IOP Conf. Series: Materials Science and Engineering **91** (2015) 012087 doi:10.1088/1757-899X/91/1/012087

Radial deformations of working cylinder of hydraulic Legs depending on their extension

G D Buyalich [1,2,3,a], K G Buyalich [1,b], V V Voyevodin [1,c]

[1] T.F. Gorbachev Kuzbass State Technical University, Vesennaya Str., 28, Kemerovo, 650000, Russia
[2] Yurga Institute of Technology of Tomsk Polytechnic University, Leningradskaya Str., 26, Yurga, 652055, Russia
[3] Institute of Coal of SB RAS, Leningradskiy Ave., 10, Kemerovo, 650060, Russia

e-mail: [a]gdb@kuzstu.ru, [b]konstantin42@mail.ru, [c]vvoevodin@yandex.ru

Abstract. Current methods of calculation of parameters of hydraulic legs of powered supports are in most cases analytical and do not consider all complex of factors. Finite element model was developed to study this problem and used to analyze the influence of hydraulic legs extension on radial deformations of cylinder of different producers of powered supports at variation of hydraulic fluid pressure. It was revealed that radial deformations of cylinders along the axis of hydraulic legs increase in magnitude in direct proportion to the hydraulic fluid pressure and extension. Research results can be recommended to define optimal geometric parameters of hydraulic legs in respect to the minimal radial deformations of hydraulic cylinder increasing its impermeability and improving the work of cup seals. It is recommended to use the obtained results at power support designing.

Introduction

Hydraulic leg is a hydraulic power cylinder. Its impermeability is determined by the size of the gap between the piston and the cylinder bridged by the seal. Numerical value of the gap includes two components:

1) tolerance for production of piston and cylinder (constant component), which determines minimal Z_{min} and maximal Z_{max} gaps during assemblage;

2) radial deformations of interior surface of cylinder (dR) under the hydraulic liquid pressure (variable component), which depend on the value of this pressure (P), production technique [1–4], support construction [5], hydraulic leg construction [6–8] and their hydraulic extension (l_p).

Methods

To calculate radial deformations finite element method was used as it is one of modern computational approaches allowing to carry out calculations with high accuracy and speed for constructions with complicated configuration using computer aids.

Work Description.

Finite element model was developed for research of the influence of hydraulic leg parameters on their strained state.

Recent researches of radial deformations of the working cylinder [6, 7] show that the curve represented in figure 1 has an expanding section from the side of the head end and a convergent section from the side of the rod end. To pit-point locations of radial deformations along the length of the cylinder during comparative calculations the following key points were used:

point 1 – has maximal radial deformations near the piston (at this point radial deformations are equal to dR_1);

point 2 – is situated in the ares of stable radial deformations in the cylinder main body (dR_2);

point 3 – has negative radial deformations (compression of the cylinder) in the limits of the piston location (dR_3). At this point the contact between the cylinder and the piston and the damage of the working cylinder surface are possible at large strain;

point 4 – is situated in the place of the first seal from the side of the head end. Radial deformations at this point (dR_4) are determined by the sealed gap which influences the work of seal and impermeability of hydraulic leg;

point 5 – is situated in the point of maximal radial deformations near the bottom of hydraulic cylinder (dR_5).

