研究速報
特集11
UDC 621.914.1.014.8
669.146−493
666.983

Production of Steel Fiber by Machining for Reinforced Concrete

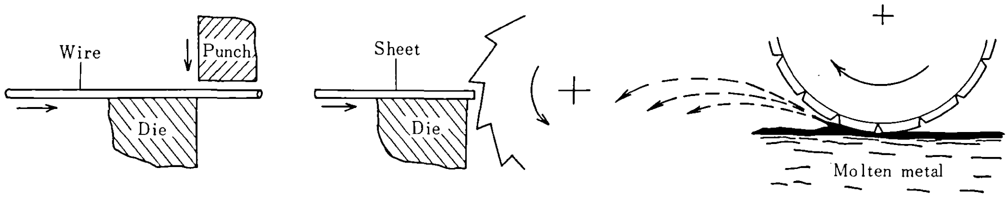
切削によるコンクリート補強用スチールファイバーの製造

by Takeo NAKAGAWA and Kiyoshi SUZUKI

中川威雄*・鈴木清*

1. Introduction

Steel fiber reinforced concrete with high toughness are increasingly used nowadays in civil construction and architecture, but its wide application is restricted because of the difficulty in obtaining suitable steel fiber. The processes already devloped for the steel fiber production are, (a) cut wire (b) shearing from sheet and (c) the melt extraction method (Battelle Memorial Institute). These are illustrated schematically in Fig. 1. Though the quality of the steel fiber for reinforcement is important the cost of the fiber is still more important, because the quantity of fiber used is very big. On this basis, at present



a) Cutting from wire　　b) Shearing from sheet　　c) Extracting from molten metal

Fig. 1　Various existing processes for the production of steel fiber

the above three processes have some drawbacks which always do not satisfy the actual requirements. This research is started to solve these problems and to develope a new method. This paper deals with an outline of this production process and give the result of a preliminary experiment.

2. Production Principle of Machined - off Fiber

In the method shown in Fig. 2, a plain milling cutter is used to machine a steel block; the needle shaped chip resulting from cutting, is the steel fiber required. The steel block used overhere is less expensive than wire and thin sheet and at the same time, the production speed is also quite high. Thus, the over all cost of the fiber produced by this method seems to be considerably lower than the cut wire and sheared fiber, which are at present mainly used in practice.

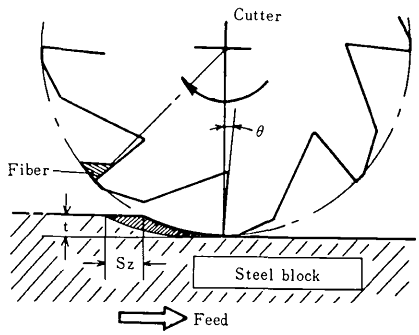


Fig. 2　Schematic of the production principle

3. Experimental Procedure of Machined - off Fiber

A commercial milling machine(No.3, 5.5kw, arbor diameter− 1½') with a plain milling cutter(H.S.S., 100∅, z = 12) was employed for the fiber production from a mild steel block of 25mm width, which corresponds to the length of the fiber. Various machining conditions were used and the quality of the fibers was checked in each case. The cutting speed was kept constant (V= 22.6 m/min.) and the same cutting oil (JIS − 2 − 4 − B212) was

* Dept. of Mechanical Engineering and Naval Archtechture, Institute of Industrial Science, Univ. of Tokyo.

used in all cases.

4. Result

(1) Influence of the block material

From the preliminary cutting experiment, it is found that only low carbon steel is suitable for this method. Different kinds of low carbon steel block used are shown in Table.1. Among these, SS41 and quenched 0.08 % C steel result in the production of fiber with big undulations as shown in Fig. 3, and their strengths are also less than the other two. The cross sections of the cut fibers from different materials are compared in Fig. 4. In ductile group, the chips are compressed sufficiently to reduce the cross section while in the latter the cross section remains elongated. This indicates that the work material should be as ductile as possible from the view point of strength. The following results are for the normalized steel (0.08 % C) block.

Table 1 Effect of block material on the fiber properties

Block material \ Mechanical properties	Steel block		Steel fiber		
	T.S. [kg/mm²]	R.A. [%]	A [mm²]	T.L. [kg]	T.S. [kg/mm²]
SS41	43	69	0.27	12	44
0.08%C Water quenched	43	72	0.26	10	38
0.08%C Normalized	33	81	0.23	17	72
0.08%C Annealed	32	81	0.24	19	80

T.S.=Tensile strength, R.A.=Reduction of area, A=Area of cross section, T.L.=Tensile Load

