Factors affecting the selection of suitable groove geometry

This chapter describes the factors affecting the selection of suitable groove geometry for edge preparation and influence of welding parameters on weld bead geometry. Additional design aspects of the weld joints have also been presented.

Keywords: Selecting groove geometry, fillet weld, bead weld, dilution, stress concentration, plug weld, weld bead geometry

24.1 Factors affecting selection of suitable groove geometry

Selection of a particular type of groove geometry is influenced by the compromise of two main factors a) machining cost to obtain desired groove geometry and b) cost of weld metal (on the basis of volume) need to be deposited, besides other factors such as welding speed, accessibility of groove for depositing the weld metal, residual stress and distortion control requirement.

U and J groove geometries are more economical (than V and bevel grooves) in terms of volume of weld metal to be deposited, and offer less distortion and residual stress related problems besides higher welding speed but these groove geometries suffer from difficulty in machining and poor accessibility of heat sources to the root of groove for achieving desired penetration and fusion of the faying surfaces. On contrary V and bevel groove geometries can be easily and economically produced by machining or flame cutting besides providing good accessibility for applying heat up to root of groove. However, these groove geometries need comparatively more volume of weld metal and so these cause more residual stress and distortion related problems than U and J groove geometries.

Square groove geometry does not need edge preparation except making edges clear and square, but this geometry can be used only up to 10 mm plate thickness. However, this limit can vary significantly depending upon the penetration capability of welding process and welding parameters. Square groove is usually not used for higher thicknesses (above 10 mm) mainly due to difficulties associated with poor penetration, poor accessibility of root and lack of fusion tendency at the root side of the weld. Therefore, it is primarily used for welding of thin sheets by TIG/MIG welding or thin plates by SAW.

Groove butt welds are mainly used for general purpose and critical applications where tensile and fatigue loading is expected during the service. Since butt groove geometry does not cause any stress localization (except those which are caused by poor weld geometry and weld defects) therefore stresses developing in weld joints due to external loading largely become uniform across the section of the weld hence fatigue crack nucleation and subsequent propagation tendency are significantly lowered in butt groove weld as compared with fillet and other type of welds.

24.2 Fillet weld

Fillet welds are used for producing lap joint, edge joint, and T joint more commonly for non-critical applications. Generally, these do not require any edge preparation, hence these are more economical to produce especially in case of comparatively thin plates as compared to groove weld. However, to have better penetration sometimes groove plus fillet weld combination is also used. An increase in size of weld (throat thickness and leg length of the weld) when welding thick plates increases the volume of weld metal in case of fillet welds significantly; hence fillet welds become uneconomical for large size weld compared to groove weld. Due to inherent nature of fillet weld geometry, stresses are localized and concentrated near the toe of the weld which frequently becomes an easy site for nucleation and growth of tensile/fatigue cracks. The stress concentration in fillet weld near the toe of the weld occurs mainly due to abrupt change in load resisting cross sectional area from the base metal to weld zone. To reduce the adverse effect of stress localization, efforts are made to have as gradual transition/change as possible in load resisting cross sectional area from the base metal to weld either by controlled deposition of the weld metal using suitable weld parameters (so as to have as low weld bead angle as possible), and manipulation of molten weld metal while depositing the same or controlled removal of the weld metal by machining / grinding.

24.3 Bead weld

The bead weld is mainly used to put a layer of a good quality metal over the comparatively poor quality base metal so as to have functional surfaces of better characteristics such as improved hardness, wear and corrosion resistance. To reduce degradation in characteristics of weld bead of good quality materials during welding, it is important that inter-mixing of molten weld bead metal with fused base metal is as less as possible while ensuring good metallurgical bond between the bead weld and base metal. The inter-mixing of bead weld metal with base metal during welds is called dilution. Higher dilution leads to greater degradation in quality of weld joint. Better control over the dilution is achieved by reducing extent of melting of base metal using suitable welding procedure such preheating, welding parameter, welding process etc. For examples plasma transferred arc welding (PTAW) causes lesser dilution than SAW primarily due to difference in net heat input which is applied during welding in two cases. PTAW supplies lesser heat compared to other processes namely MIGW, SMAW and SAW. Bead welds are also used just to deposit the weld metal same as base metal so as to regain the lost dimensions. This process is called reclamation. The loss of dimensions of the functional surfaces can be due to variety of reasons such as wear, corrosion etc. These bead welds are subsequently machined out to get the desired dimensional accuracy and finish.

