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Mechanical Self-shrinkage of Artillery Barrels

Objective of this paper is to define what self-shrink artillery barrel is. She is considered to be a compound barrel like as a thick-walled tube (k>2), in his wall being introduced a state of stress and strain using specific technological proceeds. This type of treatment is aimed to increase the artillery barrel load capacity and wear resistance in operation. The experimental part was realized using an industrial plant at Mechanical Factory of Resita. This part presents a comparative study between mechanical self-shrinkage on artillery head barrel, first using a mandrel and seconds a ball.

***Keywords**: mechanical self-shrinkage, degree of self-shrinkage, barrels, stress, strain*

1. Introduction

The self-shrink artillery barrel is different by the other kind of compound tubes. The initial stress create in different layers of the barrel wall are not maid using compression joint of two or more barrel but through a special technological process (named self-shrinkage) applied to a blank block.

The self-shrinkage process consists in subjecting the barrel to internal pressure exceeding the yield limit of material (touching the ultimate strength but without it overcome), on a certain thickness of barrel wall (partially self-shrinkage) or on the entire barrel wall (total self-shrinkage). In self-shrinkage process, in partially self-shrink barrel, when the equivalent unit stress reaches ultimate strength ($R_{p0,2}$) can be distinguish two areas (Figure 1) on layer located intermediate diameter D_c. The self-shrink barrel can be treated as a shrink tube with a infinite number of sleeves placed inside the tube.

Through self-shrinkage degree X[%] is understand on what percent of barrel wall thickness has exceeded the ultimate strength of material starting from inside diameter. The partially self-shrinkage must be made on at least X = 51% from wall thickness.

The barrel with thick wall is a barrel on which the ratio between external and internal diameter is bigger than 2 ($K = D_2/D_1>2$).

The self-shrinkage of tubes with thick wall, especially of a artillery barrel, is a technological process of elastic-plastic deformation through which is increase their load capacity. These increased load capacity is due, first to a residual stress state generate inside barrel wall by the elastic-plastic deformation, and second to a cold-hardening of barrel material.

In operation, when the self-shrink barrel is subjected to service stress from loading chamber, the compressive stresses produced by self-shrinkage are deducted from the stress arise during pull process. In this way, the barrel ability to resist at increased internal pressure grows up until at self-shrinkage pressure limit (without dimensional modification of inner).

In the same time, the barrel material, due to plastic deformations, will be cold-hardening and in this way will earn a higher yield stress than the natural one and radial variable, from inside to outside. This increase of yield stress point will be proportional with overstrain of barrel fibers (Figure 2).

The barrel, after discharge self-shrinkage pressure, is known as self-shrink artillery barrel.

