Fabrication of (6+1)-structure Superconducting Cable Based on 30-core MgB_2 Superconducting Wire

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Introduction

MgB_2 has been regarded as one of the most promising superconductor materials since its discovery in 2001 [1]. MgB_2 has high transition temperature, low raw material cost, good upper critical field and critical current density values [2]. Many groups have studied the application technologies of MgB_2 superconductor[3]-[6], such as magnets, cables, generators and so on. The high-current superconducting links (SC links) being developed at CERN[7] is the most attractive application project of MgB_2 superconductor in the world at present. The MgB_2 cables are manufactured by ex-situ MgB_2 round wires.[8] However, in general, MgB_2 wire prepared by in-situ method has higher transport performance than that prepared by ex-situ method.

Study design and methods

Mg (about 10μm, 99.9% purity) and C-coated B (about 300nm, amorphous, C: ~ 5 wt%) powders were mixed with an atomic ratio of 1:2, and then filled into 8 Nb tubes, which have size of 11.5 × 1.2 × 550 (mm). After that, the Nb tubes with Mg and B powders were put in 8 Cu tubes. The size of the Cu tube is 15.0 × 1.3 × 600 (mm). The assembled Cu/Nb/Mg-B composites were rolled and drawn into hexagonal rods with 2.65 mm diagonal margin. Then all the single-core rods were cut into 30 pieces of 2220 mm. Thirty single-core composite rods and seven NbCu rods of the same size were assembled into Monel alloy tube. Then the tube was drawn to a wire of 1.0 mm in diameter. Six-piece 30-core MgB_2 precursor wire and one-piece Cu wire in the center were twisted into cable with 3 different TP by the twisted and reacted (T&R) route.

The V-I curve of the samples were measured with 1 μV·cm-1 voltage criterion and standard four-probe method. The sintering of these samples is to raise the temperature to to 600 °C in 1 h, held at this value for 2 h, and then finally reduced to room temperature in the furnace.

