:

$$\Delta\Omega = \frac{\Omega_0}{8} \frac{\rho(1-\rho)}{T_M T_E f^2}$$

When the variation of the armature current nonlinear,

$$\Delta\Omega \approx \Omega_0 \frac{\rho(1}{T}$$

Ω_0	No-load speed of turret motor
$f = 1/T$	Frequency
$\rho = t_1/T$	Duty ratio
t_1	Duration of armature iron staying in touch with the contact

T_M Electromechanical time constant, and
T_E Electromagetical time constant.

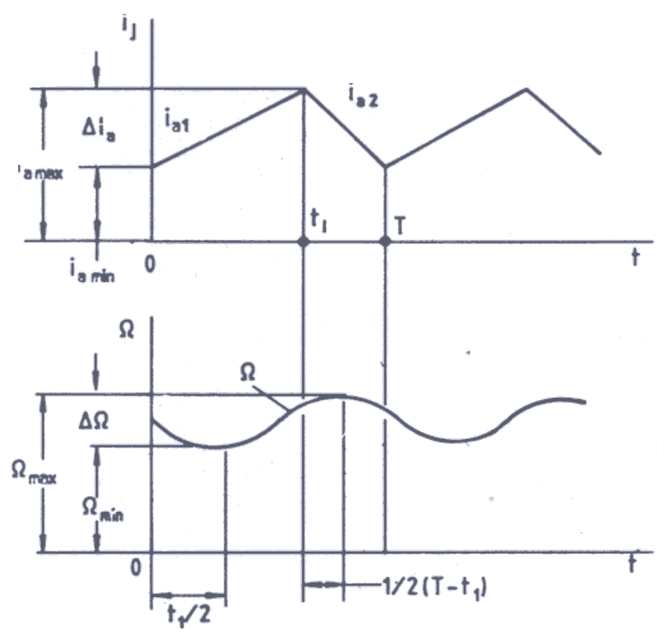

Figure 2. **Variation in speed where the variation of the armature current is assumed to be linear.**

Thus, we see that the speed pulsation $\Delta\Omega$ can be decreased by increasing the vibration frequency *f*. When an auxiliary coil FX is appended to the core of the polarizing relay the vibration frequency of the armature iron can be heightened to about 100 Hz. The pulsation of the terminal voltage generated by amplidyne as well as the pulsation of the rotating speed of the turret motor can be much weakened. The accuracy of the gun laying as well as the speed range can be heightened greatly.

The auxiliary coil FX is connected with the auxiliary winding K_3 of the amplidyne through capacitor *C*. Direct current cannot pass through the auxiliary coil FX via capacitor *C*. Only fluctuating or pulse current can pass through auxiliary coil FX via capacitor *C* when the voltage generated by the amplidyne fluctuates. Thus a so called 'flexible feedback' loop is formed. It is advantageous to eliminate the oscillation of the system and raise the stability of the system.

A tachometer device is not provided in this system. If the position of the point *d* on the shunt resistor *R* is appropriately chosen, the feedback voltage U_{dq} obtained between the point *d* and *q* is proportional to the back emf *E* of the turret motor, i.e., U_{dq} is proportional to the rotating speed *n* of the turret motor. Therefore this system can be considered equivalent to a 'rotating speed feedback system' and represented by the block diagram shown in Fig. 3.

3. SOME PARTS OF THE IMPROVED UNIT CIRCUITS

The electronic circuit shown in Fig. 4 can be used in place of the polarizing relay. The VMOS power transistor possesses very high input impedance and the driving power demanded is small. The circuit shown in Fig. 5 can be adopted for driving the VMOS transistor.

When the control winding K_1 or K_2 is controlled with the electronic circuit shown in Fig. 4, the frequency of the current flowing through K_1 or K_2 can reach a very high value much more than 100 Hz. Thus the performance of the gun laying can be improved greatly.

