MAGNETIC FIELD LINE TRACING CALCULATIONS IN DIVERTOR REGION OF TORSATRON URAGAN-2M

V.A. Rudakov

Institute of Plasma Physics, NSC "Kharkov Institute of Physics and Technology", Akademicheskaya Str.1, 61108 Kharkov, Ukraine

Torsatron Uragan-2M magnetic configuration in a divertor region was studied at different values of the factor Kφ. Kφ is the ratio between helical field B_h and total toroidal magnetic field B_0 ($K\varphi = B_h/B_0$). Values Kφ were changed in the interval $0.2 < K\varphi < 0.6$. In the cases of large Kφ values, when the closed magnetic configuration is placed inside the vacuum chamber without intersection with the wall, the footprints of outgoing field lines formed two helical lines on the vacuum chamber walls, situated between helical windings. At the small values of Kφ, when the closed magnetic configuration intersects the chamber wall, the external field lines form wide strips, which correspond to the helical trajectories of the magnetic configuration tops.

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Device Uragan-2M (U-2M) is the torsatron with double thread helical winding (4 field periods) and with additional toroidal field.

The main parameters of this installation are presented below:

Main U-2M parameters:

1. Number field periods	m = 4
2. Quantity toroidal field coils	Nt = 16
3. Major radius, m	R = 1.7
4. $K\varphi = B_h/B_0$ can be changed in interval	0.2 – 0.6
5. Total magnetic field, T	$B_0 = 2$
6. Vertical field coils, pairs	4
7. Angular width of helical coils, degree	91.46
8. Gap inside of helical coils	18°
9. Average radius of helical coils, m	$r_h = 0.445$
10. Average radius of toroidal field coil, m	$r_c = 0.686$

Helical coils law $m\varphi = -l(\theta - \alpha\sin\theta - \beta\sin 2\theta)$, where $\alpha = 0.216$, $\beta = -0.0171$, $l = 2$, $m = 4$.

There are 4 pairs of poloidal field coils. Fig. 1 shows the small cross-section of this device.

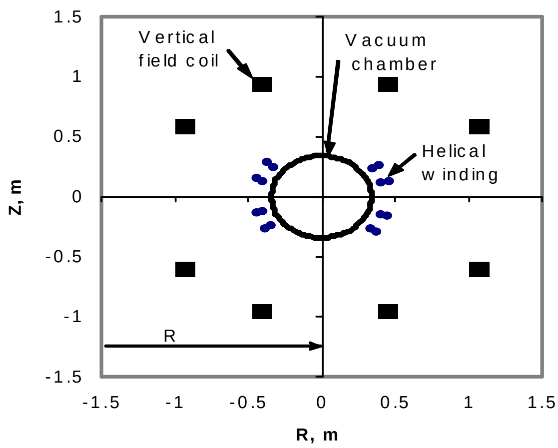
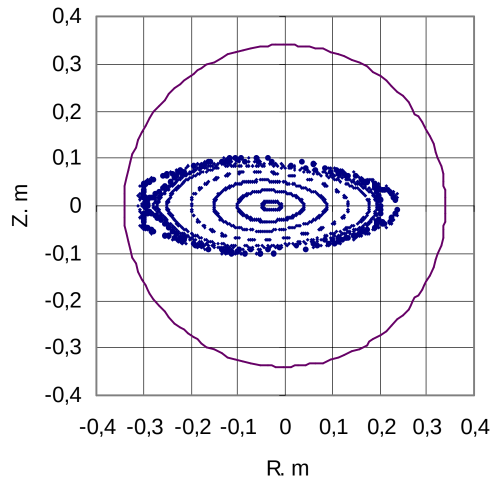


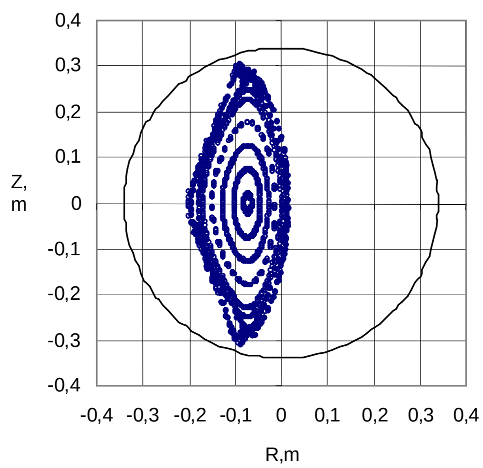
Fig. 1. U-2M cross-section

The numerical code, based on Biot-Savart law, was used for field line tracing calculations. Helical conductors simulated by eight filament currents, as can see it in Fig.1. Toroidal field coils and poloidal field coils simulated by one-filament currents.

