Development of Mass-production Technique of the ATLAS Thin Gap Chambers in Japan

INTRODUCTION

The Thin Gap Chambers (TGCs) are used for the muon trigger system in the end-cap regions of the ATLAS detector. The TGC is characteristic of fast signal response (99% of output signals are within 25 ns) for charged particles. This characteristic suits the muon trigger detector of the LHC, which is required to identify the bunch crossing of 40 MHz. Each TGC has a trapezoidal shape, whose dimensions depend on its location. A typical size is 1.3 m (longer base) x 1.3 m (height). As the anode-cathode distance is small, 1.4 mm (Fig. 1), chamber flatness is essential to achieve a uniform gas gain over the chamber. A TGC with one gas gap is called “singlet.” Two singlets or three singlets glued together with honeycomb-panel in-between are called “doublet” or “triplet,” respectively.

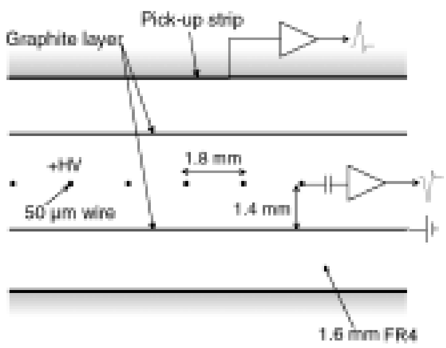

Figure 1: Schematic view of cross section of the TGC.

From March 1998 to the end of 2000, material studies and developments of production procedures of the TGCs were performed at KEK The series production of the TGCs started in January 2001. We have to produce about 1100 TGCs. Our target is to complete the production by the end of 2004. The KEK production facility was so designed that two TGCs could be produced per day by about twelve workers with three physicists as supervisors.

PRODUCTION PROCEDURES

The TGC production procedures can be roughly divided into nine stages: checking quality of materials, graphite spraying, FR4 frame gluing, wire winding, singlet closing, sealing around the singlet, making doublet or triplet module, mounting read-out boards, assembly of CO2-gas channels around the module. All procedures except the graphite spraying are performed in parallel. Most important points to keep high quality in the TGC production are the anode wire spacing (1.8mm) for the uniform time response, the flatness of both anode and cathode planes to keep uniform gas gain, and as a matter of course the cleanness of the detection gas volume to avoid discharge.

The 50μm anode wire is strung by using an auto-winding machine, which could control the wire pitch with 1μm precision and the wire tension within 3 % of designed value.

Quality of closing singlets and making doublet-modules (or triplet modules) affects the uniformity of the detection efficiency of TGCs. We have adopted the vacuum-press technique for the gluing since it can apply uniform force on the whole TGC surfaces.

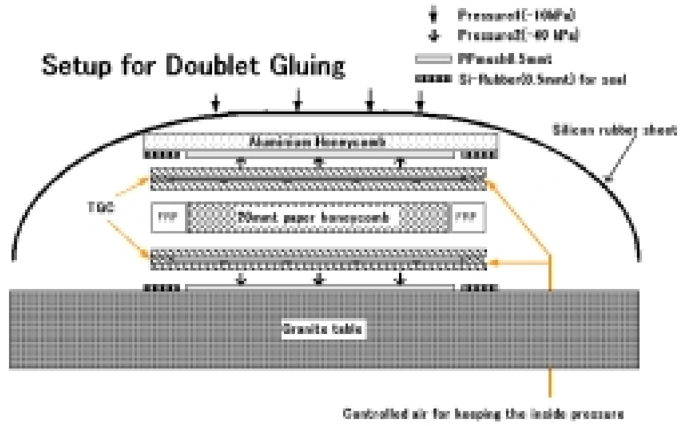

Figure 2: Schematic view of a setup of the doublet gluing process.

A dedicated air control system was developed for assembling the doublet (or triplet). Fig.2 schematically shows the doublet assembly. Two singlets are kept flat by sucking chambers (-40kPa Gauge: Pressure2) to either a granite table (bottom) or an aluminum honeycomb-panel (top). A 20-mm-thick paper honeycomb and module support frames are sandwiched by these two singlets and glued together at one time. To apply uniform force onto the TGC surface, all the sub-units of the doublet are covered by a silicon rubber sheet inside of which is decompressed to –10kPa (Pressure1). The gas volume of the singlets is slightly over-pressured (150Pa) with clean air from gas inlets as counter force against the force on the rubber sheet.

At the singlet closing, we use a similar air control system. As shown in Fig.3, we can control the uniformity of the gas gaps.

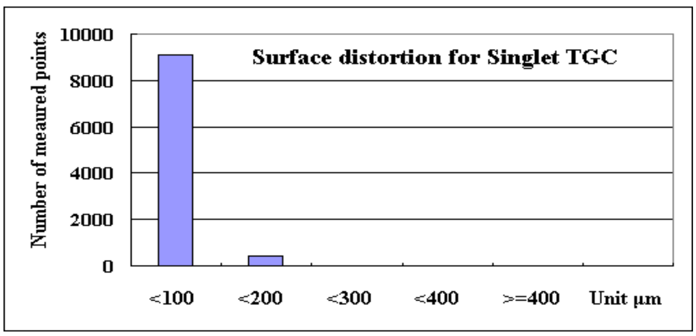

Figure 3: Surface flatness distribution of singlet TGCs.