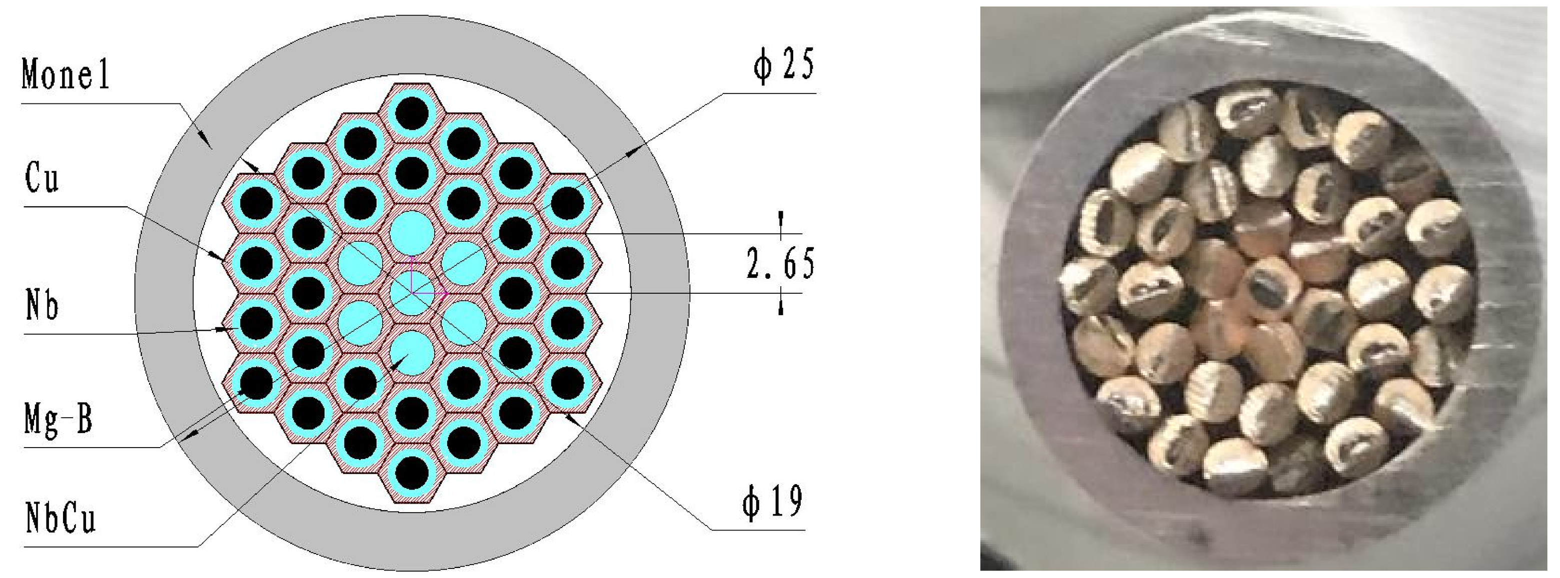

Fig. 1. Multi-core assembly (a) Sketch map (b) The assembled multi-core composite

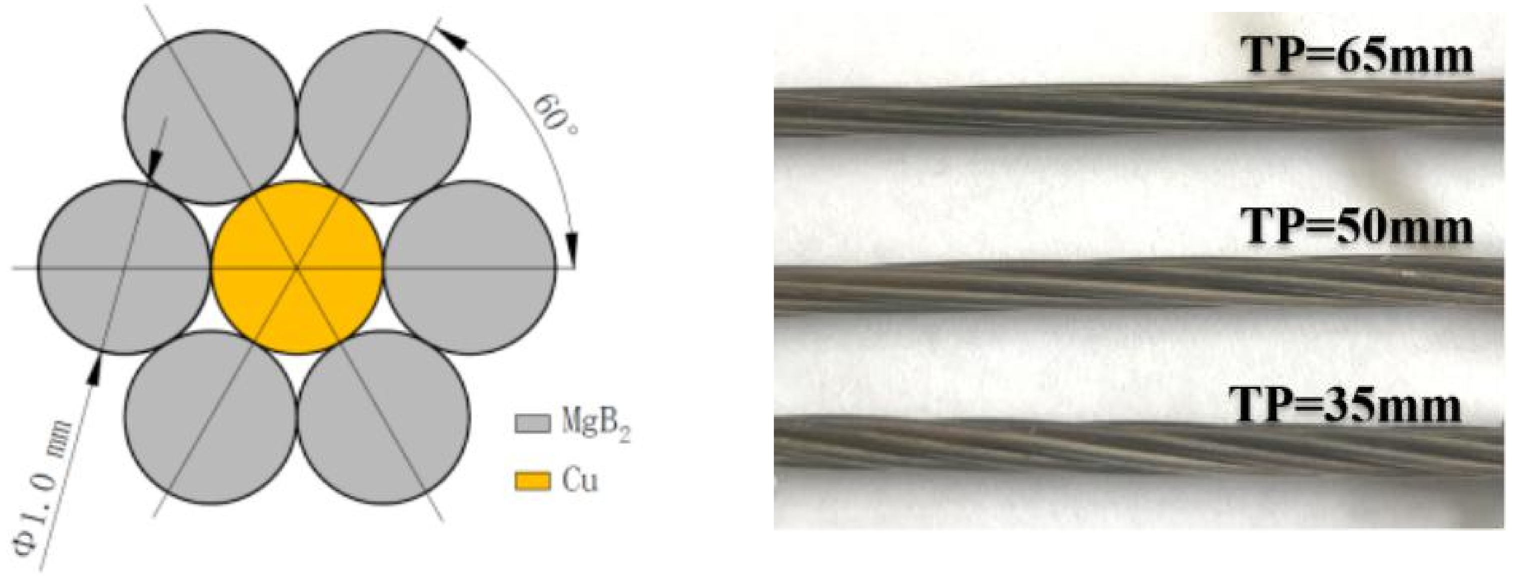

Fig. 2. (a) Schematic diagram of (6+1)-structure MgB_2 cable (b) The different twist pitches

Fig. 3. (a)Three fabricated superconducting cables (b) Cable details

Result and Discussion

A 30-core MgB_2 superconducting wire with a diameter of 1.0 mm has been successfully fabricated, which is 1030 meters long. The metallographic analysis results show that the 30-core MgB_2 wire has good uniformity in both transverse and longitudinal directions. The critical current (Ic) and critical current density (Jc) reach 82.6 A and 7.25×10⁴ A/cm² at 4.2 K and 4 T, respectively. The Jc is lower than that of MgB_2 wires with similar structures. The reason is mainly due to the two annealing processes.

