AiMT Advances in Military Technology
Vol. 7, No. 1, June 2012

Shock-less Transmission in the Breech Mechanism of a Weapon with Bound-Together Barrels and Breeches

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The manuscript was received on 22 June 2011 and was accepted after revision for publication on 23 February 2012.

Abstract:

The weapon with bound-together barrels and breeches is one of three used high rate of fire weapon principles. A very important task of the designing this weapon is to ensure the shock-less function of its mechanism. This is solved by the convenient choice of the transmission function of this mechanism. On the base of this transmission function it is possible to design the functional curve which ensures the required shock-less motion of the breech block driven by the carrier by means of the crank mechanism placed between the carrier and the breech block.

Keywords:

Shock-less transmission, breech mechanism, crank mechanism, functional curve.

1. Introduction

This high rate of fire weapon principle is known from Russian cannons and also from the new Czech 20mm aircraft cannon ZPL-20 which was introduced into Czech Air Force in the year 2004. The breech block carriers of this kind of weapon are bound together so that if one carrier moves backwards, the second one moves forwards. The breech block carrier of each barrel is driven by its gas-operated system which accelerates the carrier backwards and decelerates it before reaching its rear position. This principle ensures that the beginning of the functional cycles in the barrels is postponed; the first one with respect to the second one by one half of the functional cycle. This is the basic feature ensuring high rate of fire. The second important feature consists in the construction of the breech system. Its construction is shown in Figs 1 and 2. The breech block carrier is connected with the breech block by the **crank mechanism** (the crank and the connecting rod). This fact ensures that the displacement of the breech block is longer than the displacement of the breech block carrier [1, 2].

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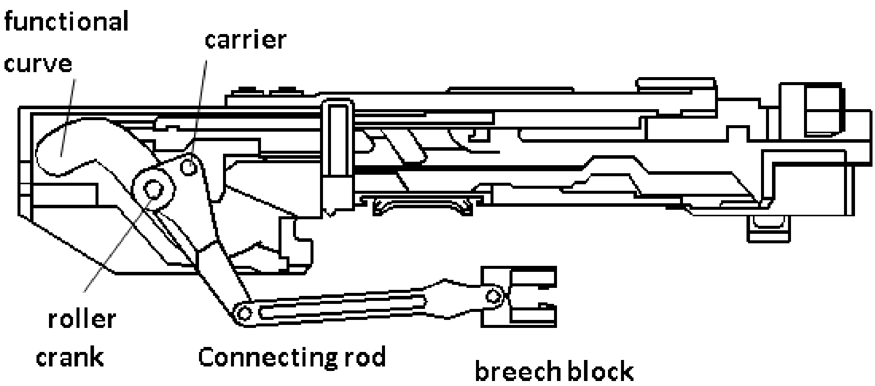

Fig. 1 Crank mechanism of the Russian cannon GSh-23

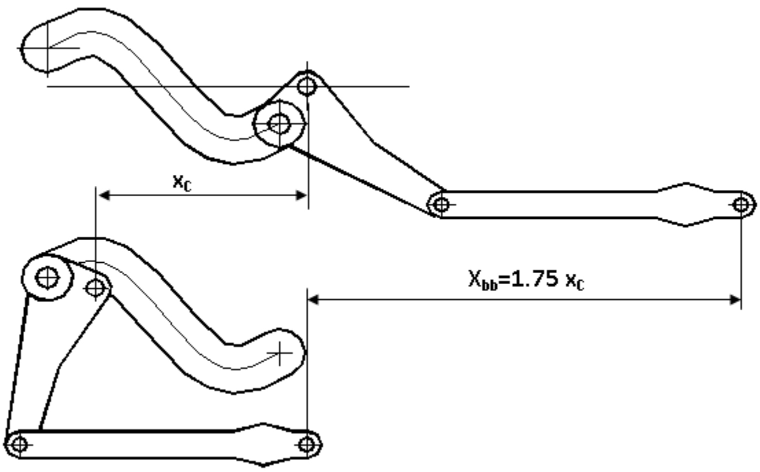

Fig. 2 Crank mechanism separated from Fig. 1 (in two limit positions of the carrier)

