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THE TYPIFICATION OF PNEUMATIC EJECTORS FOR INJECTION MOLDS

Simion HARAGÂŞ , Dumitru POP
Technical University of Cluj-Napoca
e-mail: Simion.Haragas@omt.utcluj.ro , Dumitru.Pop@omt.utcluj.ro

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Abstract. In this paper a typification variant of the double action pneumatic ejectors for the injection molds of the thin-wall parts with linear profile is presented.

1. INTRODUCTION

The design of the ejection system of the plastic injection mold is materialized related to the injected part shape, and in correlation with the injection and cooling systems of the mold. The ejection system has to be designed in such a manner to ensure the ejection of the part from the mold, fearlessly that the part will be deformed.

In this paper we consider a series of 37 thin-wall injected parts, manufactured by S.C. Napochim Cluj-Napoca and S.C. Plastor Oradea. These parts have a linear, curvilinear or combined profile. The parts are grouped in five categories: A type (high taper parts, e.g. buckets) (fig. 1 and table 1), B type (middle taper parts, e.g. flower pots) (fig. 1 and table 2), C type (parts with combined profile) (fig. 2 and table 3), D type (parts with curvilinear profile) (fig. 3 and table 4), and E type (adown taper parts, e.g. basins) (fig. 1 and table 5).

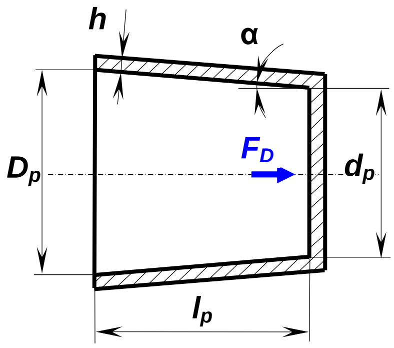

Fig.1

Table 1 ***A-type parts: High taper parts***

No.	Part	D_p [mm]	d_p [mm]	l_p [mm]	α [°]	h [mm]	Material
1	Part A1 ***P***	196	158	192		2	polypropylene
2	Part A2 ***N***	197	152	197		1.1	polypropylene
3	Part A3 ***P***	252	212	245		2	polypropylene
4	Part A4 ***N***	262	202	257		2	polypropylene
5	Part A5 ***N***	274	216	274	6	1.5	polypropylene
6	Part A6 ***N***	275	235	240		2	polypropylene
7	Part A7 ***N***	282	219	300	6	1.25	polypropylene
8	Part A8 ***N***	287	205	265		2	polypropylene
9	Part A9 ***P***	290	210	256		2	polypropylene
10	Part A10 ***N***	300	248	300	5	2.5	polypropylene
11	Part A11 ***P***	300	240	320		2.5	polypropylene
12	Part A12 ***N***	330	280	264		2.5	polypropylene

***Note: N** – parts manufactured by S.C. Napochim Cluj Napoca; **P** - parts manufactured by S.C. Plastor Oradea.*

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Table 2 *B-type parts: Middle taper parts*

No.	Part	D_p [mm]	d_p [mm]	l_p [mm]	α [°]	h [mm]	Material
1	Part B1 ***P***	96	86	88		1.8	polypropylene
2	Part B2 ***P***	120	110	110		2	polypropylene
3	Part B3 ***P***	129	96	93	10	1.2	polypropylene
4	Part B4 ***N***	138	120	85	6	1.2	polypropylene
5	Part B5 ***P***	140	103	105	10	1.3	polypropylene
6	Part B6 ***P***	152	113	110	10	1.2	polypropylene
7	Part B7 ***N***	159	135	140	5	1.2	polypropylene
8	Part B8 ***P***	168	123	128	10	1.5	polypropylene
9	Part B9 ***N***	174	130	126	10	1.3	polypropylene
10	Part B10 ***P***	194	145	138	10	1.5	polypropylene
11	Part B11 ***N***	210	168	198	6	1.5	polypropylene
12	Part B12 ***N***	224	187	214	5	1.8	polypropylene
13	Part B13 ***P***	232	171	174	10	1.5	polypropylene
14	Part B14 ***P***	355	264	258	10	2.5	polypropylene

