

Steel Lost Wax Investment Castings

Introduction

CRP has over the years moved away from the use of welded fabricated fittings manufactured from pipe and flanges through the use of sand cast ductile iron castings to steel lost wax investment castings. (Photograph 1.) A number of product quality reasons have driven this development, notably:

- No fabrication welds, therefore no concerns about weld integrity
- Greater strength
- Precise close tolerance parts for installation fit
- Dimensional accuracy for lining geometry
- No flash or parting lines
- Clear written casting detail for identification and traceability

Photograph 1. Typical Investment Casting Showing Product Detail



Lost Wax Investment Casting

The process involves producing a wax facsimile of the required casting which is made by injecting wax into an aluminium tool. (Photograph 2.) This is trimmed and depending on size attached to a wax tree which forms the running system. This is then dipped into a ceramic slip which coats the wax. This is allowed to dry and the process is repeated using different grades of ceramic. When complete the ceramic coated wax tree is heated very quickly so that the wax melts leaving a ceramic mould. This is then baked at 1000°C. The molten steel is poured into the mould, allowed to cool and then broken out, fettled, shotblast and stress relieved in the conventional manner. The component is then ready for any post-mould machining.

Photograph 2 Wax Facsimile



Strength

An explanation of the differences in metals strength is provided below. There are really only four basic metal standards which need to be considered.

- Standard pipe normally dual certified API 5L Grade B/ASTM A106M Grade B
- Forged flanges for pipe spools and fabricated fittings ASTM A105M
- Cast Steel for fittings ASTM A216M Grade WCB
- Ductile Iron for fittings ASTM A395M Grade 60 – 40 – 18

First, we should compare the specified minimum mechanical properties as set out in the respective standards. (Table 1.) These basic properties are the yield strength, ultimate tensile strength and elongation at break. It is the yield strength that is of greatest importance as this defines the maximum load that can be safely applied before the material becomes permanently deformed. The force/area unit used in the table below is the megapascal (MPa) which provides direct comparison of the data. From the table it is clear that all the metals used have similar mechanical properties. Surprisingly the standard steel tube has the lowest minimum yield requirement.

Table 1 Minimum Mechanical Properties

Metal Type	Yield MPa	UTS MPa	Elongation at Break	
			Longitudinal	Transverse
Pipe	240	415	30%	17%
Flanges	250	485	30%	30%
Cast Steel	250	485	22%	22%
Ductile Iron	275	415	18%	18%

For pipe work design a proportion of minimum yield which is used in stress analysis and in design calculations. This proportion of minimum yield stress is called the maximum allowable stress and it provides the primary safety factor in the basic design. For their design calculations CRP apply the maximum allowable stress as defined in ASME B31.3 and at an operating temperature of 204°C. (Table 2.)

Table 2 Maximum Allowable Stress Levels

Metal Type	Stress
Pipe	138 MPa
Flanges	142 MPa
Cast Steel	119 MPa
Ductile Iron	116 MPa

At first sight it would appear that pipe and flanges have a noticeably higher allowable stress level when compared to the two cast materials. However, to produce a pipe fitting the component parts will be joined by a welding process. The design standard requires a reduction in maximum allowable stress to mitigate the effects of welding. A weld efficiency factor is applied and in the case of the type of joints used in pipe work a factor of 0,85 is used. The revised allowable stress is calculated by multiplying the tabulated allowed stress by 0,85 which in the case of pipe produces a maximum allowable stress of 117 MPa. Therefore generally all the basic materials have a similar maximum allowable stress.

In practical terms the calculated maximum stress seen in CRP pipe work when operating at maximum conditions is low and only rarely reaches 50% of the allowed maximum level.

So far we have considered the unit strength of each of the materials. We should now consider the effects of material strength in combination with the actual constructions used to form a CRP fitting. This is best demonstrated by taking one design and calculating the relative minimum yield strength of the thinnest section of that design. For this purpose a 50NB equal tee is a suitable example and a simple calculation of the strength has been made.

Fabrication of Pipe and flanges minimum strength	=
Nominal wall thickness 3,91mm x minimum yield 240	= 938 MPa
Cast steel tee with integral flanges minimum strength	=
Design wall thickness 5.5mm x minimum yield 250	= 1375 MPa
Ductile Iron tee with integral flanges minimum strength	=
Design wall thickness 6,0mm x minimum yield 275	= 1650 MPa

Cast steel fittings are significantly – almost 50% - stronger than fabrications of a similar nominal bore and importantly do not contain construction welds. The grade of steel used by CRP is ASTM A216 WCB with a minimum cast wall of 5.5mm at 25NB which is some 2.12 mm thicker than schedule 40 steel tube of the equivalent nominal bore.

Other Construction Benefits

The dimensional accuracy gives improved lining control with lined faces which are square to the line axis of the fittings bores and bores that are concentric to the flange periphery and the body outside diameter. The extensive machining of the steel casting provides flat rear faces to flanges allows accurate torqueing of bolts and assists in flanges being pulled up square. The fine ceramic powder used in creating the steel casting mould allows much greater detail to be cast and moreover be readable than that provided by sand cast ductile iron and such markings are not even possible with fabricated fittings – generally leaving them anonymous and untraceable. (Photograph 3.)

Photograph 3 Product Detail after Painting

**Conclusion**

Lost wax investment cast steel fittings are the product of choice where ease of plant construction, plant life and integrity are key considerations and there is a desire to know when and where product comes from. Overall these products provide the lowest cost solution over the working life of the equipment.