The breech block carrier does not control only the rectilinear backward and forward motion of the breech block. At the beginning of the carrier motion, the unlocking of the breech block occurs in such a way that utilizing the lowering element, the vertical shift of the breech block downwards is ensured. Thus in the first portion of the carrier backward motion, there is no backward motion of the breech block. The beginning of the backward motion of the breech block begins at the instant when the carrier has been partially accelerated by the gas drive. This would cause **the impact in the breech mechanism.** To prevent this impact the crank mechanism is completed by the **roller** (placed on the crank) which meshes with the **functional curve** produced in the weapon casing (see Figs 1 and 2). The shape of the functional curve ensures shock-less continuous acceleration and deceleration of the breech block rectilinear motion at the period of the common rectilinear motion of the breech block and the breech block carrier x (see Fig. 2). In addition to the previous description of the function it is necessary to take into consideration also the functional diagram of the breech block carrier for all weapon mechanism (i.e. for both barrels), which is shown in Fig. 3. This functional diagram is drawn in two variants: 1 – complete for backward and forward motion of both carriers, 2 – only for one direction of the carriers' motion.

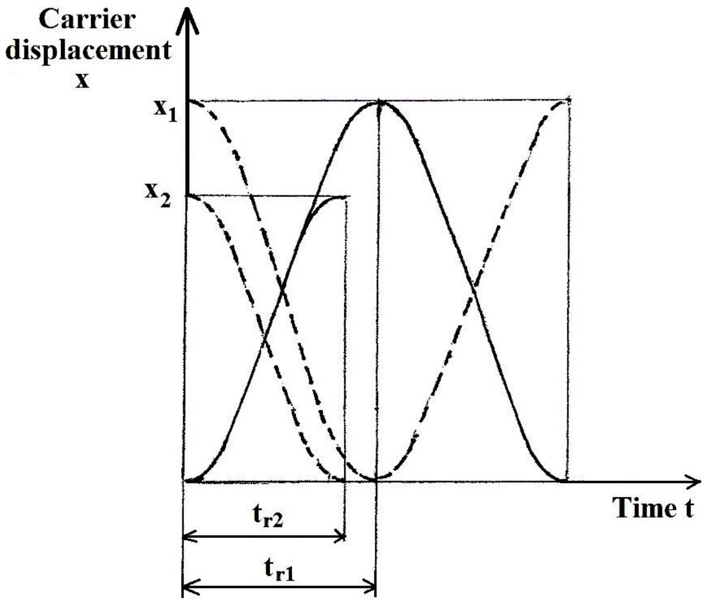

Fig. 3 Functional diagram belonging to the displacement of the breech block carrier x at the period of common motion of the carrier and the breech block for two different displacements x_1 and x_2 (continuous line – one carrier, dash line – second carrier)

2. Main Features of Shock-less Solution

The shock-less displacement of the breech block x_{bb} in dependence on the displacement of the breech block carrier x_c is shown in Fig. 4. This figure shows that the total displacement of the carrier is

$$x_c = x + x_u + x_r \tag{1}$$

where x – is the common motion of the carrier with the breech block (during it the breech block reaches the displacement $x_{bb\,\max}$),

x_u – is the displacement of the carrier at the unlocking of the breech block (there is no motion of the breech block in the direction of the carrier motion – the unlocking occurs in the vertical transversal motion of the breech block),

x_r – is the displacement of the carrier after the breech block has reached its rear position $x_{bb\,\max}$.

