Experimental research of hydraulic cylinder with the built-in throttle for steering the front landing gear wheel

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Abstract: *This paper presents the experimental research method of a hydraulic cylinder used for steering the front landing gear wheel. A mechanical-hydraulic steering system is operated by two interchangeable hydraulic cylinders acting in tandem to rotate the movable sub-assembly that contains the front landing gear wheel. Each hydraulic cylinder is designed with a built-in throttle to equalize the speed of the hydraulic cylinder rod traveling in both directions of movement (extension and retraction). During the experiments, three constructive variants of the built-in throttle will be used to obtain the optimal variant.*

Key Words: *experimental research method, hydraulic cylinder, built-in throttle, steering system, military training aircraft*

1. THE PURPOSE OF EXPERIMENTAL RESEARCH

The steering device is operated by two hydraulic cylinders (left and right) that are interchangeable. The two actuator hydraulic cylinders work in tandem to steer the rotating sub-assembly of the nose landing gear: one cylinder extends and the other retracts, after which the rollers are reversed, as shown in Figure 1.

The experimental hydraulic cylinder is presented in Figure 2. When the hydraulic cylinder is extending, the hydraulic pressure acts on the large piston surface A_1 = 490.625 mm^2, and when the hydraulic cylinder is retracting, the hydraulic pressure acts on the annular surface between the piston and the hydraulic cylinder rod A_2 = 314 mm^2, as shown in Figure 3 and Table 1.

Due to the differences in hydraulic surfaces, the extension stroke speed of the hydraulic actuation cylinders will be greater than the retracting stroke speed because of $A_1 > A_2$. To solve this technical problem, a hydraulic throttle (a hydraulic resistor) [1] is introduced on the hydraulic supply circuit of the extension stroke of each hydraulic cylinder. The hydraulic throttle consists of a series of four helical channels with a rectangular, triangular, or semicircular cross-section, executed on each shoulder with a length of 20.9 mm on the outside surface of the sleeves and mounted inside each hydraulic cylinder. The end and the beginning of helical channels are offset axially, over the canal that separated the shoulders (3.1 mm), by an angle of 90^o to increase the hydraulic resistance [2, 3].

