The comparison of cavitation erosion resistance of austenitic stainless steels 1.4541 and 1.4301

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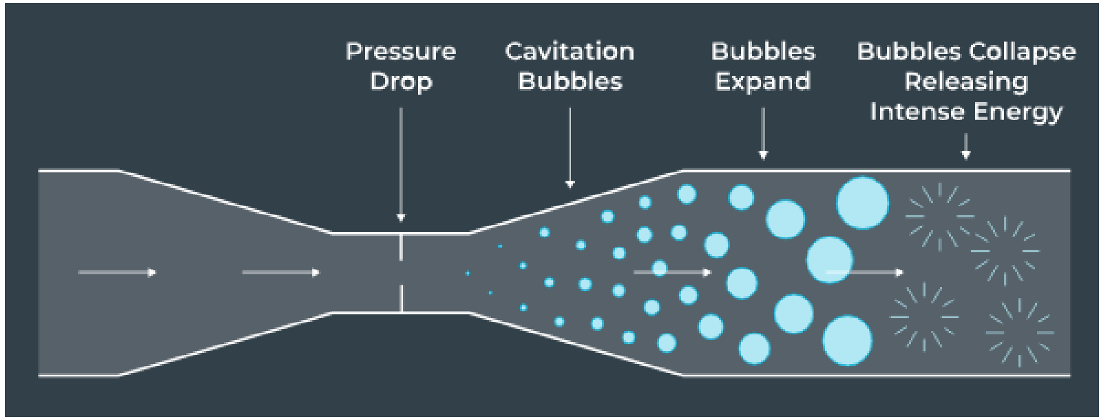
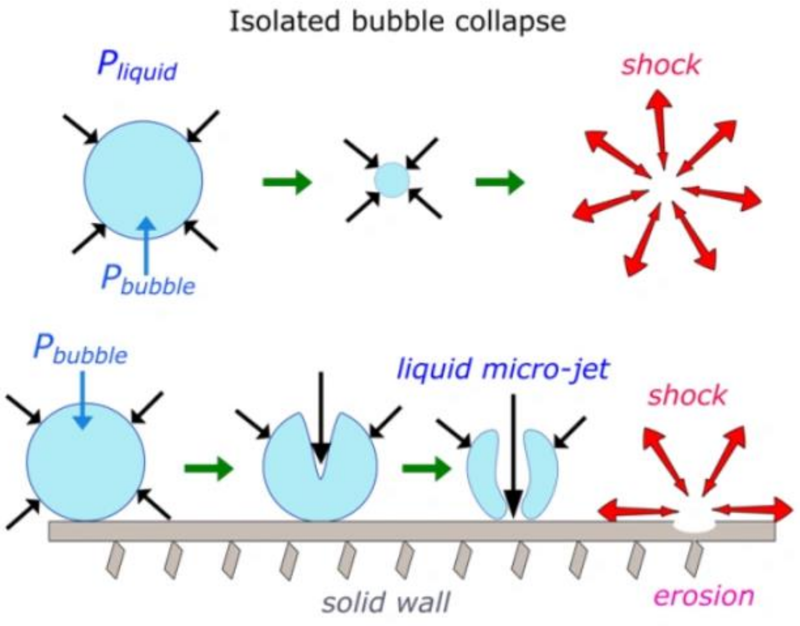
Introduction

