

# Development of water soluble cores for investment casting – A review

In Investment Casting for the production of complex castings still waxes are the suitable materials for making pattern by injecting the liquid wax in metal dies. The aim of this study is to describe possibilities of using salt cores. The primary, secondary and final residual strength tests were carried out on three different compositions in order to evaluate the possibility of salt core utilisation. Further, it is focused on the development of better mechanical properties of the casting. The positive impact of these cores on environment was also studied



**GANESH VIDYARTHEE &  
NANDITA GUPTA**

Ganesh Vidyarthee is a PhD Scholar and Nandita Gupta is Professor, Foundry Technology, NIFFT, Ranchi

**T**RADITIONALLY undercuts, channels or passages are formed by the cores in the casting. After production of the casting, the core is removed with the help of solvent, heating in a steam autoclave or flash firing at very high temperature. These procedures make the casting parts more expensive but of low efficiency.[1-3] For many castings with complicated openings, undercuts, channels or passages, salt or ceramic cores are not needed, while the wax pattern can be used directly. The problem of making difficult wax pattern is eliminated with the water soluble cores. These salt cores appeared in foundry in the 1970s and its extensive expansion took place in the 1990s in the mass production of diesel engine pistons. The cores of simple forms like rings, holes, channels are made from cooking salt (NaCl) by high pressure compacting and they serve for blank casting with an advantage that complex designs can be produced where castings

are hardly accessible to mechanical cleaning.[4-6] The salts meet the requirements of the primary strength (cold strength) and hot strength (650-700°C) of cores.

The salt melt is cast in core boxes and to prevent moistening, the crystallised cores are stored in an oven (at minimum of 200°C) and cores are made by mildly moistened salt compacted under high pressure. Grains are conglomerated and recrystallisation along the grain boundaries takes place either under low pressure of 30-50 MPa and at the heating temperature of 500-750°C or under high compacting pressure of 136-362.8 MPa and low sintering temperature of 180-300°C, allowing a stress release. Another process of manufacturing cores is by shooting the mixture with inorganic binders like Na<sub>2</sub>CO<sub>3</sub> and hardened either with the aid of CO<sub>2</sub> or with thermal dehydration normally at 180-210°C. All these cores show a relatively low strength and they are not suitable for high pressure castings.[7-9] Polyvinyl Glycol (PVG) is a waxy material that can sufficiently be dissolved in water and can be leached away from the pattern waxes, which has low hygroscopic coefficient; as a result soluble cores may remain for longer time. It is nontoxic and currently available in the market. PVG cores have a deficiency that it is supposed to be used under pasty conditions. When the core solidifies, it is easy to form cracks on the surface.[10-12] The research aimed at applying three variations of binders and checking the strength (bending) improvement, the influence of salt crystal shapes, granulometry and, above all, the composite salts with additives as well as the hydration and kinetics during dissolution of the cores in water. [13-15]

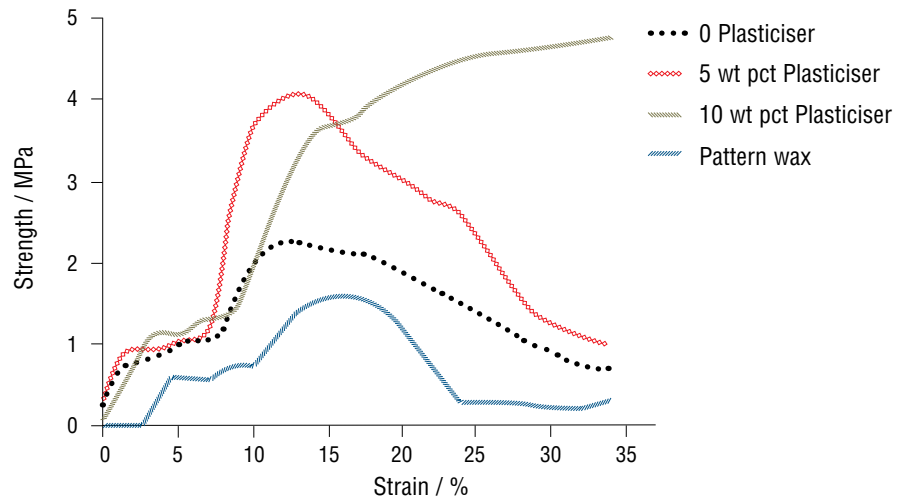
### Experimental details

The material used here is mica powder, sodium chloride, polyethylene glycol, and solvent to dissolve polyethylene. The amount of polyethylene glycol should be strictly controlled. Here plasticiser is mixed in the ratio of 0%, 5%, and 10% to

