CNTs/Al_2O_3/A356 하이브리드 복합소재의 압출성형 연구
Hot Extrusion of A356 Aluminum Metal Matrix Composite with CNTs/Al_2O_3 Hybrid Reinforcements

*,#김현호 [1], 강충길 [2]

*,# H. H. Kim[1](gn777me@pusan.ac.kr), C. G. Kang[2]

[1] 부산대학교 정밀가공시스템, [2] 부산대학교 기계공학부

Key words : Carbon nanotubes (CNTs), Al_2O_3 fiber, Metal matrix composite (MMC), Extrusion

1. Introduction

Since 1970, carbon fiber reinforcement has been extensively used in a wide array of applications in the automotive, aerospace, and military fields. Carbon nanotubes (CNTs) were discovered by Iijima [1] in 1991. Experiments have shown that CNTs have superior mechanical properties over carbon fibers; e.g., stiffness values up to 1000 GPa, strength on the order of 100 GPa [2-6], and thermal conductivity of up to 6000 Wm-1K-1.

A review of the literature shows that only limited studies have been carried out on hybrid metal matrix composites (MMCs) using nano/micro-sized reinforcements. S. C. Okumus et al. [7] studied the thermal properties of Al-Si/SiC/graphite hybrid MMCs fabricated by squeeze casting. Z. M. Du et al. [8] evaluated wear-resisting properties of Al_2O_3/Sic/Al hybrid composites. No systematic attempt has yet been made to study the effects of the hybridization of CNTs and Al_2O_3sf on the mechanical properties of aluminum-based composites, particularly by the infiltration method. Moreover, the mechanical change and workability by secondary forming of Al_2O_3/CNTs/A356, has not been reported yet. Most of the industrial parts were followed by additional processing such as compression, extrusion or machining. Therefore, the secondary formability of hybrid reinforcements composites are should be investigated also in order to reduce trial and error. The goal of this study is to develop and characterize the CNTs/Al_2O_{3sf} preform-based aluminum hybrid composites after extrusion process.

2. Experimental

For extrusion process, hybrid reinforcements MMCs, fabricated by infiltration method , were used. High temperature extrusions were conducted using an MTS testing machine (MTS 810). The extrusion specimens with a diameter of 10 mm and height of 20 mm were used. The extrusion ratio and angle is 2.04 and 45 degree, respectively. Extrusion ratio R was defined as follows.

$$R = A0/Af \qquad (1)$$

Where A0 and Af are the billet area before and after hot extrusion, respectively.

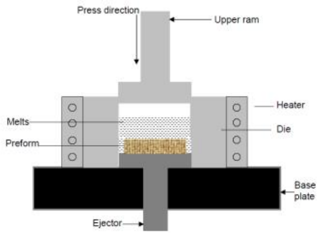
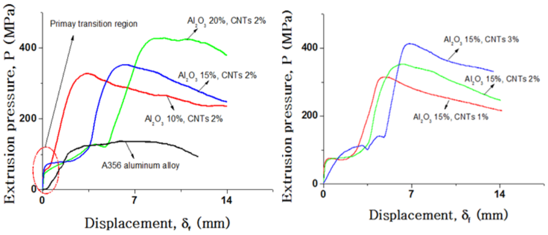


Fig. 1 Schematic diagram of infiltration method (Mold temperature: 400 ^oC, Pouring temperature of melt 700 ^oC, Infiltration pressure: 3MPa, Holding time: 30 seconds)

All process parameters were fixed to minimize the variables except for CNTs composition factors. A boron nitride lubricant was used for both preventing of sticking and lubricating. Figure 1 shows the schematic diagram extrusion process. The extrusion processes were conducted in hot chamber. Before forming, all specimens were kept in hot chamber for minimum 30 minutes for heating of specimen. The dies and ram were heated in chamber also for preventing a heat transferring between dies and hybrid material billet.

3. Results and Discussion

Figure 2 shows the displacement-extrusion pressure curve according to composition of reinforcements in hybrid MMCs. The overall curve trend, extrusion pressure was increased with increasing Al_2O_3 and CNTs fraction as shown Fig. 2 (a) and (b). Especially, the required pressure for extrusion process of hybrid material is significantly higher than A356 aluminum alloy as shown Fig. 8 (a). The deformation resistance of hybrid material is over two times that of A356 original material due to strengthening effect by Al_2O_3/CNTs reinforcements. Another unusual trend that primary transition region was founded in the hybrid material pressure-displacement curve as shown Fig. 2 (a)-(b). Al_2O_3/CNTs can lead to strengthening if they are well infiltrated with matrix and there is sufficient stress transfer to reinforcements. The first slope that in primary transition region as shown Fig. 2 (a), corresponded to reinforcement's dominant Youngs modulus (Ef) and the second slope corresponded to matrix dominant Youngs modulus (Em). Typically, elongations of reinforcements (below 4%) were limited as compare with A356 aluminum matrix elongation (over 10%). Therefore, if over the limited strain about 4%, reinforcements fracture or interfacial fracture will be happened. In addition, excessive CNTs content can cause unwanted effects such as the formation of carbide (Al_2MgC_2) .



(a) Al_2O_3 parameters (b) CNTs parameters

Fig. 2 Displacement-pressure curve of MMCs

4. Conclusion

Aluminum-based hybrid composites were fabricated using the infiltration method and characterized using hot extrusion and hardness tests. Based on our results, the following conclusions are drawn. The required pressure for extrusion process of hybrid material is significantly higher than A356 aluminum alloy. The deformation resistance of hybrid material is over two times that of A356 original material due to strengthening effect by Al_2O_3/CNTs reinforcements. In addition, unusual trend that primary transition region was founded in the hybrid material pressure-displacement curve due to affecting of hybrid reinforcements.

Acknowledgement

This work was supported by the Korea Research Foundation (KRF) grant funded by the Korea government (MEST) (grant number 2012-0001204) and the human resources development of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government, Ministry of Knowledge Economy (No.20104010100540)

References

[1] S. IIjima, Nature 354 (1991) 56-58.
[2] M. M. J. Treacy, T. W. Ebbesen, J. M. Gibson, Nature 381 (1996) 678-680.
[3] A Krishnan, E. Dujardin, T. W. Ebbesen, P. N. Yianilos, M. M. J. Treacy, Phys. Rev. B 58B (20) (1998) 14013-14019.
[4] E. W. Wong, P. E. Sheehan, C. M. Lieber, Science 277 (1997) 1971-1974.
[5] M. F. Yu, B. S. Files, S. Arepalli, R. S. Ruoff, Phys. Rev.Lett. 84 (24) (2000) 5552-5555.
[6] M. F. Yu, O. Laurie, M. J. Dyer, K. Moloni, T. F. Kelly, R. S.Ruoff, Science 287 (2000) 637-640.
[7] S. C. Okumus, S. Aslan, R. Karslioglu, D. Gultekin, H. Akbulut, Mater. Sci. 18(2012) 341-346.
[8] Z.M. Du, J.P. Li, J.Mater. Process. Technol. 151 (2004) 298–301.