MACHINE PARAMETER MEASUREMENT OF THE AMSTERDAM PULSE STRETCHER AmPS

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Machine parameters (β-functions) have been measured by successively wobbling all the ring quads and observing the subsequent tune changes. As a result a better quadrupole setting has been obtained.

I. INTRODUCTION

The electron pulse stretcher/storage ring AmPS is operational since 1991 [1–3]. Its maximum energy is 800 MeV. The machine routinely delivers extracted beam currents of up to 10 µA, with a duty factor in excess of 70 %.

In Storage Mode the circulating beam is used in conjunction with an (internal) gas-jet target. By employing beam stacking, stored beam currents of typically 100 mA are accumulated.

The lattice consists of 4 achromatic Curves (each of 21 m length), connected by Straight Sections of 32 m length. In each Curve there are two families of quads; the corresponding quadrupole groups of all four Curves are connected to one common power supply. The quads in the Straight Sections are grouped in pairs (4 per Straight). This set-up, therefore, does not allow the individual control of each of the 68 quadrupoles, necessary to measure the β-functions, see below. In order to be able to vary each quadrupole field by a few percent, each quadrupole has been shunted by a relay-activated resistor (R_{shunt}/R_{quad} = 5%).

II. THEORY

A. The concept of the measurement

A gradient error ΔK in a ring quadrupole will cause a betatron tune shift [4]:

$$\Delta\nu_z = \frac{-1}{4\pi}\int \beta_z(s)\,\Delta K_z(s)\,ds, \quad z = x, y \tag{1}$$

Since the betatron function β(s) is approximately constant over the length of the quadrupole, (1) can be approximated by:

$$\Delta\nu_z \approx (-1/4\pi)\beta_z\, l_q\, \Delta K_z, \quad z = x,y$$

l_q is the (effective) length of the quadrupole. Thus

$$\beta_z \approx -4\pi\Delta\nu_z / l_q\, \Delta K_z, \quad z = x,y \tag{2}$$

In practice, ΔK can be generated by wobbling the quadrupole; by measuring the tune shift Δν, the value of the β-function at the quad location is calculated from (2).

B. The measurement method

The betatron tune is measured by FFT-analysis (using a LeCroy 9450A scope) of a signal from one of the stripline (beam position) monitors. In order to generate a signal, the stored beam is perturbed by a kick (typically 0.2 mrad) administered by an electrostatic fast-kicker (τ~500 ns) [5]. Each measurement consists of two tune measurements: one reference tune measurement, and a measurement when one particular quadrupole shunt is activated (generating |ΔK| = 5%) – thus eliminating accumulative hysteresis effects of the quads on the tune. This procedure has been carried out for all 68 quadrupoles, and for both transverse planes.

C. Measurement errors

The measurement error of the machine function consists of two parts:

$$\delta\beta / \beta = \delta(\Delta\nu) / \Delta\nu + \delta(\Delta K) / (\Delta K) \tag{3}$$

The first term in (3) is the contribution of the tune measurement. The fractional part of the betatron tune is calculated as $\nu = f/f_r$, with f_r the revolution frequency (1.41 MHz), and f the FFT–analysed signal from a stripline monitor. So,

$$\Delta\nu = (f_0 - f_{wob}) / f_r = \Delta f / f_r \tag{4}$$

Here f_{wob} is the frequency when the quadrupole is wobbled, and f_0 is the frequency before wobbling the quadrupole. 20,000 samples were taken for the FFT analysis. The read–out error of the frequency is ~1kHz. The contribution to the measurement error from the tune shift Δν is therefore less than a few percent.

The second term in (3) is the contribution from the uncertainty in the value of the quadrupole shunt resistor. This error is estimated to be about 5%.

The total measurement error of the machine function, therefore, is expected to be within 10%.

