MEASUREMENTS OF TESLA CAVITIES FOR TTF

W.-D. Möller, M. Pekeler for the TESLA Collaboration, DESY, Hamburg, Germany

Abstract

A new infrastructure has been established to prepare and test cavities for the TESLA Test Facility (TTF) [1]. This includes automised chemistry, large clean room facilities, high temperature furnace, high pressure water rinse and vertical as well as horizontal test stands. A 5 MW klystron is available for High Power Processing (HPP). First series cavities have been treated and measured. We report about recent results like gradient Eacc, quality factor Q_0, field emission (FE) loading and thermal breakdown. These properties are discussed in respect to the applied preparation and processing techniques.

1 INTRODUCTION

TESLA (TeV Superconducting Linear Accelerator) is one of the proposed future TeV scale e^-e^+ linear colliders. It differs from other projects in its choice of superconducting accelerating structures and of low frequency (1.3 GHz).

In order to prove the technical basis of TESLA the TESLA Test Facility was established at DESY within the frame of an international collaboration. It has to show that accelerating gradients of 15 MV/m are reproducibly possible and can be kept also after assembly to the linac together with the necessary auxiliary systems [2].

To develop the fabrication procedures and surface treatment methods required to produce high gradient multicell cavities, a rich infrastructure is being built at TTF. It consists of processing and handling systems as well as of high and low power test stands. Nine 9-cell cavities, manufactured by three different companies are processed and measured so far. We report about the measurement results.

2 INFRASTRUCTURE

For clean assembly and treatment of the cavities a complex clean room (300 m^2) including class 10,000, class 100 and class 10 areas has been built. Integrated in the clean room are

- the closed loop chemical etching facility,
- the high pressure rinsing (HPR) system,
- the UHV furnace for temperatures up to 1500 °C.

For the cavity acceptance test a vertical cryostat and for the cavity system test a horizontal cryostat is used [3].

A 5 MW klystron supplies pulses of maximal 2 ms length at repetition rates between 0.2 and 10 Hz.

The cryogenic plant provides 120 W at 1.8 K Helium for the test stands and later for the test linac.

For high power coupler testing and processing a coupler test stand is available.

3 CAVITY PRODUCTION AND TREATMENT

All cavities are made of RRR 300 niobium with a sheet thickness of 2.8 mm. After forming the half cells are e-beam welded from the inside at the irises and in addition a stiffening ring is welded to provide mechanical stability. The equator welds are made from outside. One type of cavities is completed by a fully welded version of HOM couplers whereas the second type has a flange for a separate HOM coupler. Later on only the nine cells are housed in a Ti-He tank. The HOM couplers are cooled by thermal conduction [2].

The standard cavity treatment is as follows:

1 visual inspection and dimensions check,
2 field flatness measurement and tuning,
3 inner and outer Buffered Chemical Polishing (BCP) 10 µm,
4 Ti heat treatment at 1400 °C, 4 h,
5 BCP inside 90-150 µm and outside 40 µm,
6 field flatness measurement and tuning,
7 final BCP 20 µm,
8 HPR, 100 bar, drying on air in class 10,
9 assembly, HPR 100 bar, drying by pumping,
10 vertical acceptance test and possibly HPP,
11 welding of Ti-He-vessel,
12 BCP 5 µm,
13 assembly of high power- and HOM-coupler, tuning mechanism,
14 HPR at 100 bar, drying by pumping,
15 system measurements in horizontal test stand,
16 ready for string assembly.

4 MEASUREMENTS

4.1 Vertical Test Stand

The cryostat insert consists of a tuneable high power coupler ($Q_{ext} = 10^6 - 10^{10}$) and permits high Q measurements and also High Power Processing (HPP) [4] of the cavities.

First the cavity performance will be measured, followed by a possibly HPP against field emission. Due to the fact that the TTF will be operated at a pulse length of 800 µs, a measurement of the maximum field of the cavity under pulsed conditions will take place. At $Q_{ext} = 3 \times 10^6$ the cavity field is allowed to rise for 500 µs, after that an amplitude loop keeps the field constant over the operating pulse length of 800 µs ('flat top' measurement).

4.2 Horizontal Test Stand

After the acceptance test the cavity will be welded to the He-vessel. The system test in the horizontal cryostat is done with the subsystems assembled: high power coupler [5], HOM coupler and tuning system.

Due to the low Qext of the power coupler which is necessary for the TTF operation a CW measurement is not possible. The pulsed cavity performance is here measured by the field excitation vs. incident power to find the onset of field emission. Cryogenic losses during flat top measurement give the Q_0 value.