***Note: N** – parts manufactured by S.C. Napochim Cluj Napoca; **P** - parts manufactured by S.C. Plastor Oradea.*

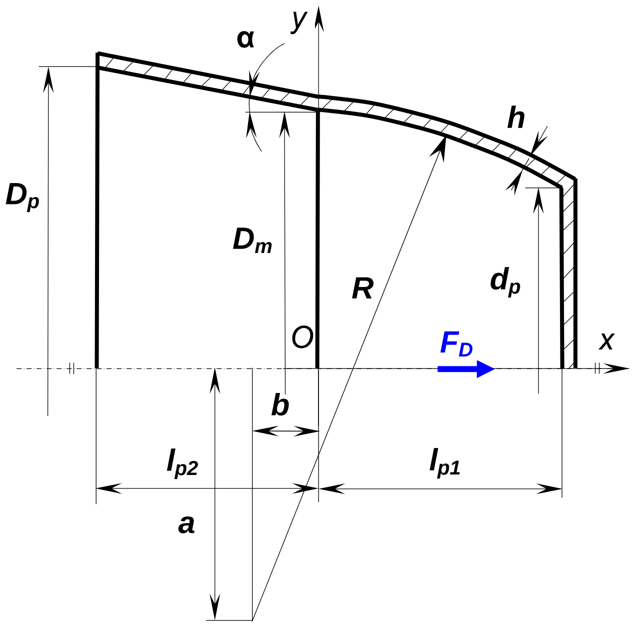

Fig.2

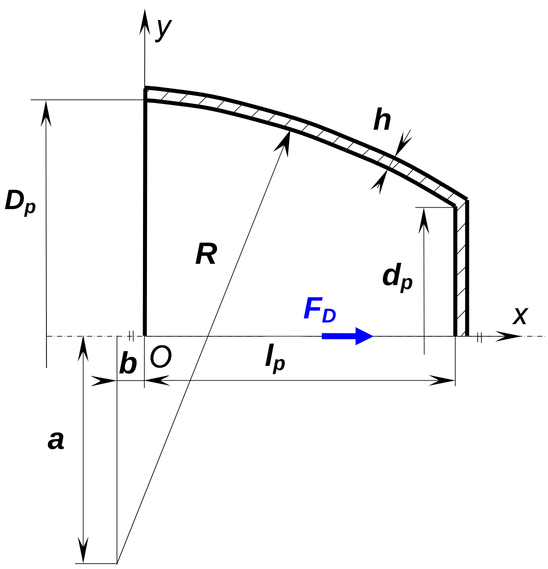

Fig.3

Table 3 *C-type parts*: *Parts with combined profile*

No.	Part	D_p [mm]	D_m [mm]	d_p [mm]	l_{p2} [mm]	l_{p1} [mm]	α [°]	R [mm]	b [mm]	a [mm]	h [mm]	Mat.
1	Part C1	220	201	108	110	80	5	110	10	9	1.5	pp
2	Part C2	284	247	133	132	108	8	180	25	55	1.6	pp
3	Part C3	360	315	203	160	120	8	250	42	89	1.8	pp
4	Part C4	440	388	254	184	150	8	320	51	122	2	pp
5	Part C5	540	472	325	240	196	8	480	67	239	3	pp

***Note:** parts manufactured by S.C. Napochim Cluj Napoca; pp – polypropylene.*

Table 4 *D-type parts*: *Parts with curvilinear profile*

No.	Part	D_p [mm]	d_p [mm]	l_p [mm]	R [mm]	b [mm]	a [mm]	h [mm]	Mat.
1	Part D1	290	228	146	404	10	259	1.6	pp
2	Part D2	295	143	104	138	20	-11	2.5	pp

***Note:** parts manufactured by S.C. Napochim Cluj Napoca; pp – polypropylene.*

Table 5 ***E-type parts: Adown taper parts***

No.	Part	D_p [mm]	d_p [mm]	l_p [mm]	α [°]	h [mm]	Mat.
1	Part E1 ***N***	312	278	137	7	1.5	polypropylene
2	Part E2 ***P***	350	310	145		2	polypropylene
3	Part E3 ***N***	400	316	156	15	2	polyethylene
4	Part E4 ***N***	460	354	221		2	polypropylene

***Note: N** – parts manufactured by S.C. Napochim Cluj Napoca; **P** - parts manufactured by S.C. Plastor Oradea.*

For all these parts are known: D_p – outer diameter of the part; d_p – inner diameter of the part; h – wall thickness of the injected part; l_p – length (height) of the injected part; the other geometrical dimensions of the injected part; the characteristics of the material of the injected part (Young modulus, specific shrinkage, allowable bearing pressure, coefficient of friction between the injected part and the core etc.); the parameters of the process.

For each of these 37 injected parts the design goal is to obtain an appropriate pneumatic ejection system of the mold so that the volume of the ejectors will be minimal. Obviously, the well and continuous operating of the mold should not be affected by this decreasing in volume. It is a good opportunity to mention here that saving space inside the volume of the mold allow, for example, an efficient design of the cooling system of the mold.

2. OPTIMAL DESIGN

The design target was to obtain an ejector with a volume as small as possible.

