Dynamic and Static Stress Analysis of the TEXTOR Poloidal Coils

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In this paper the different poloidal field coils of the TEXTOR experiment will be investigated. In particular the stresses and deformations for the inner and outer corrector field coils as well as for the vertical field coils are analysed and discussed.

The field coils are loaded by constant thermal loads and by constant and periodic magnetic loads in radial and normal (z) direction.

The vertical field coils are connected with the casings of the toroidal field coils by means of holders. There are two joints in the vertical field coils so that the coils can be disconnected into two parts. The joints are situated between two toroidal field coils. The two socket-and-plug connection parts of the coil should be as free as possible from stress and deformation. This demand has lead to a stiff boxes covering the socket-and-plug connection.

Due to lack of space this design was not possible for the corrector coils. So the supports at the holders next to the joint were fixed instead. General finite 3-D beam elements have been used for the dynamik and static stress analysis. The stress and deflection results are plotted and discussed.

1. Introduction

The TEXTOR fusion reactor experiment can be divided into two parts, so that one has better access for repair and the investigation of plasma wall interaction. Consequently the poloidal coils (Fig.1) have two joints which are 180° apart. Each joint is situated between two toroidal coils. The socket-and-plug connection should be as free as possible from stress and deformation.

2. Vertical Coils

For the vertical coils this demand has lead to a stiff epoxyde box covering the socket-and-plug connection (Fig.2 and 3). In detail we have at each side of the joint a flange fixed to the coil. The two flanges are kept together by long screws and kept apart apart by the box which is open at two sides to let the coils in and out. Somewhere the vertical coils have to be fixed. They are connected with the casings of the toroidal field coils by holders (Fig.1). In the holders themselves the vertical field coils are embedded in a rubber suspension. In addition we have disc springs in radial direction. These springs can be prestressed. Different kinds of loads have to be considered. In radial (r) and normal (z) direction we have constant and periodic magnetic loads. The alternating loads have just one period between two toroidal coils as indicated in Fig.4. Moreover thermal expansion has to be taken into account.

All coils are considered as general (3-D) curved beams. Unfortunately in general there is no axis of symmetrie and loading. So 256 finite curved beam elements have been used to discretize the different coils, i.e. every 1.4° there is one element. For the corrector coils the finite elements results are presented in greater detail. For the vertical coils we will discuss only the consequences in the following.

An increasing prestressing of the disc springs will actually correspond with increasing bending moments at he holders and at the joints. The springs were finally prestressed in such a way that the coils are just kept in position. In doing so the coils are allowed to expand thermally more freely. The longitudinal stresses however are increased due to the radial magnetic loads. The finite element calculation showed that this was in fact the better alternative. Maximum longitudinal stresses are now far away from the holders. But maximum shear stresses are still at the holders.

3. Poloidal Coils

Unfortunately a stiff box covering the joint is not possible for the corrector coils as there is not enough space available. Instead the coil is fixed in the holders near the joints (Fig.4). In the remaining holders the coils are only restricted in the normal (z) direction (Fig.4). In the joint the stiffness is supposed to be very small. The calculated results are plotted for the inner corrector only. First the temperature ($\Delta T=10^{\circ}$) and the radial load has been considered. The analysis yields the radial displacements in Fig. 5, the tangential displacements in Fig.6, the axial forces in Fig.7,

the radial shear forces in Fig.8 and the bending moment around the z-axis in Fig.9. For the normal (z) load we have the z-displacements in Fig.10, the z-shear force in Fig.11, the torsion moment in Fig.12 and the bending moment around the r-axis in Fig.13. As expected the highest stresses appear at the fixed supports near the joints. One could decrease the displacements near the joint also by fixing the coil between the two fixed supports. But then the stresses are increased.

It has to be emphasized that the increasing of the thermal loads will not have much effect on the stresses, as the vertical as well as the corrector coils can expand thermally quite freely.

4. Dynamic case

In the dynamic analysis the eigenvalues and eigenmody for the inner corrector coil have been calculated. The eigenmodes to the three lowest eigenvalues are depicted in Fig.14, 15, 16. The first eigenmode (Fig.14) has no displacement in z-direction whereas the next eigenmodes have only displacements in z-direction. The comparatively large deflections at the joints are due to the artificial small elastic constants simulating the joints.