In [1] suggests for experiments to use the regime $K\varphi = 0.375$ as more useful. The magnetic configuration for two cross-sections is shown in Fig. 2.



a



b

Fig. 2. Flux surfaces: a) $K\varphi=0.375$, half per, $B_z/B_o= 1.7\%$; b) $K\varphi=0.375$, cross-section $\varphi = 0$

The last closed magnetic surface is placed inside of the chamber without intersection with the wall. Nevertheless, the magnetic axis is displaced to the inboard part of the torus. It means that field lines, which lie in the SOL, can intersect the wall locally. It is important to know places, where diffused plasma will be hits to the wall. First of all it is necessary for diagnostics and heat system placement, divertor location.

A torsatron with additional longitudinal magnetic field allows to change ratio between helical and additional magnetic fields, which determines factor Kφ (Kφ = B_z/B_0). We changed Kφ in range 0.25-0.5. Low values of Kφ give big size magnetic configurations. The last closed surfaces intersect the chamber wall (see Fig.3).

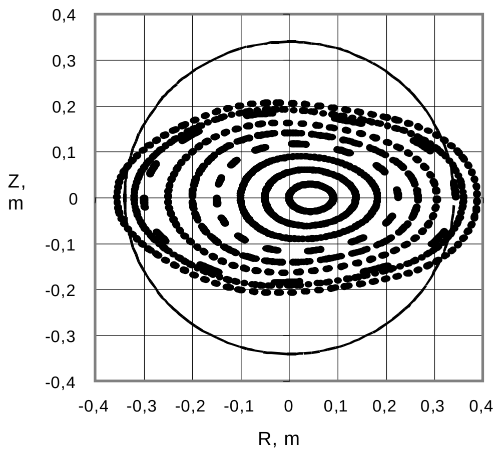


Fig.3. U-2M flux surfaces,Kφ =0.25, B_z/B_o= 1.7%

The big Kφ values lead to essential diminishing of configuration sizes, but rotational transform increases respectively (Figs. 4, 5).

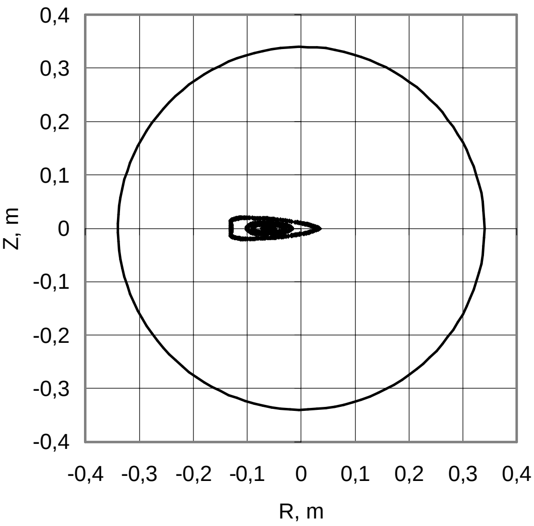


Fig.4. U-2M flux surfaces, Kφ=0.5, B_z/B_o= 1.7%

Figure 6 illustrates the ϑ–φ plane of the U-2M installation with helical winding and with field line footprints on the first wall in the case of Kφ=0.5 (Magnetic configuration see in Fig.4). The start points of these field lines lie in vicinity of the last closed magnetic surface. We draw attention to location and to density of footprints.

All footprints lie in lines between helical winding. Maximum of the density located in inner part of the torus (π > ϑ > 2 and -π > θ > -2).

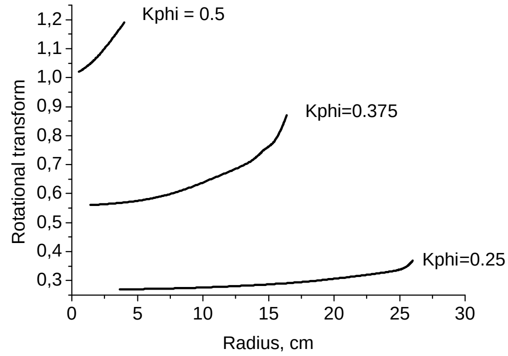


Fig.5. Angles of rotational transform depending on a flux surface's average radius

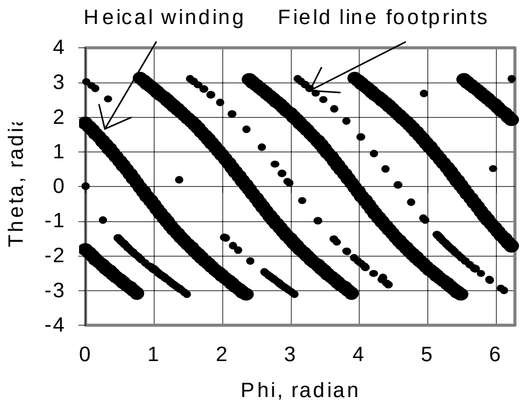


Fig.6. ϑ–φ plane. Divertor field line footprints on the first wall, Kφ=0.5

In the case of small helical winding currants (Kφ=0.25) the outer magnetic surfaces intersect the first wall. Lines of the intersection of these flux surfaces with the wall surface are shown in Fig. 7.

