



 Research Article

Technology for Assembling, Welding and Machining Dissimilar-Steel Welded Components: From Selecting the Welding Process to Assigning Cutting Conditions by Zone

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ABSTRACT

This paper presents a systematic account of the manufacturing process for a precision component made from dissimilar steels 45 and 12Kh18N10T, from selecting the welding process and preparing the blanks to assigning zone-specific cutting conditions for subsequent machining. It classifies welding methods for dissimilar metals and justifies the selection of gas tungsten arc welding (TIG). The assembly and fixturing procedure is described, including a controlled process gap and a defined tack-welding sequence. The structure of the multipass weld and the procedure for depositing its layers are considered. In view of the differences in the mechanical properties of the materials, a differentiated finishing regime is justified for the component's internal surface across three zones: steel 45, the weld transition zone and steel 12Kh18N10T.

KEYWORDS

Dissimilar steels, gas tungsten arc welding, blank assembly, multipass welding, cutting conditions, machining.

1. INTRODUCTION

The manufacture of precision components from dissimilar steels is a multistage process, and the quality of each stage directly affects the final result [1, 4]. Errors made when selecting the welding process or preparing the blanks cannot be fully compensated for during subsequent machining. Likewise, assigning a single, unsuitable cutting regime to the entire cross-section of a dissimilar component leads to increased tool wear and inconsistent surface-quality characteristics [3, 6].

It is therefore practically useful to consider the complete process chain in sequence: from classifying and selecting the welding process, through assembling and fixturing the blanks and depositing the weld in layers, to assigning zone-specific machining conditions in light of the differing properties of the materials [2, 5, 7].

This study systematically describes the principal stages in manufacturing a precision welded component of the “pipe” type from steel 45 and steel 12Kh18N10T, from selecting the welding process to assigning cutting conditions by machining zone, with quantitative justification for the decisions made.

2. METHODS

2.1. Classification of welding methods and process selection

A wide range of welding methods is used to join dissimilar metals. These can broadly be divided into fusion welding (arc and beam processes) and pressure welding (friction, explosion, diffusion, ultrasonic and resistance welding) (Figure 1).

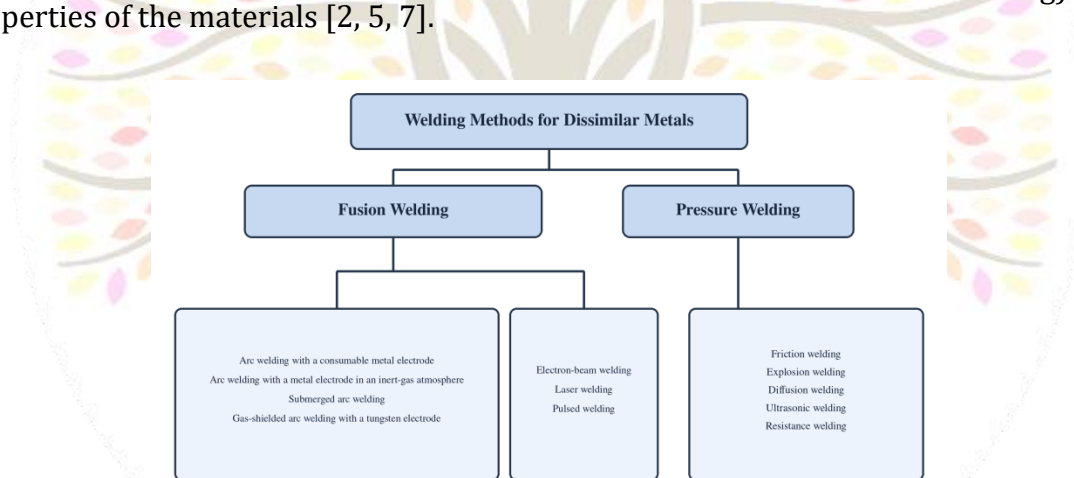


Figure 1. Classification of welding methods for dissimilar metals.

For the steel 45–steel 12Kh18N10T pair, gas tungsten arc welding (TIG) with a non-consumable tungsten electrode and Sv-08Kh21N10G6 filler metal was selected as the base process. Under the conditions of one-off and small-batch production, it offers an acceptable balance of weld quality, equipment availability and cost.

