Improving the accuracy of machining of non-rigid shaft

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Abstract. So far, due to much more strict events of operating parameters requirements, the reduction of pieces steel intensity allows to produce multiplying quantity of the highly precise Non-Rigid Pieces (NRP); most of them are supposed to be the shafts in amount. The creation of Automatic Control Systems (ACS) by mechanical operating also involves highly precise NRP production. In present paper there is Self-Centering Rest (SCR) operating hydrocylinder piston rod control system presented; it causes influence directly to the rest centering accuracy. The plant processing does not require hydrostation and pipeline; it possesses highly precise centering and it is able to function either in shaft support mode, or in active dampening one. There is the original scheme of double acting sealed hydrocylinder presented. There is the functional control scheme of hydraulic power cylinder presented. There are results of the non-rigid shaft axle research while turning presented. Thus, the beat reduction of the rigid shaft while turning in SCR system reaches 3...16 times in comparison.

1 Introduction

Nowadays much of mechanical engineering industries apply critical non-rigid pieces (NRP) production increase of which is caused by blank and construction shape optimization, constant reduction of the produce steel intensity and constant increase of precise machines production. The problems of the NRP operating reliability increase is supposed to have significance verily at the moment [1-9]. The NRP processing has a few sides of fixes, such as significant resilient and residual deformation during all the stages, the technology system units low vibration resistance and admittance, irregular residual stress having place at all the stages. These negative factors just cause the NRP operating reliability decrease.

In the modern time the NRP produce technologic operating is being improved continuously.

2 Hydraulic Control System

One of the ways to increase the NRP processing accuracy is the improving of the Automatic Control System (ACS) units used in machining. In this way, one of the basic

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units ACS bundle of which allows to stabilize NRP axle while turning, is a self-centering rest.

Before the processing, the rests are either placed along the blank depending on eq. rigidity in function of piece sizes proportion ($1/d < 5$), or set in elements and antinode zones of the pieces vibrations high main forms distribution. SCR are placed at flection vibrations elements; they are applying as eq. rigid supports. Thus, the pressure led to SCR provides piece fixing; however, controlled SCR of isolator mode operating, which are set on not turned enough surface at that pass, generate pressure providing dampening of the cross vibrations [1, 6].

The hydraulic cylinder is one of the main SCR units. The highly solid hydrocylinders common packing is seemed to be a perpetual problem [10-14].

Within the known hydrocylinders, oil stays at the piston rod shape in a form of thin layer; with it, it escapes the hydrocylinder while rod moving out and flows through by a piston ring. Such as that, tiny amount of operating environment transfers to outer one by every piston rod stroke; in other words, it flows out. It is also flooding from one cavity to other during the rod moving and the pressure stabilization. Thus, the permanent time position of the rod is not provided anyhow.

There is the highly solid hydrocylinder construction scheme represented in Fig 1.

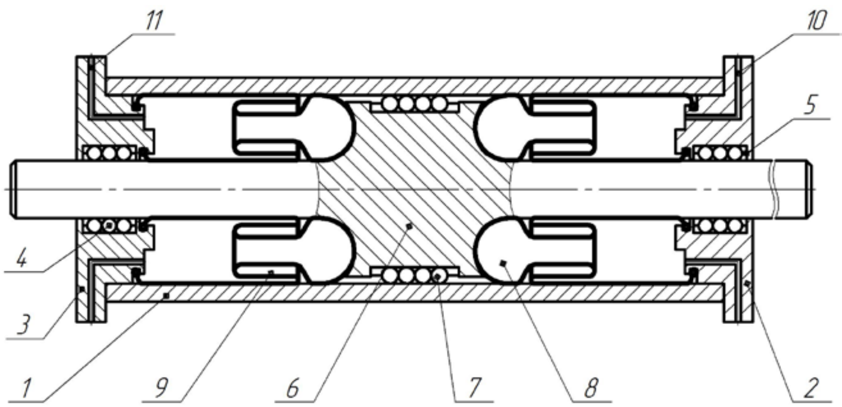

Fig. 1. The construction scheme of the double acting hydraulic cylinder.

During the double acting hydrocylinder (Fig. 1) calculating there was a seal [14] developed; that seal contains seal chamber constructed with resilient flexible material. Its form is plug truncated tube turned outside in with truncated plug smaller diameter which gains double lap-join skin, the length of which equals the piston rod double stroke length. At the same time, one end of smaller diameter is clamped on a cylinder plug shape; the one of the bigger diameter is clamped on a cylinder face plane. Lap-join skin does along the rod diameter and inner diameter of the cylinder piston rod.

The appearance of double lap-join skin, the length of which equals one of the piston rod double stroke, is supposed to provide seal chamber elongation during the rod moving all along the operating stroke length which allows to keep cylinder operating cavities isolated.

The providing of the stretching of cylinder inner shape and rod face allows to detect the flow at piston ring (when operating environment transfers from one of the cylinder cavities to another). That allows to eliminate the flooding at the piston ring shape; with the stretching of cylinder inner shape and rod face, it also allows to eliminate the flooding at the piston ring itself.

