THE ALTERNATING SURFACE SEGMENTED LAP JOINT:

A DESIGN FOR THIN HIGHLY LOADED JOINTS

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ABSTRACT

The combination of thin airfoil sections and high aerodynamic loads on many wind tunnel models presents a major problem for attachment of flap elements. Conventional methods of attaching fixed control elements such as lap and tongue-in-groove joints are not rigid enough to provide surface continuity required in high Reynolds number research. For the extreme cases, the solution has been to fabricate separate wings for each flap setting with the flap element being an integral part of the wing.

This paper presents an attractive solution to this problem, the "Alternating Surface Segmented Lap Joint." This joint provides increased rigidity and lower stress levels than conventional joints. Additionally, attachment fastener loading is low and the joint can be designed to accommodate high shear levels due to bending without the use of dowel pins.

INTRODUCTION

One of the most formidable tasks facing a designer of high-performance aircraft wind tunnel models is the attachment of flap elements to thin wings. The simplest approach is to utilize a lap joint. This joint is easy to fabricate and assemble, and requires little design input. Unfortunately, the lap joint is often structurally inadequate. The reductions in section modulus of the joined elements lead to high stress levels and distortions. Additionally, the loading may dictate use of a fastener size which cannot be accommodated with the thickness available.

A second choice of designers is the tongue-in-groove joint. This joint requires precision fabrication but provides increased stiffness. Fasteners are not as heavily loaded, but the thickness available for the fastener head is reduced significantly.

A joint concept has been developed for attachment of the trailing-edge flap to the thin, highly loaded wing of the Pathfinder II model to be tested in the National Transonic Facility. This concept promises to be a viable design for situations where a conventional configuration is inadequate.

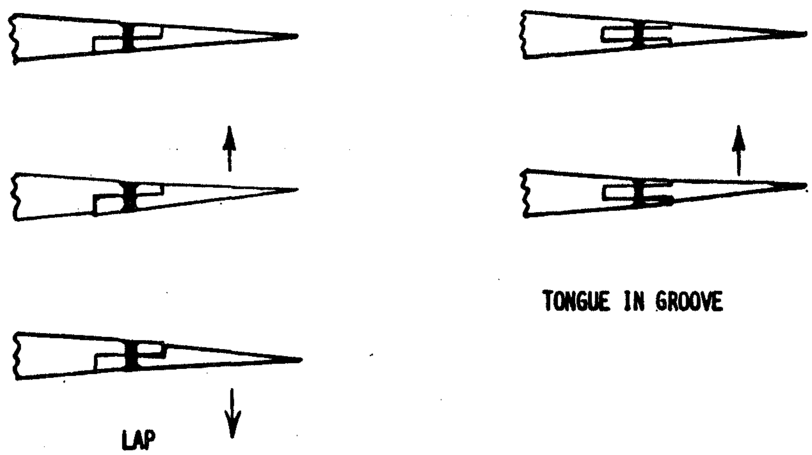
NTF CHARACTERISTICS IMPACT MODEL DESIGN

- O HIGH REYNOLDS NUMBER RESEARCH
  - o HIGH-QUALITY SURFACES
  - o MINIMUM SURFACE DISCONTINUITIES
- O HIGH DYNAMIC PRESSURES-HIGH MODEL LOADS
  - o HIGH DISTORTIONS
  - o JOINT DISCONTINUITIES
  - o HIGH BENDING STRESSES
  - o HIGH SHEAR LOADS

The National Transonic Facility (NTF) at Langley Research Center, because of its unique capabilities, imposes greater structural demands upon wind tunnel models than conventional wind tunnels. The NTF has the capability to operate at higher Reynolds numbers than any other research facility in the free world. To the model designer and fabricator, the significant consequence of this capability is the requirement to provide higher quality aerodynamic surfaces than would be required for the conventional wind tunnel model. This requirement is fulfilled by better surface finish, greater contour fidelity, and minimized distortion due to aerodynamic loading.

The capability to operate at high dynamic pressures (required for achievement of high Reynolds numbers) works against the quest to minimize surface distortion. The area most directly impacted by the requirement of minimized distortion combined with high aerodynamic loading is the attachment of flaps to thin wings.