We consider the volume of the ejector (or ejectors) as objective function:

$$V_a = \frac{\pi \cdot \left[d_f^2 \cdot l_f + d_{d1}^2 \cdot l_{d1} + d_{d2}^2 \cdot \left(l_i + l_{d2} \right) + d_c^2 \cdot l_b + d^2 \cdot l \right]}{4} \cdot n \tag{1}$$

Where: d_f is the flange diameter; l_f – flange length; d_{d1} – diameter of the portion 1 of the plug; l_{d1} – length of the portion 1 of the plug; d_{d2} – diameter of the portion 2 of the plug (equals to the inner diameter of the seat in which is fitted in the ejector); l_i – cylinder length; l_{d2} – length of the portion 2 of the plug; d_c – cylinder diameter; l_b – bush length; d – piston rod diameter; l – length of the portion of diameter d; n – number of needed ejectors.

In order to perform the optimization we used our own optimization software with genetic algorithms called *Genetikos v. 1.1.* The genes chosen for the solving of the optimal design problem are presented in Table 6. In each O-ring list there are four rings with the diameters: 1.8; 2.65; 3.55 and 5.3 mm.

Table 6 ***Genes of the optimization program of pneumatic ejector***

Gene	Part	No. of values in list	Denotation of parameter
0	Pipe (cylinder)	64	d_c - outer diameter of the pipe; h_c - thickness of the pipe
1	O-ring I	64	d - rod diameter; d_{Oring1} - diameter of the O-ring I
2	O-ring II	64	D - inner diameter of the cylinder (mobile seal); d_{Oring2} - diameter of the O-ring II
3	O-ring III	64	D - inner diameter of the cylinder (fixed seal); d_{Oring3} - diameter of the O-ring III
4	O-ring IV	64	d_{d2} - diameter of the portion 2 of the plug; d_{Oring4} - diameter of the O-ring IV
5	O-ring V	64	d_{d1} - diameter of the portion 1 of the plug; d_{Oring5} - diameter of the O-ring V

For all these 37 parts it was found an optimal pneumatic ejector [1].