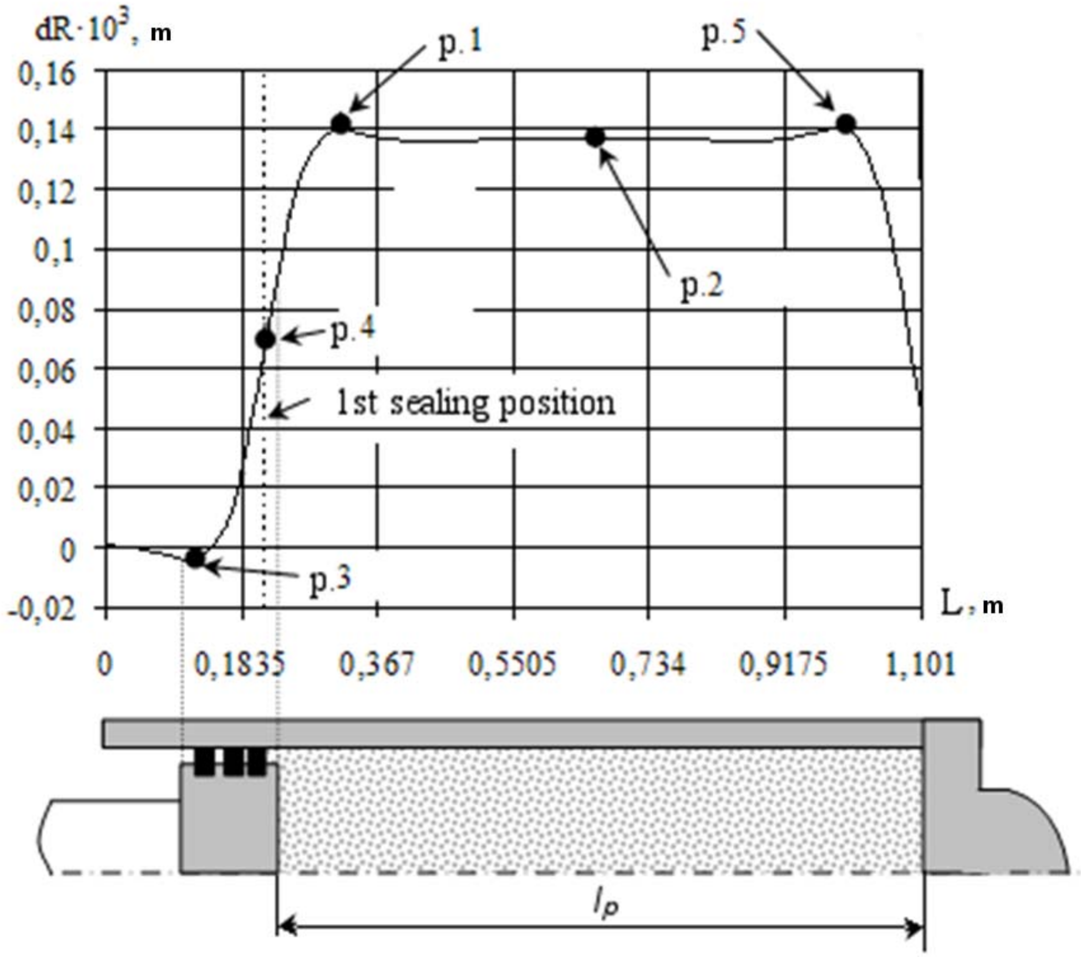

Figure 1. Radial Deformations of the Working Cylinder of Hydraulic Leg (*dR*) Along the Length of the Working Cylinder (l_c) and Location of Key Points

Radial deformations of working cylinders of hydraulic legs of powered supports at extensions equal to $l_p=(2/3)l_p^{max}$ and $l_p=l_p^{max}$ (fig. 2 and 3) were calculated using the model. It follows from this that extension does not influence the character of deformation curves especially in the piston area. At that, variation of radial deformations in the location of the first seal from the side of the head end (dR_4) owing to the pressure of hydraulic liquid in the head end (P) has linear character at different values of extension (fig.4).

