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A STUDY OF SINGLE PIECE CERAMIC SHELL CORE FOR GEOMETRICALLY COMPLEX INVESTMENT CASTING

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Abstract

Investment Casting is a manufacturing processes that uses a ceramic mould to create complex high details near net shape components with excellent dimensional accuracy and surface finish. These castings have tighter tolerances and the capability to produce thin walled sections. 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. Hence it is also called lost wax process. If the design have complex inner cavity configuration the soluble core can be incorporated into investment casting. The use of soluble salt cores allow for more intricate cavity patterns to be included in the casting reducing or eliminating the need for additional machining. The aim of this study is to describe the possibilities of using salt cores. The primary secondary and final residual strength test were carried on three different composition for salt core is tested in order to evaluate the possibility of salt core utilization. Further it is focused on the development of better mechanical properties of the casting. The positive impact of these cores on the environment were also studied.

Keywords: *Salt core, expendable core, strength, solub*ility

1. INTRODUCTION

Traditionally 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 become more expensive but of low efficiency [1-3].

For many castings with complicated openings undercuts, channels or passages the salt or ceramic cores do not need, 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 appear in foundry in the year 1970s and its extensive expansion took place in 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 design can be produced where castings are hardly accessible to mechanical cleaning[4-6]. The salt meet the requirements regarding the primary strength (cold strength) and hot strength (650-700ºC) of cores.

The salt melt is cast in core boxes and to prevent the moistening, the crystallized cores are stored in an oven (a minimum of 200ºC) cores are made by a mildly moistened salt compacted under high pressure. Grains are conglomerated and recrystallization along the grain boundaries takes place either under low pressures 30-50 MPa and at the heating temperature of 500-750ºC or under high compacting pressure (136-362.8MPa) and low sintering temperature (180-300ºC) allowing a stress release another possibility is manufacturing cores by shooting the mixture with inorganic binders like Na_2CO_3 and hardened either with the aid of CO_2 or with thermal dehydration normally at (180-210ºC) All these cores show a relatively low strength and they do not suit for high pressure castings[7-9]. Polyvinyl Glycol is a waxy material that can be sufficiently dissolved in water and can be leached away from the pattern waxes, polyvinyl glycol has low hygroscopic coefficient, as a result soluble cores remains for longer time. It is nontoxic and currently available in 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] .

2. EXPERIMENTAL

The material used here is Mica Powder, sodium chloride, the plasticizer was made from paraffin and polyethylene Paraffin was used as a solvent to dissolve polyethylene. The amount of polyethylene glycol should be strictly controlled. Paraffin is mixed in 0%, 5%, 10% to make three different composition. The salt mixture were melted in an alumina crucible with an electric resistance heater, then granular polyethylene(100ºC+-2ºC) was dissolved completely by stirring. Then polyethylene Glycol was added into the liquid and they were stirred untill the slurry became homogeneous. The samples of 8mmx8mmx12mm is composed for various test. Then Bending strenght test, compression strength test hygroscopic property and solubility test are done on all the three samples. The composition of the respective ingredients are given in the table 1

Table 1. Component of soluble core material (wt %)

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

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 is calculated. Part of the sample is exposed in air at room temperature (Relative humidity was 50%-70%) for one month and the change of the sample mass were measured to calculate the hygroscopic coefficient.