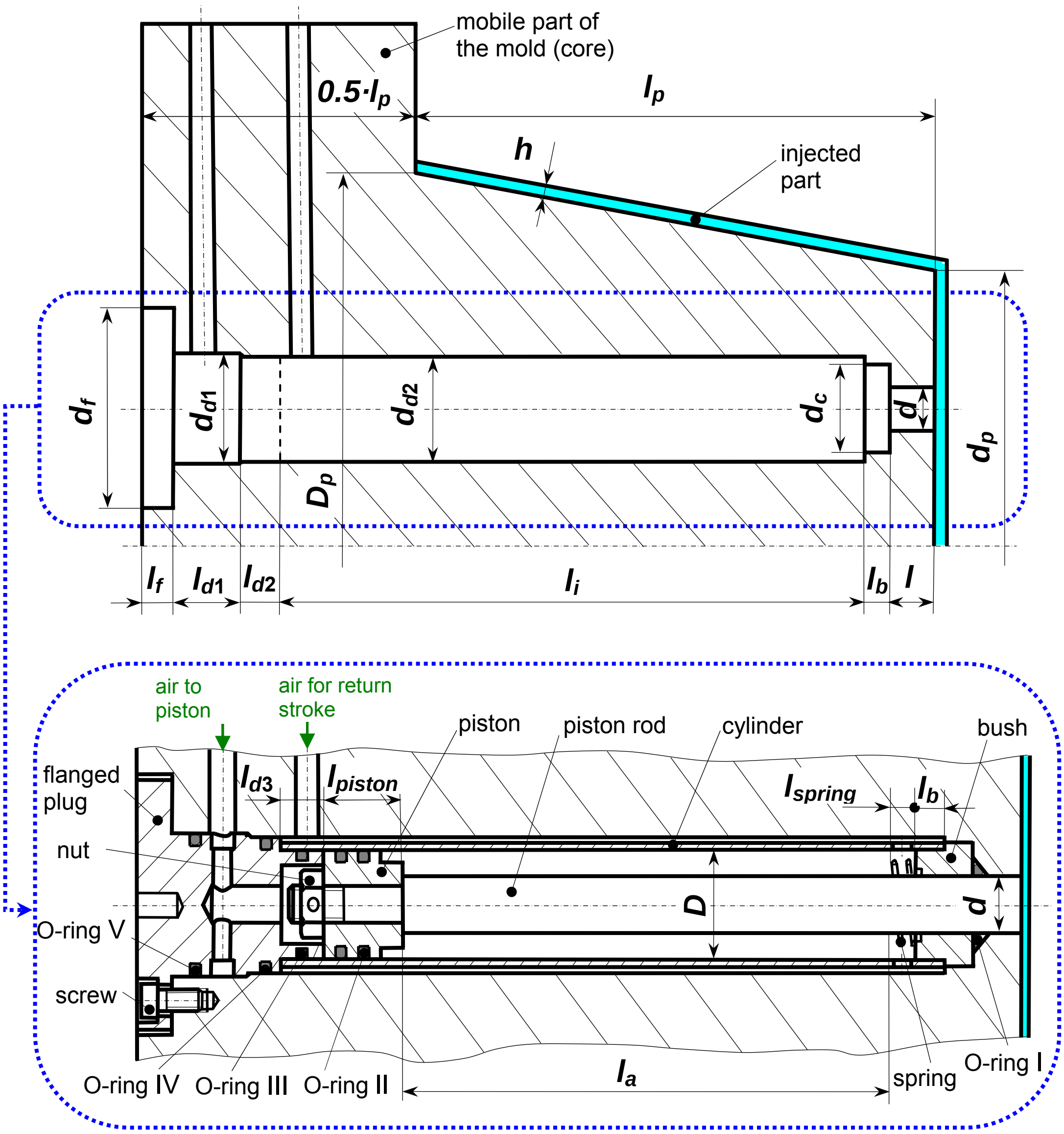

Fig.4 The pneumatic ejector and its position inside the mold

3. THE TYPYFICATION OF PNEUMATIC EJECTOR

We propose the following notation for a pneumatic ejector:

AP *d* x *D* x *L*

Where: *d* is the rod piston diameter, [mm];
D – piston diameter, [mm];
L – ejector length, [mm].

If we analyze the results about optimal ejectors for all 37 parts we observe that we can make an assortment (fig.5). We notice that we have the same dimensions (*d*x*D)* of ejector for more parts. For example, the 20x35 ejector will be found for the following parts: A12, B14, C4 and E3. The conclusion is that we can use the same ejector for four different parts. We can form the following groups regarding to the *d*x*D* dimensions of the ejector:

1. Group 10x19 for parts B1, B2, B3, B4, B5, B6, B7, B8, B9, C1 and D2.
2. Group 10x23 for part C2.
3. Group 11x19 for part A2.
4. Group 12x24 for parts B10 and B13.
5. Group 15x27 for parts A1, A3, A4, A8, A9, B11, B12, C3 and D1.