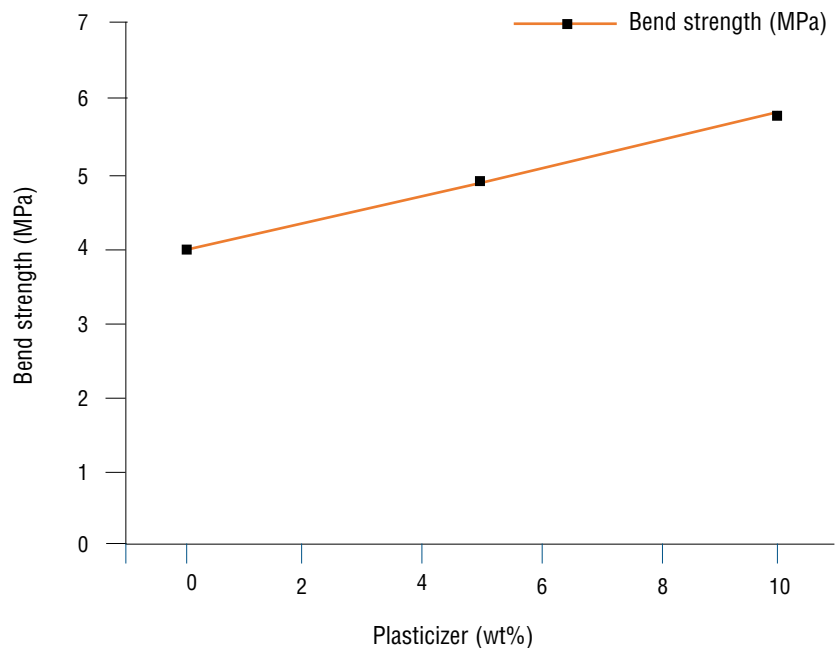
**Table1: Component of soluble core material (wt %)**

Sample No.	Polyethylene Glycol	Mica Powder	Sodium Chloride	Plasticiser
1	45	30	25	0
2	43	28	24	5
3	40	27	23	10

**Figure1: Compressive stress and strain curves of wax and core material**



**Figure2: Relationship between bend strength and the amount of plasticizer and 10 wt pct (c) 15 wt pct**



make three different compositions. Firstly, the paraffin was heated to 90-100°C in water bath until it was melt, the granular polyethylene was added into the liquid paraffin, and the polyethylene was dissolved completely by stirring. Then the polyethylene glycol was added into the liquid and mixed uniformly by stirring.

The samples of 6mm x 6mm x 10mm are composed for various tests. Then bending strength test, compression strength test, hygroscopic property and solubility test are done on all the three samples. The compositions of the respective ingredients are given in **Table1**.

The compressive strength of different samples was measured by using universal strength testing machine. The bend strength was measured by three-point bending fixture. For the solubility rate, the sample was put into water and the solubility rate calculated. Part of the sample was exposed in air at room temperature (relative humidity was 50-70%) for one month and the change of the sample mass was measured to calculate the hygroscopic coefficient. The hygroscopic coefficient can be calculated by the equation of

$$H = [(Wt - W0) / W0] \times 100\%$$

where H represents the hygroscopic property of core materials, Wt is the mass of the sample exposed in air for one month, W0 is the initial mass of sample.

The solubility rate can be calculated by the equation of

$$R = M / (S \times T)$$

where R represents the solubility rate of the sample; M, S, and T are the mass, surface area, and solution time of the sample, respectively.

**Results and discussion**

A novel soluble core is successfully developed. The yield strength of the soluble core material may reach 1 MPa and the highest compressive strength may be 4 MPa (**Figure1**). The bending strength of the soluble core materials is 4.08 to 6.65 MPa (**Table4**). The hygroscopic co-

**Table2: Mass and hygroscopic coefficient of the core material**

Plasticiser (wt%)	W0 (g)	Wt (g)	Wt-W0 (g)	H (%)
0	0.5313	0.5325	0.0012	0.22
5	0.5192	0.5199	0.0007	0.13
10	0.4975	0.4978	0.0003	0.06

**Table3: Different sample mass, surface area, and soluble time**

Plasticiser (wt %)	Initial wt (g)	Surface area (m2)	Time (min)	Final wt (g)	Solubility rate (g/min-m2)
0	0.5352	0.000320	30	0	55.75
5	0.5120	0.000310	30	0.1080	35.7
10	0.4970	0.000311	30	0.4800	1.82

**Table4: Bending strength**

Plasticiser (wt% )	Bending strength (MPa)
0	4.08
5	4.80
10	6.65

efficient is 0.06% to 0.22% per month (**Table2**) under ambient conditions. The solubility rate of core materials with zero plasticiser is 55.75 g/min-m2, with 5wt% plasticiser is 35.7 g/min-m2, which has a reducing trend with more plasticiser. Exposing the core for one hour, the surface of soluble core is loose without plasticiser (**Table3**).