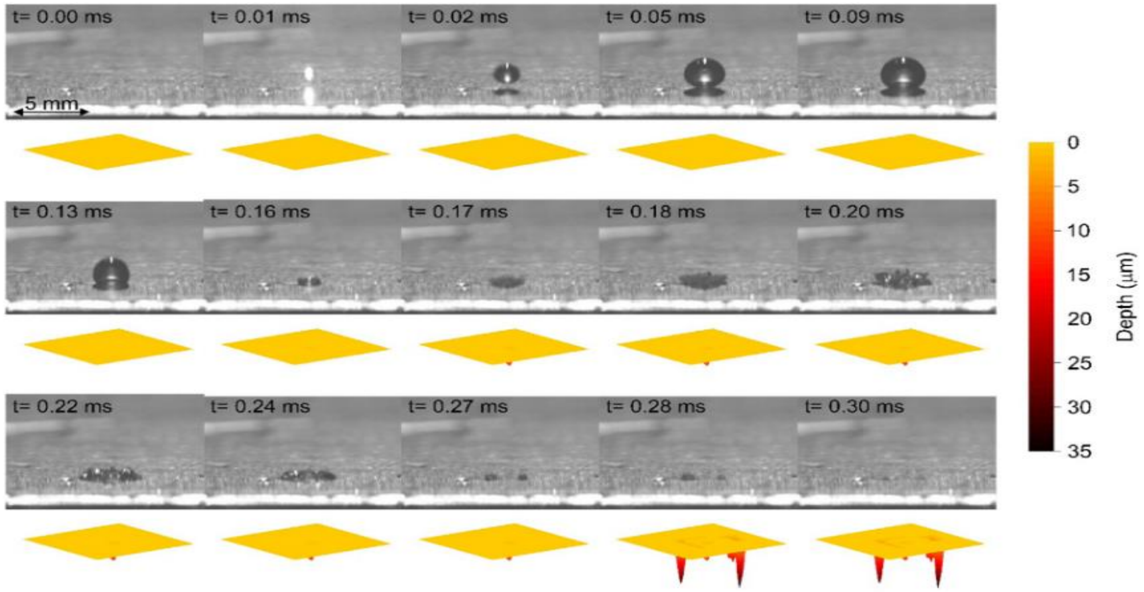
According to the ASTM G32 standard, cavitation is defined as the formation and subsequent collapse, within a liquid, of cavities or bubbles that contain vapor, gas or a mixture of vapor and gas [ASTM G-32-10 Standard]. Bubbles filled with vapor or dissolved gases form in low pressure regions and implode violently in areas of higher pressure. During bubbles implosion the micro-jets and the shock waves are generated, which are called cavitation pulses due to their short duration. The repeated impacts of the micro-jets and the shock waves can cause e.g. mass loss of material, this phenomenon is known as cavitation erosion. This affects the life of the devices [1].



How hydrodynamic cavitation works [3]



Isolated bubble collapse near a solid boundary **[2]**



Bubble and damage for collapse in the vicinity of the wall [4]

Experimental procedure

Cavitation tests

- The cavitation tests were performed in cavitation tunnel equipped with system of the barricades. The exact description of the tunnel as well as the description and diagram of the test stand is described in Refs. [5],[6]. Test rig is equipped with instruments for measuring pressure at the inlet (p_1) and outlet to the chamber (p_2), and temperature of the fluid (T). The flow velocity was measured for the selected inlet pressures. The following flow velocity values were obtained: 2.30 m/s, 2.49 m/s, 2.67 m/s and 2.83 m/s. Tap water was used as the working liquid, whose temperature was kept in 20 ± 2°C. The total time of each test was 600 min.

Roughness measurements, SEM observations

- The Ra surface roughness parameter was measured using a Mitutoyo roughness tester SJ-301. The cut-off length (sampling length) of the measurement was equal to 0.8 mm, the evaluation length equal to 4 mm. Surface roughness measurements were performed after completed cavitation tests.
- After the completed test (600 min) microscopic observations of the eroded sample surface at p_1 = 900 kPa were performed using a scanning electron microscope EVO-40 Zeiss and JEOL JSM-7800 F.