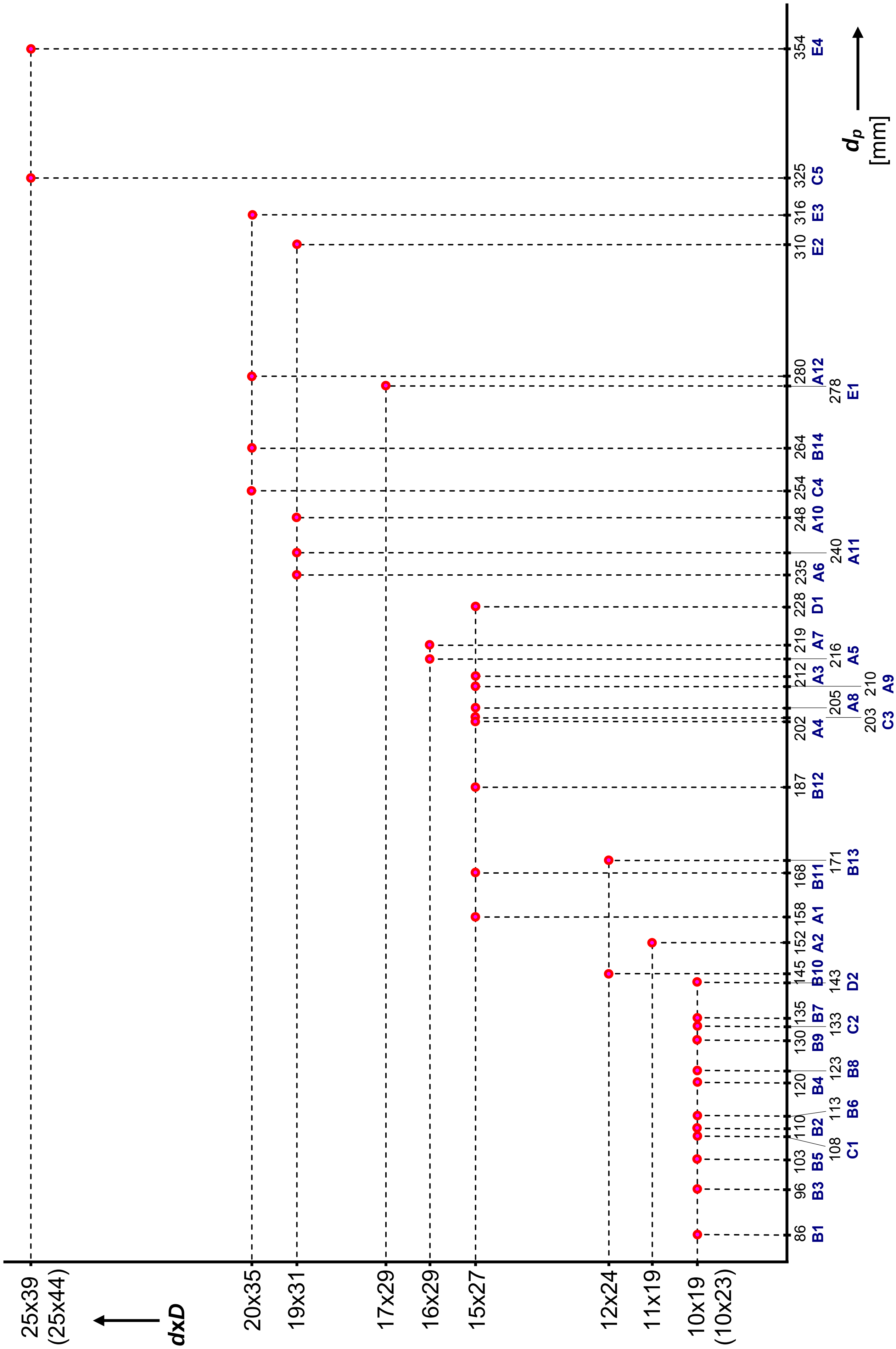

Fig.5 The pneumatic ejectors grouping

6. Group 16x29 for parts A5 and A7.
7. Group 17x29 for part E1.
8. Group 19x31 for parts A6, A10, A11 and E2.
9. Group 20x35 for parts A12, B14, C4 and E3.
10. Group 25x39 for part E4.
11. Group 25x44 for part C5.

In case of the pneumatic ejector is very important to identify the *d*x*D* dimensions, because for the same diameters d and D, the modification of the ejector length L consists of the modification of the dimensions of only two pieces of the ejector: the cylinder length and the length of piston rod. Regarding to the ejector length this will depend of the length of injected piece (l_p). In order to remove the parts from the core, it has to ensure a certain ejection stroke (ejection length l_a).

For A, B and C type parts
$$\begin{cases} l_{a\,\min} = 0.6 \cdot l_p \\ l_{a\,\max} = 0.9 \cdot l_p \end{cases} \tag{2}$$

For D and E type parts (where $D_p / h_p < 2$)
$$\begin{cases} l_{a\,\min} = 0.5 \cdot l_p \\ l_{a\,\max} = 0.9 \cdot l_p \end{cases} \tag{3}$$

The pneumatic ejector length will be calculated with relation:
$$L = l + l_b + l_{spring} + l_a + l_{piston} + l_{d3} + l_{d2} + l_{d1} + l_f \tag{4}$$

Where: l is the length of the portion of diameter d; l_b – bush length; l_{spring} – spring length; l_a – ejection length; l_{piston} – piston length; l_{d3} – length of the portion 3 of the plug; l_{d2} – length of the portion 2 of the plug; l_{d1} – length of the portion 1 of the plug; l_f – flange length.

For the same *d*x*D* group of ejectors all the values in the equation (4) are constants with the exception of the ejection length l_a which fluctuates between a minimum and a maximum value (equations (2) and (3)).

$$l = \begin{cases} d + 2.4 & if \quad d_{Oring1} = 1.8 \\ d + 3.5 & if \quad d_{Oring1} = 2.65 \\ d + 4.8 & if \quad d_{Oring1} = 3.55 \\ d + 7.3 & if \quad d_{Oring1} = 5.3 \end{cases} \qquad l_b = \begin{cases} 5 & if \quad d \le 12 \\ 8 & if \quad 12 < d \le 20 \\ 10 & if \quad 20 < d \le 30 \\ 12 & if \quad d > 30 \end{cases} \tag{5}$$

$$l_{spring} = \begin{cases} 10 & if \quad d < 20 \\ 15 & if \quad d \ge 20 \end{cases} \qquad l_{piston} = \begin{cases} 15 & if \quad d_{Oring2} = 1.8 \\ 24 & if \quad d_{Oring2} = 2.65 \\ 28 & if \quad d_{Oring2} = 3.55 \\ 30 & if \quad d_{Oring2} = 5. \end{cases} \tag{6}$$

$$l_{d3} = \begin{cases} 11 & if \quad d_{Oring3} = 1.8 \\ 13 & if \quad d_{Oring3} = 2.65 \\ 15 & if \quad d_{Oring3} = 3.55 \\ 18 & if \quad d_{Oring3} = 5.3 \end{cases} \qquad l_{d2} = \begin{cases} 10 & if \quad d_{Oring4} = 1.8 \\ 12 & if \quad d_{Oring4} = 2.65 \\ 14 & if \quad d_{Oring4} = 3.55 \\ 16 & if \quad d_{Oring4} = 5.3 \end{cases} \tag{7}$$

$$l_{d1} = \begin{cases} 18 & if \quad d_{Oring5} = 1.8 \\ 22 & if \quad d_{Oring5} = 2.65 \\ 28 & if \quad d_{Oring5} = 3.55 \\ 32 & if \quad d_{Oring5} = 5.3 \end{cases} \qquad l_f = \begin{cases} 9 & if \quad d \le 10 \\ 12 & if \quad 10 < d \le 25 \\ 14 & if \quad 25 < d \le 40 \\ 16 & if \quad d > 40 \end{cases} \tag{8}$$

It results that the ejector lengths *L* will fluctuate between a minimum and a maximum value (see tables 7, 8, 9 and figures 6, 7, 8).