The compressive strength is shown in **Figure1** for four different compositions of core with 0% plasticiser, 5% plasticiser, and 10% plasticiser while making it with wax it is found that wax pattern cannot sustain the stresses with 10% plasticiser. Whereas 5% plasticiser gives modified compressive strength, which shows its suitability for the production of cores.

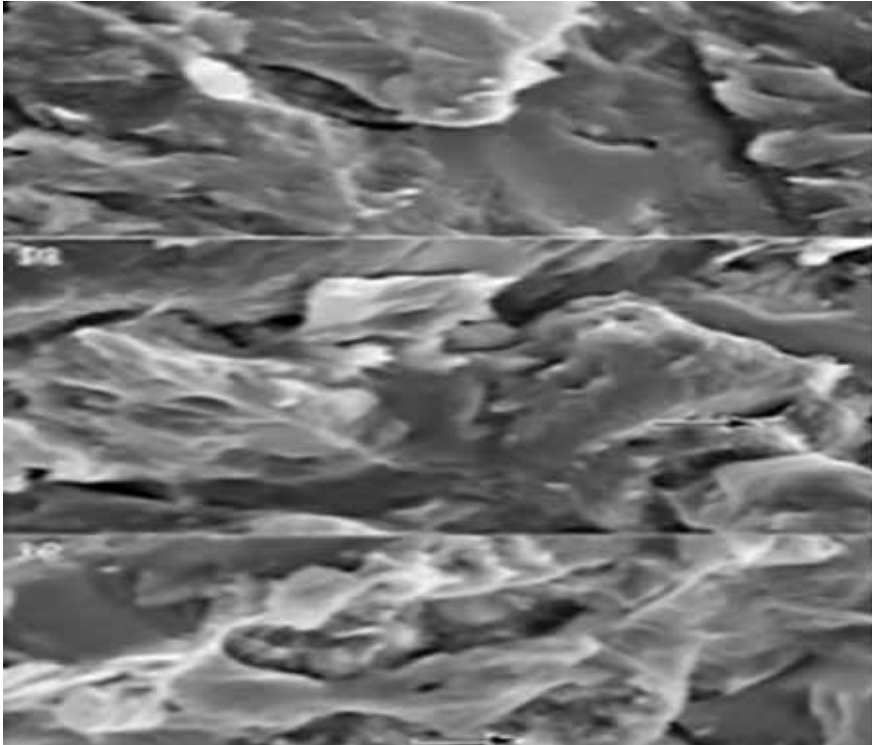
Mica is found to be a good substitute to provide strength, smoothness, etc. It is economic and eco-friendly.

Polyethylene is ductile, it is nontoxic. It is found abundant in nature. The bond strength (Figures 2, 3) is due to

the fibrous nature of plasticiser; so with increase in plasticiser, the bond strength increases.

Though mica and polyethylene do not absorb moisture from the atmosphere, they are contributing to the stability of the water soluble cores. Mica and polyethylene reduce the contact surface area between the core material and the moisture. Up to 5% weight of polyethylene glycol prevents formation of cracks, provides smooth surface and makes the core stable. Beyond 5% polyethylene glycol reduces the solubility rate of the core. A recommended mixture composed of 43% weight of polyethylene glycol, 30% weight of mica powder, 25% weight of sodium chloride powder, and 5 weight % of plasticiser give optimum strength. This kind of soluble core cannot be broken during the injection of composite pattern and it can be leached out at suitable time. Hardness plays an important role in preventing cracks. It is also found that

**Figure3: Fracture surface micrograph of the soluble core material with plasticiser 0 (a), 5 wt pct (b) and 10 wt pct (c) 15 wt pct**



increase in strength reduces the collapsibility of cores and thus needs more core removal time.

### Conclusion

- Production of dimensionally accurate and smooth castings without the use of protective coats.
- The cores though are soluble in water possibility of recyclability of the salts and water is there.
- The produced cores are environmentally-friendly.
- The cores do have sufficient storage ability under common climatic condition.
- Mechanical properties are found to be improved.
- The drawback of salt cores is that a contraction and volume shrinkage occur during solidification.

- Sometimes high density of these cores prevents the dissolution in water and therefore the cast cores are difficult to remove.
- To eliminate shrinkage a mixture of salt and sand is recommended having melting point 820°C and production of core under pressure is also recommended.

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