Materials

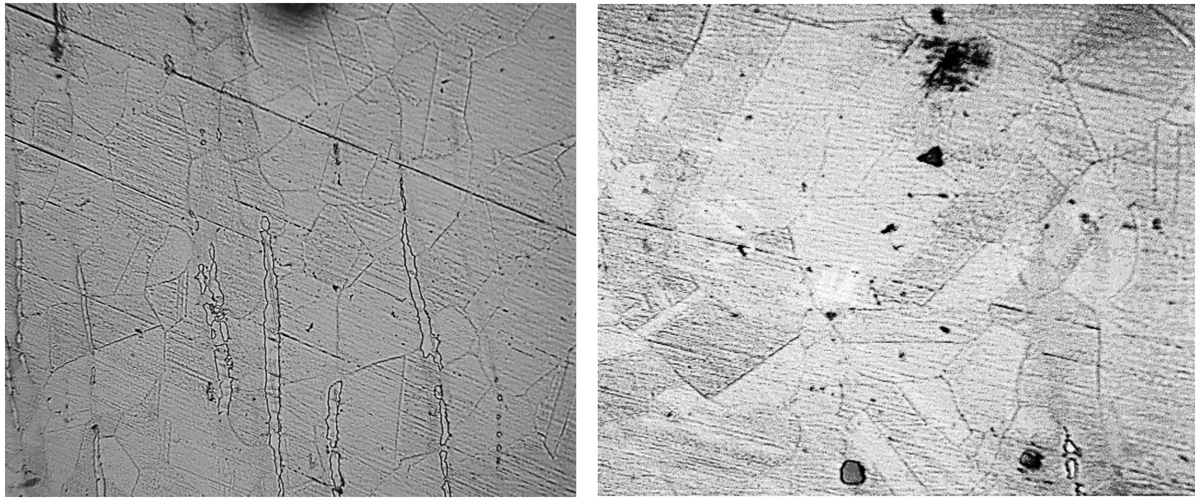
- The tested materials were two types of the austenitic stainless steels – 1.4301 and 1.4541 after heat treatment - supersaturation at 1050 °C with cooling in water.

Chemical composition and structure

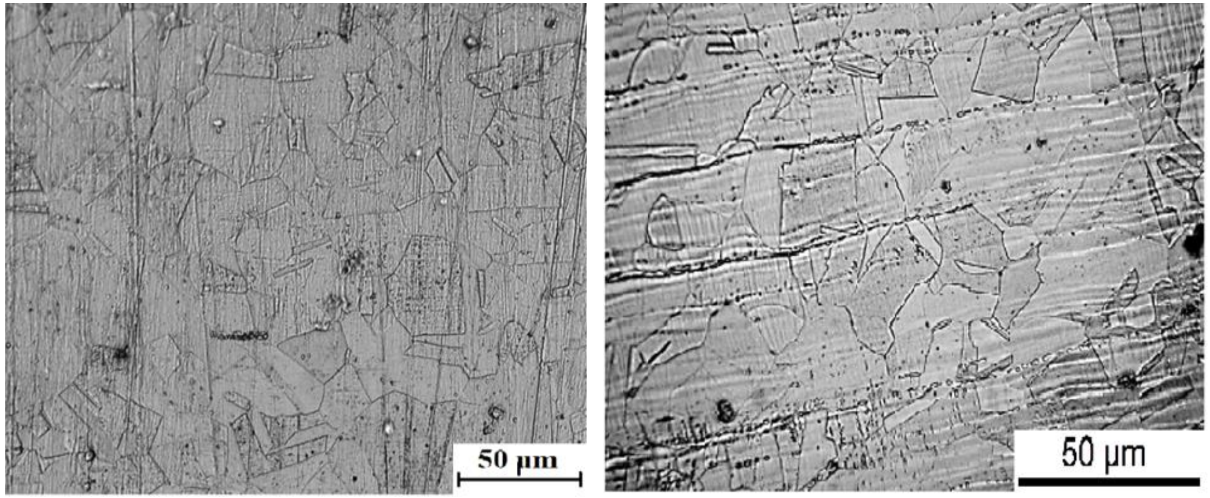
element content [%], steel1.4301							
C	Si	Mn	Ni	Cr	N	S	P
0,021	0,44	1,41	8,02	18,10	0,078	0,003	0,031

