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Fluidity characteristics of LM6/graphite particulate composite

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Abstract-

Casting processes involves flow of molten metal by a gating system and complete filling of mould cavity in order to accurately, faithfully reproduce all contours of mould. Molten metal is then poured onto mould at a particular temperature. This temperature immediately starts dropping when this molten metal enters the mould cavity and begins to flow. The main aim of such casting production is to create casting of excellent quality which carries all the intended details and contours from mould reproduced successfully on it. To accomplish such successful casting process, molten metal is required to possess certain casting characteristics like oxidation, fluidity, shrinkage, hot tear, gas absorption, etc. Amongst these characteristics, fluidity is considered to be an important parameter of molten metal. The ability of molten metal to completely fill the mould cavity is called fluidity. It can also be considered as the ability of molten metal to fill a given cross-section of the given mould. In simple terms, fluidity can be defined as mould filling capacity of molten metal.This fluidity is influenced by several parameters like pouring temperature of molten metal, type of mould used for casting, nature of metal used, temperature of mould, coating used on mould surface, and treatment of molten metal such as grain refinement and modification. In fact, fluidity is a very complex parameter which cannot be precisely measured by any means. However, there are many methods available to qualitatively and quantitatively assess fluidity of molten metal. Therefore, it is imperative to determine fluidity of molten metal under a given set of conditions which will help the practical shop floor staff to obtain an understanding regarding the precautions and errors which must be taken to produce a successful good and efficient quality casting. In this project, attempts will be made to study the fluidity of LM6 (Aluminium 12% silicon) alloy and the composite prepared using graphite particulates in the LM6 base alloy, by pouring molten metal into two different fluidity test moulds (i.e.: strip and spiral test). These moulds are standardised equipment's which are being designed by considering several parameters which can have an influence on the flowing of molten metal within the mould channels. It is proposed to study effect of pouring temperature, moulding temperature, effect of mould coating material on the fluidity of metal.

Keywords: *Fluidity, Strip test, Spiral test*

I. INTRODUCTION

Casting makes use of property of fusibility of any material. This Fusibility is the ability of a material to undergo phase changes when some energy is applied. The pouring of the molten metal onto the mould is one of the critical steps in foundry, since the behaviour of the liquid and its subsequent solidification, cooling determines whether the

January - February 2020
ISSN: 0193 - 4120 Page No. 5394 - 5401

shape of the cast will be properly formed, internally sound and free from defects.

The characteristics of the metal/alloy are of great importance in assessing the quality of the same, to understand how they behave during the process of melting, solidification, etc. The following properties are referred as casting characteristics: shrinkage, fluidity, hot tear, solidification mechanism, oxidation losses, gas solubility, etc. Among these, fluidityplays a vital role in determining the casting quality.

Fluidity of molten metal is of significant importance in producing the sound castings, particularly in thin-walled castings. To meet the industrial demands of these complex shaped castings,knowledge of the parameters affecting fluidity is required in order to have a better control of the theproduction processes. Since fluidity is one of the measures by which cast ability of metals can be quantified, a definition and a description of cast ability are presented in this report. Fluidity can be defined as that quality of liquid metal which enables it to flow throughmould passages andhence to fill all interstices of the mould, providing sharp outlines and a faithful reproduction of design details in them.

Sincefluidity cannot be evaluated from individual physical properties, many empirical tests have been performed to measure the overall characteristic in them. These are based on the conditions analogous to the casting of metals in foundry and to measure the fluidity as total distance covered by molten metal in the standardised systems of limited channels before cessation of flow.

The Strip test indicates mould filling capacity whereas the Spiral test indicates the flow properties of molten metal. The closest approach to complete standardisation is achieved in vacuum fluidity test depicted by Ragone, Adams and Taylor.

Aluminium based alloys are well known for their high durability to the weight ratio, good corrosive resistance and ease of casting into various shapes and sizes. However, their use is restricted due to poor wear and low hardness characteristics. These drawbacks can be removed by adding aluminium alloy composites which exhibits the advantages of both the constituents.

Composite materials refer to the heterogeneous combination of several materials which provideunique combinations of the properties that cannot be realized by the individual constituents acting alone.

Methods of producing composites using simple foundry-metallurgical techniques can be developed only by a thorough understanding of their foundry characteristics among which fluidity plays a very vital role and carries a huge importance.