Table 7 *The pneumatic ejectors length for A type parts molds*

Part	L_{min} [mm]	L_{max} [mm]	L [mm]
Part A1	252	296.3	280
Part A2	257	286.7	280
Part A3	305	344	320
Part A4	317	354.8	320
Part A5	334	371.1	360
Part A6	300	344.8	320
Part A7	360	394.5	360
Part A8	325	362	360
Part A9	316	353.9	320
Part A10	360	398.8	360
Part A11	380	416.8	400
Part A12	324	378.4	360

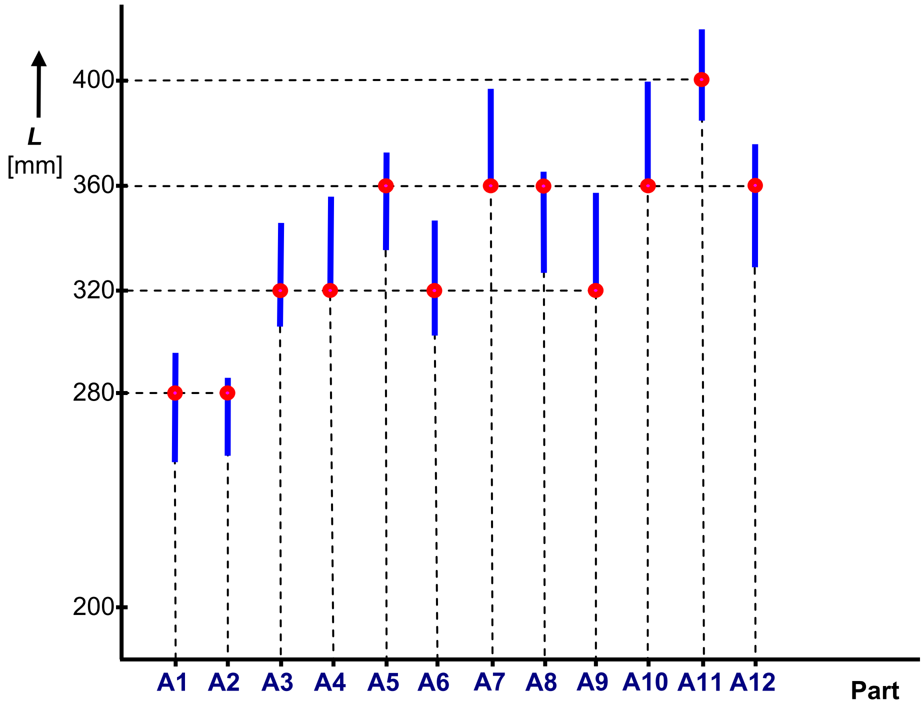

Fig.6 The pneumatic ejectors length for A type parts molds

Table 8 *The pneumatic ejectors length for B type parts molds*

Part	L_{min} [mm]	L_{max} [mm]	L [mm]
Part B1	158.2	184.6	180
Part B2	171.4	204.4	200
Part B3	163	189.1	180
Part B4	156.4	181.9	180
Part B5	168.4	210	200
Part B6	171.4	204.4	200
Part B7	200	231.4	220
Part B8	188	220.6	200
Part B9	186	218.8	200
Part B10	199.2	240.6	220
Part B11	258	301.7	280
Part B12	274	316.1	280
Part B13	234	273	250
Part B14	318	373	360