The hygroscopicity can be calculated by the equation

$H=[(wt-w0)/w0]x100\%$ wt=mass of the sample exposed in air per month

w0=initial mass of the sample

Solubility rate can be claculated by,

$R=M/SxT$,

R=solubility of the sample,

M=Mass

S=Surface area

T=Time of solubility

3. RESULT AND DISCUSSION

1) A novel soluble core is successfully developed. The yield strength of the soluble core material can reach 1MPa and the highest compressive strength can reach 4MPa (figure1) the bending strength of the soluble core materials is 4.08 to 6.65 MPa Table4. The hygroscopic coefficient is 0.06% to 0.22% per month (Table 2) under ambient conditions. The solubility rate of core materials with zero plasticizer is 55.75g/min-m^2 with 5wt% plasticizer 35.7g/min-m^2 it has a reducing trend with more plasticizer. Exposing the core for one hour the surface of soluble core is loose without plasticizer (Table 3) Mica is found to be a good substitute to provide strength, smoothness etc. It is economic and ecofriendly. Polyethylene is ductile it is also nontoxic, It is found abundant in nature. The bend strength (figure 2, 3) is due to fibrous nature of plasticizer so increasing plasticizer the bend strength increases. Though mica and polyethylene do not absorb moisture from atmosphere, they are contributing to the stability of the water soluble cores. The compressive strength is shown in figure 1 for four different composition of core with 0% plasticizer, 5% plasticizer and 10% plasticizer while making it with wax it is found that wax pattern cannot sustain the stresses at 0% plasticizer and with 10% plasticizer. Whereas 5% plasticizer give modified compressive strength, this shows its suitability for the production of cores. Mica and polyethylene reduce the contact surface area between the core material and the contact surface area between core material and the moisture. Upto 5% weight of polyethylene glycol prevent formation of cracks provide smooth surface and make the core stable. Beyond 5% polyethlene glycol reduces the solubility rate of the core. A recommended mixture composed of 43% weight of mica powder, 30% weight of sodium chloride powder, 25% weight of plasticizer, 5 weight percent polyethylene glycol 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 increasing strength reduce the collapsibility of cores and thus need more core removal time.

Table 2. Mass and hygroscopic coefficient of the core material

Core material Plasticizer 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

Table 3. Different sample mass, surface area and soluble time

Plasticizer 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

Table 4. Bending Strength

Plasticizer wt%	Bending Strength (MPa)
0	4.08
5	4.80
10	6.65

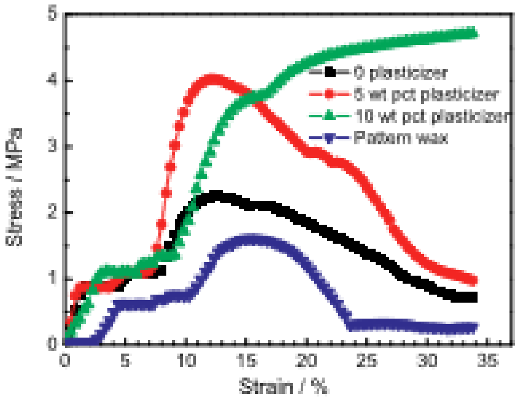

Figure 1. Compressive stress and strain curves of wax and core material

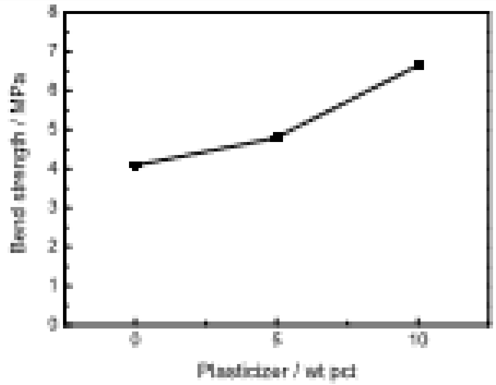

Figure 2. The relationship between bend strength and the amount of plasticizer

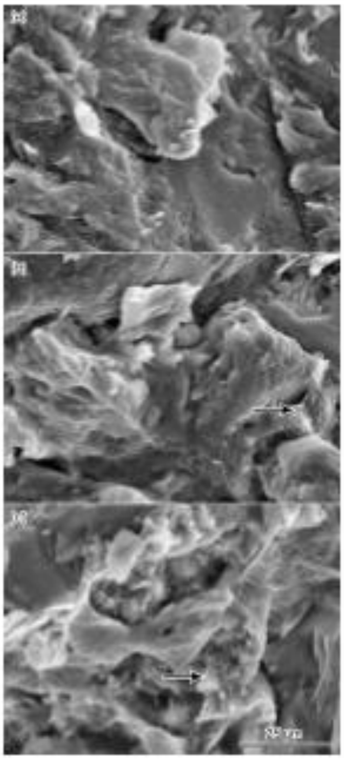

Figure 3. Fracture surface micrograph of the soluble core material with plasticizer 0 (a), 5 wt pct (b) and 10 wt pct (c) 15 wt pct

CONCLUSION

1. Production of dimensionally accurate and smooth castings without the use of protective coats
2. The cores though are soluble in water the possibility of recyclability of the salts and water is there
3. The produced cores are environmentally friendly
4. The core do have sufficient storage ability under common climatic condition
5. Mechanical properties are find to be improved

6. The drawback of salt cores is that a contraction and volume shrinkage occur during solidification
7. Sometimes high density of these cores prevents the dissolution in the water and therefore the cast cores are difficult to remove
8. To eliminate shrinkage a mixture of salt and sand is recommended having melting point 820ºC and production of core under pressure is recommended

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