II. LITERATURE REVIEW

(1) O. Bouskahas studied on the effect of various casting parameters on the relationship between flow properties and mould filling capacity and cooling conditions of Al-Si alloys had been determined. In order to achieve better reproducibility of measurements new equipment's for both procedures has been developed.

(2)A.K. Birruetalhasstudied on the fluidity of Al-Zn alloys, such as the standard A713 alloy with and without scrap addition has been performed. The scrap added comprisesthe contaminated alloy turning chips.The Fluidity measurements were performed with double spiral fluidity test consisting of gravity casting of double spirals in green-sand moulds with good and efficient reproducibility. The influence of recycled alloy on fluidity has been compared with that of the virgin alloy and the results shows that the fluidity decreases withincrease in the recycled alloy with a very minimal pouring temperature. Apparently, an appreciable improvement in the fluidity is

January - February 2020
ISSN: 0193 - 4120 Page No. 5394 - 5401

observed at maximum pouring temperature, especially for coated spirals.

(3) MarisaDiSabatinohas studied on the influence of various parameters on the fluidity of aluminium foundry alloys and particularly the Al-Si foundry alloys. The effect of casting temperature, melt, superheat, was assessed through a series of tests. A linear relationship between casting temperature and fluidity length was observed. The effect of grain refinmenton fluidity of an A356 alloy was systematically investigated. The fluidity lengths without grain refinment and with three additions of the master alloy are measured. The results showed that the grain refinement reduced the grain size throughout the spiral, particularly at the tip, but there are no statistically significant effects on the fluidity.

(4) RabindraBeheraetalinvestigatedthe effect of weight percentage of Si-Cp on the fluidity and rate solidification of stir cast mmc's. Many Experiments were carried out over many particle weight percentage of 5.0-12.5 wt.% in steps of 2.5wt%.The Spiral castings/three-stepped castings of aluminium alloy (LM6) and the composites reinforced with different mass fractions Si-Cp has produced to study fluidity of the mmc's and solidification behaviour of the castings by assembling numerousK-type thermocouples at different sections of the casting. The experimental result indicates the increase in the wt% ofreinforcedparticles, i.e. Si-Cp in aluminium alloy (LM6) mmc's, the fluidity of cast composite metal decreaseand the rate of solidification decreases due to which the total solidification time increases.

(5)VigneshRetalstudied the effect of Squeeze pressure on the Aluminium LM6 fluidity property. The distance covered by the molten metal inthe spiral channel after the application of pressure is the measure for fluidity. This fluidity keeps increasing up to a particular pressure andthe fluidity of LM6 alloy during squeeze casting increases with the increase in pouring molten metal temperature.

III.EXPERIMENTALPROCEDURE

Production of LM6 matrix composites by stir casting technique.

Weighing of Aluminium and particulates: Required number of Aluminium ingots are weighed and the required percentage (1%, 2% and 5% by weight of metal) of particulates is also weighed.

Preheating of charged materials to evaporate the surface moisture and can be extended to high temperatures to volatilize the oils, paints and other organic contaminants and also remove water for crystallization from hydrated, corrosive products. The crucible is first preheated; this heat removes all of the moisture from the furnace and crucible. Aluminium ingots to be used are thenplaced on top of the furnace so they heat up.

Melting:
Melting of LM6 alloy is carried out using Electric arc furnace (3.1) and superheated to a temperature of 800^{0}C.

Mixing of particulates:
The particulates are mixed withmolten metal using the vortex method. During mixing, magnesium chips are introduced along with the particulates. The magnesium chips form a coating around the particulates which helps in better adherence of the particulates with the metal, improving their wettability.

Fig.1 9kW electric resistance furnace and stirrer setup.

January - February 2020
ISSN: 0193 - 4120 Page No. 5394 - 5401

Adding a degassing tablet:

Hydrogen is the only element that is appreciably soluble in aluminium and its corresponding alloys. Compounds, such as Hexachloroethane are commonly used; these compounds dissociate at temperatures of molten metal to provide generation of fluxing in gas. Gas fluxing reduces the dissolved hydrogen content in molten aluminium. This usage of reactive gases such as chlorine improves rate of degassing by altering the gas-metal interface and improves diffusion kinetics in them.

