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Distribution of Creep Stresses and Creep Rates in Transversely Isotropic FGM Cylinder

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ABSTRACT

The FGM cylinder chosen in this study is assumed to contain a maximum of 20 vol% SiCw at the inner radius and having an average 15 vol% of SiCw. The content of SiCw in the FGM cylinder decreases linearly from the inner to outer radius, as shown in Fig. 5.4. The numerical results are computed for FGM cylinder subjected to two different boundary conditions: (i) cylinder subjected to only internal pressure, p = 85.25 MPa (ii) cylinder subjected to both internal and external pressures with p = 85.25 MPa and q = 21.31 MPa. In both the cases, the dimensions of cylinder used are similar to those reported by Johnson et al (1961) in their study on copper cylinder

KEYWORDS

Distribution of Creep Stresses and Creep Rates, Cylinder Subjected to Internal Pressure, Cylinder Subjected to Internal and External Pressures

CYLINDER SUBJECTED TO INTERNAL PRESSURE

The variation of creep parameters *M* and σ_0 with radial distance in FGM cylinders. The values of creep parameters in both isotropic and transversely isotropic (referred as anisotropic in this study) cylinders are equal. The value of parameter *M* increases with increasing radial distance. The increase observed in *M* may be attributed to decrease inparticle content *V(r)*, on moving from the inner to outer radius of cylinder. On the other hand, the threshold stress (σ_0) decreases linearly on moving from the inner to outer radius of FGM cylinder. The threshold stress is higher in locations having more amount of SiCw reinforcement compared to locations having lower SiCw content.

The creep stresses and creep rates have been estimated for isotropic FGM cylinder (α=1) and anisotropic FGM cylinders having α = 0.7 and α = 1.3. The value of α less than or greater than unity implies respectively the strengthening and weakening of FGM cylinder in the tangential direction as compared to radial and axial directions. The radial stress, remains compressive throughout the cylinder, with maximum value at the inner radius and zero at the outer radius, under the imposed boundary conditions given. The magnitude of radial stress changes a little in the presence of anisotropy in the FGM cylinder. Over the entire radius, the radial stress (compressive) increases a little for α = 0.7 and decreases a little for α = 1.3, when compared with isotropic FGM cylinder having α = 1. The tangential stress remains tensile throughout and is observed to increase with increasing radius to become maximum at the outer radius of the FGM cylinder. As compared to isotropic FGM cylinder, the presence of anisotropy with α=0.7, the tangential stress decreases near the inner radius but increases towards the outer radius. However, for anisotropic FGM cylinder with α = 1.3, the tangential stress increases near the inner radius but decreases towards the outer radius, when compared with isotropic FGM cylinder. The extent of variation in tangential stress observed for anisotropic FGM cylinder with α = 1.3, are slightly less than thatobserved forα= 0.7, when both the cylinders are compared with isotropic FGM cylinder (α = 1).

The axial stress,changes its nature from compressive to tensile as we move from the inner to outer radius of the isotropic FGM cylinder. For anisotropic FGM cylinder having α = 0.7, the magnitude of compressive stress, observed near the inner radius, increases but that of tensile stress, observed near the outer radius, decreases as compared to that observed in isotropic FGM cylinder. However, for anisotropic FGM cylinder having α= 1.3, the axial stress becomes tensile over the entire radius and is always higher than that observed for isotropic FGM cylinder. The effect of anisotropy on axial stress is slightly more near the inner radius than that observed towards the outer radius.

The effective stress shown in decreases with increasing radial distance. As compared to isotropic FGM cylinder, the presence of anisotropy leads to significant decrease in effective stress over the entire radial distance for α= 0.7. Whereas the effective stress increases significantly for α =1.3, when the distribution of effective stress in anisotropic FGM cylinder is compared with that observed in isotropic FGM cylinder.

It is interesting to observe that there exists a crossover in the distribution of tangential stress, somewhere in the middle of the cylinder. In order to investigate the reason for this cross over, the distribution of various terms appearing in the expression of tangential stress are plotted for different FGM cylinders and shown in . The term (X_1+X_2) is not effected much with varying extent of anisotropyα. On the other hand, the terms $I_1/r^{2/n}$ and I_2 increases and decreases respectively with increase in α from 0.7to 1.3, as evident from. As a result of this, the cumulative effect of $I_1/r^{2/n}$ and I_2, shown in , exhibits a cross over with the increase in α from 0.7 to 1.3, which is responsible for crossover in tangential stress shown in Fig.

It is revealed from the above discussion that the effect of anisotropy on the radial and tangential stresses in the FGM cylinder is not much pronounced. However, both axial and effective stresses are strongly influenced by the presence of anisotropy. The effect of anisotropy with α< 1 is just opposite to that observed or α>1.