Furthermore, the (6+1)-structure MgB_2 superconducting cables have also been successfully fabricated with different twist pitches (Tp). There are different gaps between MgB_2 strands and central copper wire. The large gaps shown in the figure with 65 mm Tp proves that the cable has not been twisted tightly enough. When Tp is 35 or 50 mm, the gaps are same small. The Ic of the (6+1)-structure MgB_2 superconducting cable with 50 mm Tp reaches 476 A at 4.2 K and 4 T, with only 5.8% loss.

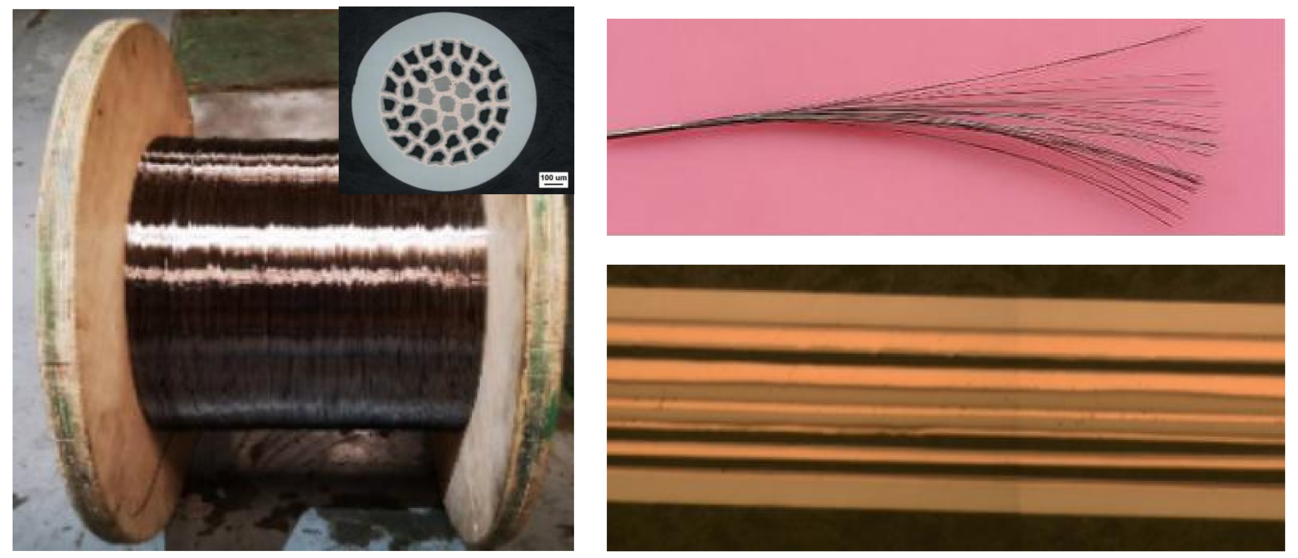

Fig. 4. (a) Km-grade MgB_2 precursor wire (b) Core wire after corrosion of Monel alloy (c) Longitudinal section of MgB_2 precursor wire