Element content [%], steel 1.4541							
C	Si	Mn	Ni	Cr	Ti	S	P
0,014	0,61	1,65	9,24	17,36	0,23	0,029	0,024

Mechanical properties	Yield point [MPa]	Tensile strength [MPa}	Elongation A_5	Hardness HV
1.4301	303	625	55,0	203,2
1.4541	262	569	49	191,6

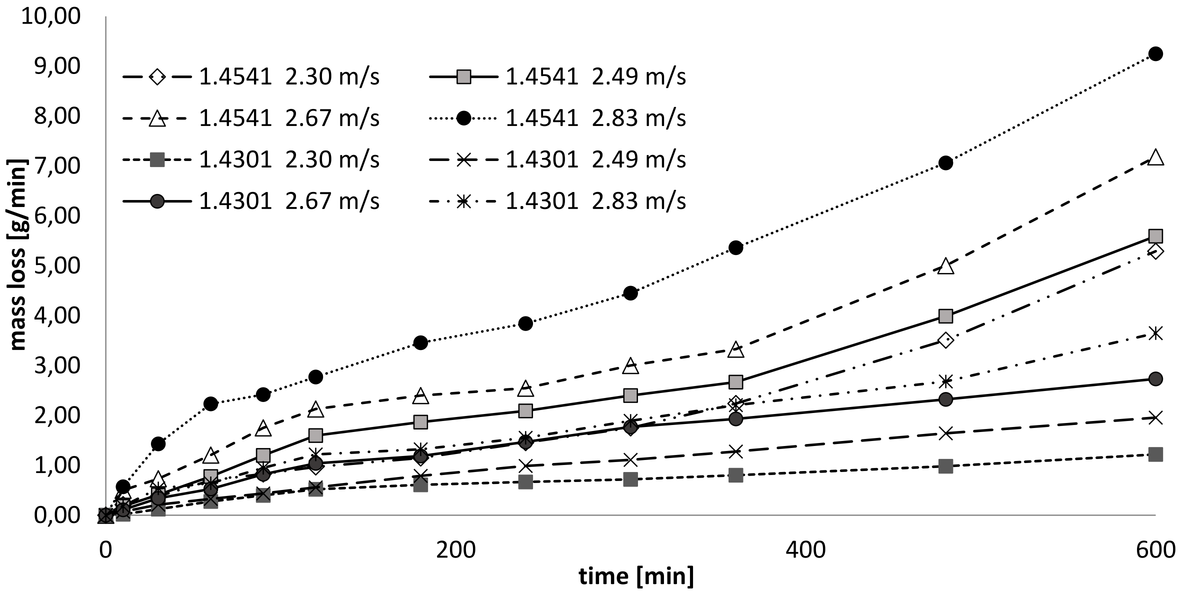


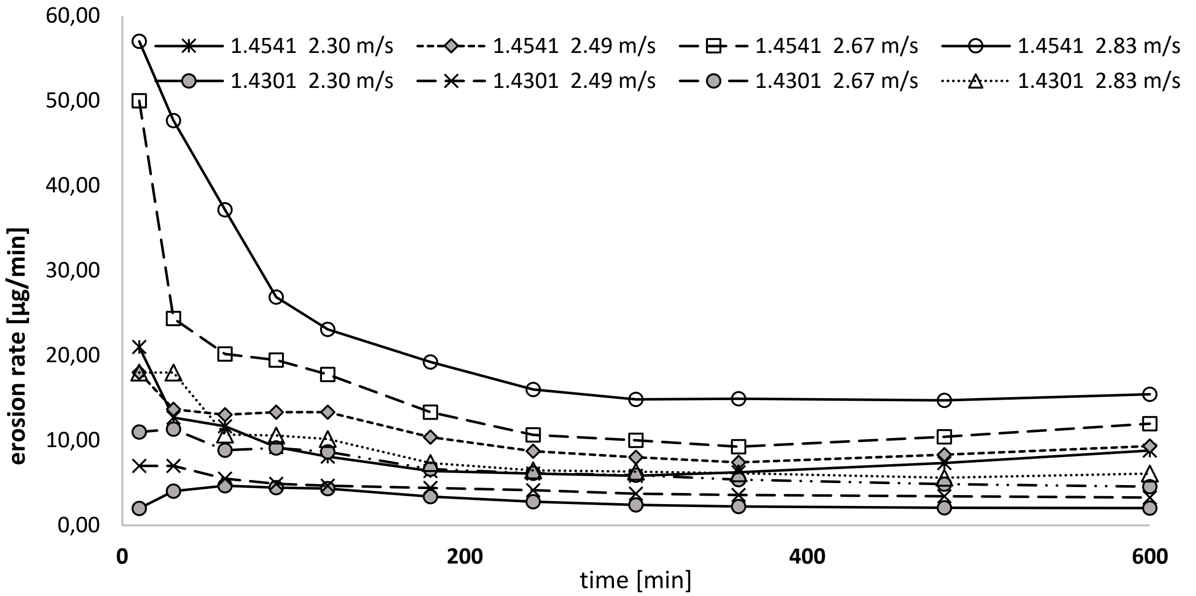