2.2. Materials and welded-joint configuration

The welded-joint configuration is shown in Figure 2. Steel 45 (GOST 1050-2013) is joined to steel 12Kh18N10T (GOST 5949-2018) with a process gap of 3–5 mm. The gap supports the formation of a sound root pass and also serves as a damping transition zone for the subsequent change in machining conditions.

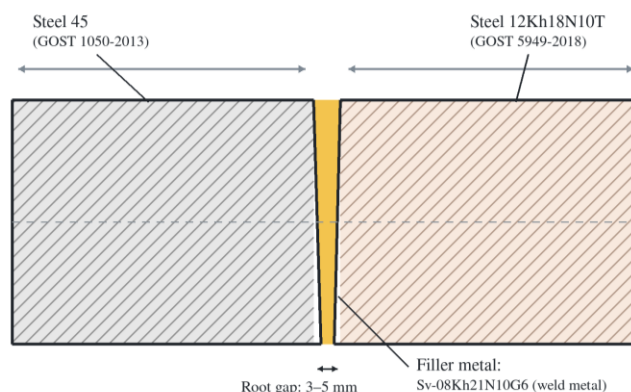
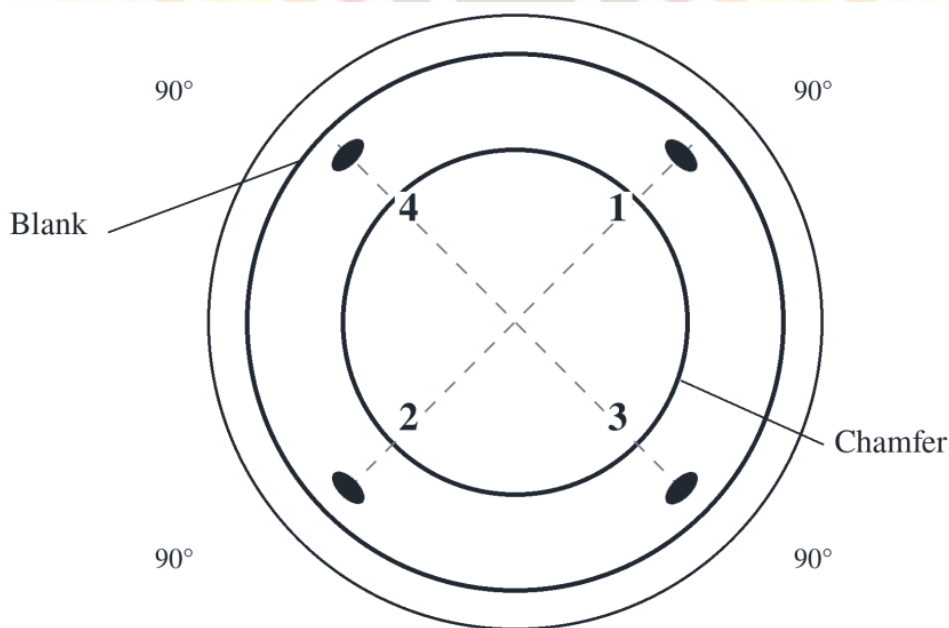


Figure 2. Configuration of the dissimilar-steel welded joint.

2.3. Assembly and fixturing of the blanks

To prevent distortion and maintain the alignment of the blanks during welding, a fixture with adjustable clamping stiffness was used; its restraint was reduced after the root pass had been formed. To maintain the set gap and prevent

the blanks from shifting, tack welds were applied in a prescribed sequence, in opposing pairs at equal 90° angular intervals (Figure 3). This distributes shrinkage stresses evenly around the joint.



Tack-welding sequence: 1 → 2, then 3 → 4

Figure 3. Sequence for applying the tack welds.

2.4. Multipass weld structure

Given the thickness of the blanks and the need to control thermal effects, welding was carried out

in several passes: a root pass, one or more fill passes, and a cap pass (Figure 4).