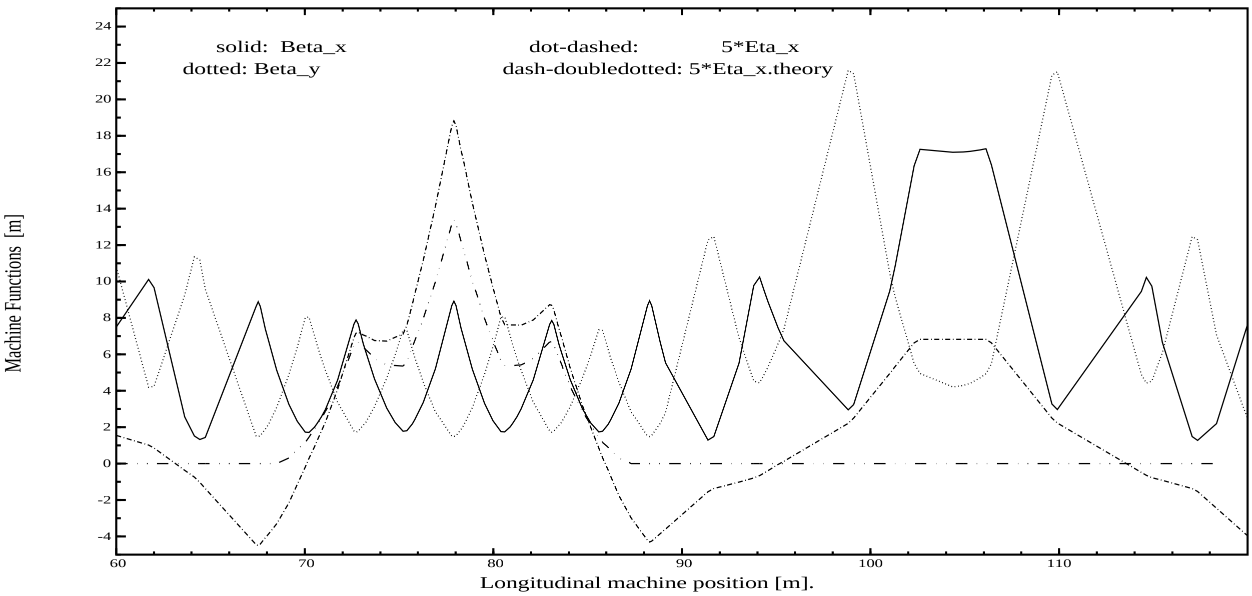

Figure 1: Machine functions for $\Delta\nu_x$=–0.174 and $\Delta\nu_y$ = +0.007; the tune change is generated by the quadrupoles in the Curved Sections only.

III. OPERATION OF AmPS

When AmPS operates in Stretcher Mode, the horizontal tune is chosen to be close to the third–integer resonance value: ν_x = 8.30. Past experience showed that the nominal setting of the machine produced a horizontal tune value that deviated substantially from its theoretical value: $\Delta\nu_x$ = +0.17. No such effects were observed for the vertical tune: $\Delta\nu_y$ = ~0.0 (these effects occur in both optical modes: Stretcher Mode and Storage Mode).

Simulations show that when *all* quadrupoles are offset by +1.5%, the ensuing tune effects are $\Delta\nu_x$ = +0.15 and $\Delta\nu_y$ = +0.14. Since field integrals of only samples of the quadrupoles have been measured (as opposite of harmonic content, which has been measured [6,7] for all quadrupoles and sextupoles), overall–errors of this magnitude can not entirely be ruled out. Why mainly the horizontal tune deviates from its theoretical value is as yet unclear.

Tune control in AmPS is accomplished by the quads in the Curves only: for small (e.g. $\Delta\nu$ ~0.015) variations this method works fine. However, substantial machine function perturbations may occur when one tries to correct the tune deviations mentioned above, see Fig.1: this figure shows β_x, β_y and η_x in case $\Delta\nu_x$ = –0.174 and $\Delta\nu_y$ = +0.007, starting from the 'theoretical' machine setting. In this case the horizontally–focusing quadrupole strength in the Curves has to be reduced by appr. 3%. It is clearly shown that this procedure can yield non–negligible dispersion values in the Straight Sections. The change in the values of the β–functions is actually much less (e.g. $\Delta\beta_x / \beta_x^{max} \approx 5\%$).

IV. MEASUREMENT PROCEDURE

Since the tune shift occurs in both optical modes, the actual measurements have been performed in Storage Mode (ν_x = 8.43; ν_y = 7.23). Machine functions have been measured for 5 different sets of quadrupole settings; all these settings produced the 'theoretical' tune values. The details of the 5 sets are summarised in Table 1 (qsh/v are quads in the Straight Sections, qch/v are quads in the Curves).