When aluminium has melted completely and is superheated to the required temperature and the furnace is put off, the crucible isthen taken out of the furnace and the degassing tablet is added to them. This removes all impurities in the form of gas.

Fig.2 Degassing in progress

Fluidity tests

Setting up of the mould:

The preheated moulds are set up such that they are parallel to the floor with the help of the spirit level such that thereisno gradient since the strip mould is very sensitive to gradients.

Fig.3 Strip mould

Fig.4 Spiral mould

Pouring of molten composite and solidification:

The molten metal mixed with the particulates are poured into the preheated moulds which are maintained at 100^{o}C. The composite is removed from the mould after solidification. Now the composite is allowed to cooldown and then the strip and spiral lengths are measured.

Fig.5 Pouring of molten metal and demoulding of spiral casting

IV. RESULTS AND DISCUSSIONS

Fluidity of base metal LM6

The following figures showvariation of fluidity and lengths with pouring temperature for LM6 alloy during the spiral test. The fluidity and length-temperature graphs areanalysed to determine the effect of pouring temperature on the fluidity length.

Spiral test

Fig.6 Variation of Aluminium LM6 spiral fluidity le0ngth with temperature

January - February 2020
ISSN: 0193 - 4120 Page No. 5394 - 5401

Fig.7 Total spiral fluidity length v/s temperature

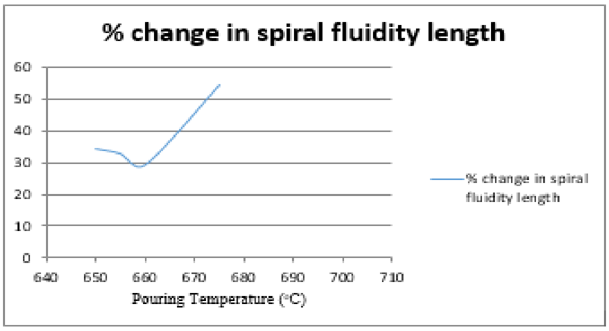
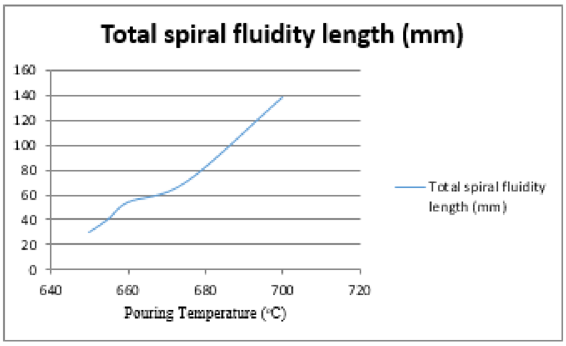