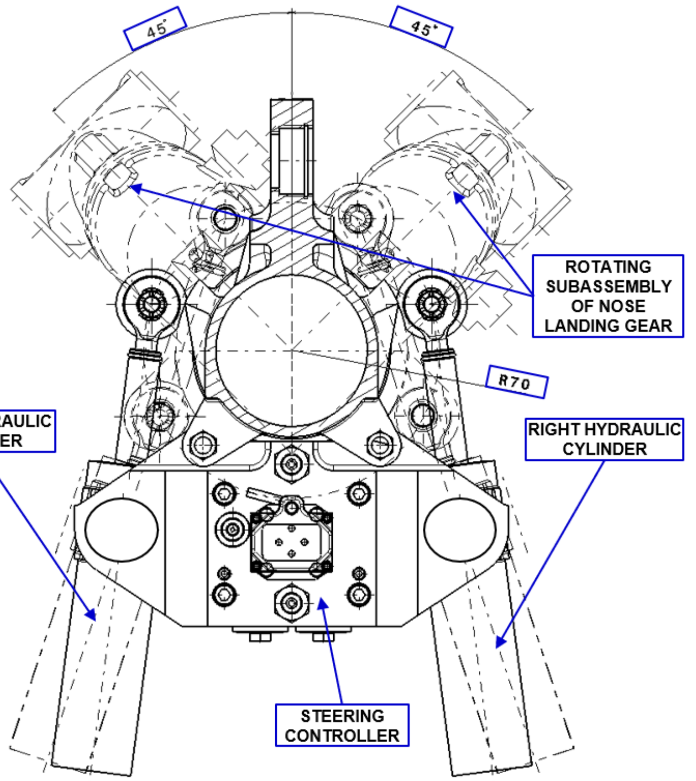

Fig. 1 Cross section through the nose landing gear

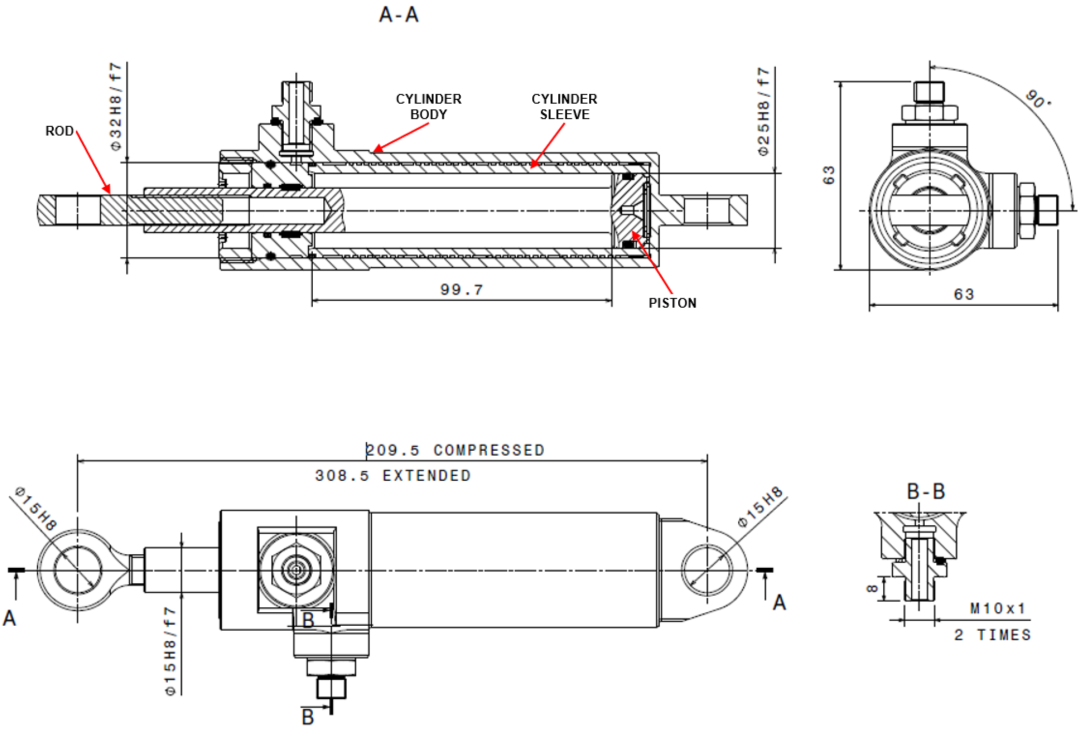

Fig. 2 The experimental hydraulic cylinder

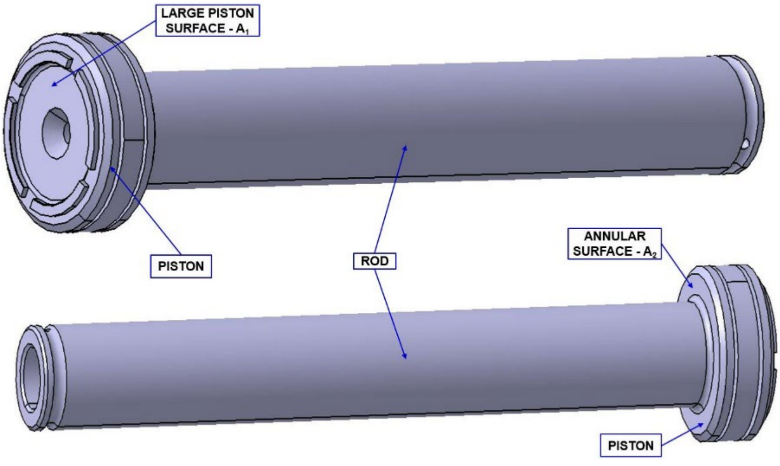

Fig. 3 Piston rod surfaces of hydraulic cylinder

Table 1. Nominal construction data

Parameter	**Value**
The nominal outer diameter of the piston d_c	25 mm
Large piston surface A_1	490.625 mm^2
The nominal outer diameter of the rod d_t	15 mm
The annular surface between the piston and rod A_2	314 mm^2

Three sleeves for the hydraulic cylinder will be manufactured and tested for the experimental research:

• a sleeve with helical channels of rectangular “R” cross-section with a pitch of 2.5 mm, as shown in figure 4;