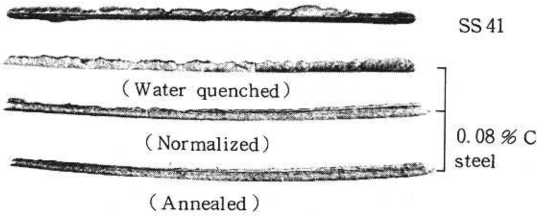


Fig.3 Effect of block material on the appearances of fiber

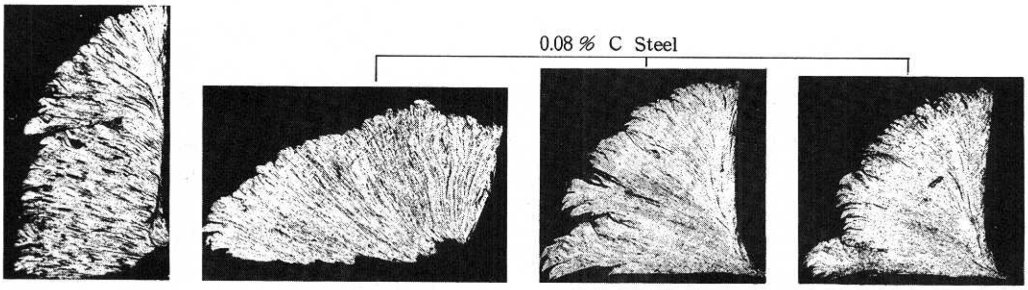


Fig. 4 Effect of block material on the cross-section geometry of fibers ($\theta = 0°$)

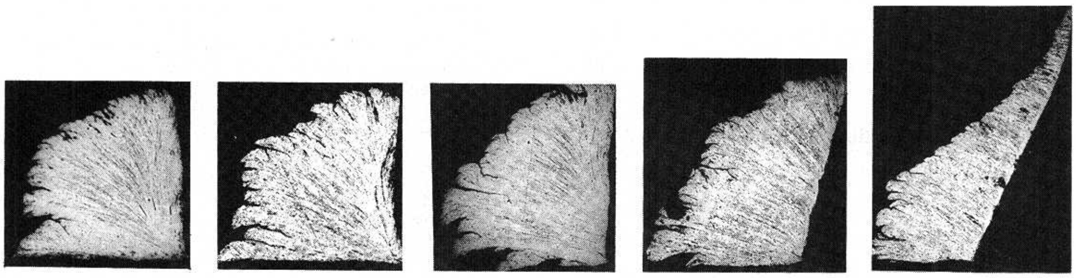


Fig. 5 Effect of rake angle on the cross-section geometry of fiberes (Normarized)

(2) Influence of the cutter geometry

The effect of rake angle on the cross-sectional geometry of the fiber is shown in Fig. 5. By comparison, one can judge that the cross sections produced by 0 and −5° rake angles may be suitable for fiber. Further, the strength of these fibers are also examined and the result is produced in Fig. 6, where each point corresponds to an average of 30 fibers. From this result, it is clear that zero rake angle gives maximum strength and hence in further

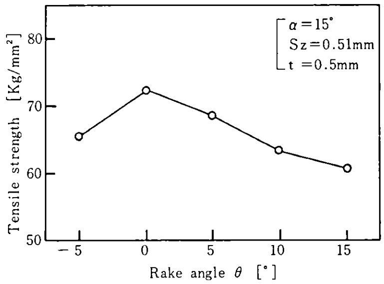
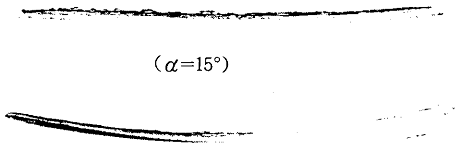


Fig. 6 Effect of rake angle on the fiber strength

Table 2 Effect of helix angle of the cutter on the fiber

Fiber property / Helix angle[°]	Area of cross section [mm²]	T.S. [kg/mm²]	Angle of twist [°/cm]
15	0.22	65	12
25	0.19	72	43

(θ=-5°, S_Z=0.51mm, t=0.5mm)



(α=15°)

(α=25°)

Fig. 7 Effect of helix angle on the appearances of fiber

work only zero rake is used.

The effect of the helix angle of the cutter is shown in Table 2. An increase in the helix angle increases the twist angle of the fiber and its longitudinal curvature as shown in Fig.7. The twisting of the fiber seems to be advantageous in the reinforcement of the concrete.

(3) **Influence of the cutting condition**

The relation between feed, depth of cut and the resulting area of cross section of the fiber is shown in Fig. 8. From this result, it is apparent that a particular area of cross section required may be easily obtained by selecting a suitable feed and the depth of cut. Fig. 9 and 10 show the effects of feed and the depth of cut respectively on the strength of the fiber produced. In both the cases, the increase in the cross section results in the increase of strength per unit area.

