6.5.1 Evolution of the rotational velocity

One of the main factors for the emission lines in the spectra of Be stars is the rapid rotational velocity. However, the evolution of this rotational velocity in B type stars that changed into Be stars, or vice-versa, is still open for debate within the international community. One of the outputs of the stellar evolution process that we generated using the code is the star's rotational velocity, as this parameter has been used as one of the initial parameters for the numerical process. During the evolution, it is assumed that at all stages of evolution the star is in a state of uniform rotation. The evolutions have been run at four different initial rotational velocities: 0, 270, 300 and 345 km/s for Z = 0.01 and 0.02 with the same initial mass 12.5 M⊙. Figure 6.4 shows the evolutions of the star's rotation rate to its critical velocity as a function of time. We found that the rotation rate of all models gradually increased from the ZAMS to point B (Figure 6.3) and that the gradient becomes significantly high during the contraction phase from B to C, before it decreases abruptly to a very slow rate after the TAMS and the following phases.

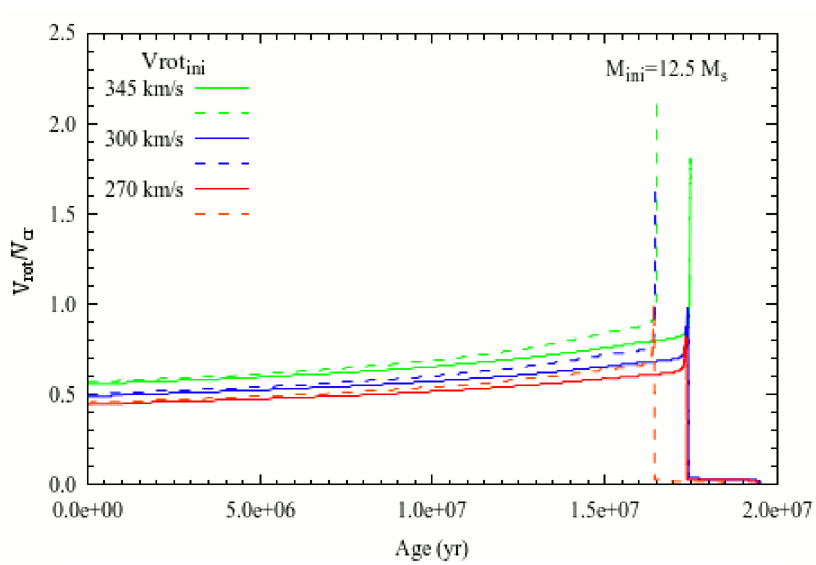

Figure 6.4 – Ratio of rotational velocity to the critical velocity varies with time from ZAMS to the red giant branch. Solid lines represent Z = 0.01 and dashed lines Z = 0.02.

The evolution of rotational velocity v_{rot} with its rotation rate, i.e.,v_{rot}/v_{cr} for Z = 0.01 is shown in Figure 6.5. At an initial rotational velocity of 345 km/s, the rotation rate was increased continuously until the evolution breakdown. On the other hand, the rotation rate has a limit of 1 when the initial v_{rot} is set at 300 km/s. Therefore, for lower initial rotation velocity the maximum rotation rate becomes smaller. For instance, the initial v_{rot} of 270 km/s had about 0.8 of maximum rotation rates. The evolutions of all parameters used in this study are tabulated in Table 6.2. From Table 6.2, the rotation rate of the star of all models that shows at current status for Z = 0.01 was found larger than 0.5 and smaller than 0.5 for Z = 0.02.

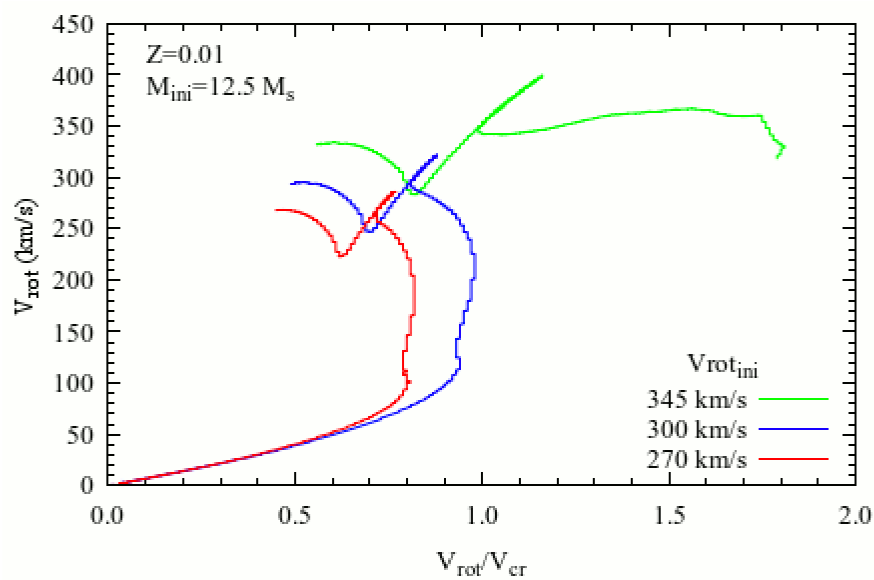

Figure 6.5 – Model evolutions of V_{rot} with rotation rate at different initial V_{rot} for Z = 0.01 with initial mass of 12.5 M⊙ .

Based on the model of $Vrot_{ini}$ = 270 km/s and 300 km/s for Z = 0.01, the rotation rate was found larger than 0.7 when it approached the contraction phase, which happened after the second half of the main sequence phase. This is in accordance with Porter (1996) and Chauville et al., (2001), which suggests that the distribution of rotational velocity as a function of critical velocity of Be stars had sharply peaked at 0.7 v_{cr}. According to Townsend (2004), if the rotation does play a direct role in the Be phenomenon, then the rotation must be greater than 0.7 v_{cr}. From this study, we found that the rotation velocity of δ-Sco is only about 0.5 v_{cr}; however, the star has already shown evidence of the Be phenomenon since 1990, when a weak emission line in H_α was detected in its spectra. In this case, we believe that the periastron passage of the companion does have an effect on the appearance of the Be phenomenon of this star.

Based on the evolutionary models that we performed in this study, we found that the current status of δ-Sco can be identified on model of $Vrot_{ini}$ = 270 km/s with initial mass of 12.5 M⊙ and metallicity, Z = 0.01. The physical parameters of the current status of this star based on the model are listed in the table below:

Table 6.3 – Physical properties generated from the evolution process.

Parameter	Value
Log Teff	4.43
Log L	4.21
Age	9.5 Myr
Mass	12.46 M⊙
Radius	5.84 R⊙
v*rot**	266 km/s
vrot/vcr	0.51

* - rotation velocity on its axis