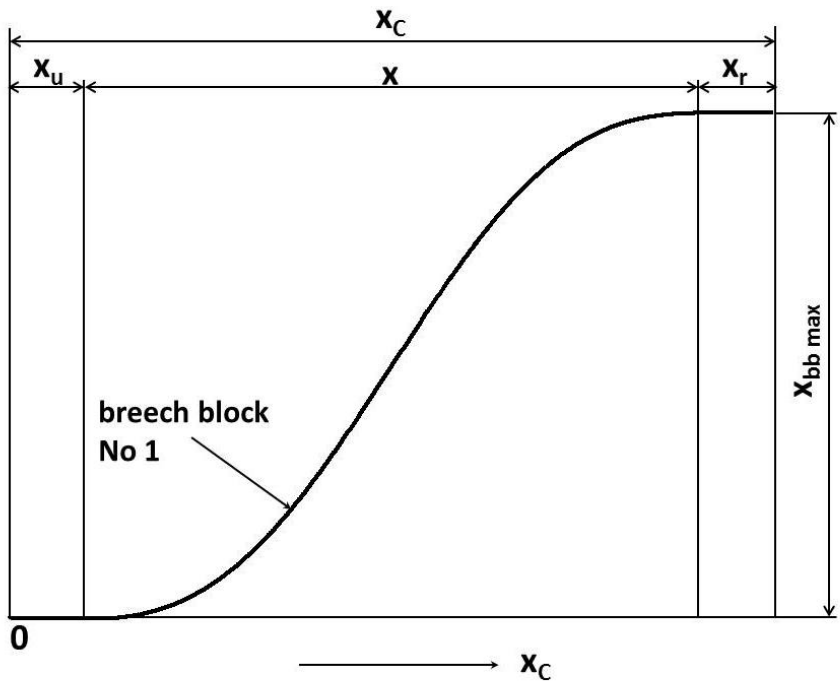

Fig. 4 Dependence of the breech block displacement on the carrier displacement

Since the motion of the breech block in the backward and forward direction occurs only during the carrier displacement x, the solution of shock-less transmission between the carrier and the breech block belongs only to the portion of the common displacement of the breech block and the breech block carrier x, as it is apparent from Fig. 4. Thus only for the curve shown in Fig. 4, the **problem of the shock-less transmission must be solved.** The maximum displacement of the breech block $x_{bb\,\max}$ is determined from the length of the cartridge used (it must be slightly longer than the length of the cartridge).

The **transmission** between the breech block and the breech block carrier is

$$i = \frac{v_{bb}}{v_c} = \frac{\Delta x_{bb}}{\Delta x_c} \tag{2}$$

where v_{bb} – is the velocity of the breech block,
v_c – is the velocity of the breech block carrier,
Δx_{bb} – is the change of the breech block displacement,
Δx_c – is the change of the carrier displacement at the same interval.

To ensure the shock-less transmission, the breech block displacement x_{bb} at any position of the carrier during common displacement x must correspond with the equation [1]

$$x_{bb} = \frac{x_{bb\max}}{x}\left[x_{in} - \frac{x}{2\pi}\sin\left(\frac{2\pi}{x}x_{in}\right)\right] \tag{3}$$

where x_{in} – is the instantaneous carrier displacement in the interval x.

The **transmission function *i* = *f*(*x*)** is calculated utilizing the equation

$$i = \frac{x_{bb\max}}{x}\left[1 - \cos\left(\frac{2\pi}{x}x_{in}\right)\right] \tag{4}$$

In both Eqs (3) and (4), it is possible to replace the ratio in front of the bracket by the **transmission of the crank mechanism as follows**

$$i_{crm} = \frac{x_{bb\max}}{x} \tag{5}$$

E.g. in Fig. 2 this transmission is $i_{\mathrm{crm}} = 1.75$.

Examples of the utilization of equations (3) and (4) for the determination of the shock-less transmission between the breech block and the breech block carrier for two different values of the crank mechanism transmission ratio i_{crm} are in Fig. 5.

For both cases compared in Fig. 5, the use of the same cartridge is presumed,. i.e. the same maximum displacement of the breech block $x_{bb\ \max} = 0.18$ m is used. The continuous shape of both kinds of curves – especially of the transmission function $i= f(x_{in})$ – meets the requirement to reach the shock-less transmission .between the breech block and the breech block carrier at their common motion during the carrier displacement x . The diagram in Fig. 5 compares also the influence of the magnitude crank mechanism transmission I_{crm}. For this purpose, two values of this transmission ($i_{\mathrm{crm}} = 1.5$ and $i_{\mathrm{crm}} = 2.0$) are used. These diagrams serve as the basic document for the design of the mechanism functional curve. Especially the shape of the curve $x_{bb} = f(x_{in})$ is utilised for this purpose.