(4) **Scattering in the fiber property**

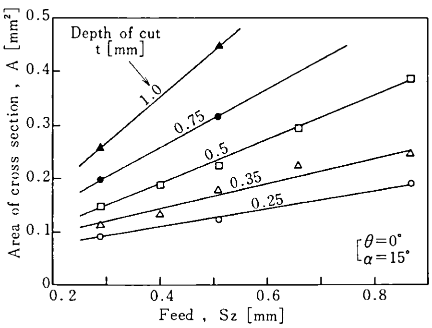


Fig. 8 Effect of cutting condition on the area of cross-section

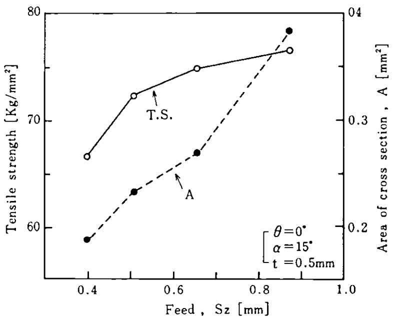


Fig. 9 Effect of feed on the strength of fiber

Table 3 Comparison of the properties of fibers produced by different methods

Property of fiber / Process classification		Area of cross section [mm²]	Tensile load [kg]	Tensile strength [kg/mm²]
Machined off fiber*		0.25	18	71
Cut wire		0.10	23	235
Sheared fiber	I	0.11	9	79
	II	0.26	14	54
	III	0.25	12	46
Melt extracted fiber	I	0.26	14	53
	II	0.27	6	21
	III	0.23	6	27
	IV	0.14	5	40

(* θ=0°, S_Z=0.51mm, t=0.55mm)

The fibers mentioned above were produced by up-cut milling. In case of down-cut milling, a big scattering in the area of cross section is observed. Even in case of up-cut milling, the scattering as shown in Fig. 11 is rather bigger

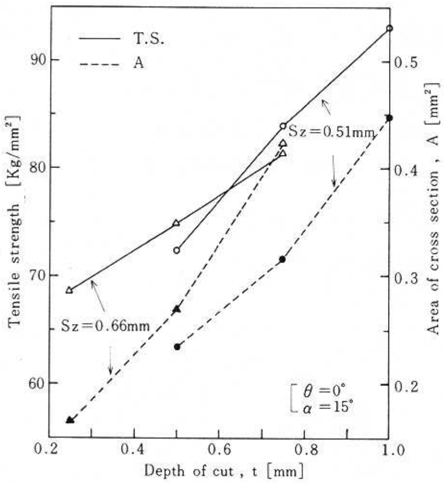


Fig. 10 Effect of the depth of cut on the strength of fiber

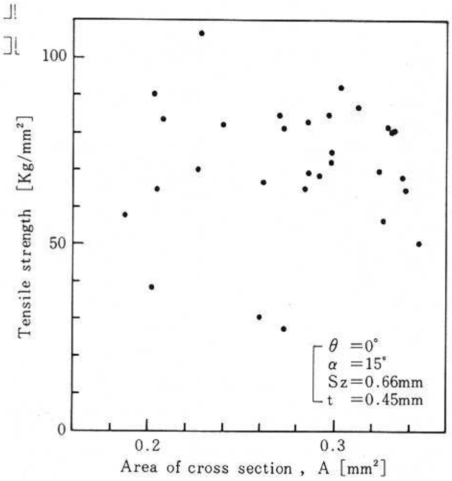


Fig. 11 Scattering in the fiber property

formed on the block surface after the former cutting. This scattering in property, however, can be reduced by using specially designed machine for the purpose. In addition, down-cut is also possible to use.

(5) Comparison with existing fiber

Fibers from three different kinds of existing processes are shown in Fig.12 and their strengths are given in Table 3. The strength of machined fiber when compared with others is not inferior. On the other hand, this fiber cannot bent to sharp angle because of severe work hardening at the time of machine.

5. Conclusion

It is confirmed from these results that the production of steel fibers by machining is possible. And the required fiber property can be obtained by selecting a suitable machining condition and material. The next step would be to check the fiber properties with concrete in future.

Acknowledgement

This work was started with the suggestions and encouragement given by Prof. Kazusuke Kobayashi and supported by the 1975 research fund of the Institute of Industrial Science, University of Tokyo. The authors would like to extend their thanks to Mr. Yoshiaki Aoyama for his assistance in this experiment. (Manuscript received, September 7. 1976)

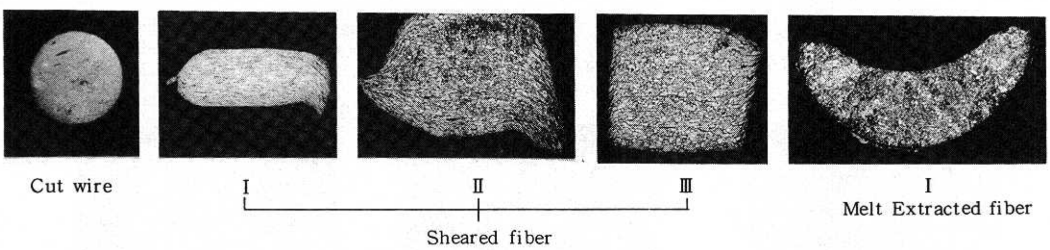


Fig. 12 Comparison of cross sections of fiber produced by various methods

than the cut wire and sheared fibers. This scattering comes from the tool and machine vibration due to lack of rigidity and also from the waves

Reference

(1) K. Kobayashi, Fiber Reinforced Concrete, Journal of concrete technology, 13, 8, Aug. 1975, p.21−28.