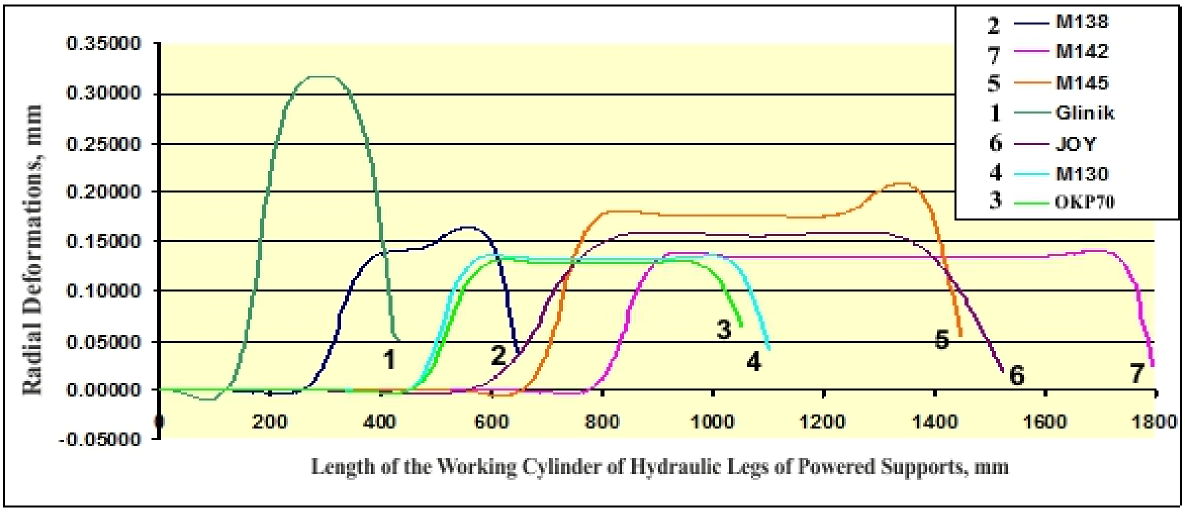

Figure 2. Radial Deformations Along the Length of the Working Cylinder of Hydraulic Legs of Powered Supports at Extension $l_p=(2/3)l_p^{max}$ and $P=50$ MPa

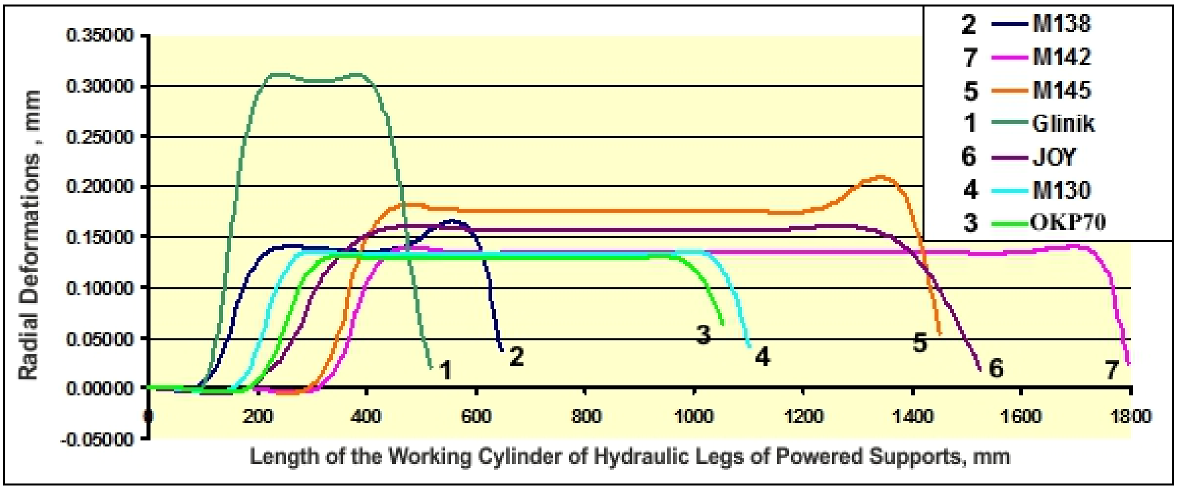

Figure 3. Radial Deformations Along the Length of the Working Cylinder of Hydraulic Legs of Powered Supports at Extension $l_p=l_p^{max}$ and $P=50$ MPa

Numerical values of radial deformations for hydraulic legs at extension $l_p=(2/3)l_p^{max}$ and $l_p=l_p^{max}$ and pressure P are given in Table 1. Hence it follows that the leg of support M142 has minimal absolute values at extension $l_p=(2/3)l_p^{max}$ and pressure *32MPa*, *50 MPa* and *70 MPa*. At maximal extension l_p^{max} we observe another situation: hydraulic leg Joy has minimal deformations dR_4 at pressure of initial thrust P=32MPa whereas hydraulic leg OKP70 has it at pressure close to nominal (P=50 MPa) and sesquialteral (P=70 MPa). With increase of extension we observe the increase of radial deformations dR_4. It can be explained by the rise of total load on the cylinder wall from hydraulic liquid pressure. As a result of this phenomenon absolute values of constringent radial deformations in the piston area (dR_3) also increase by absolute value.

