*Numerical and experimental investigation of leaks in viscoelastic pressurised pipe flow: short period analysis*, by S. Meniconi, B. Brunone, M. Ferrante, and C. Massari

***Reply*** **to Referee #1**

General Comments

The main objective of the article is to analyse the importance of un-steady friction and viscoelasticity in numerical modelling of transients in plastic pipes with an external flow due to a leak. The article is interesting, the problems are presented very clearly, the experimental part and numerical analysis have been carried out at excellent level. For the numerical simulation different 1-D numerical models have been used. The literature review in the Introduction (Section 1) of the article is profound. The results indicate the importance of viscoelasticity in simulating the transient flow with a leak.

*Reply: We thank Referee #1 for the attention he/she paid to our work and the interesting comments.*

Specific Comments

1. The article of Zielke (1968) on unsteady friction could be considered as "classical", similar to the Allievi-Joukowsky model for transient, and mentioned separately in the Introduction (Section 1) of the article but not in the list of motivated publications in the last two decades.

*Reply: We completely agree with Referee #1. As a consequence we have modified profoundly the text as it follows (page 3, from present row 7 to row 19).*

*"... This result has motivated the intense research activity in the field of simulating transients in pressurised pipes in the last decades (Ghidaoui et al. 2005). Particular attention has been devoted to the modelling of unsteady friction (UF) and viscoelasticity (VE). In fact the damping and rounding of pressure peaks in a single pipe has to be ascribed to UF in elastic pipes whereas in plastic pipes the effect of VE becomes more and more dominant with respect to UF as time progresses (Duan et al. 2010).*

*With regard to the analysis of UF, the 1-D model proposed by Zielke (1968) has to be considered as a milestone. In fact, it not only solved analitically the problem of laminar transients but it also gave rise to the "family" of the so-called Convolution Based (CB) models for initially turbulent transients. In such models the unsteady component of the instantaneous wall shear stress, $\tau_u$, is assumed as a weighted integral of fluid acceleration (e.g., Vardy and Brown 2007). An alternative to the computationally demanding CB models, is given by the Instantaneous Accelerations-Based (IAB) models where $\tau_u$ is evaluated as a combination of the instantaneous local and convective accelerations (e.g., Brunone et al., 1991,1995; Pezzinga 2000, 2009; Bergant et al. 2001; Adamkowski and Lewandowski 2006; Storli and Nielsen 2011). The role played by $\tau_u$ with respect to the quasi-steady component, $\tau_s$, at different positions of a given pipe has been pointed out by Brunone and Berni (2010) and Storli and Nielsen (2011a) on the basis of laboratory and numerical tests, respectively. The relevance of $\tau_u$ to pipe size and length has been demonstrated quantitatively by Duan et al. (2012). With regard to the analysis of VE, an additional term is considered in the continuity equation to take into account the viscous behavior of pipe material. Present research trend ascribes great importance to the Kelvin-Voigt models to simulate VE by means of n — usually just one — element consisting of a* *viscous damper and elastic spring connected in parallel and jointed to a simple elastic spring in series (e.g., Covas et al. 2004, 2005; Ferrante et al. 2011; Franke and Seyler 1983; Ghilardi and Paoletti 1986; Meniconi et al. 2012a,b; Soares et al. 2008)."*

Further References

*Storli, P.-T., and Nielsen, T.K. (2011). Transient friction in pressurized pipes. I: Investigation of Zielke's model. J. Hydr. Eng. - ASCE, 137, 577-584.*

*Duan, H. -F, Ghidaoui, M.S., Lee, P.J., and Tung, Y.K. (2012). Relevance of unsteady friction to pipe size and length in pipe fluid transients, J. Hydr. Eng.- ASCE, 138, 154-166.*

2. The term "rectangular leaks“ is given in Experimental setup (Section 2). The authors consider a rectangular hole, but the leak flow is probably not rectangular. There should be some influence of inversion on the shape of outflow.

*Reply: This is an interesting point from both the experimental and numerical point of view. In the revised version of the paper, we could modify the text as it follows (in red the changes):*

a) page 5, row 4: *" ... to simulate rectangular holes of different size by ..."*

b) Table 1, row 1: *" ... steel plate with a hole hole area, ..."*

c) page 7, row 9: " *... to the leak. According to Eq. (5), by means of $C_L$ the effective area of the flow through the leak is taken into account in the 1-D model; the values of $C_L$ have been determined by means of steady-state tests. During tests no inversion on the shape of outflow has been observed"*

3. The used 1-D numerical model is introduced in Section 4. To solve the system of Eqs.(1)-(2), models are used for unsteady friction and viscoelasticity (retarded strain). Modelling of friction is given in the article but how viscoelasticity is modelled is not explained. For prospective reader of the article short comments about the used model of viscoelasticity would help to understand the modelling section of the article.

*Reply: We completely agree with Referee #1. As a consequence we have modified profoundly the text as it follows: on present page 6 at row 8 we will include the following phrases: "The third term in Eq. (1) takes into account the viscoelasticity of pipe material; the total strain, $\varepsilon$, is given by the following relationship:*

$$\varepsilon = \varepsilon_i + \varepsilon_r \tag{3}$$

*where $\varepsilon_i$ ($\varepsilon_r$) is the instantaneous (retarded) strain. To simulate the viscoelastic behavior, a single element Kelvin-Voigt model is considered consisting of a viscous damper and elastic spring connected in parallel and jointed to a single elastic spring in series. The two components of the total strain can be expressed as:*

$$\varepsilon_i = \frac{\alpha}{E_i} \tag{4}$$

$$\alpha = \varepsilon_r E_r + \frac{E_r}{T_r}\frac{d\varepsilon_r}{dt} \tag{5}$$

*where $\alpha$ = circumferential stress, $E_i$ ($E_r$) = instantaneous (retarded) Young's modulus of elasticity, and $T_r$ = retardation time of the damper."*
*See also the reply to Referee #3 about the value of the model parameters.*

*Of course in the revised version the numbering of the equations will be modified to take into account the relationships added to describe the viscoelastic behavior of pipe material.*