1.4541



1.4301

Mass losses and erosion rates





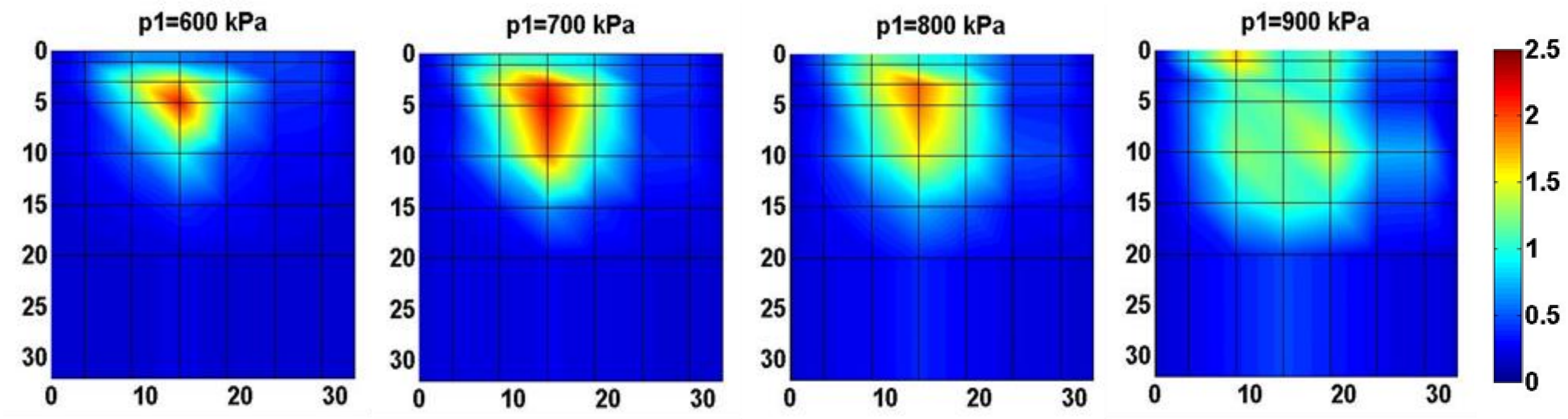
- For both steels, the cumulative mass losses increase with the set fluid flow velocity.
- 1.4541 steel has almost 1.5 times higher mass losses compared to 1.4301 steel, for each fluid flow velocity.