The double acting hydrocylinder contains: body 1 with face-settled housing caps 2 and 3, liner clamps 4 and 5, piston rod 6 with foreseat movement bracket in - 7, seal chambers 8 with double lap-join skin 9, intake and outtake fillers 10-11 moving from operating environment. Toroidal face plane of the piston rod 6 increases solidness of the hydraulic power cylinder by the seal chambers deformation path specification and cavities creation for their distribution.

Due to sealing rings, the seal chambers 8 are stabilized at housing caps 2 and 3. Furthermore, the piston rod 6 is centered and gets filled with operating environment through by fillers 10 and 11. One of the hydrocylinder cavities gets filled with operating liquid under pressure; in such way, the piston rod moves to direct side by pressure control unit (s. Fig. 2). The liner clamps 4, 5 and the foreseat movement bracket 7 provide uniform motion of the piston rod 6, same as its smaller operating torque.

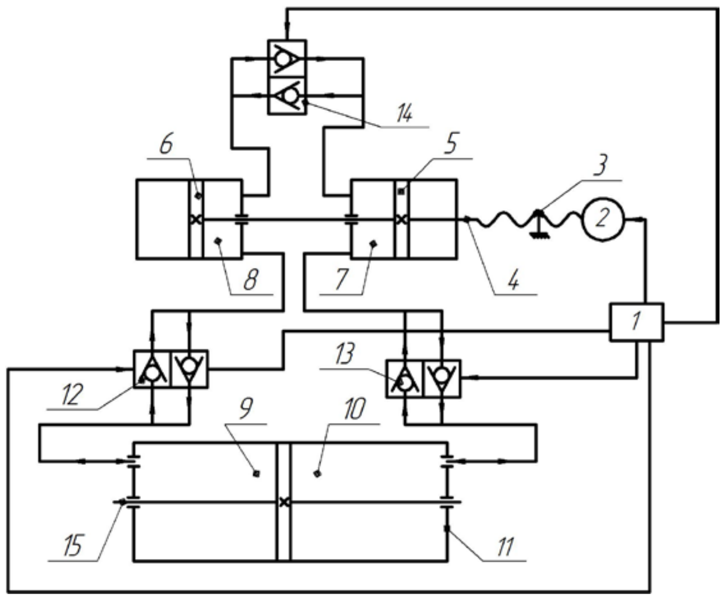

Fig. 2. The functional scheme of electrohydraulic actuator.

The pressure control unit performing the hydrocylinder piston rod motion (Fig. 2) contains electric drive, hydraulic lines with outtake and intake fillers being set, hydraulic power cylinder.

Electrohydraulic actuator is applied at different industries even more and more often cause of its power consumption efficiency which is higher than simple hydraulic one has [15-17].

Electric actuator contains in-series connected stepping drive, ball-and-screw unit and eccentric shaft. The pumping station contains two hydrocylinders connected one to another with shaft and fluid conductor with outtake and intake fillers being set. The hydraulic power cylinder contains control circuit of piston rod uniform motion which possesses functions of stroke limiter and its data unit. At the same time, actuator contains control unit end of which charges the stepping drive and the fillers.

The electric actuator with in-series connected stepping drive, ball-and-screw unit and eccentric shaft provides precision of the eccentric shaft uniform motion; it also allows to set that value by the control system.

The functional control scheme of the hydraulic actuator contains control circuit 1, stepping electric drive 2, ball-and-screw unit 3, shaft 4 with rams being set up 5 and 6, their operating chambers 7 and 8, controlled fillers 12-13 connecting operating chambers 9 and 10 of the hydraulic power cylinder 11. The chambers 7 and 8 are connected each to another by controlled fillers 14.

The principle of electrohydraulic actuator operation is following. By a control circuit 1 program, the stepping drive 2 moves shaft 4 through the ball-and-screw unit 3 with clamped rams 5 and 6 into the extreme right position. The piston rod 15 is set manually centering cylinder 11. All four chambers are filled up under small pressure and get sealed. Furthermore, control circuit 1, as it has to, opens controlled fillers 14 and shuts down fillers 12-13; at the same time it controls stepping drive 2 rotation to direct side and moves definite times rams 5 and 6 to the left with the ball-and-screw unit 3. Thus, under the increasing pressure oil amount in cavity 7 gets into the chamber 10 of the power cylinder 11 through by the opened filler 13. The displaced volume of the chamber 9 gets into the free one of the chamber 8 through by the opened filler 12.

The control circuit 1 commands to stepping drive 2 back draft. That one rotates into opposite way and moves shaft 4 and rams 5, 6 to the right through by the ball-and-screw unit 3. That is where turnover begins: the piston rod 15 moves to extreme left position. The control circuit 1 commands to fillers 12-13 to shut down, then it commands to fillers 13-14 to open. Then the loop comes again: the piston rod moves into opposite way, from left to the right.

The electrohydraulic actuator functional control scheme applying just allowed to increase accuracy of the double acting hydraulic cylinder piston rod position control, as same as solidness and durability of the electrohydraulic actuator.