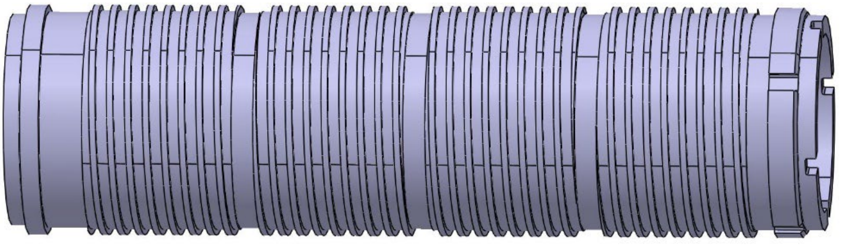

Fig. 4 Sleeve with helical channels of rectangular “R” cross-section

• a sleeve with helical channels of the triangular “T” cross-section with a pitch of 2.5 mm, as shown in figure 5;

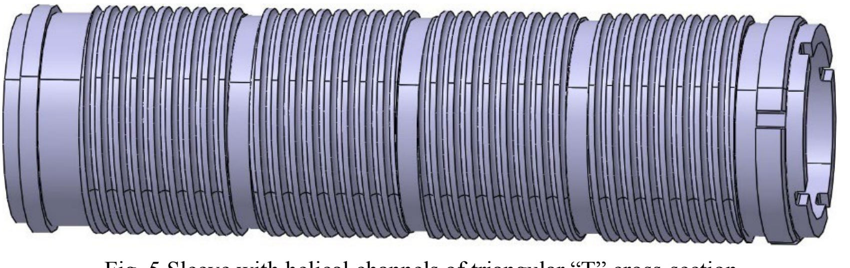

Fig. 5 Sleeve with helical channels of triangular “T” cross-section

• a sleeve with helical channels of the semicircular “S” cross-section with a pitch of 2.5 mm, as shown in figure 6;

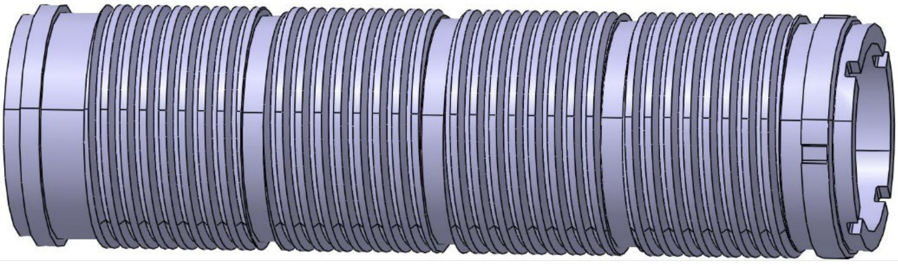

Fig. 6 Sleeve with helical channels of semicircular "S" cross-section

The 3.1 mm groove at the end of each 20.9 mm shoulder ensures the exit of the lathe tool with which the helical grooves are made and automatically axially offsets the end and beginning of the helical grooves by 90 degrees. The first groove on the left of the sleeve is the O-ring housing. The 2nd groove from the left of the jacket is the receiving groove for the hydraulic fluid which will then be routed through the series of 4 helical grooves. The last shoulder on the right has 4 grooves of 2.5 mm wide for draining hydraulic fluid to the last groove on the right which in turn has 4 grooves of 2.5 mm wide for draining hydraulic fluid to the large surface of the hydraulic piston, as shown in figures 4, 5 and 6.

2. PRESENTATION OF THE INSTALLATION FOR EXPERIMENTAL RESEARCH

The scheme of the installation for the experimental research of the hydraulic throttle incorporated in the hydraulic actuation cylinder is shown in figure 7.

