Basalt fiber from Indian Deccan Plateau. A preliminary study about the raw materials

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Abstract

Basalt fibers are one of the most interesting reinforcement which are being used in last few decades. The fibers are manufactured from basalt raw materials.

In order to determine their process ability for the production of basalt fibers their composition was investigated and based on material modeling, the viscosity of several samples was calculated. The results show that, the Indian basalt composition varies from location to location. The Indian basalt composition shows the viscosity profile similar to the commonly used basalt for fiber production.

Introduction

The Deccan-Trapp in the region of Deccan in western-central India is one of the largest volcanic basalt deposition regions on earth. It consists of a stair-like formation (Trapp) of flood basalt formed by an overlay of flat-lying basalt layers and it covers an area of more than 500,000 square kilometers [1]. (Fig 1)

Fig. 1: Map of the Deccan Plateau

The original Deccan plateau extension prior erosion reached 1.5 million square kilometers and spreads up to the Arabian Sea. The Deccan plateau formation is estimated by paleontology in both Late Cretaceous eruptions and eruptions during the Eocene and Oligocene. By using radiometry it has been reported that the formation was in between 102 and 30 million years ago.[1] [2] [3]

The Deccan plateau is divided in several regions. The most relevant region are Kalsubai, Lonavala and Wai. Those regions are than divided into sub regions. In Fig. 2 ~~are~~ describes ~~d~~ the Deccan’s subdivisions.

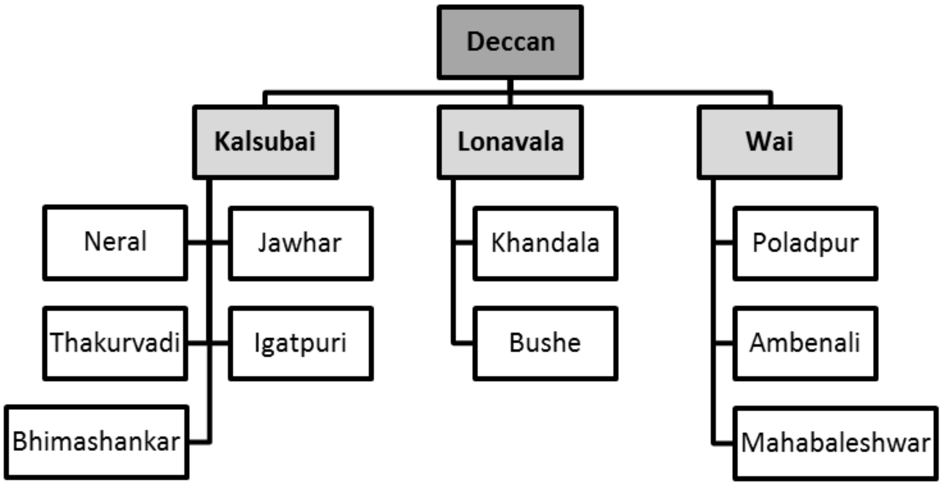

Fig. 2: Deccan Subgroup definition

Kalsubaiflow is divided into Jawhar, Igatpuri, Neral, Thakurvadi and Bhimashankar formations. These formations are having high MgO content and traces amygdules. These flows are separated by others which contain giant plagioclase phenocrysts. The Lonavala Subgroup overlies the Kalsubai and is composed of two formations, the Khandala and the Bushe. The Wai Subgroup includes the three formations, Poladpur, Ambenali, and Mahabaleshwar. The whole subgroup is composed of simple flows with well-developed flow tops, small phenocrysts of plagioclase, pyroxene and olivine, and relatively evolved bulk. [1]

For this study the author used the analysis of the chemical composition made by Beane et al.. In his work all the Deccan region basalt was analyzed and categorized (Fig. 2) based on the chemical composition.

Basalt Viscosity

Basalt fibers, as well as glass fibers require a forming viscosity ranging from 100 Pa·s to 36 Pa·s. The viscosity of a basalt melt depends on the temperature (Fig. 3). The Basalt fiberization strongly depends on the temperature gradient between the two viscosity points (100 Pa·s to 36 Pa·s) [4]. A wider temperature interval indicate the higher stability of the fiberization process.