3 The experiment results

The experimental refinement accuracy control of the NRP mechanical processing was performed on laboratory-scale plant based on a thread-cutting lathe.

During the experiment, the operated blanks were covered by beat ranges. The operating was performed both ACS processing and without ACS processing. The blank beat range was measured just before and after the mechanical processing. The results are represented in Fig. 3, where OX contains input values feed rate (*S*) and OY contains values of ratio of the blank beat range without ACS processing (Δy) to the blank beat range with ACS processing ($\Delta y(ACS)$). As blanks, there were used to be rigid shafts with char. 1/d = 25. The cutting depth value always did 0.25 mm. The cutting speed (*V*) did varied.

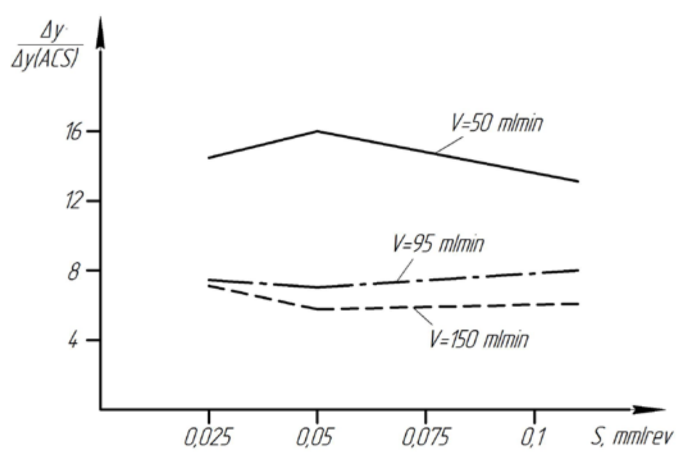

Fig. 3. The experiment results.

The analysis of obtained regularities proves that applying of ACS with the electrohydraulic actuator functional control scheme decrease blank vibrations range; due to it, the processing precision raises in several times. The examined input range shows verily determined extreme at 0.05 mm/r point. Besides, it may be as minimum as maximum.

4 Conclusions

During the year of the streamlined double acting hydraulic cylinder operation there was no oil flooding detected. The readjustments amount is taken down to min.

The suggestion about significant influence of the electrohydraulic actuator control loop dynamic parameters to the processing accuracy was confirmed.

The operated rigid shafts axle distortion while ACS processing at position in environment during the 30 days has reached only 10 mcm or less; that allows to suppose a regularity of the residual stress distribution.

The blank axle stabilization with the electrohydraulic actuator functional control scheme while ACS processing gets multiplied in several times. For the instance, in examined mods the beat had reduced in 3...16 times.

References

1. O.I. Drachev, *Control of technological heredity of non-rigid parts* (Irbit, ONYX, 2011)
2. Yu.V. Maksimov, A.V. Ankin, 6th International Congress of Precision Machining, **496**, 168 (2006)
3. Xianguo Han, Huajiang Ouyang, Minjie Wang, Nurhafizzah Hassan, Yuming Mao, Proc. IMechE Part C: J. Mechanical Engineering Science, **226**, 1958 (2012)
4. A. Świć, D. Wołos, J. Zubrzycki, M. Opielak, A. Gola, V. Taranenko, Applied Mechanics and Materials, **613**, 357 (2014)
5. Yu.V. Maksimov, A.V. Ankin, A.I. Chebyshev, Russ. Engin. Res., **36**, 394 (2016)
6. A. Świć, V. Taranenko, A. Gola, Applied Mechanics and Materials, **791**, 238, (2015)
7. S.L. Vasilevykh, E.S. Shelihov, MATEC Web of Conferences, **129**, 01023, (2017)
8. R. Venkata Rao, *Advanced Modeling and Optimization of Manufacturing Processes*, (Springer, London, 2011)
9. A. Świć, A. Gola, D. Wołos, M. Opielak. Iran J Sci Technol Trans Mech Eng , **41**, 159 (2017)
10. K.T. Koskinen, J. Aaltonen, *Hydraulic Cylinders. Encyclopedia of Tribology*. (Springer, Boston, 2013)
11. V.V. Burenin, Russ. Engin. Res., **31**, 1036 (2011)
12. V.V. Burenin, Russ. Engin. Res., **29**, 219 (2009)
13. F. Zhang, H. Liu, L. Zhang, *The Innovative Design of Reciprocating Seal for Hydraulic Cylinder Based on TRIZ Evolution Theory*. (Springer, Boston, 2006)
14. Patent 2478856
15. JY. Oh, GH. Jung, GH. Lee, YJ Park, CS Song. Int. J. Precis. Eng. Manuf., **13**, 1445 (2012)
16. S.A. Nahian, D.Q. Truong, P. Chowdhury, D. Das, K. K. Ahn, Int. J. Precis. Eng. Manuf., **17**, 1285 (2016)
17. B. Xu, M. Cheng, Front. Mech. Eng., **13**, 151 (2018)