Fig.8 Percentage change in spiral fluidity length v/s temperature



Strip test

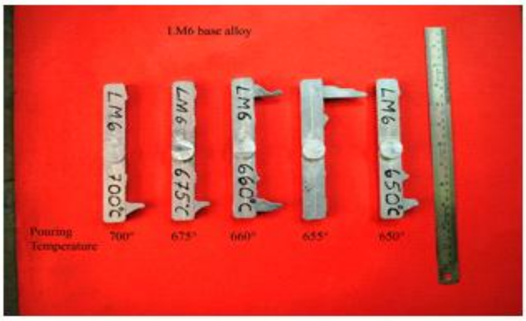


Fig.9 Variation of Aluminium LM6 strip fluidity length with temperature

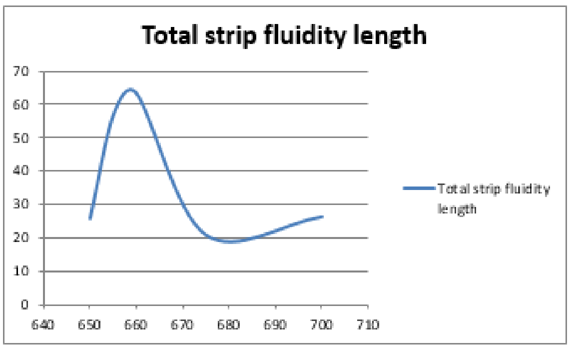


Fig.10 Total strip fluidity v/s temperature

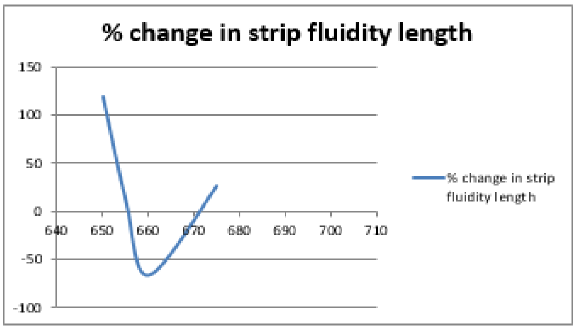


Fig.11 Percentage change in strip fluidity length v/s temperature

Discussion:

(a) In case ofthe spiral test the relationship between the fluidity length and temperature is linear and the maximum fluidity length is obtained at 700^{o}C. The linearity is valid in the temperature range chosen in the experiment indicating that the fluidity increases with temperature.

In case of strip testthe fluidity increases with temperature till 660^{0}C then the temperature deceases, indicating the filling capacity of the alloy. This could be due to theeasily melting eutecticsolidification of the alloy at that temperatures.

Fluidity of the composite.

The subsequent figures show the variation of fluidity length with percentage of graphite reinforcement in the composite. The tests were carried out using Spiral and Strip moulds, and the graphs were analysed to determine the effect of particulates on fluidity of a composite material.

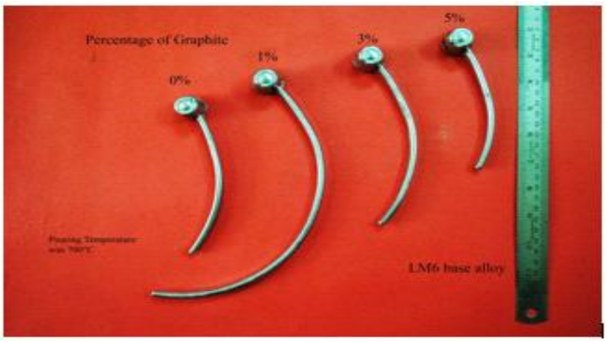


Fig.12 Variation of spiral fluidity length with % graphite

January - February 2020
ISSN: 0193 - 4120 Page No. 5394 - 5401

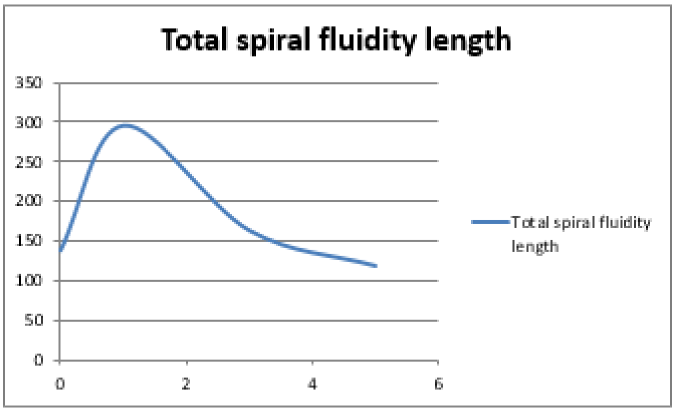


Fig.13 Variation of spiral fluidity length with % graphite

Fig.14 Variation of strip fluidity length with % graphite

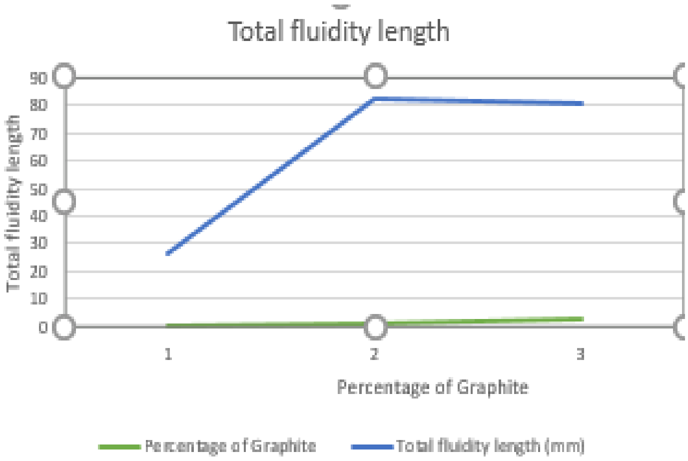


Fig.15 Variation of total strip fluidity length with % graphite

The study indicates that fluidity of the molten composite was highest when it contained 1% by weight of graphite particulates, and subsequently decreased with the increase in quantity of particulates. This could be due to the decrease in eutectic solidification temperature with increase in reinforcement percentage.

