On the need to account changes in hydraulic performance of worn out metal water pipes

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Abstract. During the operation [illegible] hydraulic [illegible] pumping units and water consumers.

Keywords: metal water pipe, hydraulic calculation, dependence [illegible] power consumption, pumping units.

Introduction

The hydraulic potential of metal pipes that changes during the operation of pipelines is calculated according to the well-known formula given below (Fig

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Fig. 1. Characteristics of steel pipes with internal deposits.

1 RWDWLRQV LQ) LJ DUH WKH IROORZ LQJ

6H LV WKH HVWLP DWHG Z DOO WKLFNQHVV RI WKH SLSH DFFRUGLQJ WR * 2 67 IRU VWHHO DQG FDVW LURQ SLSHV P PP

6D LV WKH DFWXDO Z DOO WKLFNQHVV RI WKH SLSH Z LWK D OD\HU RI GHSRVLWV /I P PP

/D LV WKH DFWXDO WKLFNQHVV RI WKH GHSRVLW OD\HU PP

$$\delta_a = S_a - S_e \quad \text{PP P}$$

GR LV WKH RXWHU GLDP HWHU RI WKH SLSH DFFRUGLQJ WR * 2 67 PP P

d^a_{in} LV WKH DFWXDO LQQHU GLDP HWHU RI SLSHV Z LWK GHSRVLWV /D PP P

$$d^a_{in} = \left(d_o - 2S_e\right) - 2\delta_a \quad \text{PP P}$$

7KH DFWXDO K\ GUDXOLF SRWHQWLDO RI WKH SLSHV d^a_{in} 9I LL LV FDOFXODWHG DFFRUGLQJ WR WKH IRUP XODV d^a_{in} DFFRUGLQJ WR IRUP XOD GD± DFFRUGLQJ WR IRUP XOD

$$d_a = d^a_{in} - d_{re} \quad \text{PP P}$$

Z KHUH d_{re} LV WKH UHGXFHG GLDP HWHU RI WKH SLSHV GHWHUP LQHG E\ WKH IRUP XOD > @

$$d_{re} = \sqrt{d^2_{in} - \left(d_{in} - 2\delta_a\right)^2} \quad \text{PP P}$$

7KH DFWXDO DYHUDJH YHORFLW\ RI Z DWHU P RYHP HQW LQ D SLSH 9D Z LWK D OD\HU RI GHSRVLWV /D P V LV GHWHUP LQHG E\ WKH IRUP XOD

$$V_a = \frac{4 \cdot q}{\pi \cdot (d^a_{in})^2} \quad \text{P V}$$

Z KHUH d^a_{in} LV WKH DFWXDO LQQHU GLDP HWHU RI WKH SLSH Z LWK D OD\HU RI GHSRVLWV δ_a P

T LV WKH VHW IORZ UDWH OV P V

7KH DFWXDO K\ GUDXOLF VORSH RI SLSHV LD Z LWK D OD\HU RI GHSRVLWV /D LV FDOFXODWHG DFFRUGLQJ WR WKH IRUP XOD RI 3URIHVVRU) $ 6KHYHOHY D KDYLQJ WKH IRUP > @

$$i_a = 0.00107 \frac{V^2_a}{\left(d^a_{in}\right)^{1,3}} \quad \text{PP PP P}$$

7KH IRUP RI IRUP XOD   VSHFLILHG E\ WKH DXWKRUV WDNLQJ LQWR DFFRXQW WKH WKLFNQHVV RI WKH OD\HU RI LQWHUQDO GHSRVLWV /D ORRNV DV IROORZ V > @

$$i_a = 0.00107 \frac{V^2_a}{\left[\left(d_o - 2S_e\right) - 2\delta\right]^{1,3}} \quad \text{PP PP P}$$