The curves of the erosion rate as a function of time for steel 1.4541 show high values after 10 minutes of the test, followed by a gradual decrease in the erosion rate leading to stabilization after 240 minutes of the test, for each fluid flow velocity.

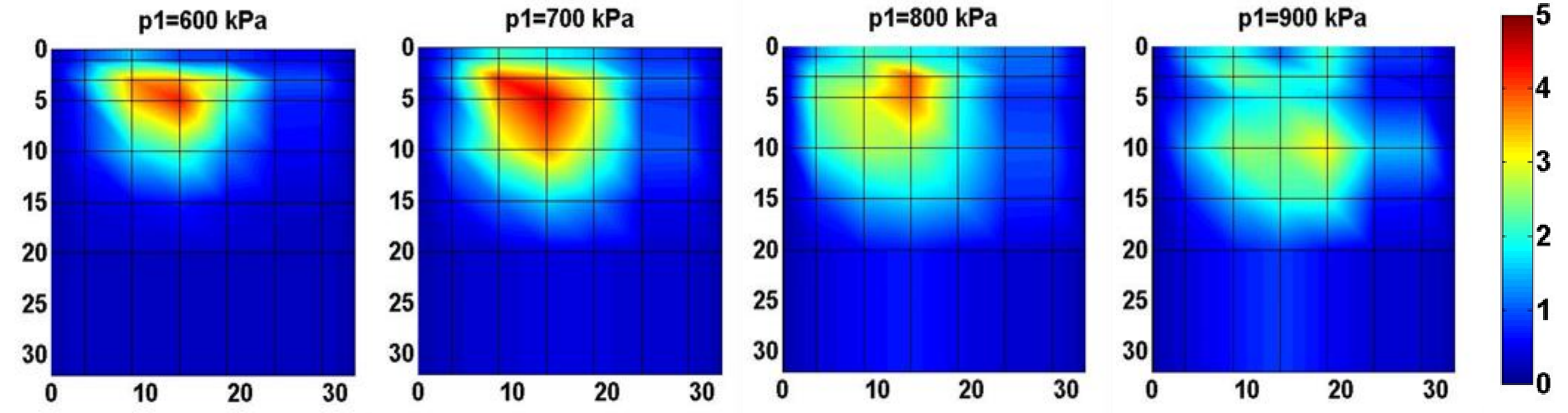
For steel 1.4301, only at the highest flow velocity there was a visible decrease in the erosion rate between 10 and 30 minutes of the test, while for the remaining velocities, the curves show a fairly stable erosion velocity

Roughness

1.4301 steel



1.4541 steel



As in the case of mass losses, 1.4541 steel showed higher maximum Ra values for each flow velocity. Moreover, steel 1.4541 also shows a larger area of erosion on the surface of the sample as compared to steel 1.4301 (for each flow velocity).