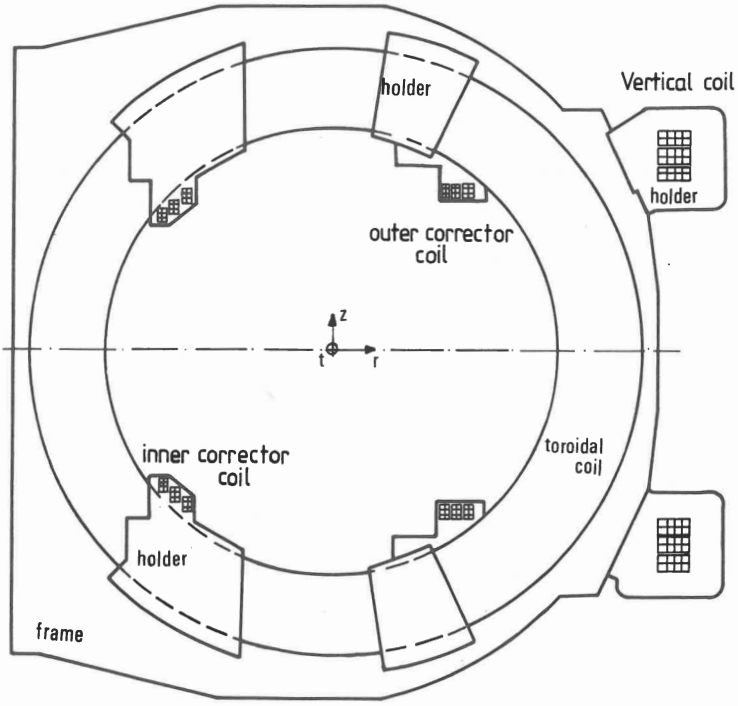


Fig.1 Poloidal Coil System

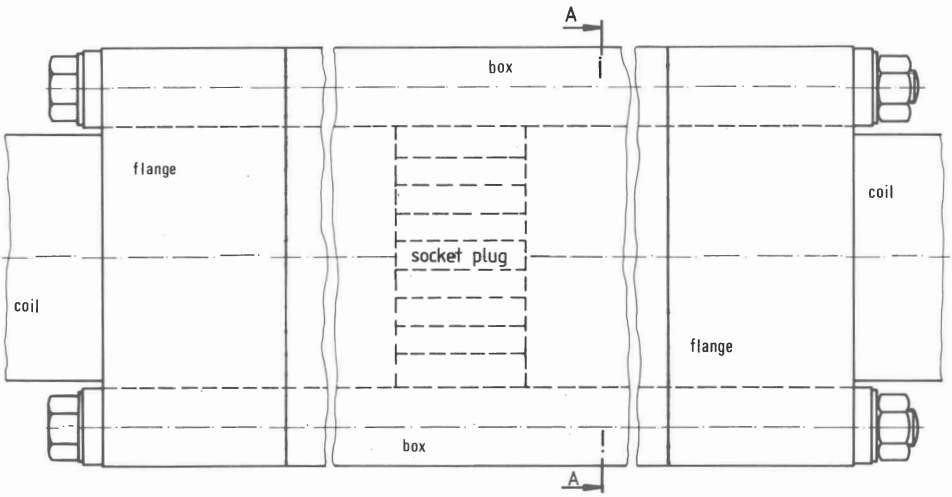


Fig. 2 Joint of Vertical Coil

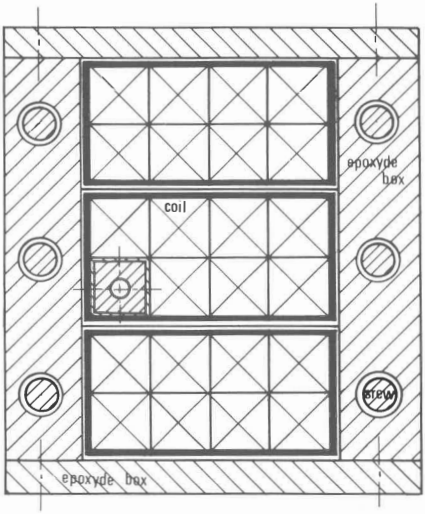


Fig. 3 Cross Section A-A of V-Coil in Fig. 2