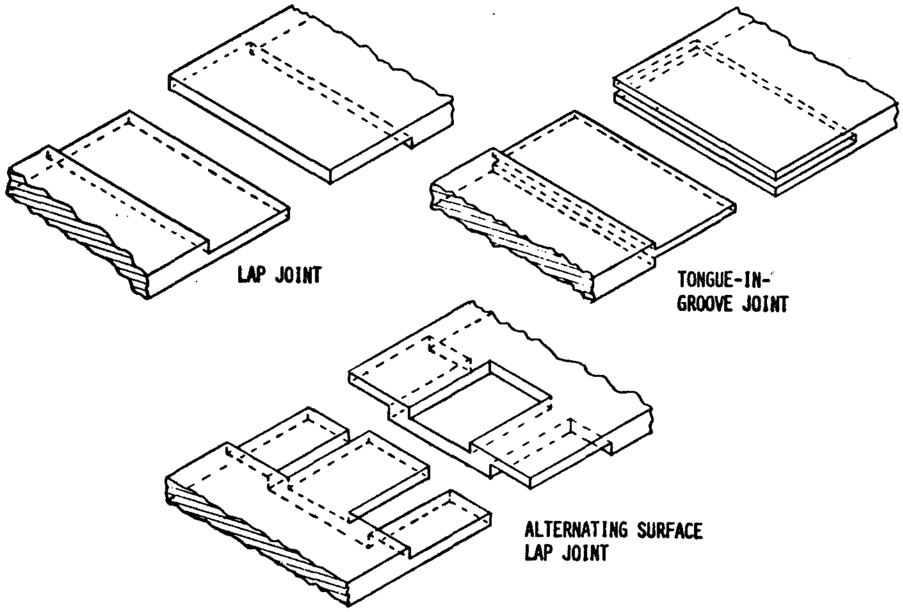
CONVENTIONAL JOINT DISTORTION TENDENCIES



Examining the distortion tendencies of the typical lap joint as applied to a model wing's trailing-edge flap attachment reveals the potential for surface steps at the wing-flap interface. With a positive load on the flap, the upper joint element tends to deform as a cantilever beam forming a concave upper surface. The lower element aft of the fasteners deforms to match the curvature of the upper element. Forward of the fasteners, however, the lower element tends to maintain its original geometry, thus departing from the mating surface and creating a forward facing step on the lower surface. With reversed loading, the aft portion of the lower element bends while the aft portion of the upper element remains straight, thus creating an aft facing step. It is also worth noting that joint separation is resisted by tensile forces in the fasteners.

The tongue-in-groove joint adds stiffness to the portion of the joint being bent and consequently has less departure from the original contour than the lap joint. The aft portion of the flap element is assisted by the aft portion of the upper wing element in resisting distortion caused by positive loading. In this instance, an aft facing step is created on the lower surface. With reversed loading the end result is an aft facing step on the upper surface. The fasteners are subjected to tensile loading to minimize separation of the female element on the side opposite the loading direction.

COMPARISON: NEW DESIGN VERSUS CONVENTIONAL DESIGN



Comparing the stiffness of the two conventional joints, there is a marked decrease in the section modulus at both ends of the lap joint and at one end of the tongue-in-groove joint. Each area of marked section modulus decrease results in increased rate of distortion and an increased stress level.

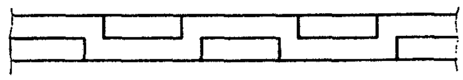
The alternating surface segmented lap joint combines features of both conventional joints. By appearance, the simplest half can be described as a series of lap joint elements which alternate from one surface to the other. The section modulus at the joint interface on this half has the element thickness as the lap joint elements and the male portion of the tongue-in-groove joint. The section modulus is greater than either of the conventional joints by virtue of the displacement of the segments about the neutral axis. The mating half has essentially the same geometry but the individual segments are joined resulting in a slightly higher section modulus. As with the tongue-in-groove joint, fasteners would be utilized to minimize separation from the mating surface of the segment on the surface opposite the loading direction.

