CHAPTER - I

INTRODUCTION

1. General Background :

The investment casting process is believed to be one of the oldest process of founding in the production of metallic shapes. The process, now referred to as the ceramic shell investment casting process, has off late gained an important position in the family of precision casting techniques owing to the scientific advances in many of its aspects. In the recent years, a number of reports[1-13] have appeared claiming advantages of the process in the economic manufacture of intricate castings with close dimensional tolerence and good surface finish. Various alloys like aluminium, copper and titanium based alloys, alloy steels, super alloys and reactive metals have been successfully cast by this technique particularly for the production of complex parts for the aerospace and automobile industries[7,8]. Such achievements are primarily the consequences of the developments in three distinct areas of the process viz., i) pattern material[14-17], (ii) binder solution[13,18-25] and (iii) mechanisation and automatisation[26,27]. While the mechanisation and automatization have mainly contributed to the economics of production, the availability of good quality pattern material and thermally stable ceramic shell moulds have paved the way for the production of precision castings. However, the quality of the ceramic shell moulds largely depends on the nature of the binder solutions employed.

The ceramic shell moulds are normally composed of a major portion of highly refractory particles like fused silica and zircon bonded by a minor amount of ceramic/refractory binder. While the refractory particles, possesing low thermal expansion characteristics and high fusion temperature, ensures the production of castings with close dimensional tolerance, the binder solution employed provides the ceramic/refractory bond between the particles. The ceramic shell moulds are prepared by repeated dip coating of a wax pattern into a slurry consisting of the binder solution and refractory particles followed by stuccoing and drying after each dip. After the desired thickness is achieved, the wax pattern of low thermal expansion characteristics is melted out. The ceramic shell mould so obtained is subsequently fired before pouring of molten metal.

The roles of the binder solution in the ceramic shell mould is not only to provide the refractory/ceramic bond, but also to impart sufficient strength to the mould to withstand the stresses that develop during dipcoating, drying and dewaxing operations. Further, after firing the moulds should be strong enough to withstand thermal shock, errosion and pressure of the molten metal during pouring. The moulds are also required to withstand high temperature under the metallic pressure for a long time, particularly when directional solidification of super alloys is involved. Past studies[19] have revealed that the properties required of a ceramic shell mould primarily depend on the nature and the amount of the binder solution employed which controls the important factors like slurry viscosity, immersion time, drying time, firing time and temperature. Thus, amongst all the factors, the selection and control of the binder solution play the pivotal role in the success of ceramic shell investment casting process.

In the past years, use of the both aqueous and organic solvent based binder solutions meeting such stringent requirements as above have been suggested[13,18-25].

Amongst the various types of binder solutions developed, the colloidal silica aquasols and the hydrolysed ethyl silicate appears to be the most popular ones. The majority of the past work on the ceramic shell investment casting process is related to the use of these two types of binder solutions which are known[22] to provide silica bond between the refractory particles. Unfortunately, these binders posses such problems as long cycle of drying and poor bench life and various attempts have been made to counter the same[28]. Use of alternative binder solution such as organosols of various kinds have also been suggested[28].

An acetone based polysilicic acid binder was thought[13] to be a substitute for colloidal silica aquasols and hydrolysed ethyl silicate. This solution, apart from providing silica bond, is believed to have the potentials for overcoming the problems posed by the latters. But the details of the preparation of this solution are not available. Further, no systematic and significant amount of work have so far been reported on the characteristics and performance of this binder solution in the ceramic shell investment casting process. A review of the past work suggests that the mechanism of forming silica bond from colloidal silica aquasols and hydrolysed ethyl silicate is well understood[22]. But nothing is known about the bonding mechanism of the polysilicic acid binder taken in non-aqueous medium and the acetone based one is no exception. Thus substantial amount of work is required not only on the preparation of the acetone based polysilicic acid binder but also on the suitability of its application in ceramic shell investment casting process. Such work together with the fundamental studies on the mechanism of bonding can be expected to establish this binder on a sound footing.

2. Objective of the work :

Systematic studies on the acetone based polysilicic acid binder has been undertaken with the following objectives :

a) to optimise the process parameters ensuring preparation of the binder containing a maximum amount of silica and a minimum amount of Na, water and other impurities.

b) to understand the properties and behaviour of both the binder solution and the ceramic shell samples prepared from fused silica particles bonded by the former.

c) to throw some light on the mechanism of formation of silica bond from polysilicic acid in acetone, and

d) to explore the utility of the binder in the ceramic shell investment casting process.

3. Scope of the work :

The present work confines itself to the preparation and characterisation of the acetone based polysilicic acid binder, preparation of ceramic shell samples from fused silica particles employing the same and studies on their properties and behaviour and application of the binder in ceramic shell investment casting process.

The work starts with the review of the available literatures[1-142] relevant to the subject as presented in Chapter II. The experimental work starts with the preparation of the binder from commercial grade sodium silicate solution by the solvent extraction method[125]. In course of this part of the work, the process parameters involved have been studied in some detail with a view to prepare a binder containing maximum amount of silica and minimum amount of sodium and other impurities. Thereafter the binder solution and the gels prepared therefrom have been characterised by various techniques like viscosity measurement, assessment of bench life, kinetics of gelation, infrared study, DTA-TGA and X-ray diffraction. Further, the ceramic shell samples prepared from fused silica particles bonded by the binder have been studied by Scanning Electron Microscope, X-ray diffraction and through the measurement of their strength properties. From the studies as above, an attempt has been made to throw some light on the mechanism of forming silica bond from the polysilicic acid binder in acetone medium.

Finally, an attempt was made to pour molten steel in a ceramic shell mould prepared from the fused silica particles employing the acetone base polysilicic acid binder. It should be pointed out at this stage that since the work was mostly development oriented with rather broad objectives it has not been possible to go into the deep details in any aspect of the work.