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7KH HQHUJ\ FRQVXPSWLRQ RI SXPSLQJ XQLWV 1$_{G\,Y}$ WUDQVSRUWLQJ ZDWHU WKURXJK QHZ DQG ZRUQ SLSHV LV GHWHUPLQHG E\ WKH IRUPXOD> @

$$N_{dv}^{e(a)} = 10^{6} \cdot i_{e(a)} \cdot \left(d_{in}^{e(a)}\right)^{2} \cdot V_{e(a)} \cdot \frac{0.00808}{\eta}$$ N:K

ZKHUH $i_{e(a)}$ LV WKH HVWLPDWHG DFWXDO K\GUDXOLF VORSH RI WKH SLSHV GHWHUPLQHG E\ IRUPXODV PP P

$d_{in}^{e(a)}$ LV WKH HVWLPDWHG H DFWXDOO PHDVXUHG LQQHU GLDPHWHU RI SLSHV D ZLWK DOOD\HU RI GHSRVLWV /D)LJ DFFRUGLQJ WR *267 P

$V_{e(a)}$ LV WKH WKH HVWLPDWHG DFWXDO VSHHG RI ZDWHU PRYHPHQW LQ QHZ H DQG ZRUQ D SLSHV P V

η LV WKH HIILFLHQF\ RI WKH SXPSLQJ XQLW)RU SUDFWLFDO FDOFXODWLRQV ¦ LV DVVXPHG> @

0DWHULDOV DQG PHWKRGV

$FFRXQWLQJ IRU WKH DFWXDO K\GUDXOLF FKDUDFWHULVWLFV RI ZRUQ RXW PHWDO ZDWHU SLSHV LV WKH EDVLV IRU SUHGLFWLQJ WKH UHVLGXDO VHUYLFH OLIH RI SLSHOLQHV ZLWK LQWHUQDO GHSRVLWV DQG PDNLQJ D GHFLVLRQ ZKHWKHU WKHLU UHFRQVWUXFWLRQ SURWHFWLRQ DUH UHTXLUHG> @

$ TXDQWLWDWLYH DVVHVVPHQW RI WKH K\GUDXOLF HIILFLHQF\ RI WKH RSHUDWLQJ ZRUQ RXW PHWDO ZDWHU VXSSO\ QHWZRUNV LV FDUULHG RXW DFFRUGLQJ WR WKH GLPHQVLRQOHVV FRHIILFLHQW RI WKHLU RSHUDWLRQ HIILFLHQF\ GHWHUPLQHG E\ WKH IRUPXOD > @

$$K_{ef} = \frac{N_{dv}^{e}}{N_{dv}^{a}} = \frac{\left(d_{in}^{e}\right)^{2} \cdot V_{e} \cdot i_{e}}{\left(d_{in}^{\phi a}\right)^{2} \cdot V_{a} \cdot i_{a}},$$

ZKHUH $N_{dv}^{e(a)}$ LV WKH HVWLPDWHG DFWXDO HQHUJ\ FRQVXPSWLRQ RI WKH SXPSLQJ XQLW N: K

$d_{in}^{e(a)}$ LV WKH HVWLPDWHG DFWXDO LQQHU GLDPHWHU RI SLSHV P

$V_{e(a)}$ LV WKH HVWLPDWHG DFWXDO ZDWHU YHORFLW\ P V

$i_{e(a)}$ LV WKH FDOFXODWHG K\GUDXOLF VORSH IRU QHZ SLSHV H DQG DFWXDO K\GUDXOLF VORSH IRU ZRUQ SLSHV D PP P

$Q H[DPSOH LV JLYHQ EHORZ FRQILUPLQJ WKDW D FKDQJH LQFUHDVH LQ WKH K\GUDXOLF FKDUDFWHULVWLFV RI ZRUQ VWHHO ZDWHU SLSHV OHDGV WR DQ LQFUHDVH LQ WKH HQHUJ\ FRQVXPSWLRQ RI SXPSV DQG HQVXUHV WKDW VXFK FKDQJHV PXVW EH WDNHQ LQWR DFFRXQW WR LPSURYH WKH DFFXUDF\ RI K\GUDXOLF DQDO\VLV RI ZRUQ PHWDO ZDWHU SLSHV