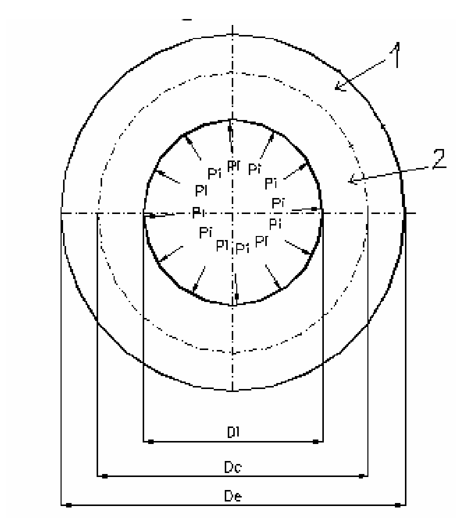


Figure 1. Partial self-shrinkage

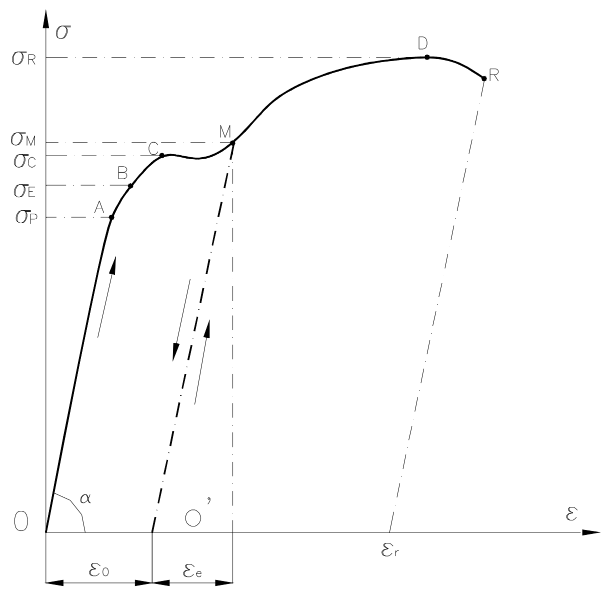


Figure 2. Cold-hardening process

When the self-shrink pressure p_F are remove, in barrel will be find radial residual stresses $(\sigma_r)_{rem}$ and stresses placed on the circumference $(\sigma_\varphi)_{rem}$ whose value can be determined by adding self-shrinkage stresses with discharge stresses. It is considered that to the discharge, the barrel is elastic strained to a internal pressure equal and counter-current from shrinkage pressure ($-p_F$).

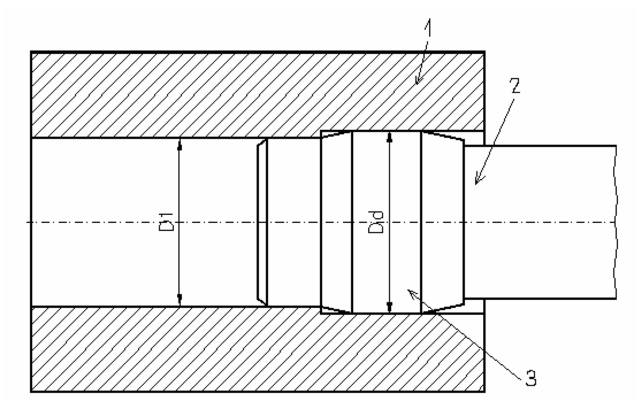
In operation, the self-shrinkage barrel behaves elastic if pressure on the inner will be $p_s \leq p_F$.

The self-shrinkage produces a radial variable self-camping from fiber to fiber (similar with multiple shrinkages) and increased elastic limit (yield stress point) bay hardening.

Calculation in terms of relieving self-shrink stresses are made in the third theory (maxim tangential stress) or fifth (modifying the shape energy theory of Mises-Henky-Mises).

2. Mechanical self-shrinkage. Experimental tests with mandrel and ball on barrel's heads.

This method for barrel elasto-plastic deformation is realized through passing a mandrel (or a set of mandrels) through the drift barrel channel. The mandrel will always have a bigger diameter then inner diameter of blank barrel. (Figure 3.)



1 - the blank barrel to self-shrink
2 - the push shaft
3 - the mandrel

Figure 3. Mechanical principle of self-shrinkage

If to the hydrostatic method the process was controlled by self-shrink pressure, this time the self-shrinkage is conditioned by tightening of the blank barrel and mandrel. For moving the mandrel is needed a force that can overcome the friction between mandrel and the inner surface of blank barrel subject to self-shrinkage.

The mathematical relation who determines the force required to advance the mandrel is:

$$F = \pi \cdot D_d \cdot l \cdot \mu \cdot p_F \tag{1}$$

where: μ – the coefficient of sliding friction;

p_F – the contact pressure, equivalent to needed self-shrink pressure.

To realize an optimal self-shrinkage using this method is necessary to have a high precision machining of barrel inner channel.

The main advantages of mechanical self-shrinkage are related to a simple processing installation and the improvement quality of the surface layer of inner blank barrel.

The most important disadvantages are:

- a very big force is required for moving the mandrel;
- a high dimensional precision of blank barrel before self-shrinkage;
- unable to self-shrinkage of inner barrel profiled surface;
- the processing installation occupies a large space, at least twice the maximum length of the blank barrel.

The mechanical self-shrinkage process was developed after year 1960 in S.U.A., being experimental tested for the first time in Romania in 1999 at Mechanical Factory of Resita. The machining installation was designed and made in Romania (Figure 4.).