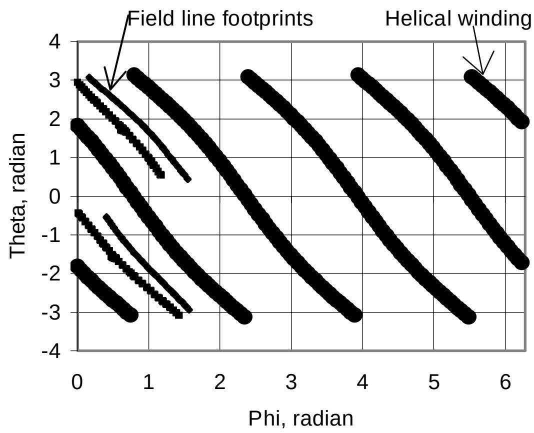


Fig.7. ϑ–φ plane. Divertor field line footprints on the first wall, Kφ=0.25

The two lines of field line footprints lie between helical coils positions and they correspond to the both sides of the last closed surface.

The more interesting case is the case of Kφ=0.375. In this case an average radius of the last closed magnetic surface equals about 17 cm (see Figs. 2, 5). The tops of the configuration do not intersect the chamber wall.

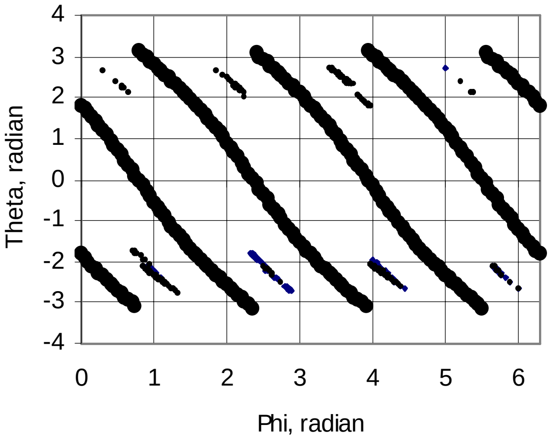


Fig.8. ϑ–φ plane. Divertor field line footprints on the first wall, Kφ=0.375

Values of rotational transform angles conform to the region 0.55 < t < 0.8. It was interesting to find regions, where the SOL field lines intersect the first wall. Footprints of these field lines are shown in Fig. 8. All footprints are placed in vicinity of poloidal angles θ = +2 and θ = -2. It means that we have to wait maximum plasma fluxes to these regions of the chamber wall.

CONCLUSIONS

1. Behavior of field lines placed in vicinity of the last closed surface was studied.
2. Three types of configuration were studied. Kφ = 0.25, 0.375 and 0.5.
3. In the case of Kφ = 0.25 the last closed surface intersects the first wall and consequently the field line footprints lie on the line intersection of the first wall with the magnetic surface.
4. Kφ = 0.375. The last closed surface lies inside of the vacuum chamber, but the top of the surface placed near the wall. In this case divertor lines intersect the wall in vicinity of ϑ = ±2 radian.

REFERENCES

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ЧИСЛЕННОЕ ИССЛЕДОВАНИЕ ДИВЕРТОРНЫХ ПОТОКОВ МАГНИТНОГО ПОЛЯ В ТОРСАТРОНЕ УРАГАН-2М

В.А. Рудаков

Проведено численное исследование диверторных потоков в торсатроне Ураган-2М. Изучены конфигурации магнитного поля при различных соотношениях между винтовым и продольным магнитным полем 0.2 < Kφ < 0.6. Показано, что в случае больших значений параметра Kφ, когда замкнутая магнитная конфигурация полностью размещается внутри вакуумной камеры без пересечения со стенкой, следы уходящих силовых линий образуют на стенке камеры две винтовые линии, расположенные между полюсами винтовой обмотки. При малых значениях Kφ, когда замкнутая магнитная конфигурация пересекает стенку камеры, внешние силовые линии образуют широкую полосу, соответствующую винтовой линии, по которой проходит вершина магнитной конфигурации.

ЧИСЛОВЕ ДОСЛІДЖЕННЯ ДИВЕРТОРНИХ ПОТОКІВ МАГНІТНОГО ПОЛЯ У ТОРСАТРОНІ УРАГАН-2М

В.А. Рудаков

Проведено числове дослідження диверторних потоків у торсатроні Ураган-2М. Вивчені конфігурації магнітного поля при різних співвідношеннях між гвинтовим і продольним магнітним полями 0.2 < Kφ < 0.6. Показано, що у разі великих значень параметру Kφ, коли замкнута магнітна конфігурація повністю розміщується у нутрі вакуумної камери без пересічення зі стінкою, сліди силових ліній, що виходять, створюють на стінці камери дві гвинтові лінії, розміщені між полюсами гвинтової обмотки. У разі малих значень Kφ, коли замкнута магнітна конфігурація пересікає стінку камери, зовнішні силові лінії створюють широку смугу у вигляді гвинтової лінії, вздовж якої проходе вершина магнітної конфігурації.