5HVXOWV

3UREOHP FRQGLWLRQV

&RPSDUH WKH K\GUDXOLF SRWHQWLDO RI QHZ VWHHO HOHFWULF ZHOGHG SLSHV ZLWK DQ RXWHU GLDPHWHU G$_{R}$ PP ZDOO WKLFNQHVV 6S PP WUDQVSRUWLQJ GULQNLQJ ZDWHU T OV P V ZLWK WKH FKDUDFWHULVWLFV RI ZRUQ SLSHV RI WKH VDPH GLDPHWHU ZLWK D OD\HU WKLFNQHVV RI LQWHUQDO GHSRVLWV /$_{D}$ PP P

/HW XV EXLOG $i_{e(a)} = f\left(\delta_{a}\right)$ YV $N_{dv}^{e(a)} = f(\delta_{a})$ JUDSKV

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6ROXWLRQ

7KHPHWKRG RI K\GUDXOLF FDOFXODWLRQ RI ZRUQ PHWDO ZDWHU SLSHV LV GHVFULEHG LQ GHWDLO LQ WKH VFLHQWLILF SXEOLFDWLRQ > @ 7R DQDO\]H DQG FRPSDUH WKH FDOFXODWHG DQG DFWXDO K\GUDXOLF FKDUDFWHULVWLFV RI QHZ DQG ZRUQ SLSHV IRU WKH FRQGLWLRQV RI WKH JLYHQ H[DPSOH 7DEOH SUHVHQWV WKH K\GUDXOLF SRWHQWLDO RI WKH FRPSDUHG SLSHV DW GLIIHUHQW WKLFNQHVVHV RI WKH LQQHU GHSRVLW OD\HU LQ WKH UDQJH RI /I YDOXHV PP

,Q 7DEOH DFFRUGLQJ WR WKH IRUPXOD WKH HQHUJ\ FRQVXPSWLRQ RI SXPSLQJ XQLWV IRU WKH FRQGLWLRQV RI WKH SUREOHP DUH FDOFXODWHG

Table 1. Hydraulic potential of new and worn pipes with a diameter of do=426 mm.

$FWXD WKLFNQRQ GHSRVLV δ_a PP	0HDVXUHG KHDG FKDUDFWHULVWLFV RI WKH SLSHV EHLQJ FRPSDUHG						
	QHZ			ZRUQRXW			
	d_{in}^{e} P	V_e P V	i_e PP P	d_{in}^{a} P	V_a P V	i_a PP P	.H
3HUFHQWDJH LQFUHDVH LQ WKH FKDUDFWHULVWLFV RI WKH SLSH ZLWK GHSRVLWV DPRXQW δ_h HU PP DQG LQFUHDVH LQ WKLFNQHVV							

Table 2. Energy consumption of pumping units with different thickness of internal deposits in a pipe with a diameter of do = 426 mm.

$FWXDO WKLFNQHVV RI LQWHUQDO GHSRVLWV δ_a	$FWXDO HQHUJ\ FRQVXPSWLRQ RI SXPSLQJ XQLWV IRU WKH FRQGLWLRQV RI WKH SUREOHP IRUPXOD N_{dv}^{a} N:K			

$FFRUGLQJ WR 7DEOH JUDSKV RI GHSHQGHQFH DUH SORWWHG LQ)LJ

$$N_{dv}^{e(a)} = f\left(\delta_{e(a)},\ V_{e(a)}\right)$$

Fig. 2. Dependency graph $N^{e(a)}_{dv} = f\left(\delta_{e(a)},\ V_{e(a)}\right)$