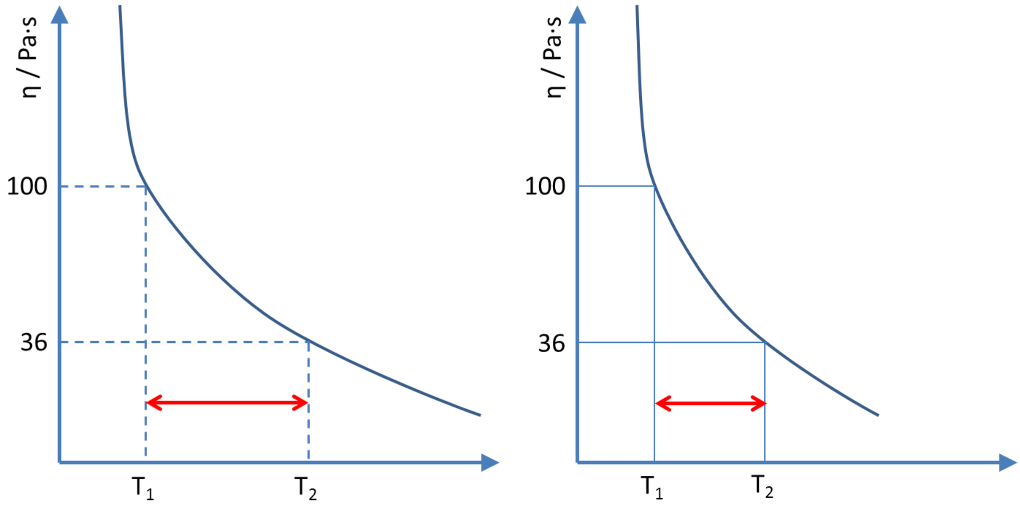

Fig 3. Plot of viscosity vs. temperature. Examples of melts with wide (left) and narrow (right) temperature interval of fiberization and their dependency with the viscosity.

In order to determine the viscosity, the authors applied the model described by Giordano et. al. [5] for predicting the non-Arrhenian temperature dependence of viscosity for naturally-occurring silicate melts at atmospheric pressure (10^5 Pa) that is based on the chemical composition of the raw materials.

Temperature dependence of viscosity (η) is modelled by the following equation

$$\log \eta = \mathrm{A} + \frac{B}{\mathrm{T(K)} - \mathrm{C}}$$

where ***A*** is an independent constant of the composition. ***B*** and ***C*** are the adjustable parameters.

The Compositional dependence parameters ***B*** and ***C*** are described as linear combinations of oxide components (mol%) and several multiplicative oxide cross-terms:

$$B = \sum_{i=1}^{7} [b_i M_i] + \sum_{j=1}^{3} [b_{1j} (M1_{1j} \cdot M2_{1j}]$$

$$C = \sum_{i=1}^{6} [c_i N_i] + [c_{1i} (N1_{11} \cdot N2_{11})]$$

where the ***M***'s and ***N***'s are combinations of mol % oxides.

The model has the following attributes:

1. it spans most of the compositional range found in naturally-occurring volcanic rocks.
2. the chemical model captures the effects of 10 major and minor oxide components and the volatile components H_2O and F.
3. it is computationally continuous across the entire compositional and temperature spectrum of the database.
4. it is capable of accommodating both strong (near-Arrhenian T-dependence) and fragile (non-Arrhenian T-dependence) behaviour of silicate melts.

5. it reproduces observed relationships between melt composition and transport properties such as glass transition temperature (T_g) and fragility (m).

The multicomponent model is calibrated on melt compositions spanning oxide contents (wt. %) of: SiO_2 (41-79), TiO_2 (0-3), Al_2O_3 (0-23), FeO_{Total} (0-12), MnO (0-0.3), MgO (0-32), CaO (0-26), Na_2O (0-11), K_2O (0.3-9), P_2O_5 (0-1.2).

The detailed explaination of the model and the calculator are described by [7]