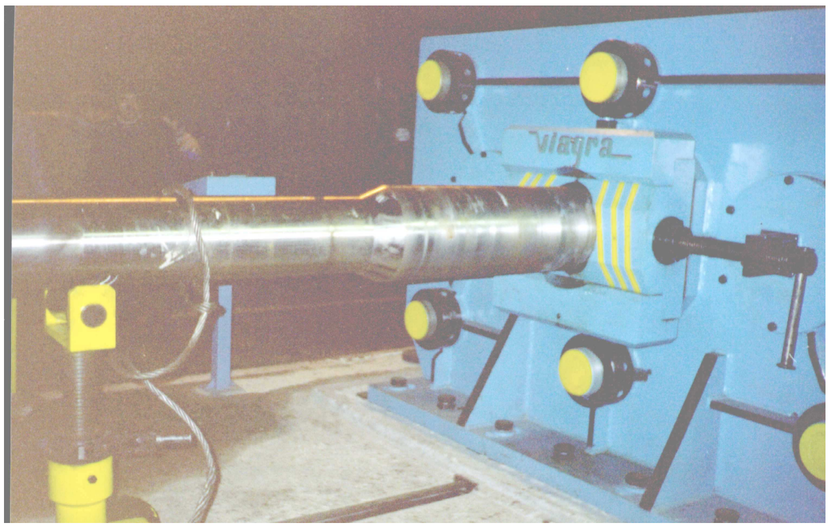


Figure 4. Mechanical self-shrinkage installation

The procedure was approved although the self-shrink barrels were never made because the manufacturing of artillery fire vents was stopped. Because of high costs, the self-shrink study of artillery barrel on industrial plant initially was made on heads barrels.

To verify the study made at Mechanical Faculty of Timisoara [4], for comparison, was made a self-shrinkage of a steel specimen OHN_3MFA having length L = 280 mm, with ball and mandrel, for a 85 mm bore. The specimens were phosphate immersed in bath, both interior and exterior side, shaped as shown in Figure 5. and having the dimensions before self-shrinkage given in Table 1.

Table 1.

Tool	D_3	d (mm)	D_2 (mm)	D_1 (mm)	K	L (mm)	l (mm)	S (mm)
BALL	84,30	84,989	187,94	84,23	2,23	282	-	0,789
MANDREL	85,35	85,01	187,91	84,23	2,23	280,5	123	0,81

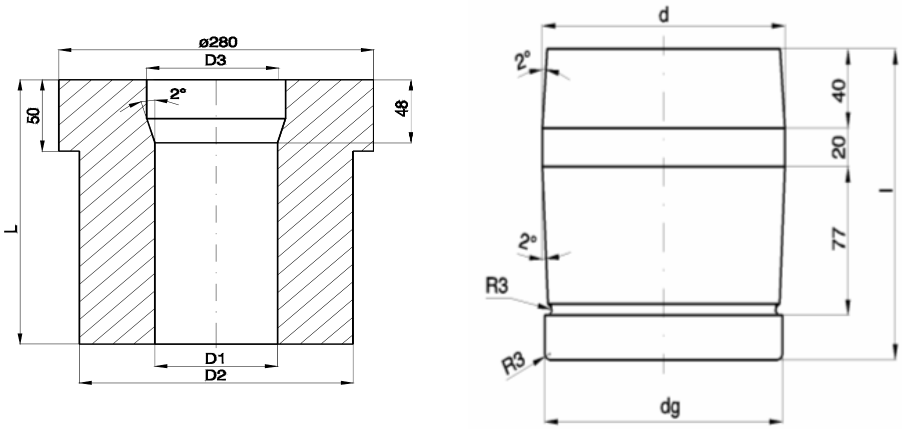


Figure 5.

The mandrel was made from one piece, from steel RUL 1 having the initial hardness of 57,05 HRC. The ball bearing used have de initial hardness of 795 HV (approximately 63,2 HRC).

The residual strain and working speed obtained after self-shrinkage are presented in Table 2.

Table 2.