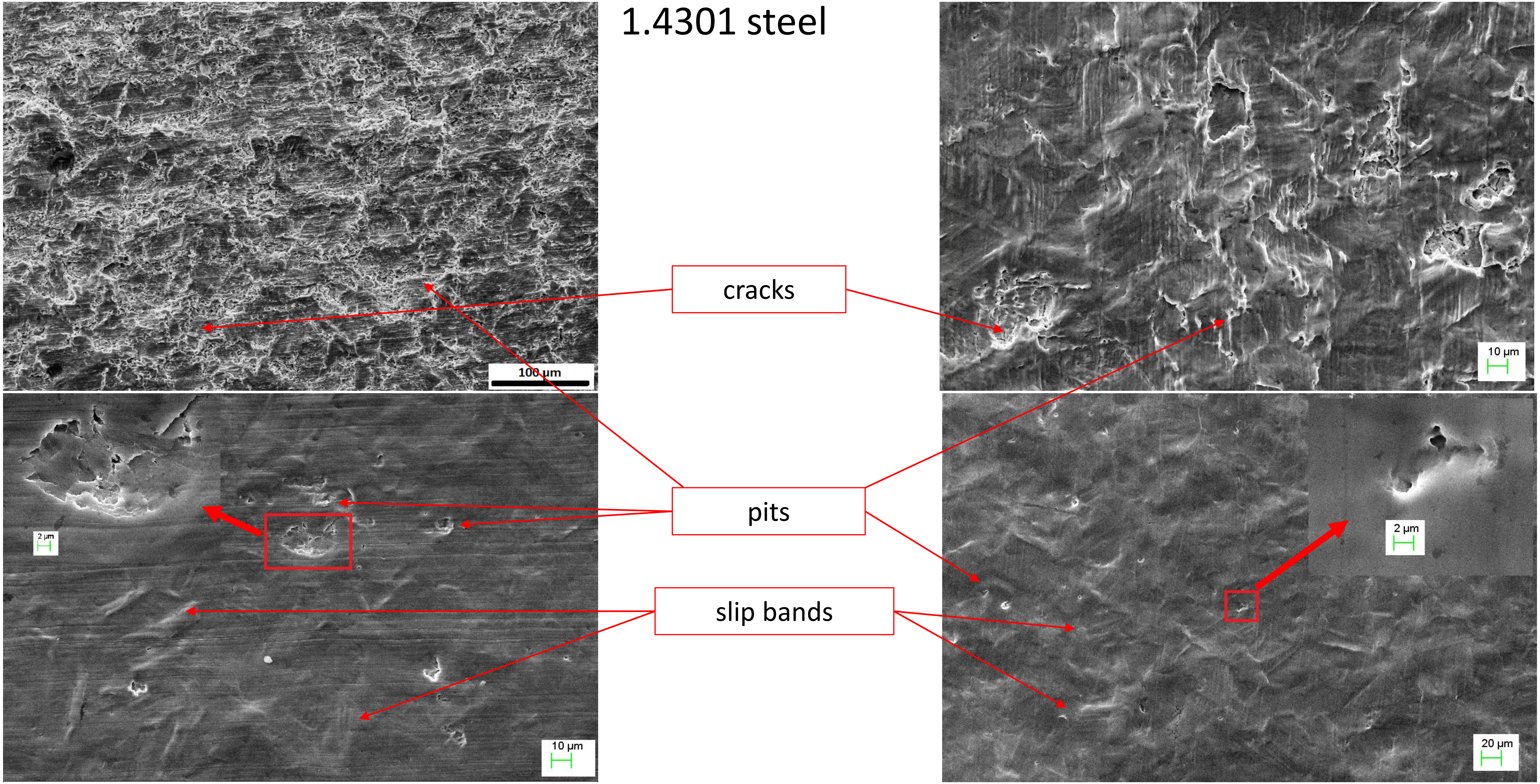
In addition, both steels showed the highest value of Ra at a flow velocity of 2.49 m / s, while the largest erosion area at a flow velocity of 2.83 m / s.