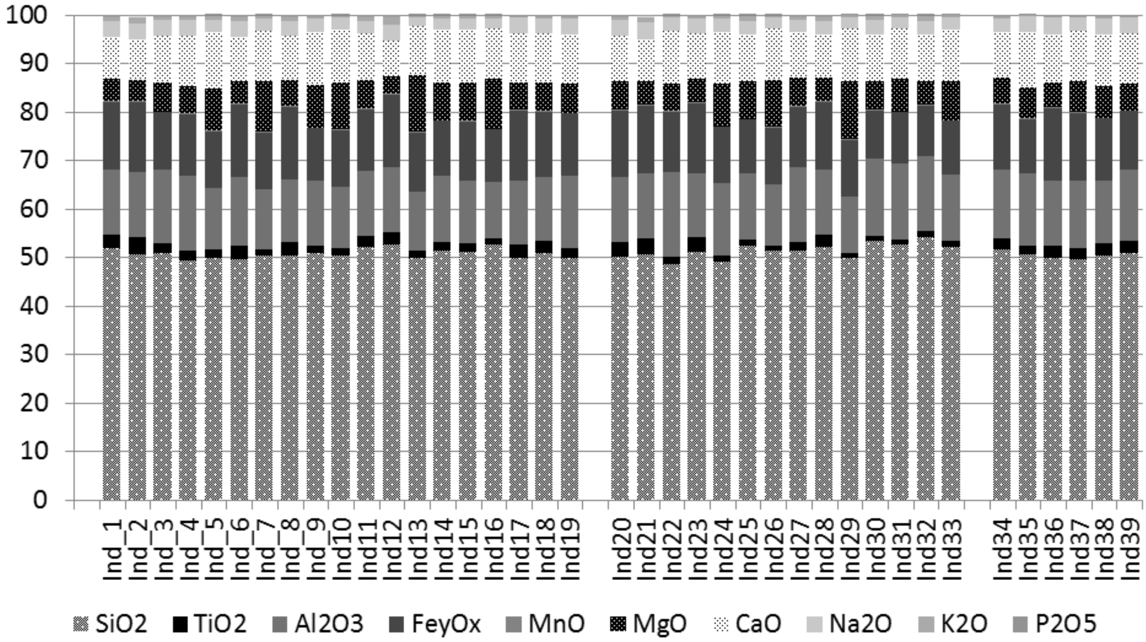

Fig. 4: Chemical composition of different Indian basalts [1].

The chemical composition of the Deccan samples has been measured by Beane et al. [1] and is shown in Fig. 4. The samples have been divided into three different regions such as Kalsubai samples from Ind_1 to Ind_19, Lonavala samples from Ind_20 to Ind_33 and Wai samples from 34 to 39 (Figure 2). In addition to the samples from India, the viscosities of three commonly used basalt used for fiberization were calculated [7]. Their chemical compositions are given in Fig. 5.

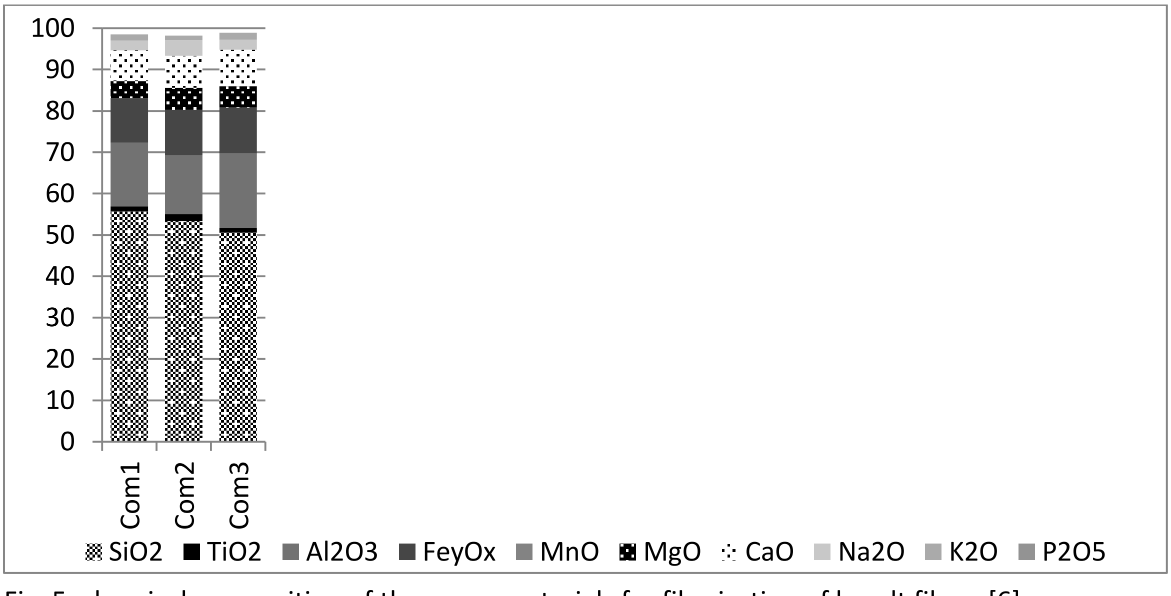

Fig. 5: chemical composition of three raw materials for fiberization of basalt fibers [6].