Tool	δ_1 [mm]	δ_2 [mm]	δ_d [mm]	Vt m /min.
BALL	0,22	0,14	- 0,006	0,4
MANDREL	0,15	0,12	- 0,04	0,4

Based on a calculus algorithm prepared after III-rd and V-th theory from strength materials, and on experimentally determined mechanical characteristics of specimens subjected to self-shrinkage (E=207000 MPa, E_p=2860 MPa) are resulting the following:

a). self-shrinkage with ball (the specimen have $R_{p0,2}$=1050 MPa)

- diameter ratio $K=D_1/D_2$=2,23>2, so we hae a thick-walled tube;
- self-shrink pressure p_F=696,84 MPa (The III-rd theory) and p_F=821,1 MPa (the V-th theory);
- degree of self-shrinkage X=67%.

b). self-shrinkage with mandrel (the specimen have $R_{p0,2}$=1150 MPa)

- diameter ratio $K=D_1/D_2$=2,23>2, so we hae a thick-walled tube;
- self-shrink pressure p_F=747,51 MPa (The III-rd theory) and p_F=885,45 MPa (the V-th theory);
- degree of self-shrinkage X=66%.

3. Conclusion

In both experimental situation was created a self-shrinkage pressure bigger than maximum pressure which can be developed in that moment by flinging dusts existing ($p_{max\ adm}$=530 MPa for a barrel caliber of 125 mm), surpassing the self-shrinkage degree X_{min}= 51%.

After self-shrinkage the hardness of tools are increased with approximately 2-3 HRC:

- the mandrel hardness reached 59,5 HRC;
- the ball hardness reached 800 HV (approximately 63,5 HRC).

The specimens hardness increased after self-shrinkage overage of about 3 HRC (at self-shrinkage with mandrel we have a raise from 39,46 HRC to 42,58 HRC).

The length of mandrel and specimens did not changed from the primary measurements, so we have not any axial strain.

Other important conclusions that can be drawn after the study made are:

- the residual strains of mandrel are bigger that the ones of the ball;
- the residual strains of specimens that were self-shrinkage using balls are bigger than the ones obtained using mandrels for self-shrinkage;
- the self-shrink process is ongoing, without noise and very smooth eliminating the slip phenomenon, known under the name "Stick-Slip", that appears at tests on hydraulic presses using specimens that are not phosphate inside;
- the outgoing of tool from the specimens is done without shock, very smooth in a way that she can be supported only with hand, a special device for catching the tool being unnecessary.

All these results confirm the need to manufacturing a phosphate installation for artillery barrel to reduce the friction coefficient.

References

[1] Buzdugan Ghe., *Rezistenţa materialelor*. Editura Academiei Bucureşti, 1986.

[2] Deutsch I., *Rezistenţa materialelor*. Editura Didactica si Pedagogica Bucureşti, 1979.

[3] Iclanzan T., Dumitru I., *Determinarea caracteristicilor mecanice ale otelului tevilor de artilerie.* Contract de cercetare nr.304/1997 cu Uzina Mecanica Resita.
[4] Iclanzan T., Tulcan A., Stan D., Seiculescu V., *Cercetari privind procesul de autofretare a tevilor de artilerie-Incercari experimentale pe presa*. Contract nr.452/1997 cu Uzina Mecanica Resita.
[5] Ciorba I., *Aspecte privind rezultatele unor prime încercări experimentale de autofretare mecanică a unor tuburi cu pereţi groşi din* OHN_3MFA*"*. Simpozionul "Un sfert de veac de la fondarea învăţământului superior la Reşiţa", 25 – 26 oct. 1996 , (pag.257-260).
[6] Ciorba, I., *Cercetarea procesului de autofretare a tevilor de artilerie*. Teza de doctorat, Timisoara 2001.
[7] Tulcan A., Stan D., Seiculescu V., Iclanzan T., Ciorba I., **"***Ĺ Etude Experimental des Parametres Ď Auto Fretage des Tubes a Parois Epais***"** Revista "Academic Journal of Manufacturing Engineering", Volume I nr. 4/2003.

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