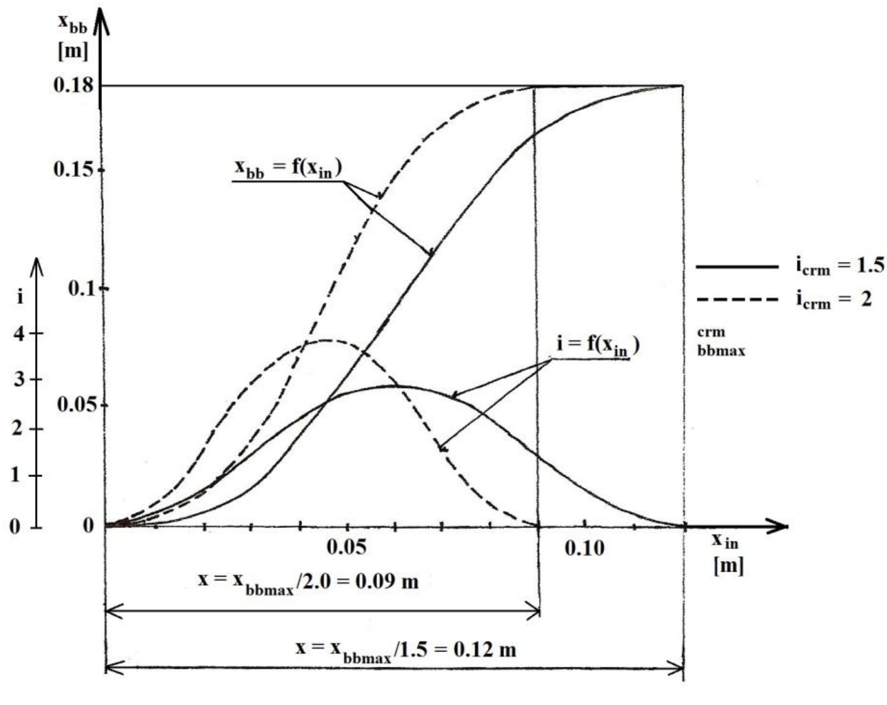

Fig. 5 Dependencies $x_{bb} = f(x_{in})$ and $i = f(x_{in})$ for two different cases of the crank mechanism transmission

3. Design of Functional Curve [3]

The functional curve – the groove produced in the weapon casing - ensures the shock-less function of the crank mechanism. The way of the design of this curve is shown in Fig. 6. The upper part of this figure represents the graph showing the dependence of the breech block displacement x_{bb} belonging to the period of the common motion of the breech block and breech block carrier x, as shown in Fig. 4. The substance of the solution is to ensure such a motion of the crank which results in the motion of the end of the connecting rod (i.e. the breech block) corresponding to the mentioned graph $x_{bb} = f(x)$. In this case (Fig. 6), the transmission of the crank mechanism is $i_{\mathrm{crm}} = 2.0$. The triangles drawn below the rectangle represent different positions of the crank. The hypotenuse of the triangle is the length of the crank l_{ck} and on the top of this triangle is the place of the roller axis (compare with Fig. 2). Two limit positions of the roller in the functional curve for the displacement x are marked ***R*** and ***R'***. The shape of the functional curve between these two limit positions of the rollers is obtained by means of the drawing of the triangle representing the crank for cases of the breech block displacement x_{bb} marked A, B, C, D, E in the rectangle. The result of this drawing are the points of the same marking completing the **functional curve** belonging to the carrier displacement x.