Effect of mould coating on fluidity at a standardised pouring temperature of 700^{o}C.
The tests were conducted for:
1.China clay coating

2.Graphite coating

3.No coating

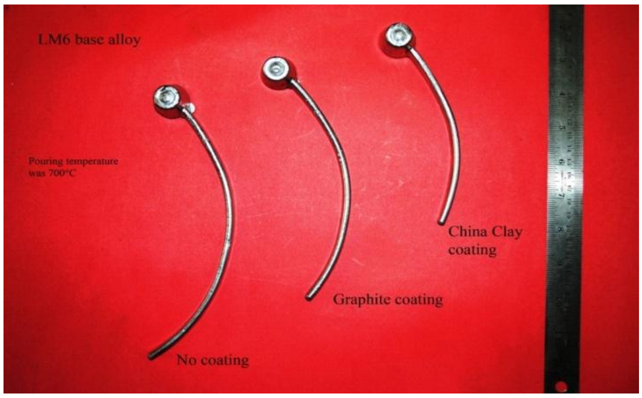


Fig 16 Variation of spiral fluidity length with mould coating

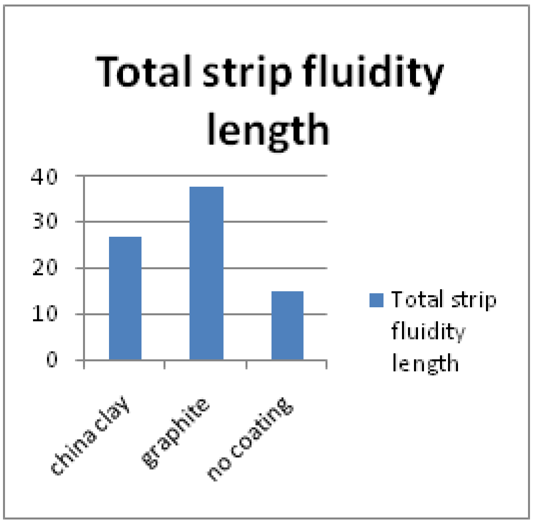


Fig 17 Graphical variation of spiral fluidity length with mould coating

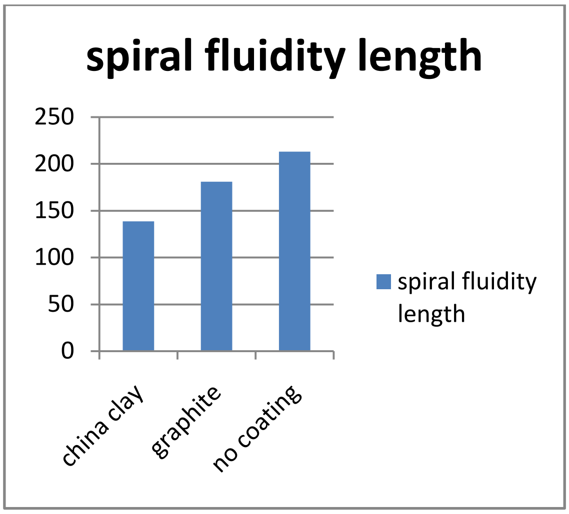


Fig 18 Variation of strip fluidity length with mould coating

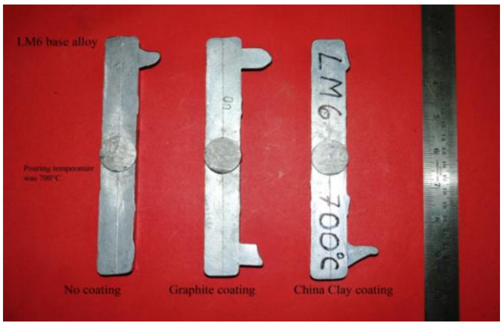


Fig19 Graphical variation of total strip fluidity length with mould coating

The Surface coating of the moulds influenced the fluidity of composite material.