From the chemical composition reported in Fig. 4 and Fig. 5, it is possible to determine the relationship between temperature and viscosity for each sample by using the viscosity model of Gordano [5]. In general the basalt of Indian Deccan plateau has a lower spinning temperature range. Additionally, it was possible to determine how different samples of Indian basalt present a viscosity/temperature profile that is very similar to the material used for commercial basalt fiber (Fig. 6).

Figures 6 represents the viscosity-temperature graph for Indian basalt (sample with lower viscosity -▲-, higher viscosity - -●- and an average viscosity - -■-) which are very close to the profile of the common basalt (com1, com2 and com3) used for the fiber production. For this comparison 39 Indian Basalt sample have been used.

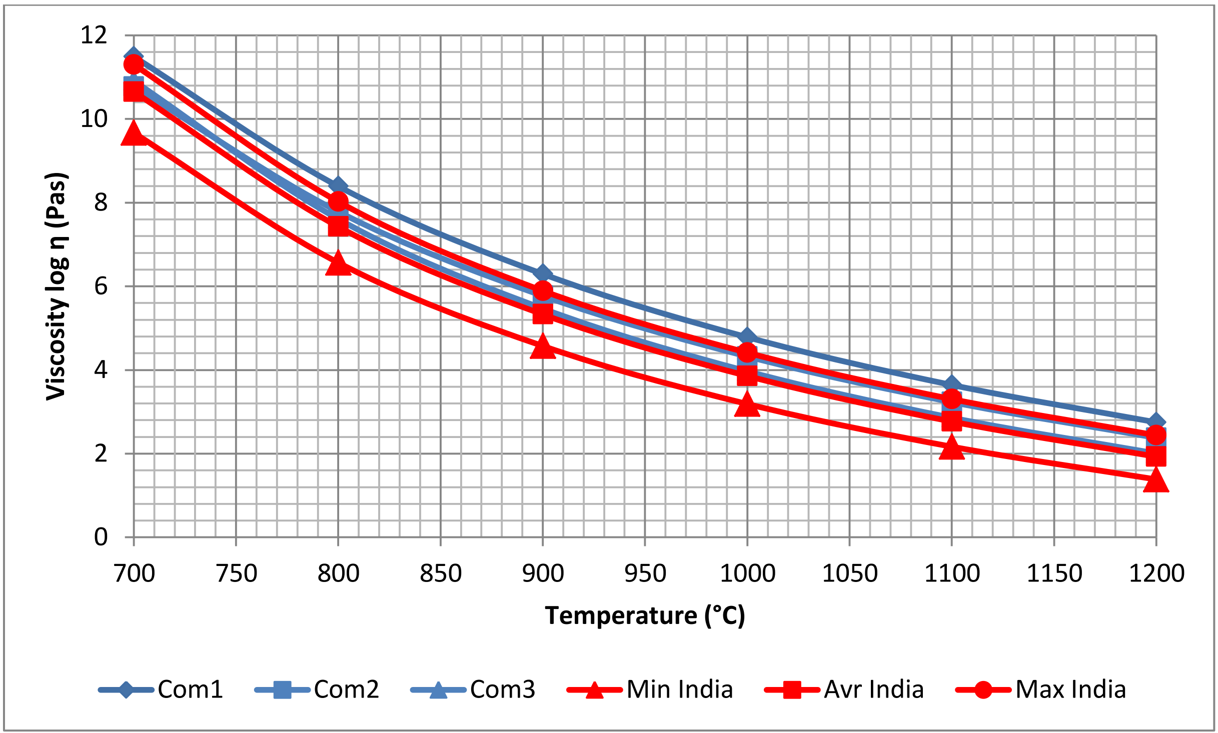

Fig. 6: Plot for viscosity vs Temperature of different basalt raw materials (commercial basalt fibers in blue and Indian Basalt in red)

Conclusion

The fiberizability of a basalt melt depends on several factors like mineralogy, surface tension, and emissivity coefficient. However, the most relevant parameter remains the viscosity. In this paper the viscosity of several samples from Indian Deccan have been determined, by applying the model of Giordano et al. [5], based on their chemical compositions and they have been compared with commercial basalt fiber. Even if the Deccan plateau is characterized by several different basalts with different chemical compositions, the results confirm that among them several Indian basalts would fit the requirements for a basalt fiber spinning plant.

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