Multipass Weld Structure in Dissimilar Steels

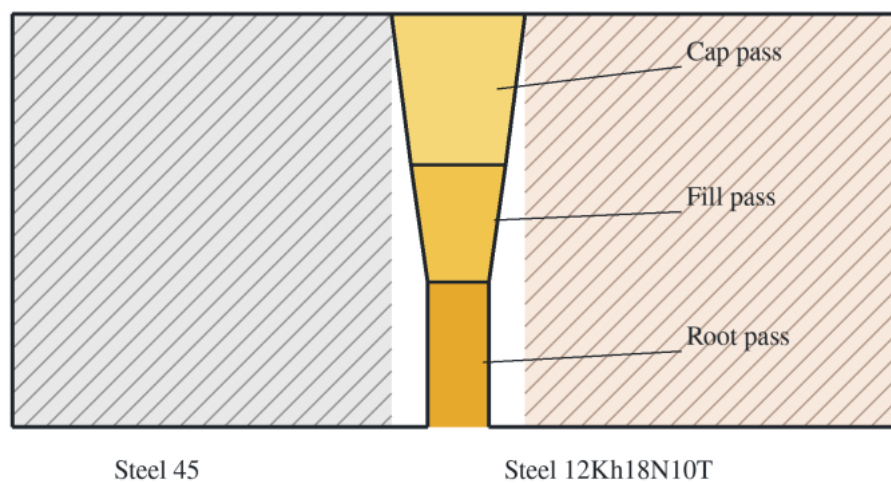


Figure 4. Weld structure in multipass welding of dissimilar steels.

2.5. Method for assigning machining conditions by zone

Finishing of the precision internal surface of the welded component was performed on a model 16A20F3 lathe fitted with a CNC system and a boring tool with a VBMT 11 03 04-PF 4315 carbide insert. Because steel 45 and steel 12Kh18N10T have different mechanical properties, cutting conditions (depth of cut, feed, spindle speed and cutting speed) were assigned separately for three machining zones—the steel 45 section, the weld transition (damping-transition) zone and the steel 12Kh18N10T section—for both semi-finishing and finishing passes.

CNC control was used to vary spindle speed and feed smoothly within the transition zone and to

retract the tool without impact when changing sections. The tool-retraction path was modelled in a CAM system in advance, allowing abrupt, unmodelled tool movements to be ruled out before the CNC programme was run.

3. RESULTS

3.1. Calculated confirmation of the weld structure

Calculations of the chromium and nickel equivalents, based on the actual chemical composition of the materials, confirmed that the weld metal retains an austenitic structure at the adopted filler-metal dilution by the base metals (30%). The calculated equivalents and PREN index are summarised in Figure 5.

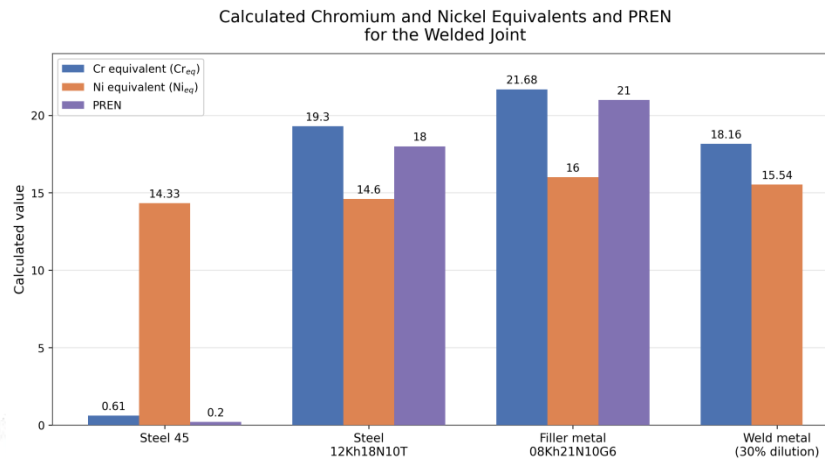


Figure 5. Calculated chromium and nickel equivalents and PREN index for the materials to be welded and the weld metal.

3.2. Mechanical properties of the materials to be welded

The difference in the mechanical properties of steel 45 and steel 12Kh18N10T, which underpins the differentiated cutting regime, is shown in

Figure 6. The tensile strength of steel 45 is higher (600 versus 510 MPa), whereas the hardness of steel 12Kh18N10T is slightly higher (179 versus 170 HB) because its austenitic structure is prone to work hardening during machining.