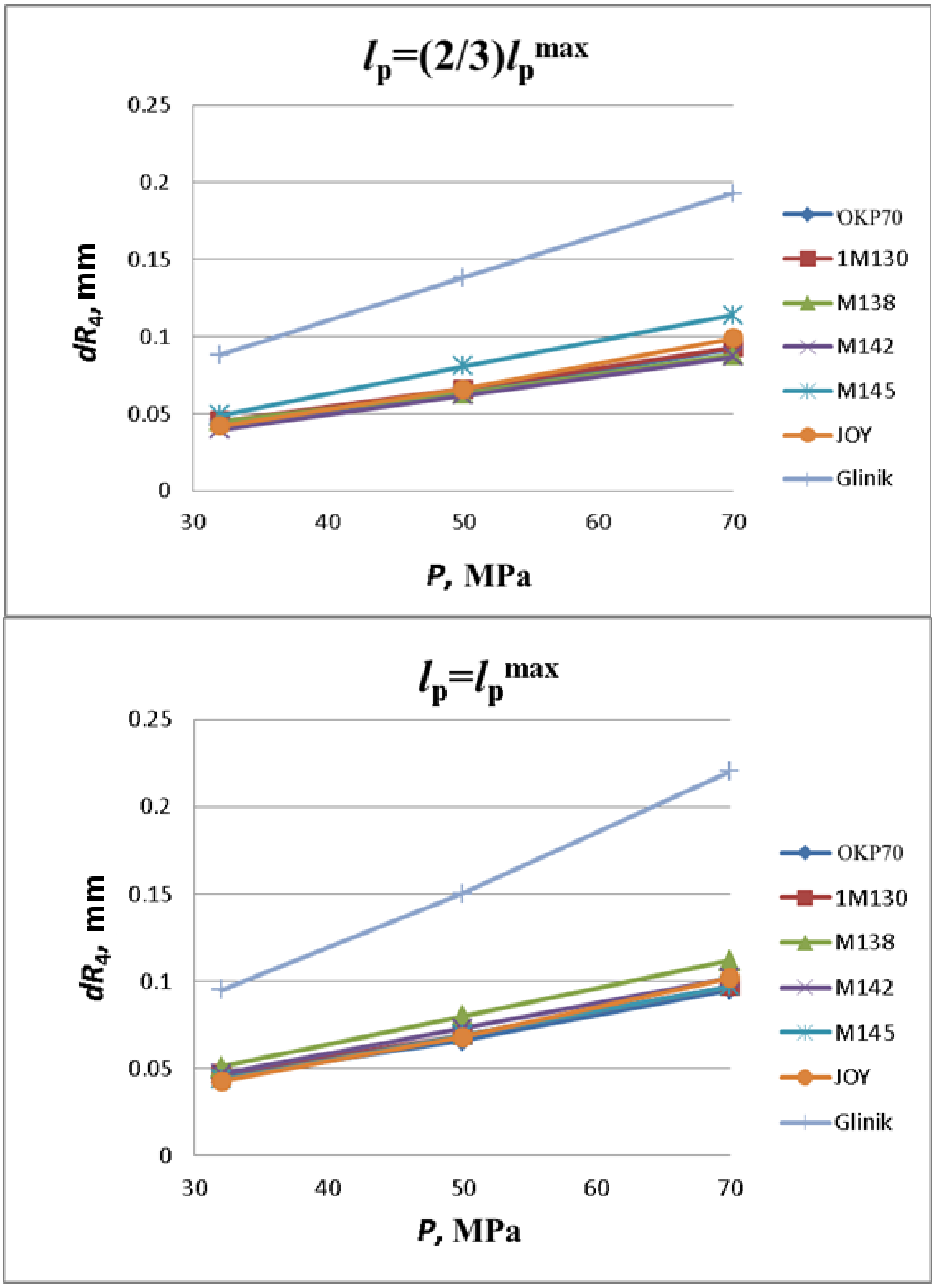

Figure 4. Variation of Radial Deformations (dR_4) of Hydraulic Legs of Powered Supports Due to the Hydraulic Liquid Pressure (P) at Extensions (l_p)

