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Research on fire hose couplings damages

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Abstract. This paper presents a part of a research on the damaging of fire hose coupling. These are important components of the hydraulic systems used by firefighters to deliver one or more suppression agents into the fire. The operating regime parameters, working environment and general functioning conditions during fire suppression operations may lead to malfunctions and/or damaging of the couplings.

1. Introduction

1.1. General presentation and background

Fire suppression remains one of the basic missions of Romanian firefighter units. To accomplish this task, firefighters use a wide range of equipment, designed to deliver suppression agents into the fire.

Water and foam are the two most used substances for fire dousing. [1] These are delivered through a hydraulic chain that starts with the fire truck pumps, continues with the fire hoses and ends with a nozzle.

Fire hoses are connected to the fire truck or to the hydrants with couplings. [2] When needed, one or more sections can be extended with couplings, which makes these components very important parts of fire control operations. Damaging of the couplings leads to serious delays of the fire extinguishing actions and might have serious effects on the rescue operations.

1.1. Fire hose couplings

Couplings' main role is to connect flat hoses in order to ensure the normal flow of fire suppressing substances, mostly water and foam, during firefighting operations. Romanian firefighters are using the so called" Storz" type couplings, that allow connection by interlocking lugs (or hooks) and flanges then rotating these with a quarter of a turn. "Storz" type couplings can be classified, according to usage, as hose couplings, adaptors and blank caps. [3] The characteristics of delivery and suction couplings given by Romanian standards are shown in Table 1.

The Storz couplings used by Romanian firefighters are fabricated of die cast (pressure cast) aluminum, more specifically- AlSi5Cu1 alloy. It's chemical composition, according to [4-6] is given in Table 2. The range of mechanical properties of AlSi5Cu1 alloy, according to [4], [6], [7] is shown in Table 3.

Table 1. Delivery and suction couplings characteristics according to Romanian standards [2]

Type	**A**	**B**	**C**	**D**
Diameter d [mm]	96	62	43	18
Mass [kg]	2,1	1,67	0,86	0,24

Table 2. Chemical composition of AlSi5Cu1 alloy [4], [6], [7]

Alloy	Chemical composition [%]						Impurities [%]		
	Cu	Si	Mg	Mn	Al	Fe	Zn	Pb	Ni
ATP AlSi5Cu1 Mg SR EN 1706:2010	1-1,5	5-6	0,3-0,6	0,2-0,5	rest	0,8	0,5	0,2	0,3

Table 3. Range of mechanical properties of AlSi5Cu1 alloy, according to [4], [6], [7]

Mechanical properties					
Rp02 [MPa]	*Rm* [MPa]	*A5* [%]	*Rsm* [MPa]	*Rsm/ Rp02*	*Kic* [MPa]
140 - 210	230 - 280	1 - 3	240 - 318	1,51 - 1,71	22,05 – 26,50

where:

- *Rp02* represent yield strength;
- *Rm* -tensile strength;
- *A5*-elongation;
- *Rsm*-sharp notch tensile strength;
- *Kic*-plain strain fracture toughness

These couplings are used to connect hoses to pumps, to fire hydrants and hoses to hoses. Its basic design is shown in Figure 1, an exploded view in Figure 2, and connected couplings in Figure 3 and Figure 4.