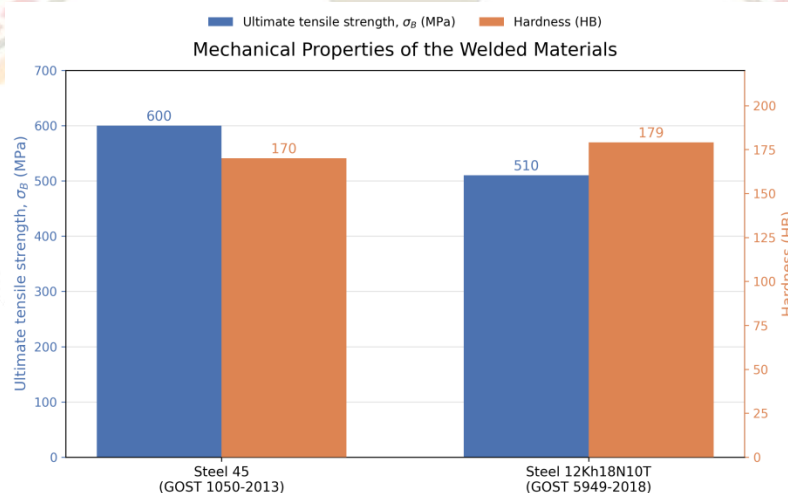


Figure 6. Mechanical properties of the materials to be welded.

3.3. Welding conditions by layer

The welding parameters—current, shielding-gas flow rate and arc voltage—increase from the root pass to the cap pass (Figure 7): current rises from

120 to 160 A, inert-gas flow from 6 to 7 dm³/min, and arc voltage from 12 to 16 V. This provides controlled total heat input while ensuring complete penetration of each successive layer.

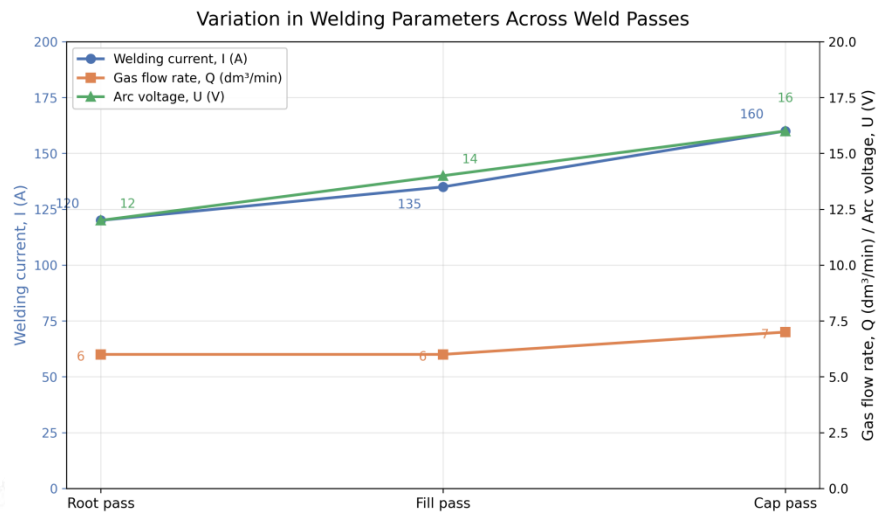


Figure 7. Variation in welding parameters across the weld layers.

3.4. Machining conditions by zone

Taking account of the differences in the materials' mechanical properties (Figure 6) and the damping-transition zone in the weld, a differentiated finishing regime was developed.

Spindle speed and cutting speed decrease as machining moves from the steel 45 section to the steel 12Kh18N10T section, with the parameters changing gradually within the weld zone (Figure 8).