Because electronic circuit has been used in place of the polarizing relay, the turret drive system is turned into a fully electronic system. This system can be designed according to the theory of the electronic optimal regulation, to obtain the further advantage of

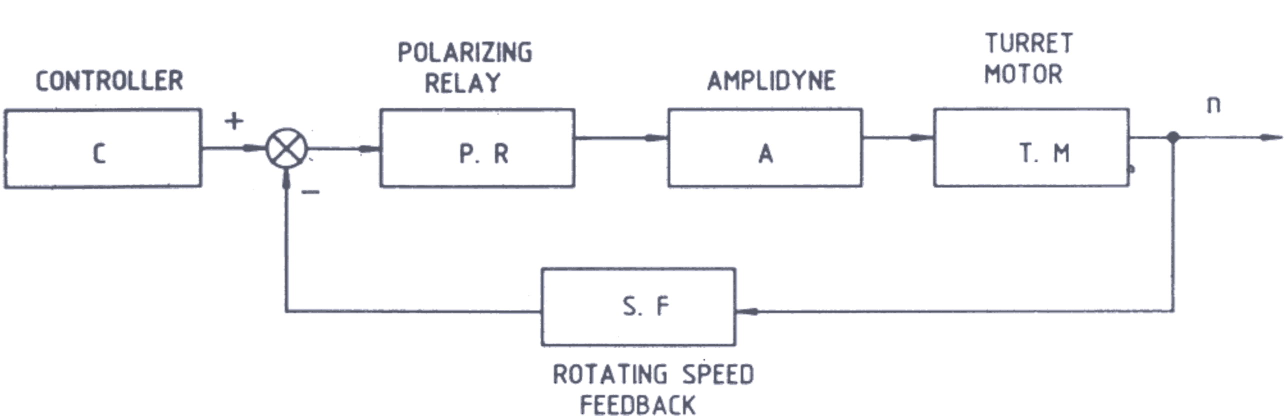

Figure 3. **System block diagram.**

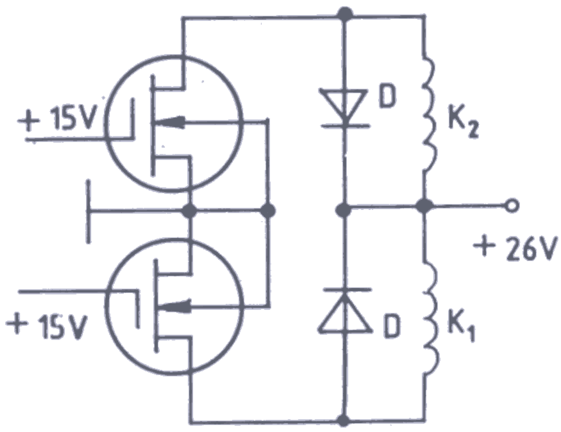

Figure 4. Switching circuit consisting of VMOS transistor.

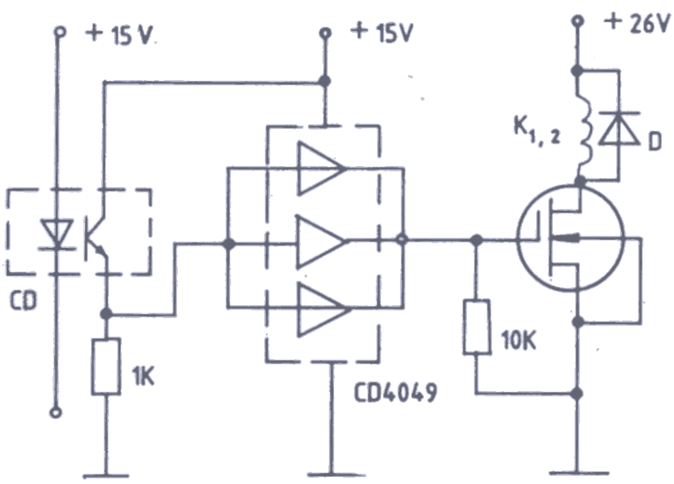

Figure 5 Driving circuit of VMOS transistor

raising the performances of the electric turret drive.

The block diagram of the improved system can be represented as shown in Fig. 6. LEM is a Hall-effect transducer which is used as a current feedback element and an overcurrent protection element. LAER is a voltage segregator used as a voltage feedback element; it can also segregate the lower voltage of the control circuit with the higher voltage of the power supply.

Because the tachometer device is not mounted in the system, a compensation circuit is added to the voltage feedback circuit, and it is equivalent to a speed feedback. The voltage feedback from compensation circuit is shown in Fig. 7.