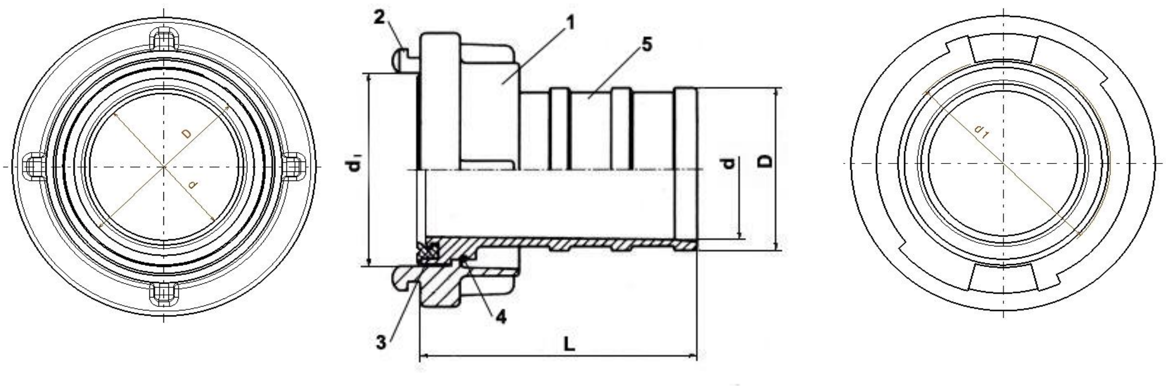


Figure 1. Storz type fire hose coupling basic design
(1 body; 2 hooking lugs; 3 sealing ring/gasket; 4 safety ring for pipe's position locking; 5 tail)

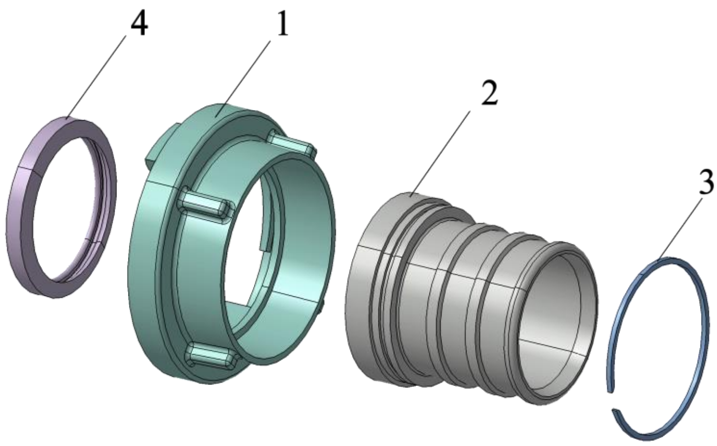
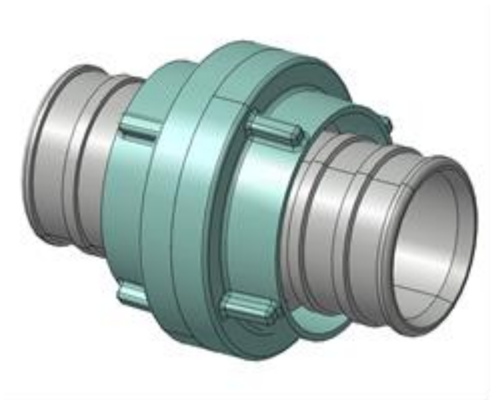


Figure 2. Fire hose couplings- exploded view
(1 body with hooking lugs; 2 tail piece;3 safety ring for pipe's position locking; 4 sealing ring)



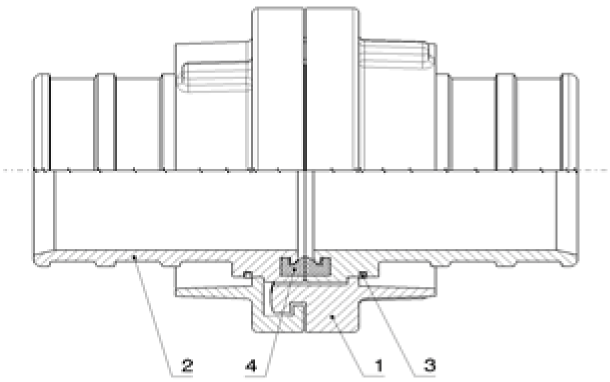


Figure 3. Connected couplings in operating position

Figure 4. Connected couplings

2. Analysis of Potential Failures. Analysis of couplings operating regime

While in use, fire hose couplings are subjected to important strains that could lead to a wide range of damages and even loss of functional properties, i.e. failure. Considering one of the main fire engines in use in Romania, the APCA R 12215 type pumper, the operating parameters for the couplings would include:

- pump pressure in the 7.8 - 22.55 [bar] range;
- flows in the 1500 to 5000 [l/min] range;
- pump rotational speeds from 2200 to 2900 [rpm].