Table 1 Five data sets used to measure β–functions. Each data set yielded ν_x = 8.43 and ν_y = 7.23.

	data sets; ΔB(q) [%]				
quad	# 1	# 2	# 3	# 4	# 5
qsh	–	–2.0	–1.0	–2.0	–2.0
qsv	–	–1.0	–1.0	–1.0	–1.0
qch	–4.3	–1.1	–1.5	–3.0	–2.3
qcv	–2.1	0.1	0.6	–2.0	–0.3

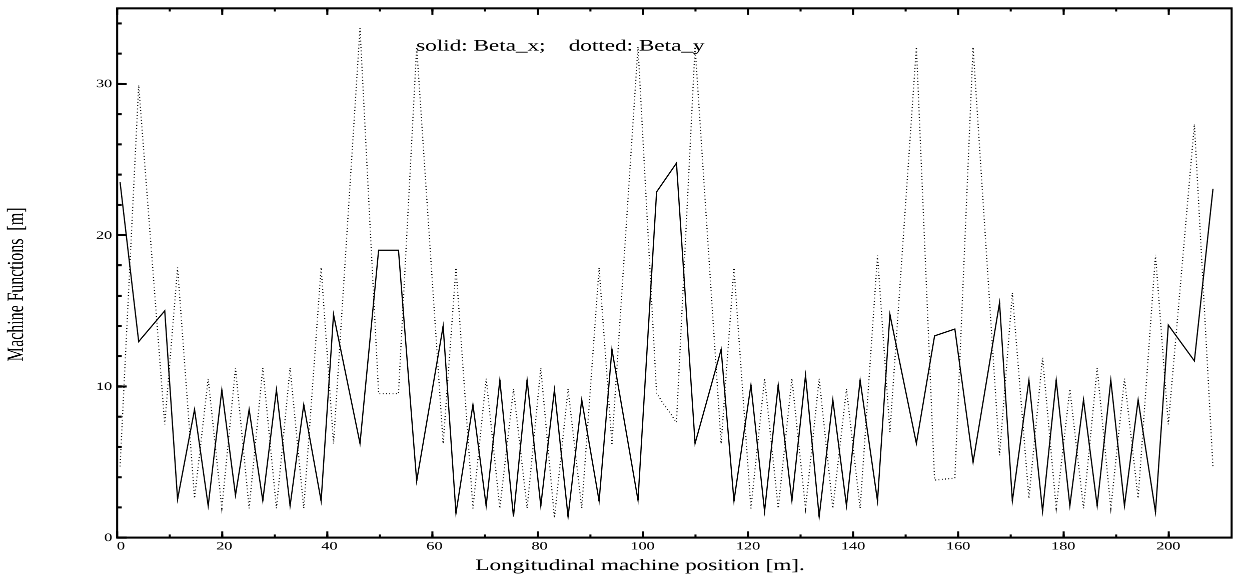

Figure 2: Result of machine function measurement for data set # 2, see Table 1.

Analysis of the results was off–line, so it was not possible to interactively change the settings. Data set # 2 produced the best results, especially with regards to the behaviour of β_x and β_y in the Curves, see Fig. 2.

V. CONCLUSION

Measurement of the machine functions has resulted in a new calibration for the quadrupole settings; with this new setting both the tunes and the machine functions (in both Storage Mode and Stretcher Mode) are now close to their theoretical values.

VI. REFERENCES

[1] R. Maas and Y.Y. Wu, "Optics of the Amsterdam Pulse Stretcher (AmPS)", Proc. of the IEEE Part. Acc. Conf., Chicago 1989, March 20-23, pp 1698–1700.

[2] G. Luijckx e.a., "The Amsterdam Pulse Stretcher project (AmPS)", Proc. of the IEEE Part. Acc. Conf., Chicago 1989, March 20-23, pp 46–48.

[3] G. Luijckx e.a., "The AmPS ring: Actual Performance and Future Plans", this conference.

[4] M. Sands, "The Physics of Electron Storage Rings", SLAC–121.

[5] J.G. Noomen e.a., "Beam Diagnostics at the Amsterdam Pulse Stretcher AmPS", this conference.

[6] H. Boer Rookhuizen e.a., "Magnetic Devices of the Amsterdam Pulse Stretcher Ring AmPS, Proc. of the IEEE Part. Acc. Conf., San Francisco, 1991, pp 2366-2368.

[7] Y. Wu e.a., "Parametrization of AmPS magnets for the control system", Proc. of the IEEE Part. Acc. Conf., Washington, 1993, pp 1901-1902.