SHEAR LOADING COMPARISONS

LAP

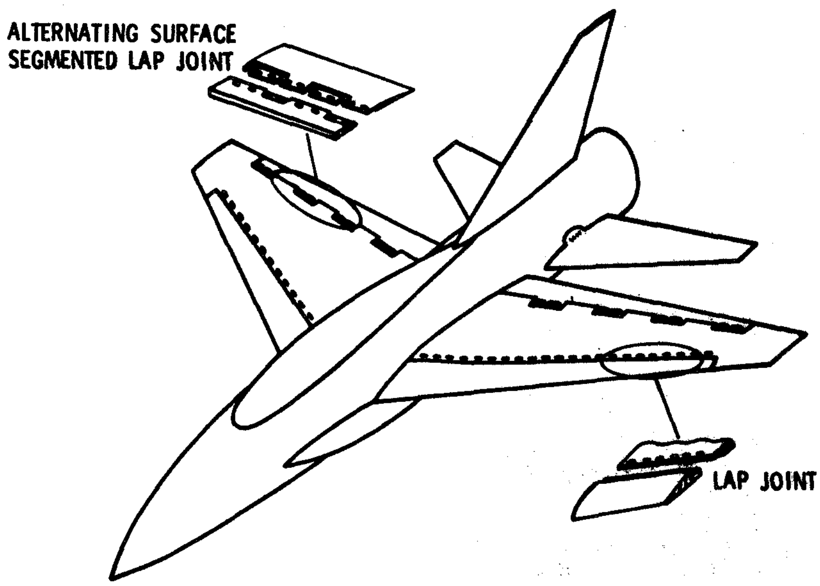
TONGUE IN GROOVE

ALTERNATING SURFACE SEGMENTED LAP



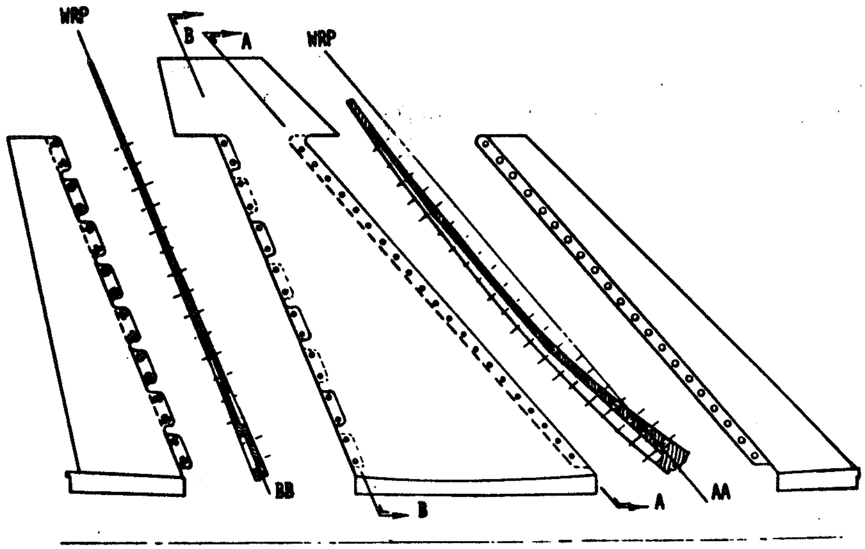
A major consideration in flap element attachment is the shear loading due to spanwise bending. The lap joint relies on fasteners in single shear to resist the shear load. The advantage enjoyed by the tongue-in-groove joint of having the fasteners in double shear is offset by the limitations imposed by the limited bearing area. For both joints, the fastener size is restricted by the meager joint thickness and the necessity of having the head below the aerodynamic surface. The alternating surface segmented lap joint is not dependent upon fasteners to carry the shear loads. The joint segments themselves can act as shear ties provided that tolerances are controlled to maintain adequate contact between the sides of the individual segments and the mating recesses.

PATHFINDER II FLAP ATTACHMENTS



The alternating surface segmented lap joint was developed and will be used for attachment of the trailing-edge flap to the wing of the initial configuration of the first high-performance fighter model to be designed and fabricated for testing in the National Transonic Facility. This generic model, designatd the Pathfinder II, features the capability of testing several aerodynamic configurations. The forebody, strakes, canopy, lower fuselage, wings, and stabilizers are all replacable, allowing incorporation of swept wings, delta wings, forward swept wings, and modified area distributions.

NTF PATHFINDER II WING



The Pathfinder II wing is thin (4% t/c) and twisted. The thickness distribution was such that a conventional lap joint was suitable for the leading-edge attachment, although the wing twist dictated that the mating surfaces had to consist of three inclined planes. The severity of the problem due to thickness of the trailing-edge flap attachment is illustrated in the drawing above. The airfoil thickness in the region for this joint ranges from a quarter of an inch at the root to less than a tenth of an inch at the tip.

A proof-of-concept specimen which will duplicate the wing geometry and trailing-edge flap attachment is being fabricated at this time. This test article will be subjected to thermal cycling between room and cryogenic temperatures, static loading, and dynamic loading at cryogenic temperatures to validate the design before final processing of the wing tunnel model component.

CONCLUSIONS

THE ALTERNATING SURFACE

SEGMENTED LAP JOINT OFFERS:

- O INCREASED STIFFNESS
- O DECREASED STRESS LEVELS
- O REDUCED FASTENER LOADS
- O ELIMINATION OF SHEAR PINS
- O MODERATE COST

In conclusion, a unique joint configuration has been developed which offers a more efficient method of attaching thin highly loaded members. This joint features increased stiffness and reduced stress levels when compared to conventional lap and tongue-in-groove joints. The joint also reduces the tendency of mating elements to separate under loading thus reducing the need for fasteners. The joint elements themselves provide shear ties thus eliminating the need for shear pins. The manufacturing cost should be similar to that associated with manufacture of precision tongue-in-groove joints.

BIBLIOGRAPHY

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