Working and environment conditions of the firefighter units during fire suppression operations also imply [8]:

- mechanical shocks due to human manipulation;
- hydraulic shocks (“water rams”);
- high level of vibrations
- accidental exposure to high temperatures;
- incorrect connection of the couplings;
- sand, dirt, vegetation, various type debris;
- wide range of chemicals, petroleum fuels and oils;

Analyzing the operating parameters, the couplings characteristics and the specialty literature [9-12] we found that the following damages might occur during fire suppression operations. These and their effects were identified as process related potential failures:

- accidental exposure to high temperatures and incorrect assembly could lead to breaking of the safety ring- non critical failure - shown in Figure 5

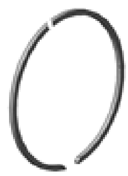


Figure 5. Breaking of the safety ring

- contact with chemicals, petroleum fuels and oils and vibrations could lead to wear of the sealing gasket- important but non critical failure- shown in Figure 6.

Figure 6. Wear of the sealing gasket

- Incorrect connecting, vibrations plus penetration of sand and/or other abrasive materials from the environment in the connected area could lead to leakage and fretting wear marks on the flanges- important but non critical failure- shown in Figure 7.

Figure 7. Wear marks on the flanges

- Mechanical shocks that occur during firefighting operations, due to incorrect manipulation and operating environment such as concrete floors around and inside buildings could lead to the cracking of the couplings' body- important, potentially critical failure-shown in Figure 8.

Figure 8. Cracking of the couplings body ("the Storz head")

- Hydraulic shocks ("water ram"), mechanical shocks due to incorrect manipulation of the equipment, vibrations that generate fretting fatigue could lead to the breaking of the lugs - critical failure-shown in Figure 9.

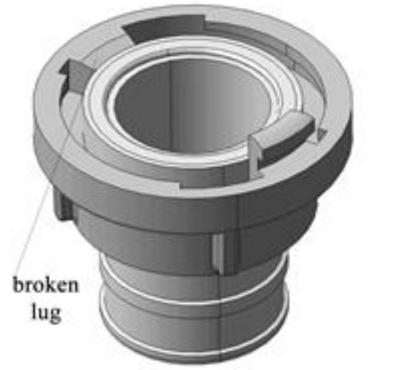


Figure 9. Breaking of the lugs

This leads to the basic failure mode and effects diagram for potential coupling damages during firefighting operations shown in Figure 10.