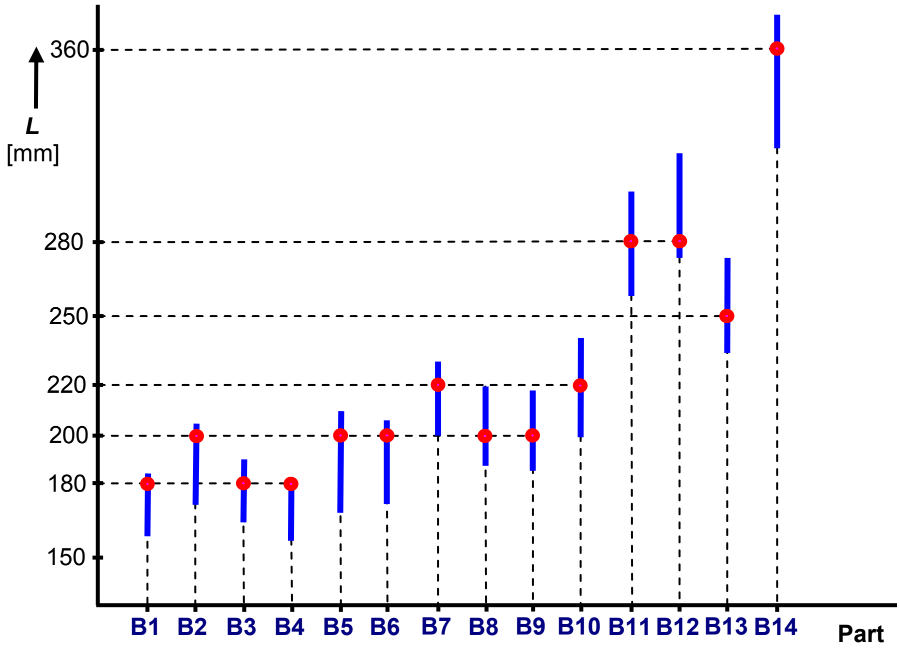

Fig.7 The pneumatic ejectors length for B type parts molds

Table 9 ***The pneumatic ejectors length for C, D and E types parts molds***

Part	L_{min} [mm]	L_{max} [mm]	L [mm]
Part C1	250	276.4	250
Part C2	300	321.4	320
Part C3	340	375.5	360
Part C4	394	441.4	400
Part C5	436	542.2	500
Part D1	206	254.9	250
Part D2	164	208	200
Part E1	197	250.1	250
Part E2	205	259.3	250
Part E3	218.8	281.2	250
Part E4	281	348.7	320

When we chose the ejector length we need to consider also the existence of the necessary space in the mold needed for the two channels of air supply:

$$L \geq l_p + 60 \ \text{[mm]} \qquad (9)$$

We can notice that for parts with different length we can choose a pneumatic ejector with the same length. We can form the following groups:

1. Group **10x19** AP 10x19x180 for parts B1, B3 and B4;
AP 10x19x200 for parts B2, B5, B6, B8, B9 and D2;
AP 10x19x220 for part B7;
AP 10x19x250 for part C1.

2. Group **10x23** AP 10x23x320 for part C2.

3. Group **11x19** AP 11x19x280 for part A2.

4. Group **12x24** AP 12x24x220 for part B10;
AP 12x24x250 for part B13.

5. Group **15x27** AP 15x27x250 for part D1;
AP 15x27x280 for parts A1, B11 and B12;
AP 15x27x320 for parts A3, A4 and A9;
AP 15x27x360 for parts A8 and C3.