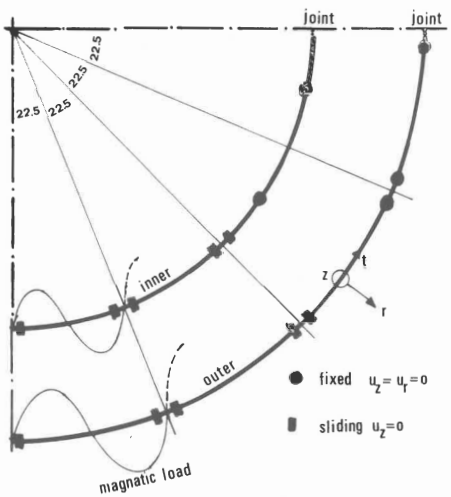
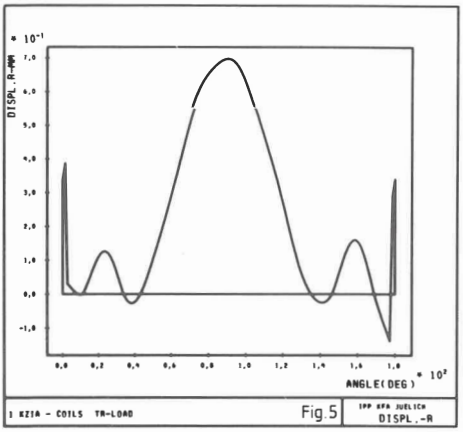
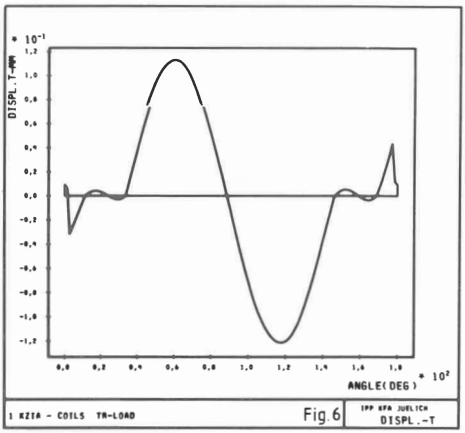
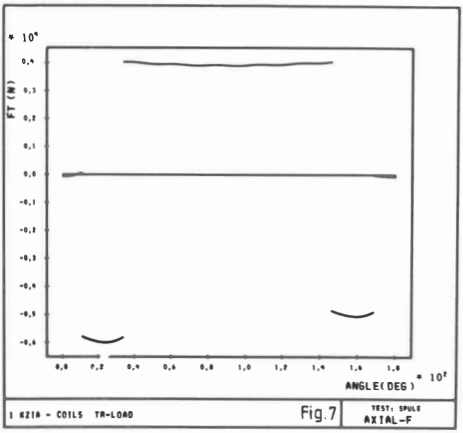
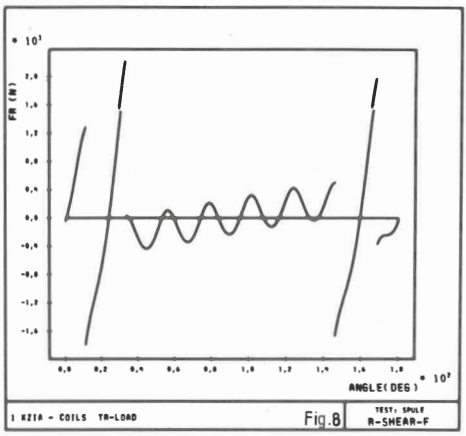