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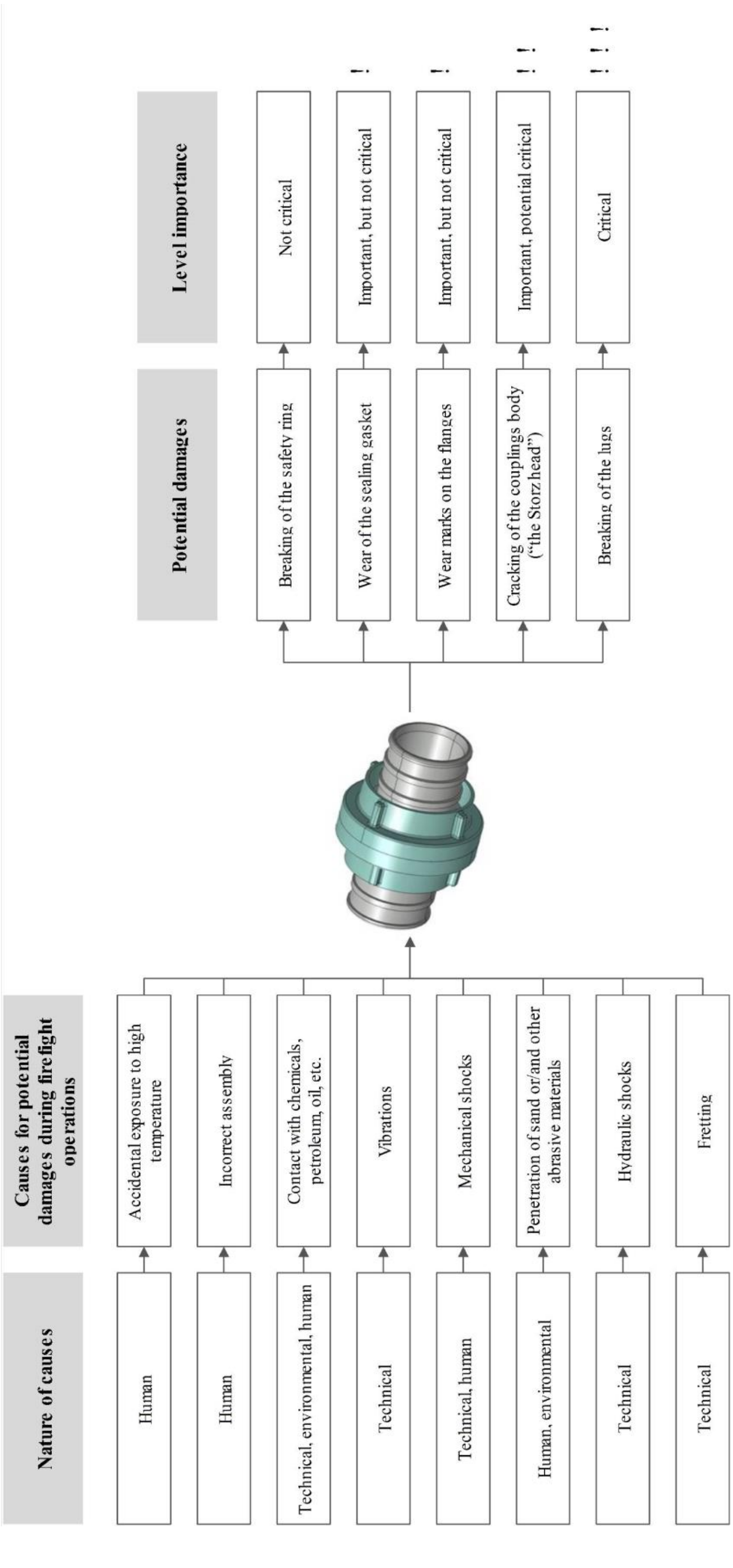

Figure 10. Basic failure mode and effects diagram for potential coupling damages

3. Conclusions

This paper presents a part of a theoretical research on the potential damages of the fire hose couplings during firefighting operations. It is shown that the different damage types could occur due to the operating conditions, that were identified and used for potential failure prediction.

Technical, environmental and human manipulation related parameters could lead to a series of failures that were evaluated from non-critical to critical, with total loss of function of the analyzed fire hose connectors.

This study was conducted based on theoretical research on firefighting operations and the direct practical experience pf the main author in this field. The present study is a starting point for an ensuing research, both theoretical and experimental.

From a theoretical point of view, the effects of hydraulic shocks ("water rams") will be investigated, as well as the influence of the fretting phenomenon- the fretting wear. The following study will investigate the effects of the vibrations generated by the flow of the suppression agents through the components of the hydraulic chain.

From an experimental point of view, the next study will investigate the damages that occur during and/or related to the fire suppression operations. The results will be compared with the predictions, identify the matches and differences, if there are any, and investigate the parameters of the damages that occur in real firefighting situations.

The results of this study will be subsequently used to compile a handbook of guidelines, based on Figure 10, that will address every type of damage identified. The handbook is intended to provide recommendations for the available maintenance and reconditioning methods, that would ensure the life extension and reuse of these parts.

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