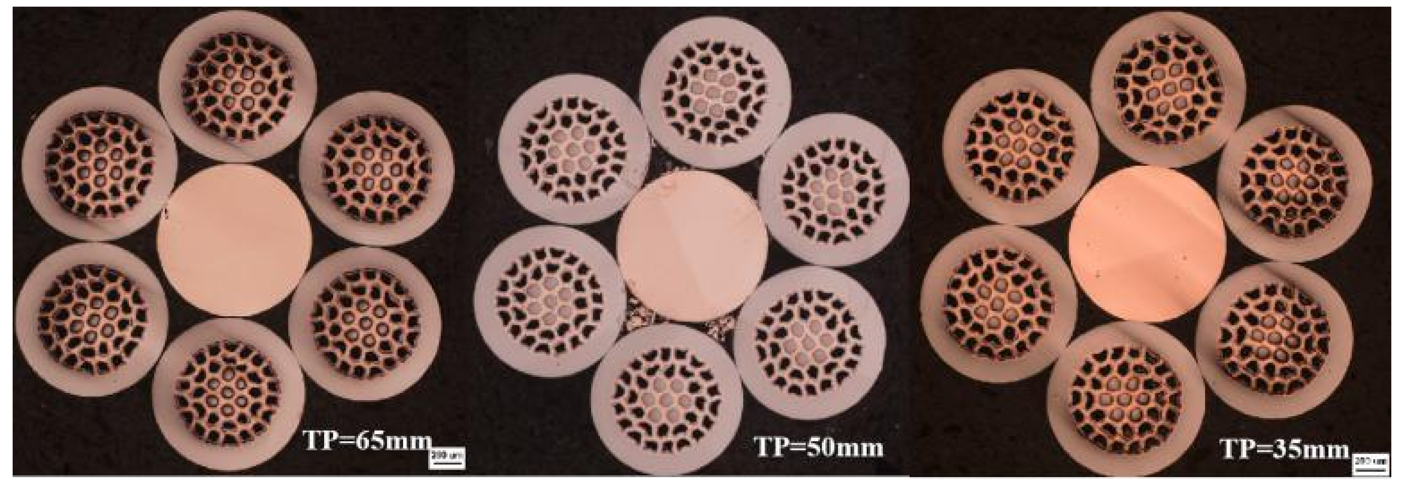

Fig. 5. Cross section of MgB_2 cables

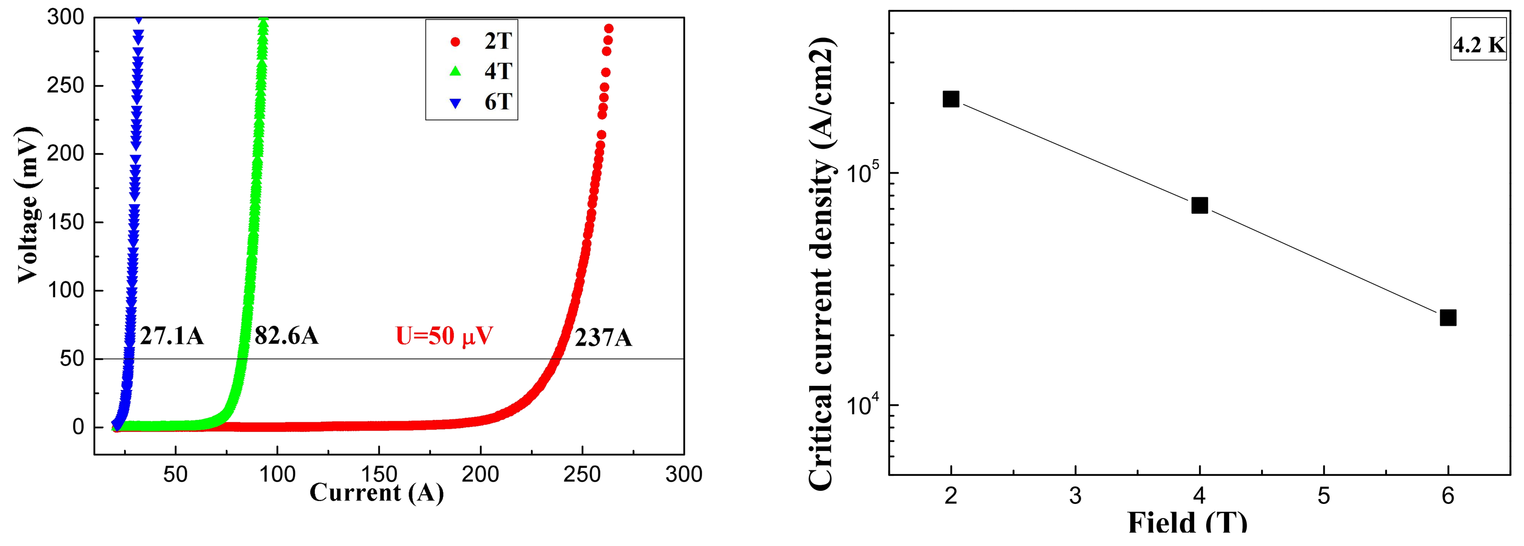

Fig. 6. Transport critical current properties of the 30-core MgB_2 wire

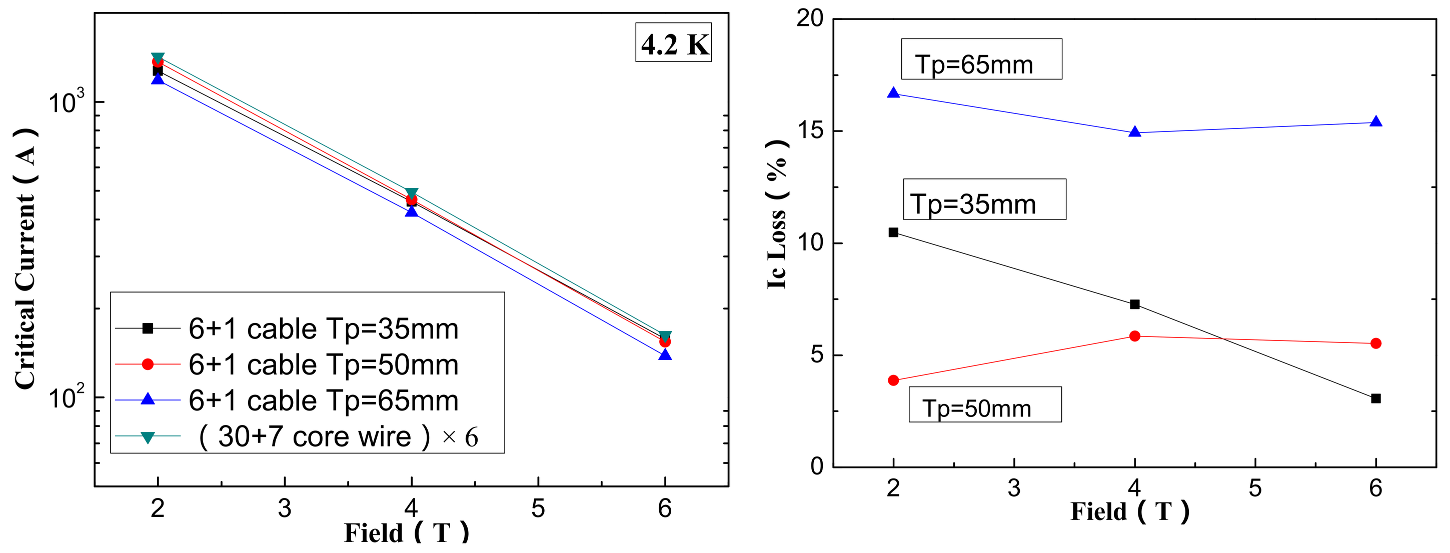

Fig. 7. (a) The Ic-B cure of the MgB_2 cables (b) The Ic loss percentage

Conclusion

In this work, we reported the manufacturing process and critical current properties of a 30-core MgB_2 superconductor and (6+1) structure superconducting cables based on this wire prepared by the in-situ PIT method. The result suggests different twist pitches have an effect on the electrical and thermal contacts between the strands and the central Cu-wire, thus affecting the critical current performance of cables. While the twist pitch is 50 mm, the critical current (Ic) of the (6+1)-structure MgB_2 superconducting cable reaches 476 A at 4.2 K and 4 T, and the loss of critical current is only 5.8%. This work suggests that MgB_2 superconducting cable have a huge potential to the application of practical engineering application. If the wire processing technology is improved and the final deformation step (adopted by T Holubek et. al.)[9] is introduced in the process of stranding, the MgB_2 superconducting cable with greatly improved performance is expected to be fabricated.