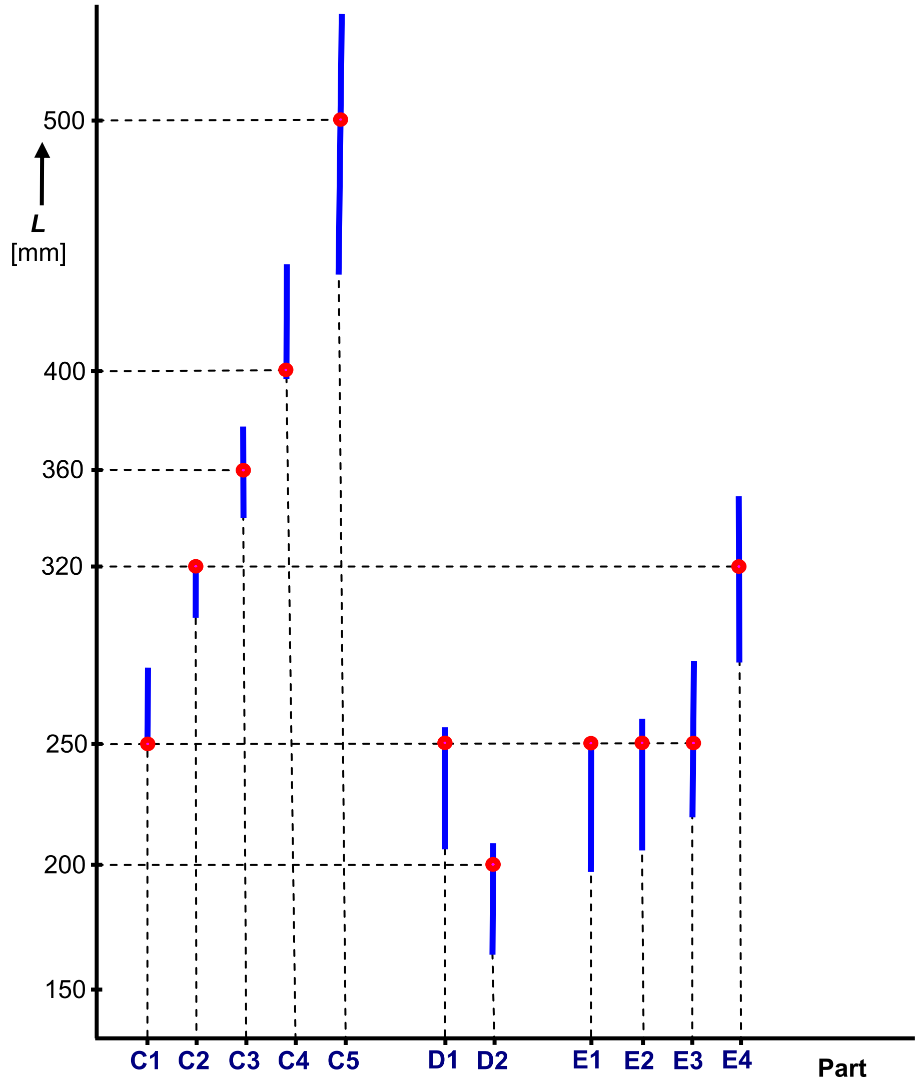

Fig.8 The pneumatic ejectors length for C, D and E types parts molds

6. Group **16x29**	AP 16x29x360 for parts A5 and A7;
7. Group **17x29**	AP 17x29x250 for part E1.
8. Group **19x31**	AP 19x31x250 for part E2;
	AP 19x31x320 for part A6;
	AP 19x31x360 for part A10;
	AP 19x31x400 for part A11.
9. Group **20x35**	AP 20x35x250 for part E3;
	AP 20x35x360 for parts A12 and B14;
	AP 20x35x400 for part C4.
10. Group **25x39**	AP 25x39x320 for part E4.
11. Group **25x44**	AP 25x44x500 for part C5.

In case of the injected parts with thin walls and curvilinear profile (D type) and of the parts with combined profile (C type) because we analyzed a small number of parts (2 for D type and 5 for C type) we can not come to the conclusion about typification of pneumatic ejectors for these parts.

Considering the results obtained for the injected parts with thin walls and linear profile of small diameter d_p between 80 and 350 mm we propose the following typification variant of pneumatic ejectors for these parts (see table 10). At typification of pneumatic ejectors length we use the row Ra20 of normal, linear dimensions (according to STAS 75-90).

Table 10 *The typified pneumatic ejectors for injected parts with thin walls and linear profile*

Diameter of the part d_p [mm]	Pneumatic ejector	
	Group ***dxD***	Length ejector ***L*** [mm]
80...135	10x19	180; 200; 220; 250; 280; 320
135...150	12x24	180; 200; 220; 250; 280; 320
150...215	15x27	200; 220; 250; 280; 320; 360
215...235	16x29	200; 220; 250; 280; 320; 360
235...250	19x31	220; 250; 280; 320; 360; 400
250...300	20x35	250; 280; 320; 360; 400; 450
300...350	25x39	280; 320; 360; 400; 450;500

In figure 9 we present one of these ejectors.

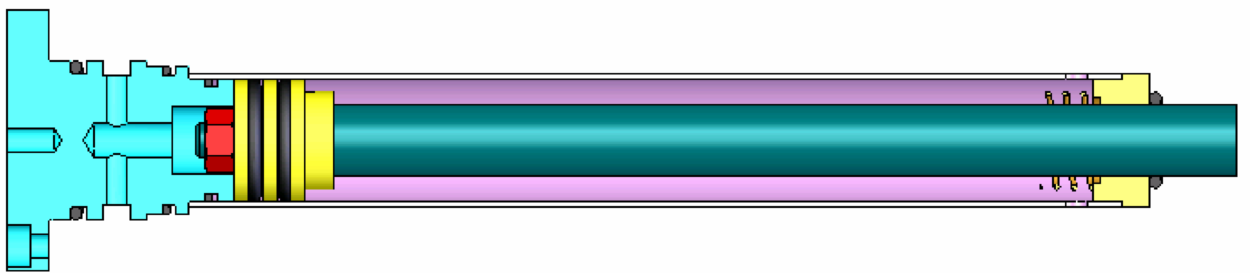

Fig.9 The ejector AP 20x35x360

4. CONCLUSIONS

We can draw the following conclusions:

- For certain injected pieces like buckets and flower pots we can replace the mechanic ejection systems with pneumatic ejection system which contains air valves and pneumatic ejector. The pneumatic ejector can be optimal designed with the Genetic Algorithms method.
- It is important that the pneumatic ejectors have a volume as small as possible in order to allow using of the extra-space for a better cooling of the mold. For this reason the optimal design of pneumatic ejectors becomes important.
- We can group the pneumatic ejectors using some certain criteria. The research shows that the pneumatic ejector with double action for injected parts with thin walls molds can be typified.
- The typification has a sequential character and it has to follow the phases:
  - The grouping of injected parts with thin walls according to dimensional criteria.
  - For each group we design the optimal pneumatic ejector.
  - We realize typo-dimensional series for these ejectors.
- It is essential that the typification should be based on clear premises which should express both the functional and strength conditions of pneumatic ejectors and marketing conditions of the product.

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