Numerical values of radial deformations of hydraulic leg M138 at the point situated in the limits of piston area (dR_3) are two times less than these of the rest (table 2), as this leg has minimal length of piston (75mm) and maximal value of constringent deformations is beyond its limits. Thus, for example, for this leg deformations in the piston area dR_3= -0,0000214 mm at $P=50$ *MPa* and $l_p=(2/3)l_p^{max}$ whereas minimum value of these deformations is -0,00410 mm. The length of piston of the rest of legs is 90 mm (table 2) and minimum values of radial deformations dR_3 are situated in piston area.

Table 1.

Numerical Values of Radial Deformations in the Seal Area (at point 4) at Extension l_p and hydraulic liquid pressure P

Powered Support	Radial Deformations (dR_4), mm					
	P=32 MPa		*P*=50 MPa		*P*=70 MPa	
	$l_p=(2/3)l_p^{max}$	$l_p=l_p^{max}$	$l_p=(2/3)l_p^{max}$	$l_p=l_p^{max}$	$l_p=(2/3)l_p^{max}$	$l_p=l_p^{max}$
ОКП70	0,042	0,045	0,064	0,066	0,092	0,095
M130	0,045	0,047	0,066	0,069	0,093	0,097
M138	0,045	0,051	0,063	0,080	0,088	0,112
M142	0,040	0,047	0,062	0,073	0,087	0,102
M145	0,049	0,044	0,081	0,069	0,114	0,097
JOY	0,042	0,043	0,066	0,068	0,099	0,102
Glinik	0,088	0,095	0,138	0,150	0,193	0,220

Table 2.

Numerical Values of Parameters and Radial Deformations of Hydraulic Legs of Powered Supports at P=50 MPa

Параметр	OKP70	1M130	M138	M142	M145	Joy	Glinik
Diameter of the cylinder, mm	220	200	220	220	250	350	280
Ehickness of the cylinder wall, mm	26,5	22,5	27,5	27	24,5	65	20
Length of the piston, mm	95	95	75	92	108	296	90
Z_{min}, mm	0,05	0,05	0,05	0,05	0,05	0,062	0,056
Z_{max}, mm	0,28	0,28	0,28	0,28	0,28	0,342	0,316
$l_p=(2/3)l_p^{max}$							
dR_4, mm	0,064	0,066	0,063	0,062	0,081	0,066	0,138
dR_3, mm	-0,00262	-0,00286	-0,0000214	-0,00233	-0,00510	-0,00440	-0,00643
$l_p=l_p^{max}$							
dR_4, mm	0,066	0,069	0,08	0,073	0,069	0,068	0,15
dR_3, mm	-0,00385	-0,00402	-0,00224	-0,00242	-0,0053	-0,00548	-0,00961

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Variation of radial deformations (dR_3 and dR_4) at extension alteration from $l_p=(2/3)l_p^{max}$ to $l_p=l_p^{max}$ (change of relative extension l_p/l_p^{max} from 2/3 to 1) is shown in Figure 5.

The leg M138 is exposed to maximal variations of constringent radial deformations dR_3 due to small piston length. The change of dR_3 by 40–50 % corresponds to legs OKP70, 1M130 and Glinik. Variations of hydraulic leg Joy make up 25 % and these of legs M142 and M145 – near 4 %.