There is a hard ware interlock, reading the vacua and temperatures of windows and HOM couplers and the e^- and light detectors of the power coupler.

The calculated errors of the measurements are: ±7% for Eacc and ±20% for Q_0 measured with cryogenic methods.

5 MEASUREMENT RESULTS

5.1 Vertical Measurements

Nine cavities have been measured so far. Fig. 1 shows the curves of the four accepted cavities which all have CW gradients well above 20 MV/m. All cavities are limited by a quench. One cavity (C19) shows field emission loading.

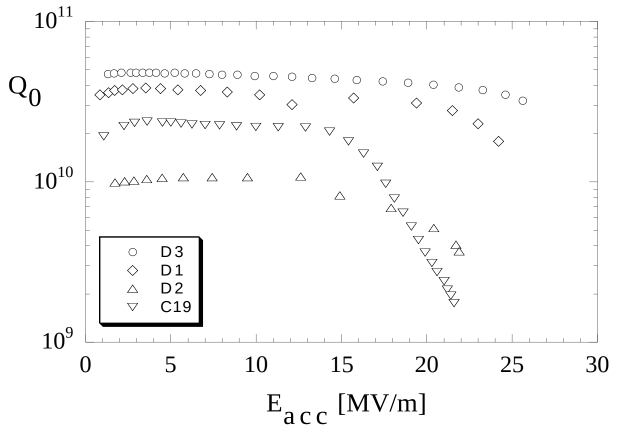

Fig 1: Vertical test results of the four cavities which are accepted for He-vessel welding. Cavity D3 is measured without any HPP.

The last cavity (D3) did not experience any FE. This good result could be reached without any HPP. This is due to progress in dust free assembly technique and high presure water rinse.

HPP sometimes is accompanied by a reduction of the low field Q_0. After a warm up- and cool down cycle the Q_0 usually recovers (Fig. 2).

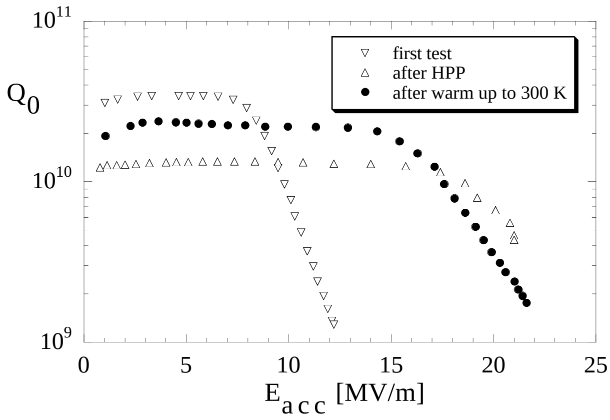

Fig. 2: Cavity C19 before and after HPP. The Q_0 recovered partially after warm up to room temperature.

The relation of maximum pulsed field ('flat top' measurement) to the quench field at CW is shown in Fig 3. As one would expect, the pulsed field is higher than the quench field, however there is not a fixed relation [6].

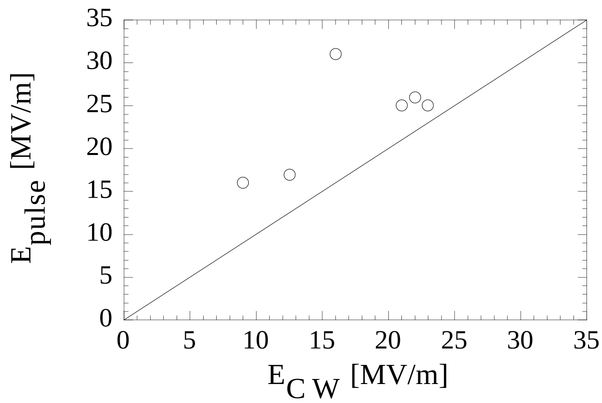

Fig. 3: The correlation between quench fields at cw (Ecw) and maximum field during 'flat top' measurement (Epulse).

An example of a not accepted cavity is shown in Fig.4. The typical signature is a jump in Q_0 (Q-switch) and a degradation of Q_0 when raising the field. No field emission was observed. After additional BCP the cavity improved somewhat (Fig. 4).

By measuring the excitation curves of all passband modes and considering the various field distributions we located the defect which is responsible for the Q-switch. The T-map showed a heating spot at the same location. Non destructive investigation methods like eddy current and γ-ray absorption with one cavity and the improvement after more BCP with cavity D4 (see Fig. 4) indicate that material defects might be responsible for the Q-switch.