' LVFXVVLRQ

$ QDO\VLV RI WKH FKDUDFWHULVWLFV RI WKH FRPSDUHG SLSHV 7DEOHV DQG WKH JUDSKV LQ) LJ DQG FRQILUP WKDW LW LV UHTXLUHG WR FRQVLGHU FKDQJHV LQ WKH K\GUDXOLF SRWHQWLDO FKDUDFWHULVWLFV RI VWHHO DQG FDVW LURQ Z DWHU SLSHV $d^{a}_{in},\ V_{a},\ i_{a}$ GXULQJ WKHLU RSHUDWLRQ 7KH SXUSRVH RI VXFK DFFRXQWLQJ LV WR FUHDWH RSHUDWLQJ FRQGLWLRQV IRU Z RUQ RXW PHWDO Z DWHU SLSHV LQ Z KLFK WKH HQHUJ\ FRQVXPSWLRQ RI SXPSLQJ DQG SRZ HU HTXLSPHQW Z LOO KDYH UDWLRQDO DQG UHDVRQDEOH OHYHOV 7KLV UHTXLUHV

- DWOHDVW RQFH D \HDU PRQLWRULQJ FKDQJHV LQ WKH DFWXDO WKLFNQHVV RI WKH OD\HU RI LQWHUQDO GHSRVLWV LQ VWHHO DQG FDVW LURQ Z DWHU SLSHV PDGH RI JUD\ FDVW LURQ > @
- TXDQWLI\LQJ WKH HIILFLHQF\ RI WKH RSHUDWLRQ RI PHWDO Z DWHU SLSHV XVLQJ WKHLU RSHUDWLRQ HIILFLHQF\ FRHIILFLHQW $_{HI}$ IRUPXOD
- DFFRUGLQJ WR . $_{HI}$ PDNLQJ DQ H[SHUW TXDQWLWDWLYH DVVHVVPHQW RI WKH HIILFLHQF\ RI Z DWHU VXSSO\ RSHUDWLRQ XVLQJ WKH UHFRPPHQGDWLRQV SXEOLVKHG LQ WKH PRQRJUDSK > @
- SUHGLFWLQJ WKH FKDUDFWHULVWLFV RI WKH K\GUDXOLF SRWHQWLDO RI SLSHV WKDW FKDQJH GXULQJ WKH RSHUDWLRQ RI PHWDO Z DWHU SLSHV $d^{a}_{in},\ V_{a},\ i_{a}$) DOORZ V QHWZ RUN RSHUDWRUV WR SURYLGH ILQDQFLDO UHVRXUFHV LQ DGYDQFH IRU WKH GHYHORSPHQW RI UHFRQVWUXFWLRQ SURMHFWV RI PHWDO QHWZ RUNV DQG UHSODFH Z LWK QHZ RQHV

& RQFOXVLRQ

7KXV WKH HQHUJ\ FRQVXPSWLRQ RI SXPSLQJ XQLWV VXSSO\LQJ Z DWHU WR FRQVXPHUV FDQ DOVR EH GHWHUPLQHG E\ WKH DFWXDO WKLFNQHVV RI WKH GHSRVLW OD\HU /$_{I}$ PHDVXUHG XVLQJ D WKLFNQHVV JDXJH DV SDUW D SRUWDEOH IORZ PHWHU RU RWKHU FRQWUROV > @

Fig. 3. Dependence graph $h_{e(a)} = f\left(\delta_{e(a),}\ V_{e(a)}\right)$

Table 3. Design characteristics [illegible]

Estimated diameter of the new pipes d^e_{in}, m	Hydraulic characteristics	
	Estimated speed V_e, m/s (formula)	Calculated hydraulic slope of the pipe i_e, mm/m (formula)

According to Table Figure shows $i_{e(a)} = f\left(\delta_{e(a),}\ V_{e(a)}\right)$ dependence graphs and according to Table Figure shows $N^{e(a)}_{dv} = f\left(\delta_{e(a)},\ V_{e(a)}\right)$ dependence graphs confirming the need to take into account changes in the hydraulic characteristics of worn metal water pipes that change the energy consumption of pumping units.