The strain rates given are dependent on the effective strain rate ($\dot{\varepsilon}_e$), which ultimately depend upon the stress difference (σ_e - σ_o), as revealed from creep law given. Therefore, to investigate the effect of anisotropy on creep rates, the distribution of (σ_e - σ_o) is plotted in. The trend of variation observed for (σ_e - σ_o) is similar to those noticed for effective stress in. The stress difference (σ_e - σ_o) observed for isotropic FGM cylinder is relatively lower over the entire radius than that observed for anisotropic FGM cylinder having α=1.3. However, when α< 1 (*i.e.* ~ = *0.7*), the stress difference (σ_e - σ_o) decreases significantlyover the entire radius when compared with isotropic FGM cylinder. As a result of significantly lower values of (σ_e - σ_o) in anisotropic FGM cylinder having α =0.7, the effective strain rate in this cylinder is lower everywhere compared to any other cylinder. On the other hand, the anisotropic FGM cylinder having α = 1.3, exhibits significantly higher effective strain rate over the entire radius. The presence of anisotropy affects the radial and tangential strain rates ($\dot{\varepsilon}_\theta = -\dot{\varepsilon}_r$) in a similar way as observed for effective strain rate in . The radial as well as tangential strain rates decrease by almost two orders of magnitude, when α decreases from 1.3 to 0.7. The decrease is less than one order of magnitude on decreasing αfrom 1.3 to 1.0. Therefore, by increasing the strength of SiCw reinforcement in the tangential direction (α< 1), as compared to radial and axial directions, the strain rates in the cylinder are significantly reduced when compared with isotropic FGM cylinder (α =1) . On the contrary, the FGM cylinder having weaker strength in tangential direction (α> 1) shows much higher creep rates than those observed in isotropic FGM cylinder.

The effect of anisotropy on the maximum and minimum values of stresses in the FGM cylinder has also been investigated. The maximum tangential stress, observed at the outer radius of FGM cylinder, decreases with increasing value of anisotropic parameterα, Fig. 5.10. Whereas, the minimum tangential stress, observed at the inner radius, increases with increase in extent of anisotropy α. The radial stress (compressive) is maximum at the inner radius and minimum at the outer radius, under the imposed boundary conditions given . As a result of this, the maximum and minimum radial stress in the cylinder will not be affected by the presence of anisotropy. The minimum and maximum values of axial stress, observed respectively at the inner and outer radii, increases with increasing extent of anisotropy α from 0.7 to 1.3, Fig. 5.11. With the increase inα, the nature of minimum axial stress changes from compressive to tensile.

The stress inhomogeneity is defined as the difference of maximum and minimum values of stress in the cylinder. The tangential stress inhomogeneity decreases from 45.9 *MPa* to 32.6 *MPa* with the increase in α from 0.7 to 1.3 The axial stress inhomogeneity also decreases from 75.6 *MPa* to 40.7 *MPa*with the increase in α from 0.7 to 1.3. However, the inhomogeneity in radial stress remains constant under the imposed boundary conditions, which lead to fixed values of maximum and minimum radial stresses in the FGM cylinder.

The magnitude of maximum and minimum value of strain rates (tangential/radial), observed respectively at the inner and outer radii of the cylinder, increases with the increase in α, as shown in . The tangential/radial strain rate inhomogeneity increases significantly with the increase inα.Though, the inhomogeneity in axial and tangential stresses are minimum corresponding to α = 1.3, but the inhomogeneity in strain rate is the lowest corresponding to α = 0.7. Therefore, by increasing the extent of anisotropy *i.e.* decreasing the strength of FGM cylinder in the tangential direction, the strain rate inhomogeneity in the FGM cylinder increases, which may enhance the chances of deformation in the FGM cylinder.

CYLINDER SUBJECTED TO INTERNAL AND EXTERNAL PRESSURES

This section investigates the effect anisotropy on creep response of the FGM cylinders subjected to both internal and external pressures (p = 85.25 *MPa*, q = 21.31 *MPa*), the results for which are indicated. It is observed that the effect of anisotropy on creep stresses in the FGM cylinder subjected to internal and external pressures is similar to those noticed for FGM cylinder subjected to internal pressure alone. However, the magnitude of stresses in the FGM cylinder are reduced on applying both internal and external pressures, as compared to those observed in FGM cylinder subjected to internal pressure alone.

The influence of anisotropy on strain rates in FGM cylinder subjected to both internal and external pressures, is also similar to those observed inFGM cylinder under internal pressure alone, Fig. 5.9. Though, the order of strain rates in FGM cylinder subjected to both internal and external pressures is significantly lower than that observed for FGM cylinder operating under internal pressure alone.

By introducing anisotropy with α = 0.7, the effective as well as tangential/radial strain rates reduce by about four orders of magnitude as compared to those observed is isotropic FGM cylinder (α = 1.0). However, on increasing α from 1.0 to 1.3, the order of strain rates increases by about one order of magnitude. The stress inhomogeneity in FGM cylinder, operating under both internal and external pressures, decreases with the increase in extent of anisotropy. As compared to FGM cylinder operating under internal pressure alone, the axial stress inhomogeneity is significantly lower in FGM cylinder subjected to both internal and external pressures. The influence of anisotropy on tangential/radial strain rate inhomogeneity in FGM cylinder, operating under both internal and external pressures, is similar to those noticed for FGM cylinder subjected to internal pressure alone.However, the simultaneous presence of internal and external pressures significantly reduces the inhomogeneity in strain rates as compared to that observed for FGM cylinder subjected to internal pressure alone. Therefore, the chances of distortion in an anisotropic FGM cylinder operating under internal and external pressures will reduce as compared to that observed in a similar cylinder subjected to internal pressure alone.

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