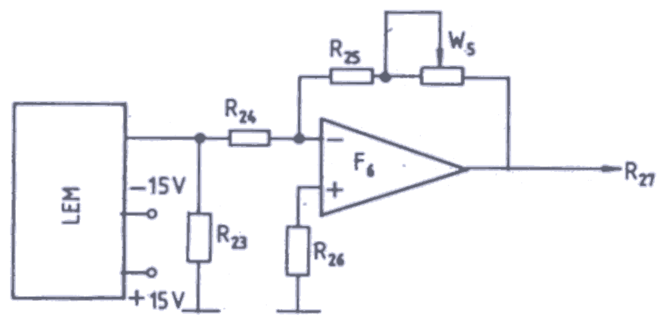

Figure 7. Voltage feedback from compensation circuit (where $R_{23} = 220$, $R_{24} = 10k$, $R_{26} = 10k$, $R_{25} + W_5 = 50k$).

The changeable feedback circuit is represented in Fig. 8. When the feedback voltage signal changes from weaker to stronger, i.e., the turret motor speed changes from lower to higher, the feedback coefficient changes from larger to smaller and vice versa. Hence the relation between the turret rotating velocity ω and the controller turn angle θ is as shown in Fig. 9.

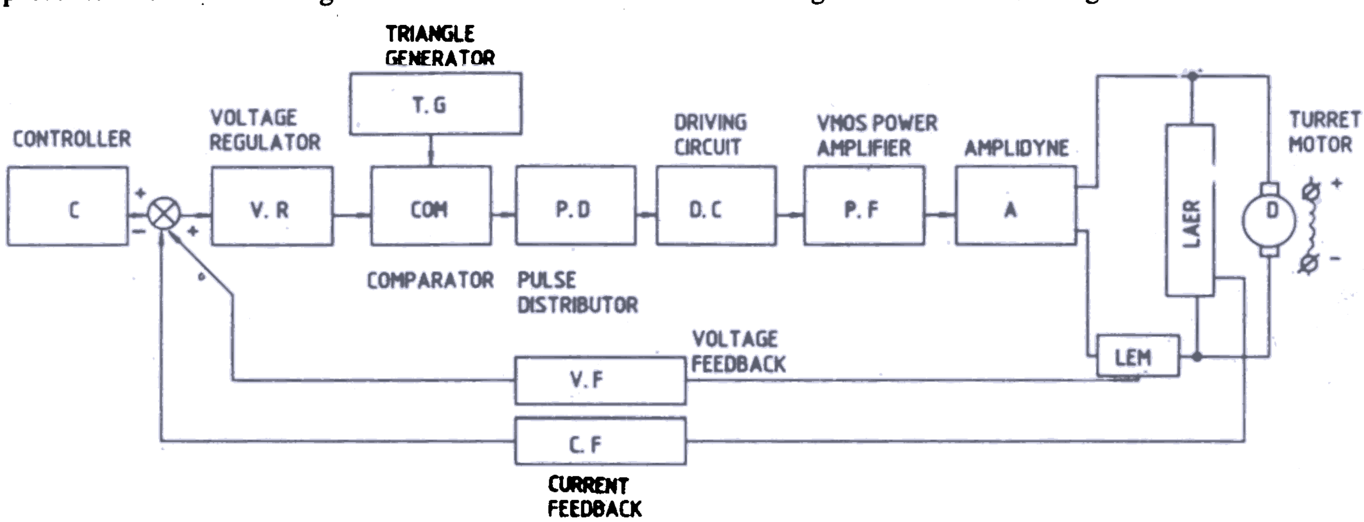

Figure 6. Improved system block diagram.