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2 $ 3URGRXV 3 3 <DNXEFKLN '   , 6KO FKNRY) HDWXUHV RI K\ GUDXOLF DQDO\VLV RI
Z DWHUSLSHV P DGH RI P HWDO SRO\P HU DQG P HWDO SRO\P HU SLSHV $ VWHP LQRORJLFDO
GLFWLRQDU\ RQ RXWGRRU Z DWHU VXSSO\ DQG VHZ HUDJH QHWZ RUNV 3HUR 3XEOLVKLQJ + RXVH 6W
3HWHUVEXUJ 0 RVFRZ

2 $ 3URGRXV ' HSHQGHQFH RI WKH SHULRG RI XVLQJ P HWDO SLSHOLQHV RI Z DWHU VXSSO\
V\VWHP V RQ WKH WKLFNQHVV RI WKH GHSRVLWV OD\HU RQ WKH LQQHU VXUIDFH RI WKH SLSHV LQ
&ROOHFWLRQ RI UHSRUWV RI WKH ; 9 ,QWHUQDWLRQDO 6FLHQWLILF DQG 7HFKQLFDO &RQIHUHQFH
<DNRYOHY UHDGLQJV SS 0 DUFK 3XEOLVKLQJ + RXVH RI 0 68 &(
0 RVFRZ

2 $ 3URGRXV : DWHU 7UHDW : DWHU 3XULI : DWHU 6XSSO\ **1(157)**

2 $ 3URGRXV 3 3 <DNXEFKLN ([SHUWDVVHVVP HQW RI WKH UHVLGXDO SHULRG RI RSHUDWLRQ RI
Z RUQ RXW Z DWHU VXSSO\ QHWZ RUNV Z LWK LQWHUQDO GHSRVLWV LQ 3URFHHGLQJV RI WKH ; ,9
,QWHUQDWLRQDO 6FLHQWLILF DQG 3UDFWLFDO &RQIHUHQFH SS $ SULO
. LVORYRGVN

2 $ 3URGRXV '   , 6KO FKNRY %XO 7RP VN 6WDWH 8 QLY $ UFKLW &LYLO (QJ **24(6)**

2 $ 3URGRXV 3 3 <DNXEFKLN 6 6 %DODVKRY 4 XDQWLWDWLYH DVVHVVP HQW RI WKH HIILFLHQF\
RI P HWDO Z DWHU VXSSO\ QHWZ RUNV LQ &ROOHFWLRQ RI UHSRUWV RI SDUWLFLSDQWV RI WKH ; 9 ,,,
,QWHUQDWLRQDO 6FLHQWLILF DQG 7HFKQLFDO &RQIHUHQFH GHGLFDWHG WR WKH P HP RU\ RI
$ FDGHP LFLDQ RI WKH 5 XVVLDQ $ FDGHP \ RI 6FLHQFHV 6 9 <DNRYOHYD SS 0 RVFRZ
0 DUFK 0 68 &(3XEOLVKLQJ + RXVH 0 RVFRZ

2 $ 3URGRXV 3 3 <DNXEFKLN '   , 6KO FKNRY &LYLO (QJ %XO &DVS 6HD **2(44)**

'   , 6KO FKNRY ,QQRY ,QYHVW **4**

'   6KO FKNRY 2 SFLRQ **35(24)**

2 $ 3URGRXV '   , 6KO FKNRY $ $ 6KHVWDNRY $ *   &KHORQHQNR $ UFKLW &RQVW
7UDQVS **4(106)**

2 $ 3URGRXV '   , 6KO FKNRY ' HYLFH IRUP HDVXULQJ WKH GHSRVLW WKLFNQHVV LQ SLSHV
8 WLOLW\ P RGHO SDWHQW 1 R ' DWH RI VWDWH UHJLVWUDWLRQ LQ WKH 6WDWH 5 HJLVWHU RI
8 WLOLW\ 0 RGHOV RI WKH 5 XVVLDQ) HGHUDWLRQ