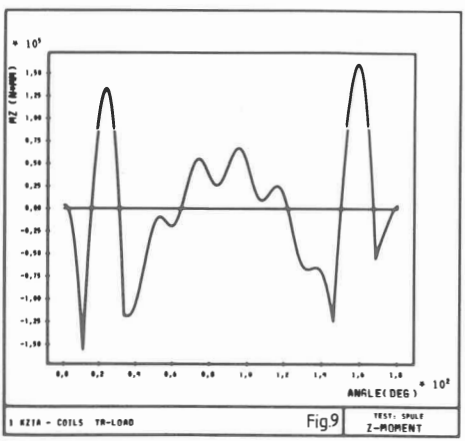
Fig. 4 Corrector Coils

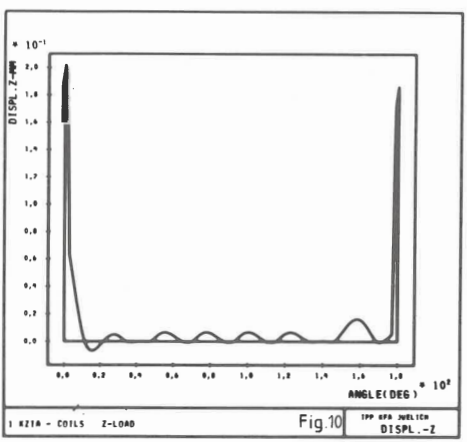

* 10⁻¹
DISPL.R-MM
ANGLE(DEG)
* 10²
1 KZIA - COILS TR-LOAD
Fig.5
IPP KFA JUELICH
DISPL.-R


* 10⁻¹
DISPL.T-MM
ANGLE(DEG)
* 10²
1 KZIA - COILS TR-LOAD
Fig.6
IPP KFA JUELICH
DISPL.-T


* 10⁴
FT (N)
ANGLE(DEG)
* 10²
1 KZIA - COILS TR-LOAD
Fig.7
TEST: SPULE
AXIAL-F


* 10³
FR (N)
ANGLE(DEG)
* 10²
1 KZIA - COILS TR-LOAD
Fig.8
TEST: SPULE
R-SHEAR-F


* 10⁵
MZ (NMMM)
ANGLE(DEG)
* 10²
1 KZIA - COILS TR-LOAD
Fig.9
TEST: SPULE
Z-MOMENT


* 10⁻¹
DISPL.Z-MM
ANGLE(DEG)
* 10²
1 KZIA - COILS Z-LOAD
Fig.10
IPP KFA JUELICH
DISPL.-Z

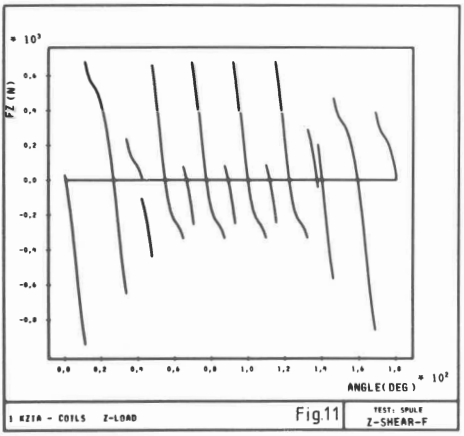


Fig.11

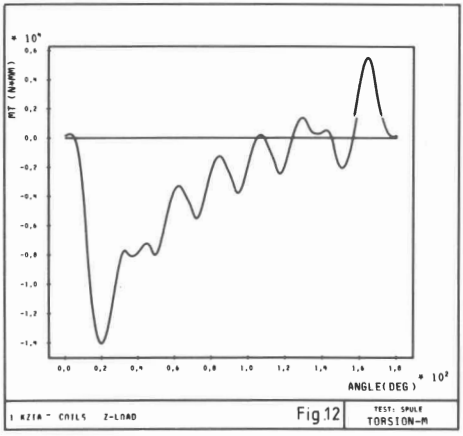


Fig.12

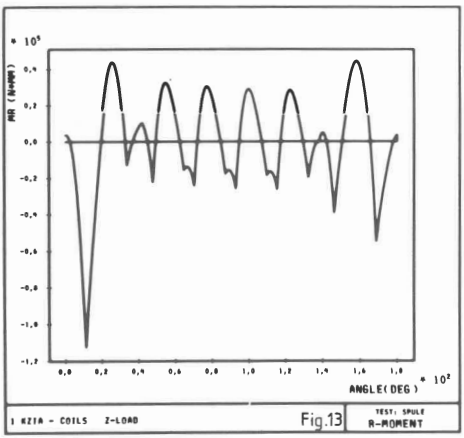


Fig.13

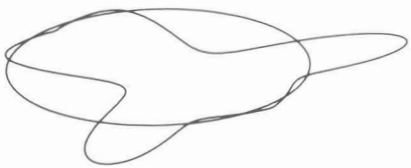


Fig.14

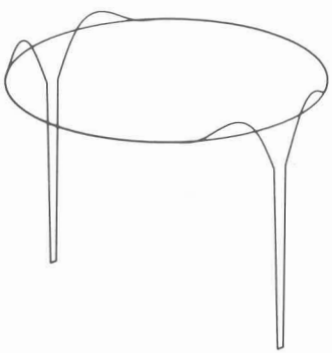


Fig.15

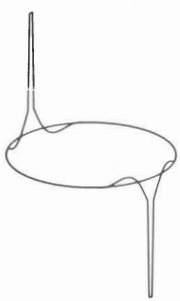


Fig.16