Design and development of anti-G suit: Critical considerations

Wg Cdr VN Jha, Wg Cdr PS Sodhi, Dr Lazar Mathew

Defence Bioengineering and Electromedical Laboratory, PB No. 9326, C. V. Raman Nagar, Bangalore 560 093, India

In experience in the design and development of the cut-away type of anti-G suit certain critical areas need careful consideration. There is scope to increase the least cylindrical configuration in a conventional anti-G suit in order to increase the pressure contact area. Certain aspects of suit design are considered critical for optimum performance. These include the inflation characteristics of the suit, the outer garment fabric, stitches, seams and joints, zip, lacing, etc. With increase in suit pressure, the slide fasteners become vulnerable along their stitch lines. Pockets stitched on the outer garment can nullify all the advantages unless specific care is taken.

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New-generation combat aircraft have the capability to impose accelerations far in excess of the tolerance level of a pilot. Hence, to enable him to withstand such high accelerations, various changes are being incorporated in the existing anti-G suits to make them more effective. These suits, along with anti-G straining manœuvre (AGSM) and G-induced pressure breathing performed optimally, can provide a desired protection against high sustained +Gz. The anti-G suit increases tolerance by two means. Firstly, it applies counter-pressure over the contact surface of the body to prevent pooling of blood in the capacitance vessels, thus increasing the venous return. Secondly, counter-pressure over the abdomen prevents the descent of the diaphragm and the consequent increase in heart-to-brain distance [1].

Protection given by an anti-G suit is a result of the following factors:

(a) The pressure contact area of suit.
(b) The pressure applied.
(c) The suit design.

The pressure contact area

The protection given by an anti-G suit is directly proportional to the pressure contact area. The contact area in a cut-away suit is limited to only *the least cylindrical configuration* of the suit because of its inflation characteristics, which in turn, applies tension on the outer fabric. The least cylindrical configuration in a cut-away type of anti-G suit measures vertically from the lowest cut margins on the thigh and calf flaps to the uppermost cut margins on the respective flaps. Thus, in a conventional cut-away type of suit as much as 30% of the lower limbs are practically without counter-pressure. Hence, there is a scope for increasing the pressure contact surface area by various means. A full-coverage anti-G suit, however, will be the final outcome. With increase in the surface area of the suit, the bladder dimension will also have to be increased for effective inflation, which in turn will increase the bladder volume. Hence, compatibility of such suits with the type of anti-G valve available with the aircraft has to be checked whether it can be inflated in less than 3 s to provide an adequate counter-pressure. If the increase in the bladder volume is of the order that it increases the inflation time to more than 3 s, it will be undesirable to have such a suit.

The suit pressure

The effect of suit pressure on the G-tolerance has been studied and various pressure schedules

are followed in different aircraft. The commonest pressure schedule followed is that the suit inflation starts after +2 Gz and increase in the suit pressure is effected at a rate of 1–1.2 psi per additional +Gz. A minor deviation in pressure schedule is incorporated for exposure to very high +G forces. Developmental work is in progress to incorporate an electronic sensor for very high onset rates and effect the suit inflation accordingly. For the bladder pressure to be transmitted to the skin, the following considerations are critical:

(a) Inflation of bladders must cause adequate tension of the outer fabric.

(b) Outer fabric should be least stretchable.

(c) Bulge of inflation should mostly be inwards.

(d) Inner fabric should be loose enough so as to allow inward bulge for an effective counter-pressure.

(e) Seams of the bladder joint are to be incorporated inside the fabric in such a way that it occupies the least space and allows adequate inflation of the bladders.

(f) Provision of height tapes in the bladder limits the bulge in its cross-section.

(g) Provision of an inner reinforcement tape will make the joint strong to withstand the requisite pressure.

(h) Adhesive strength *per se* should be adequate to withstand the pressure inside the bladders.

(i) Stitching on outer fabric will make it vulnerable to outward inflation due to warp or weftwise squeeze.

The suit design

Various materials for the bladder have been tried out. Some of them are polyurethane/polyamide 66 sealable with a single-layer coating, neoprene-coated fabric, natural rubber, etc. Each of them has its own advantages and disadvantages. A double-sided neoprene-coated nylon fabric developed indigenously has light weight (300 gm/m^2), requisite strength (80 kg), long shelf-life (3–5 yr), a good adhesive surface along with an anti-crack and anti-crease property. The material has withstood the environmental and pressure tests (22 psi) satisfactorily and is considered a good indigenous material for enhanced anti-G suit.

Other considerations which are critical for the optimal function of an anti-G suit concern the zips and the lacing. Heavy-duty metallic/synthetic zips are usually strong enough to withstand the requisite pressure. But the stitching pattern is an important variable which determines the pressure at a particular point of the zip. The stitching thread has to match the specification to withstand the pressure. Any break in the integrity of the zip can nullify all the advantages so gained. The lacing of concealed pattern must tighten smoothly and uniformly all along during its adjustment. A usual problem is a 'loose lace in the intermediate parallels', which makes the suit a loose fit during inflight inflation.

Therefore, it is evident that to achieve good anti-G protection certain considerations are important in the design and development of modern anti-G suits.

References

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