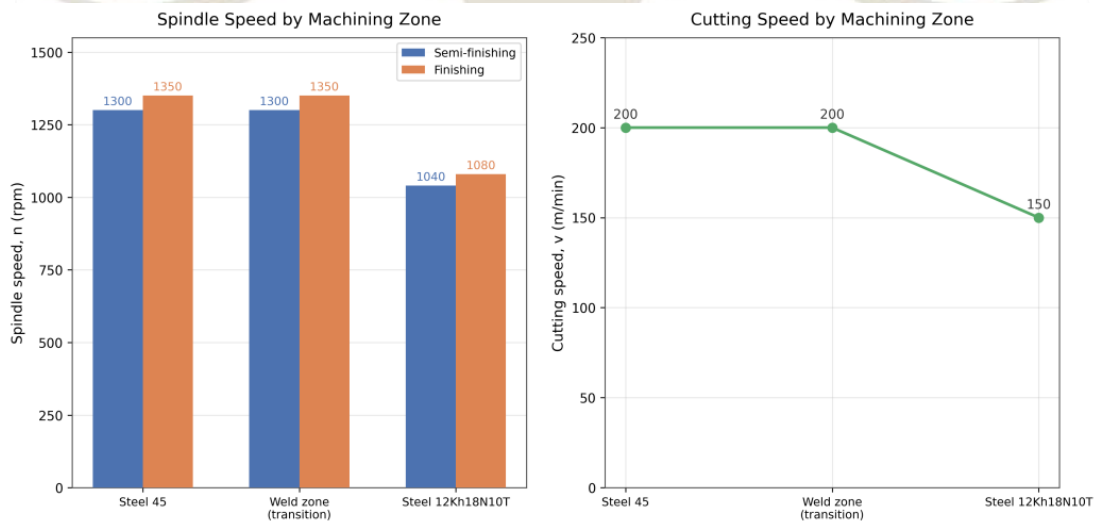


Figure 8. Spindle speed and cutting speed by machining zone.

The full parameters for the developed semi-finishing and finishing regimes—depth of cut t , feed S , length of the machined section L , spindle

speed n and cutting speed v —are given by zone in Table 1.

Table 1. Semi-finishing and finishing conditions for the welded component made from steel 45 and steel 12Kh18N10T, by zone.

Parameter	Steel 45 section	Weld zone	Steel 12Kh18N10T section
t, mm (semi-finishing/finishing)	0.4 / 0.3	0.4 / 0.3	0.4 / 0.3
S, mm/rev	0.12	0.12 → 0.1 (≈ 0.11)	0.1
L, mm (semi-finishing/finishing)	63.05 / 63	4.9 / 5.0	47.05 / 47
n, rpm (semi-finishing/finishing)	1300 / 1350	1300 → 1040 / 1350 → 1080	1040 / 1080
v, m/min	200	200 → 150	150

As shown in Table 1, the weld transition section is the most technically demanding. Spindle speed and cutting speed change gradually, without an abrupt step, which reduces dynamic loading on the tool as it passes through a zone where the material properties are non-uniform.

4. DISCUSSION

Considering the complete process chain in sequence shows that decisions made at the early stages—the choice of welding process (Figure 1), the assembly configuration and tack-welding sequence (Figures 2–3)—create the conditions for successfully producing the multipass weld (Figure 4) and achieving the predicted austenitic structure of the weld metal (Figure 5). In turn, knowledge of the actual mechanical properties of the materials (Figure 6) is needed not only to set the welding conditions (Figure 7), but also to justify the differentiated machining regime across the zones (Figure 8).

A single cutting regime calculated without accounting for property variations along the component is inevitably suboptimal for at least one zone: it is too low for steel 45, reducing productivity, or too high for steel 12Kh18N10T,

increasing tool wear and the risk of vibration, particularly in the weld transition zone. The proposed differentiated regime (Figure 8), aligned with the multipass weld structure (Figure 4), avoids these drawbacks and supports consistent surface quality along the component. This is consistent with the aims of extending tool life [3] and ensuring the quality of the surface layer [5] when machining dissimilar and alloyed materials.

From an economic perspective, carrying out each stage of the process chain in a considered and justified sequence—from selecting the welding process to assigning zone-specific cutting conditions—reduces the likelihood of defects and repeat machining, thereby lowering the overall cost of manufacturing precision components from dissimilar steels [8].

The relationship between the assembly procedure (Section 2.3, Figure 3) and the final component quality also deserves attention. Departing from the prescribed tack-welding sequence or placing the tacks arbitrarily rather than in opposing pairs may cause the blanks to lose alignment before the main weld is made. This misalignment cannot subsequently be compensated for by changing the welding conditions or by machining within the positional



tolerance for the machined surface. Similarly, failing to model the tool-retraction path in a CAM system in advance (Section 2.5) increases the risk of the tool colliding with an unmachined surface or of unjustified changes in cutting conditions when the CNC programme is run. The process chain therefore requires the parameters at each stage to be coordinated.

5. CONCLUSION

This paper systematically describes the process chain for manufacturing a precision welded component from steel 45 and steel 12Kh18N10T. It justifies the selection of gas tungsten arc welding with a non-consumable electrode; describes assembly and fixturing with a controlled gap and a defined tack-welding sequence; considers the structure and conditions of multipass welding; and develops a zone-specific finishing regime based on the differences in the materials' mechanical properties. The findings show that coordinated decisions at every stage—from selecting the welding process to assigning cutting conditions—are necessary to produce a high-quality precision component from dissimilar steels while minimising process risks and costs.

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