Spiral fluidity is maximum when there is no coating. But the mould with graphite coating improved the strip fluidity. This could be due to the variation in different coating thicknesses or different surface roughness of the mould coatings.

Effect of mould coating on surface roughness

The following figures show the variation of roughness parameters with various mould coatings. The graphs were analysed to:

(a) determine the effect of coatings on surface roughness of the strip mould.
(b) study the variation of fluidity length with respect to surface roughness of the mould.

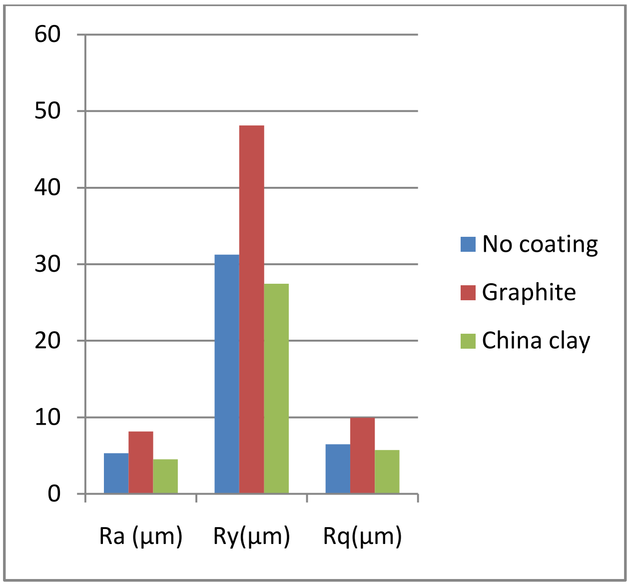


Fig 20 Effect of coating on surface roughness of the strip mould

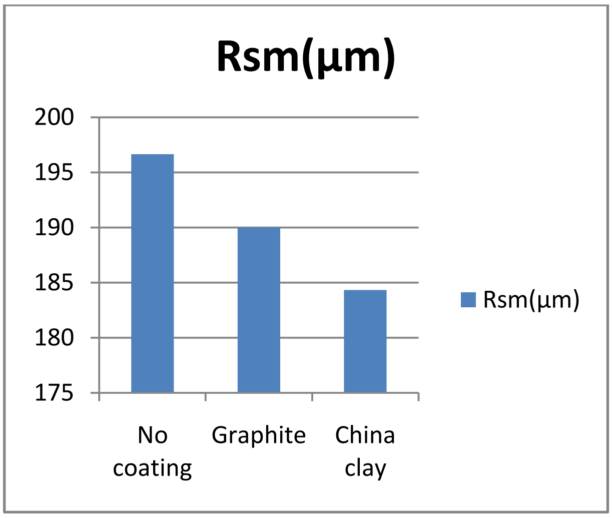


Fig 21 Variation of fluidity length with respect to surface roughness

The study of the figures indicates the following:

(a) There was conclusive evidence of the effect of mould coatings on the surface roughness. The surface roughness increased with the graphite coating and reduced with china clay coating compared to the standard uncoated strip mould.There were no conclusive proof of variation in the strip fluidity length due to the changes in surface roughness with various coatings

January - February 2020
ISSN: 0193 - 4120 Page No. 5394 - 5401

V. CONCLUSIONS

Results of the investigations carried out to study the influence of various parameters on the fluidity of aluminium alloy and its composite indicate the following:

- The pouring temperature influenced the fluidity to a large extent. Fluidity increased linearly with increase in the pouring temperature when all other factors such as composition of alloy, mould temperature, mould coating etc. were kept constant.

- The degree of purity of the alloy had a profound effect on the fluidity length observed after the experiment. The fluidity length decreased with the increase in impurity or other alloying elements. The eutectic alloy is observed to have the highest fluidity among the base metals.

- The introduction of graphite particulates to the base alloy resulted in discernible changes in the fluidity. The fluidity length decreased with the increasing percentage of the particulates.

- The surface roughness of the mould influenced the fluidity length on molten metal. The fluidity length found to be the highest when no coating was applied.

- For the spiral test, similarities in the percentage change in the fluidity were observed for the base alloy and the composite material.

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