SEM observations

1.4301 steel

2.30 m/s

2.83 m/s

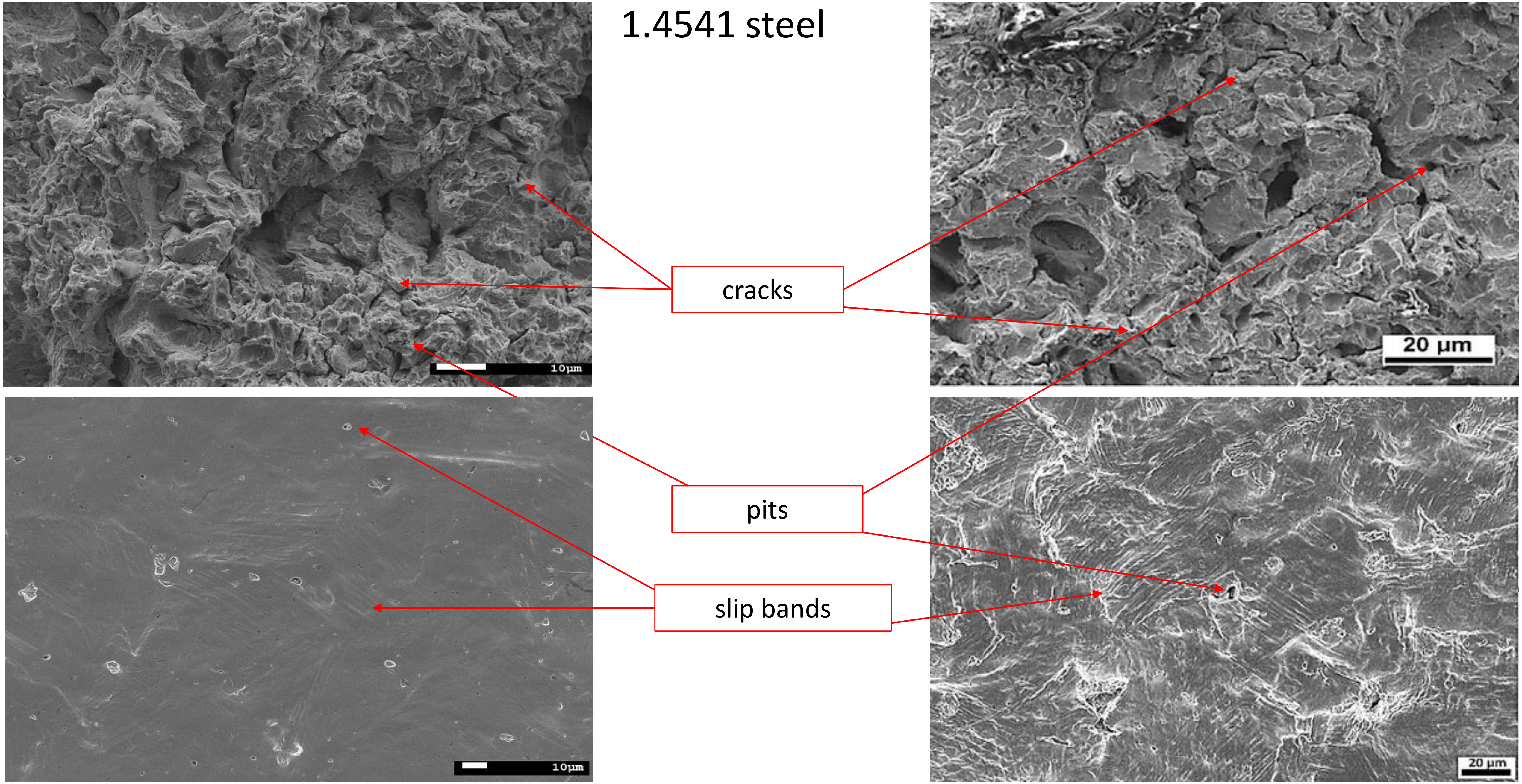


SEM observations

1.4541 steel

2.30 m/s

2.83 m/s



Summary

- Higher resistance to cavitation erosion was achieved for steel 1.4301.
- The tests showed almost 1.5 times lower weight loss for steel 1.4301 compared to steel 1.4541 and almost two times lower maximum values of the Ra parameter.
- Nevertheless, the SEM observations showed a similar capacity of damage on the surface of both steels.
- The obtained test results indicate that such large differences in resistance to cavitation erosion may be influenced by even small differences in chemical composition or mechanical properties and grain size in the microstructure.

Literature

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[4] Dular M., Pozar T., Zevnik J., Petkovsek R.: High speed observation of damage by a collapse of a single cavitation buble, Wear 418-419, 2019.

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[6] Krella A., Zakrzewska D., Buszko M., Marchewicz A.: Efect of thermal treatment and erosion aggressiveness on resistance of S235JR steel to cavitation and slurry, Materials 14(6), 2021.