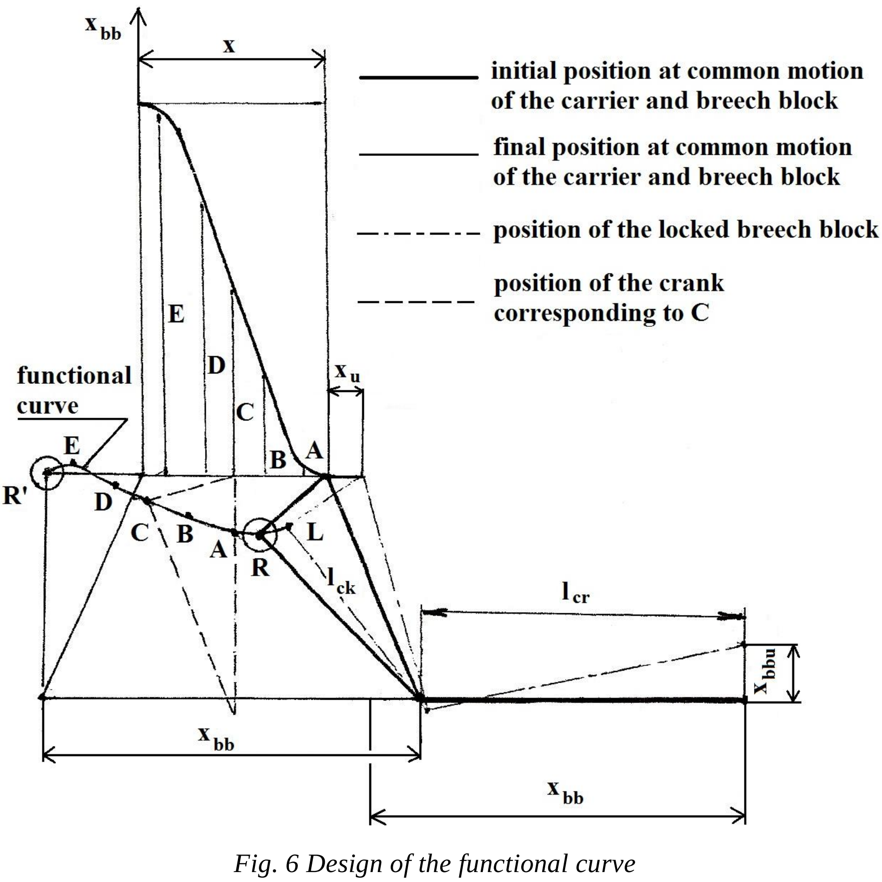

Fig. 6 Design of the functional curve

In addition to the previous design belonging to the common motion of the breech block and the breech block carrier x, the functional curve must be completed also for the carrier displacement x_u during which the breech block is locked and its unlocking occurs. For locking the breech block is shifted upwards and for unlocking it must be pressed downwards, as it is shown by the displacement of the breech block x_{bbu} on the right part of Fig. 6. The **position of the crank mechanism for the locked breech block** is drawn in dot-and-dash line. From this the additional prolongation of the functional curve results (it is given by the position of the roller $\boldsymbol{L}$). It is possible to determine the **rear position of the roller** in a similar way. Thus the functional curve is complete.

4. Conclusion

The previous explanations result in the following conclusions:

- The shock-less transmission between the breech block and the breech block carrier must be ensured for the period of the common motion of these two components of the breech mechanism.
- The maximum displacement of the breech block $\boldsymbol{x_{bb\ max}}$ is determined from the length of the cartridge used.
- The characteristics of the crank mechanism placed between the breech block and the breech block carrier are (see Fig. 6):
  - the length of the crank $\boldsymbol{l_{ck}}$,
  - the position of the roller placed on the crank,
  - the length of the connecting rod $\boldsymbol{l_{cr}}$,
  - the shape of the functional curve (the groove in the weapon casing with which the roller of the crank meshes).
- The dependence of the breech block displacement $\boldsymbol{x_{bb}}$ on the carrier displacement $\boldsymbol{x}$ (see Fig. 4) must correspond with the equation (3), for which the transmission function is given by the formula (4). Therefore the graph corresponding with the dependence (3) serves as the basic document for the design of the functional curve.
- The procedure of the functional curve design is shown in Fig. 6. It consists of two periods. The **first period** belongs to the common motion of the breech block with the carrier $\boldsymbol{x}$. It consists of the drawings of triangles replacing the crank in different positions between the displacements $\boldsymbol{x = 0}$ and $\boldsymbol{x}$. Thus individual positions of the roller axis between two limit positions $\boldsymbol{R}$ and $\boldsymbol{R'}$ form the shape of the functional curve in the first period. The **second period** belongs to the design of the functional curve before the beginning of the breech block backward motion (i.e. during the interval of the locked breech block and its unlocking by shifting it downwards). The initial position of the crank mechanism results in the initial position of the roller $\boldsymbol{L}$. This is the beginning of the functional curve. In a similar way, it is possible to design the **rear portion of the functional curve shape** after the common displacement of the breech block with its carrier (i.e. after the breech block has stopped).

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