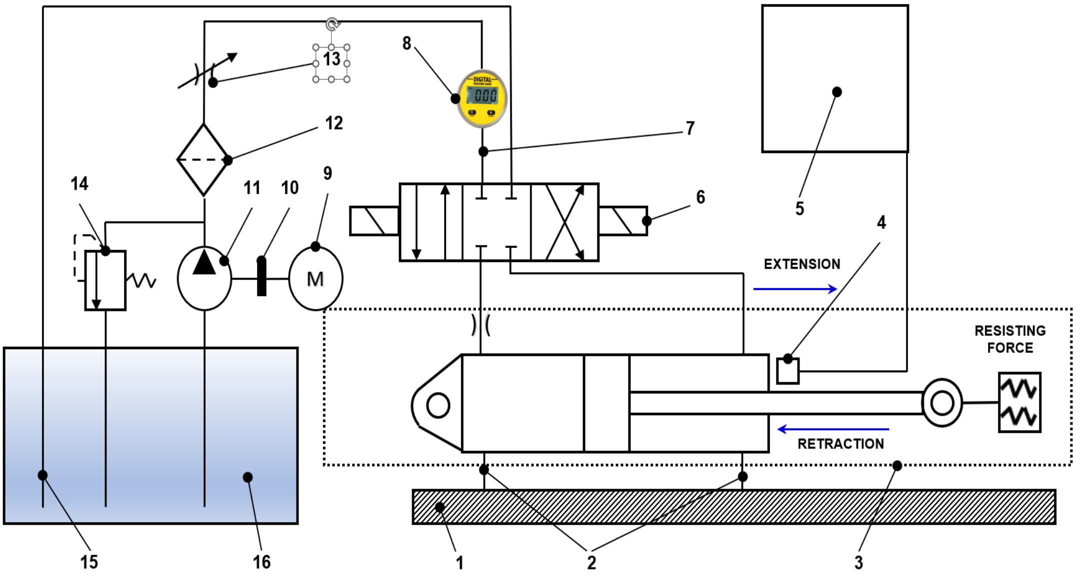

Fig. 7 Installation for experimental research of the hydraulic throttle incorporated in the hydraulic cylinder

The component elements of the installation are presented in table 2.

Table 2. The component elements of the installation

1	Rigid support	9	Electric motor to drive the pump
2	Hydraulic cylinder supports	10	Flexible coupling
3	Hydraulic cylinder with a built-in hydraulic throttle	11	Variable flow hydraulic pump
4	Transducer for displacement speed of the hydraulic cylinder rod	12	Filter
5	Computer recorder of experimental data	13	Variable hydraulic throttle for adjusting the working pressure
6	Two-way, three-position hydraulic distributor, electrically controlled	14	Safety valve
7	Hydraulic pressure pipe (TOUR)	15	Hydraulic pressure pipe (RETOUR)
8	Digital or analog manometer	16	Tank for hydraulic fluid

The value of the resisting force (Fr), for both directions of movement of the hydraulic cylinder rod, is 8000 N.

3. EXPERIMENTAL RESEARCH PROGRAM

The experimental research program includes three groups of experimental tests carried out with the hydraulic actuation cylinder equipped in three variants R, T, and S, according to the type of helical grooves on the outside of the interchangeable sleeve, (R – rectangular, T - triangular and S – semicircular), position 2 in figure 2.

The extension and retraction strokes of the piston rod will be a maximum of 99 mm so that a reserve of at least 0.7 mm is guaranteed at each end of the stroke. The pressure with which the hydraulic cylinder will be tested will be 10 MPa and 20 MPa for each group of experimental tests.

Each hydraulic cylinder is equipped in variants R, T, and S (successive), and it shall be subjected to a minimum number of 50 double strokes. The rod speed shall be recorded in both directions (extension and retraction), as presented in the synthesis of the experimental research program in Table 3.

Table 3. Synthesis of the experimental research program

Equipment variant	**Hydraulic pressure**	**No. of extension strokes** / **No. of retraction strokes**	**The average speed of the rod in the extension** / **The average speed of the rod in retraction**
R Fr ≈ 8000 N	10 MPa	minimum 50	
		minimum 50	
	20 MPa	minimum 50	
		minimum 50	
T Fr ≈ 8000 N	10 MPa	minimum 50	
		minimum 50	
	20 MPa	minimum 50	
		minimum 50	
S Fr ≈ 8000 N	10 MPa	minimum 50	
		minimum 50	
	20 MPa	minimum 50	
		minimum 50	

4. CONCLUSIONS

The paper presented above contains the presentation of the purpose of experimental research, the presentation of the installation for experimental research, and the experimental research program.

During the experimental research, three different sleeves with helical grooves with a rectangular, triangular, or semicircular cross-section will be tested, acting as a hydraulic throttle (a hydraulic resistor) for the hydraulic cylinder. Based on the experimental research it will be determined which of the three sleeves will achieve the best equalization of the extension and retraction speeds of the hydraulic cylinder rod.

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