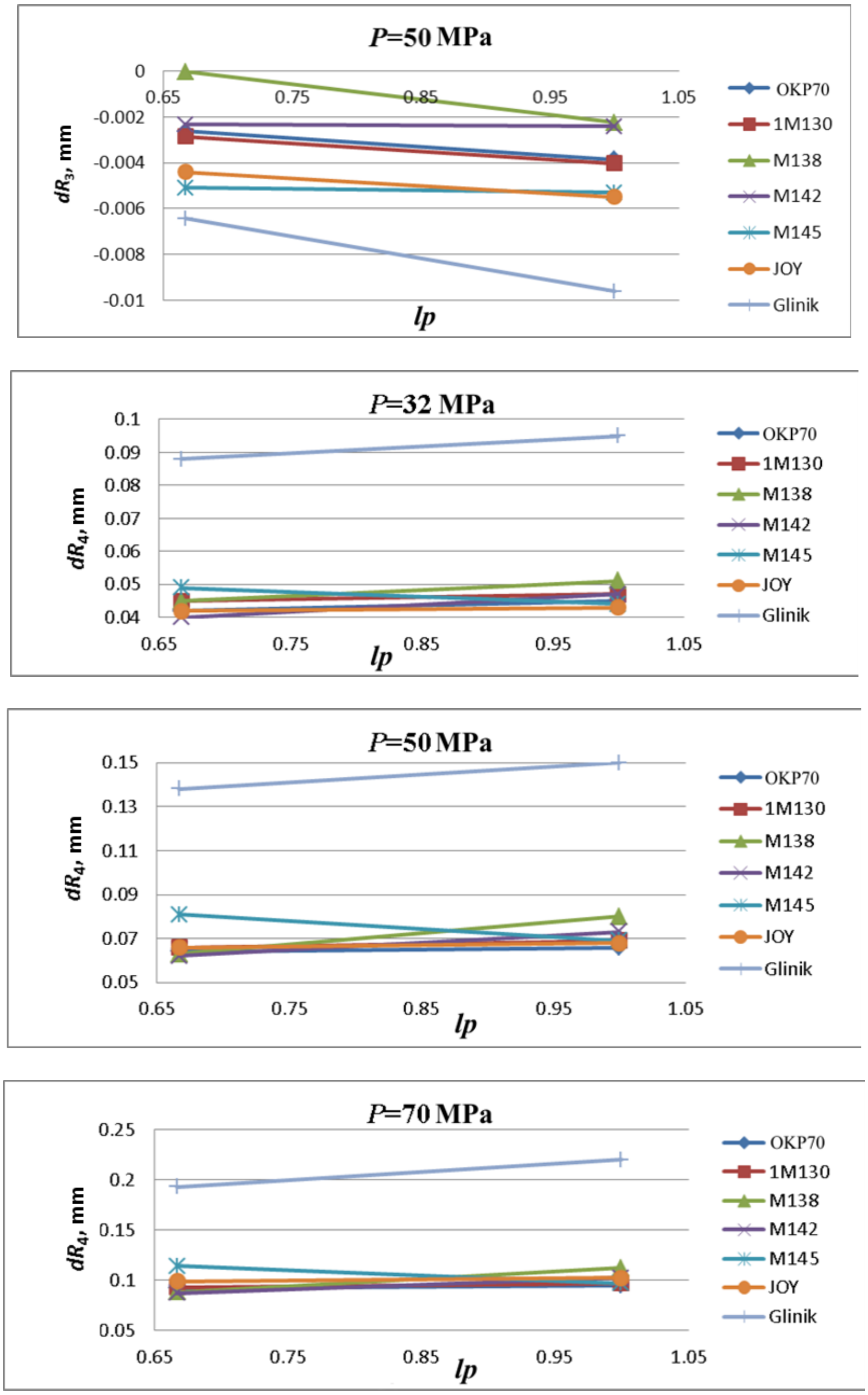

Figure 5. Variation of Radial Deformations (dR_3 and dR_4) Due to Relative Extension (l_p/l_p^{max})

Radial deformations in seal area (dR_4) at $l_p=l_p^{max}$ increase: for hydraulic leg M138 – at initial thrust pressure (32 MPa) by 13 %, approximately, and at high pressure (50 and 70 MPa) – by 27 %, approximately; for hydraulic leg M142- by 17,5 % over all pressure range; for the rest of hydraulic legs over working range of pressure – from 2,5 to 8 %.

For hydraulic leg M145 radial deformations (dR_4) at $l_p=l_p^{max}$ decrease by 10–15 % at different hydraulic liquid pressure.

Conclusions. Realized researches allow to conclude that with increase of hydraulic leg extension the gap between the piston and the cylinder increases in the area of the first seal from the side of the head end ($+dR_4$) and decreases from the side of the rod end in the limits of the piston (dR_3).

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