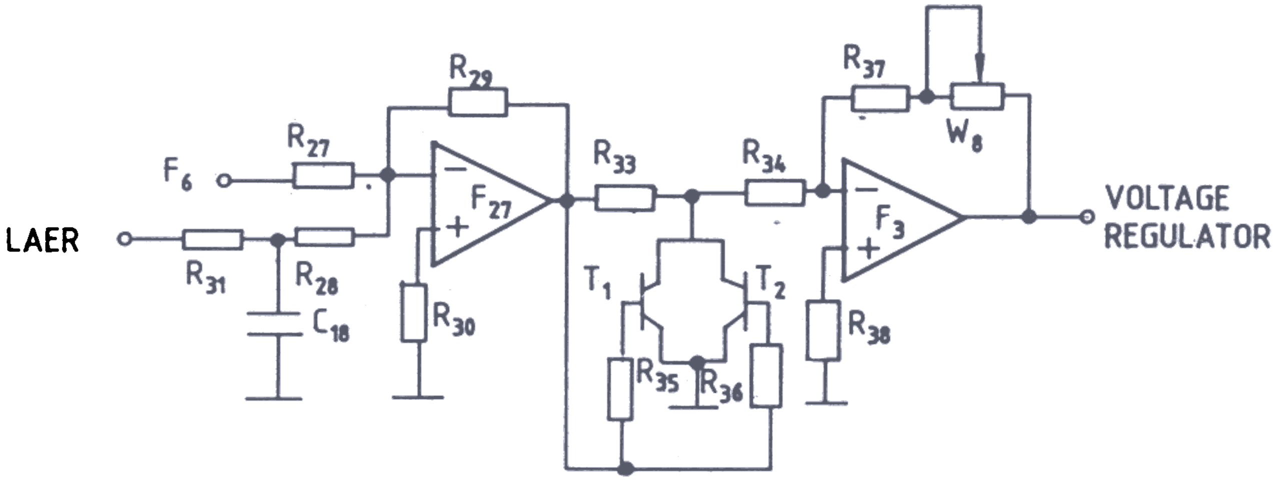

Figure 8. **Changeable feedback circuit (where R_{27} = 10*k*, R_{28} = 5*k*, R_{29} = 10*k*, R_{30} =10*k*, R_{31} = 5*k*, R_{33} = 1*k*, R_{34} = 10*k*, R_{35} =120*k*, R_{36} = 120*k*, R_{37} + W_1 = 50*k*, R_{38} = 10*k*, C_{15} = 0.1 μF).**

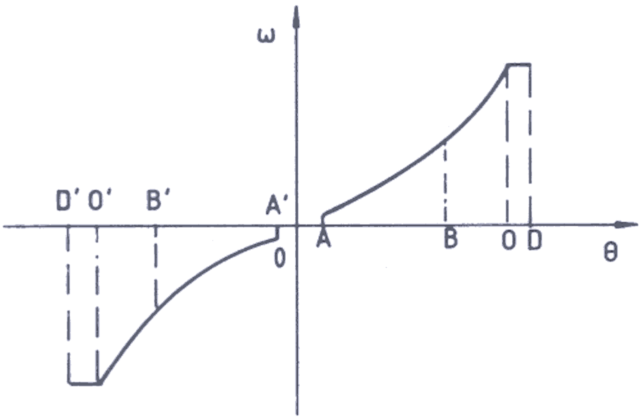

Figure 9. **Relation between turret rotating velocity ω and controller turn angle θ.**

As a result of removing the polarizing relay and the capacitor C of the flexible feedback and resistor associated with it, the volume of the sample product of the improved electric turret drive can be made of the same size as before.

4. TEST DATA

According to the method mentioned above, an improved electric turret drive is made and mounted on a Type-A tank and tested for its performance. The test data are shown in Table 1.

The original data of the electric turret drive of the Type-A tank: maximum laying speed, 10°/s; minimum

Table 1. Test data of the improved turret drive

	Minimum laying speed		Maximum laying speed		Speed range
	(rpm)	(°/s)*	(rpm)*	(°/s)	
Rotation to the left		0.006	9800	11.76	1960
Rotation to the right	4	0.0048	9800	11.76	2450
To left	6	0.0072			1633
To right	4	0.0048			2450
To left	5	0.006	–	–	1960
3 To right	5	0.066	–	–	1960

(rpm)*, rotating speed of the turret motor; °/s, rotating speed of the turret; and ( ), conversion value.

laying speed, 0.05°/s; speed range, 200. The minimum laying speed of M1 tank (USA), AMX30 tank (France) and Leopard I tank (Germany) all are 0.018°/s; Chieftain tank (England) is 0.012°/s.

5. CONCLUSION

It is obvious that the method recommended for improving the turret drive is quite effective. This methodology can be applied to other tanks, such as Type-B and Type-C, for obtaining minimum laying speed, because their turrets also are the amplidyne-motor control system with the polarizing relay[2].

REFERENCES

1. Wang, Lijiu & Huang, Jinen. Transistorized PWM speed control system, Ed. 1. Centrechina Publishing House, Wuhan, China, 1988.
2. PLA Armored Force Board, Handbook of fighting vehicle, Ed. 1. Military Publishing House, Beijing, China, 1988.