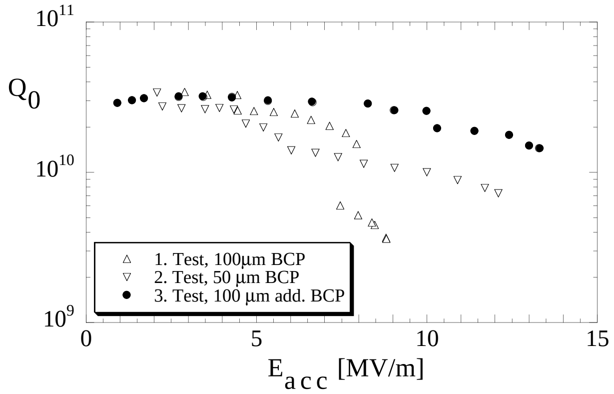

Fig. 4 Cavity D4 with a strong Q-switch after titanification and 100 µm BCP. After additional BCP the performance improved somewhat.

6.1 Horizontal Measurements

In spite of the prior coupler processing on a coupler test stand the coupler needs to be conditioned again on the horizontal test stand. This is caused by exposing the coupler surface to air during the cavity assembly.

After coupler processing with the cavity detuned (standing wave) up to 1 MW at 500 µs and 400 kW at 1.3 ms no electron activites were seen on both sides of the cold coupler window.

With the cavity on resonance there is more need for processing due to electron activites in the coupler at the end of cavity filling time. This is caused by a change of the standing wave pattern in the coupler line at this time. Finally the coupler was free of any vacuum-, e^-- or light-activities for an incident power of 0 - 250 kW with the cavity on resonance.

The external Q was adjusted to 3 x 10^6 and can be tuned within a range of a factor of 5.

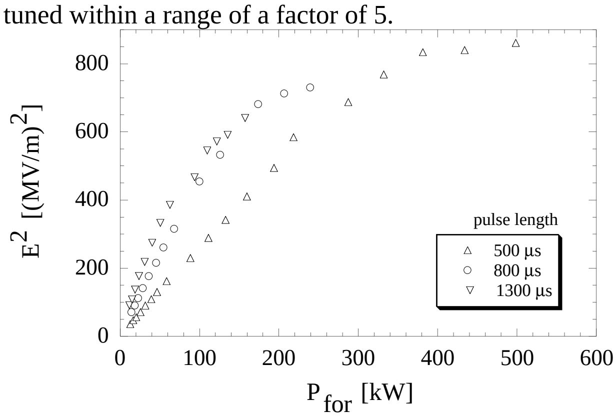

Fig. 5: Horizontal test of C19. Cavity field vs. the forward power for different pulselength. The deviation from a straight line indicates the onset of field emission.

The mechanical stability of the cavity was measured in respect to helium bath pressure as 30 Hz/mbar and also the Lorentz-force-detuning-coefficient as K =0.98. Both numbers agree well with the predictions.

The onset of field emission is at about Eacc = 22 MV/m as shown in the plot E^2 vs. P_{for} in Fig. 5.

During a 'flat top' field of 17 MV/m at the operational repetition rate of 10 Hz the cryogenic losses of the cavity are measured to be 280 mW. This gives a Q_0 value of 1.5 x 10^{10}.

The amplitude stability during 'flat top' is<0.3% and phase stability is <0.5 degree (Fig. 6) [7].

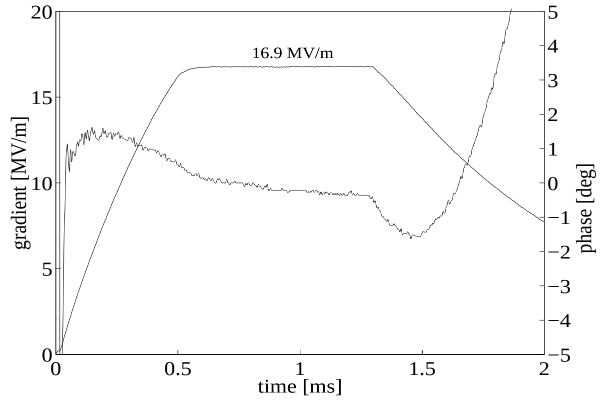

Fig. 6 Amplitude (upper trace) and phase (lower trace) of cavity C19 during horizontal test conttrolled by a digital loop.

6 CONCLUSION

Four cavities passed the vertical acceptance test so far with an average accelerating field of 23.5 MV/m. The best cavity reached a maximum accelerating field of 26 MV/m at a Q_0 of 3 x 10^{10} without field emission. This could be established without any high power processing.

First horizontal tests of the fully dressed C19 cavity showed that the system consisting of a high power coupler, HOM-coupler, the tuning mechanism and He-vessel works as specified. This cavity will be used as the capture cavity in TTF.

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