24.4 Plug welds

These welds are used for comparatively less critical applications. For developing plug weld first a through thickness slot (of circular/rectangular shape) is cut in one of plates and the same is placed over another plate to be welded then weld metal is deposited in the slot so that joint is formed by fusion of both bottom plate and edges of slot in upper plate.

24.5 Welding and weld bead geometry

For developing a fusion weld joint, it is necessary that molten metal from electrode/filler and base metal fuse and mix together properly. Heat of arc/flame must penetrate the base metal up to sufficient depth for proper melting of base metal and then mixing with fused filler/electrode metal to develop metallurgical weld joint. Heat generation in case of arc welding is determined by welding current, voltage and welding speed. An optimum value of all three parameters is needed for sound welding free from weld discontinuities.

24.5.1 Welding current

Low welding current results in less heat generation and hence increased chances of lack of fusion and poor penetration tendency besides too high reinforcement owing to poor fluidity of comparatively low temperature molten weld metal. On the other hand, too high welding current may lead to undercut in the weld joint hear the toe of the weld due to excessive melting of base metal and flattened weld bead besides increased tendency of weld metal to fall down during vertical, horizontal and overhead welding owing to high fluidity of weld meal caused by low viscosity and surface tension. Increase in welding current in general increases the depth of penetration/fusion. Therefore, an optimum value of welding current is important for producing sound weld joint.

24.5.2 Arc voltage

Similar to the welding current, an optimum arc voltage also plays a crucial role in the development of sound a weld as low arc voltage results in unstable arc which in turn results in poor weld bead geometry is obtained while to high voltage causes increased arc gap and wide weld bead and shallow penetration.

24.5.3 Welding speed

Welding speed influences both fusion of base metal and weld bead geometry. Low welding speed causes flatter and wider weld bead while excessively high welding speed reduces heat input which in turn lowers penetration & weld bead width and increases weld reinforcement and bead angle. Therefore, an optimum value of welding speed is needed for producing sound weld with proper penetration and weld bead geometry.

24.6 Design aspects of weld joint

Strength of weld joints is determined by not only the properties of weld metal but also characteristics of heat affected zone (HAZ) and weld bead geometry (due to stress concentration effect) as sometimes properties of HAZ are degraded to such an extent that they become even lower than weld metal due to increased a) softening of the heat affected zone and b) corrosion tendency of HAZ. Assuming that the effect of weld thermal cycle on properties of HAZ is negligible, suitable weld dimensions are obtained for a given loading conditions by weld joint design. Design of a weld joint mainly involves establishing the proper load resisting cross sectional area of the weld which includes throat thickness of the weld and length of the weld. In case of groove butt weld joints, throat thickness becomes equal to shortest length of the line passing across the weld (top to bottom) through the root of weld. Conversely, throat thickness becomes the minimum thickness of weld or thickness of thinner plate when joint is made between plates of different thicknesses. While in case of fillet welds, throat thickness is shortest length of line passing root of the weld and weld face. Any extra material (due to convexity of weld face) in weld does not contribute much towards load carrying capacity of the weld joint.

In practice, however, load carrying capacity of the weld is dictated not just by weld cross sectional area but also by properties of weld metal and HAZ and stress concentration effect induced by weld bead geometry and weld discontinuities under the static as well as fatigue loading conditions.

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