GLUING METHOD AND SOLDER

At the start of the TGC test productions, it was the most important subject to establish gluing method. Especially, quality control of epoxy resin and way to apply the adhesive on FR4 parts are crucial. If the epoxy resin is forced out from glued frames to the inside of the gas-gap, discharge can occur along the squeezed-out epoxy and sometimes the insulation is broken by the surface discharge. Moreover, the temperature of the epoxy resin is closely correlated with its amount as shown in Fig.4. Cure time and viscosity of the epoxy could be changed by the amount applied to parts. To solve these problems, a screen-printing method is adopted. We use a poly-arylate mesh screen (145 meshes per inch) to apply the epoxy to the wire-supports and frames. Thickness and width of the adhesive can be uniformly adjusted. The screen is tough enough for multi-use and the residual resin can be easily removed by water.

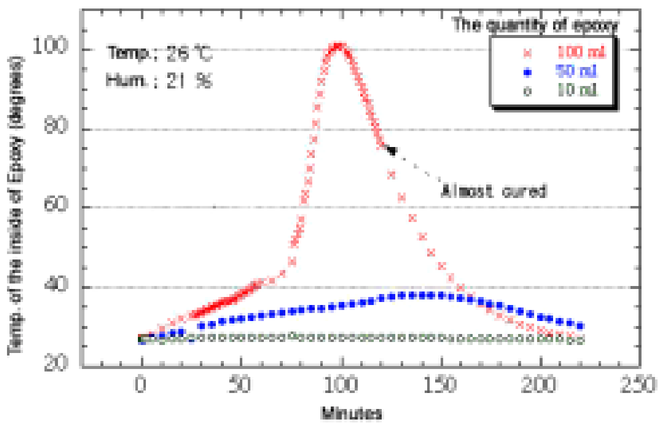

Figure 4: Time dependence of the internal temperature of the epoxy for several epoxy quantities.

As a solder for the anode wire, we use tin-zinc (80/20) solder. It can hold the wire against higher tension than normally used tin-lead based solder. Since residual of the solder flux causes the ion-migration and weaken the strength, we choose a water-soluble flux. We can clean the soldered region with dematerialized water by applying the supersonic wave.

DETECTOR PERFORMANCE

As a final quality check for all the produced TGCs, we measure the uniformity of detection efficiency using a dedicated test bench at Kobe University. We set the operating point of the TGC just above the shoulder of the HV curve to emphasize the non-uniformity if it exists while keeping high detection efficiency for the normal TGC. Up to now we have tested 100 triplets, or equivalently 300 singlet TGCs. The Kobe cosmic ray test bench has an ability to test 24 singlets at a time.

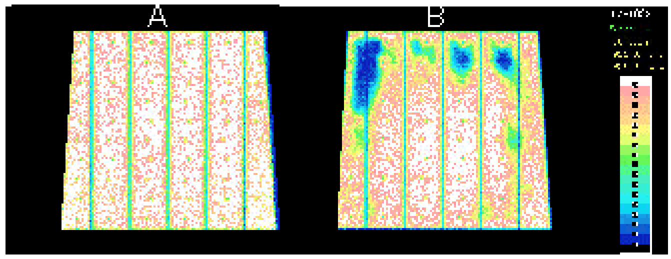

Figure 5: Examples of detection efficiency maps. White dots show the region better than 99%, dark blue less than 60%. (A) Typical chamber showing good uniformity. Five vertical lines correspond to the wire supports. Small zigzag points in-between correspond to button spacers. (B) Bad chamber having several inefficient regions.

Position dependence of the efficiency was measured with a granularity of 5mm-by-5mm. It takes about two weeks for data-taking to get one full map. Fig.5 shows two examples of the detection efficiency maps. Fig.5A is a typical example. Excluding the wire-supports and spacers, the efficiency is achieved to be better than 99%. Fig.5B is a sample of a few worst chambers. There are ten chambers showing similar non-uniformity in total. These chambers were produced in relatively early period of the production. A suspected reason is a gluing-off or applying thicker glue during the triplet assembly. It could happen due to the failure of the viscosity control of the epoxy adhesive.

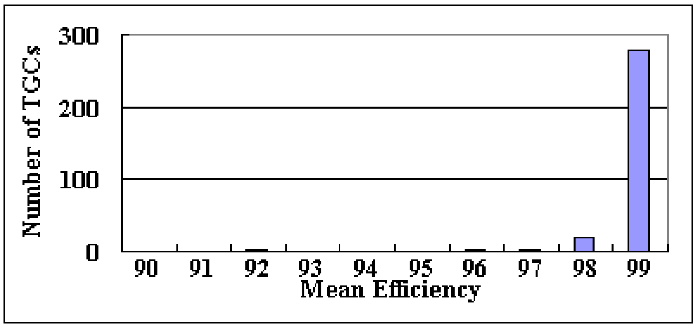

Figure 6: Mean detection efficiency distribution for each chamber.

We summarize the mean detection efficiencies in Fig.6. There are 27 TGCs having less than 99% detection efficiency. Excluding the above-mentioned 10 TGCs with the epoxy problem, the rest of 17 TGCs show somehow poor quality. There is correlation between the non-uniformity or lower efficiency and the flatness of the triplet, but little correlation to the flatness of the singlet. It indicates that the flatness of singlet can be damaged at the doublet (or triplet) assembly. We still continue studying the problems and try to reduce the number of poor-performance TGCs. All the other produced TGCs have good uniformity with high detection efficiency.