ABSTRACT

Twin Roll Casting Process, also called as Direct Strip Casting (DSC), is an efficient way of making sheets of aluminium alloy directly from liquid melt. The advantages of twin roll casting include lower investment and operating costs, lower energy consumption and avoids or minimizes the hot rolling, continuous operation can be carried out and generates less re-melt scrap, higher tensile strength with good elongation etc. The consumption of energy required by various manufacturing processes clearly shows the enormous decrease in energy consumption for direct strip casting and thick slab casting compared with conventional casting. In fact it has now been believed that strip casting will use up to 90% less energy to process molten metal into sheet form and will reduce greenhouse gas emissions by up to 80% over conventional continuous casting and secondary processing. This proves DSC is an environmental friendly process. A further notable advantage of DSC is the scale of the operating plant. It is clear that a significant reduction in land usage will minimize both environmental impact and capital costs required for setting up a new casting facility. An additional environmental impact associated with DSC is the ability to make better use of scrap and recycled products. DSC produces high solidification rates which will reduce problems associated with segregation of residual elements in materials.

The review of literature clearly indicates that aluminium strip production is currently happening through traditional rolling process technique. There is a lack of standardization of the process especially with respect to the production of aluminium and aluminium alloys strips using twin roll casting. Another fact is that no attention is paid for developing the aluminium metal matrix composites strips using the twin roll casting process. Thus no study is made on the evaluation of the properties of the metal matrix composites especially on the aluminium - SiC composites strips which are twin rolled. In
other words, a systematic investigation of the effects of the operational parameters on strip castability optimization has not been done. It is very essential to establish better understanding of the principles and problems to widen the application of the process. In our country there is no manufacturer of twin roll casting machines or data available for making such a machine. Consequently effort has been made in this research work to address these problems. The current research work includes

a) Design and development of twin roll casting machine.

b) Optimizations of process parameters of twin roll caster for making high quality strips.

c) Study and Evaluation of physical characteristics of twin roll cast strips.

d) Determination of mechanical properties of twin roll cast strips.

e) Metallographic studies of twin rolled metal matrix composites (MMC) strips.

It is observed that the machine for producing twin roll casting aluminium is not available in the market. Hence it became necessary for the design and development of a twin roll casting facility. Two type’s of machines were designed and fabricated, the first one is vertical twin roll casting machine. Based on the experience of using the vertical twin casting machine and to eliminate the gross casting defects in the strips, second machine was developed. It was a liquid metal vertical entry and rolled strip angular exist strip making machine.

The alloy used in the study for producing twin roll strips were ASTM Al 2025 and Al 6061 high strength aluminium alloy. For producing MMC the reinforcing material was silicon carbide of 25-35 μm, 15-25 μm and 5-15 μm particle size that corresponds to BS 400, BS 500 and BS 800 respectively. For making MMC facilities were established. At each particle size of silicon carbide of its quantity was varied from 2 to 6% in steps of 2%.
The twin roll casing process has several steps and at each step controlling the parameter is critical. The basic parameters are shape and size of liquid melt flow controlling device, preheating temperature of rollers and distance between the rollers. After standardization of the basic parameters, two major parameters that govern the production of quality and defect free twin roll cast strip are standardized. They are twin roll caster speed and twin casting liquid metal pouring temperature.

The twin roll strips has to qualify as an acceptable material for use by designers. The physical nature of the strip and mechanical properties form major deciding entities in qualifying the strips for industrial usage. In order to identify the best processing conditions during twin roll casting process, it becomes essential to carefully examine the mechanical and microstructural properties of the twin roll cast strips in addition to the measurement of physical characteristics like consistency in the strip thickness and strip width uniformity. The mechanical properties, ultimate tensile strength, % elongation and hardness, were measured for the strips produced. The effect of speed of the rollers and pouring temperature on these properties was closely examined and reported. The outcomes of the current research work are as follows:

a) TWIN ROLL CASTING PARAMETERS

i) It is essential to preheat the roller and pouring basin to about 150 °C.

ii) When the liquid metal pouring temperature was 670, 680, 690 and 700 °C the formation of good strips happens between 11 to 13, 9 to 11, 9 to 10 and 8 to 9 rpm respectively. Below these ranges of speeds it is generally observed that there is premature solidification of liquid metal above the rollers. This solidified mass acts like a wedge and does not allow rolling process to proceed further.

iii) There is a small range of roller speed for any given pouring temperature wherein sound strips were obtained. In this range of speed it was found that for 670, 680, 690
and 700 °C pouring temperature the best tensile strength was obtained for the strip at roller speed of 12, 10, 10, 9 rpm respectively. This is an inverse relationship between pouring temperature and roller speed and the equation is $S = -0.09 T + 71.9$. Where $S =$ Rolling speed in rpm and $T =$ Temperature in °C

iv) It was found that an inclined strip drawing is an essential part of the system. Under this condition it was possible to consistently obtain sound and long strips.

b) TWIN ROLL STRIP - PHYSICAL CHARACTERISTICS

i) The strip width is directly proportional to pouring temperature. If $W$ is the strip width in mm and $T$ is pouring temperature in °C then the equation governing the strip width is $W = 0.0537 T - 2.999$. There is 22% increase in strip width when the pouring temperature is raised from 670 to 700 °C.

ii) The strip thickness throughout the rolled length of the strip remains inversely proportional to the roller rpm.

iii) Irrespective of pouring temperature the strip thickness almost remains constant.

iv) It may be noted that closer to the high rpm of the strip forming rpm many defects sets in. The same is aggravated as the pouring temperature is increased. Some such defects are centerline shrinkage, heat lines and hot tears.

c) MECHANICAL PROPERTIES

i) The Ultimate Tensile Strength was the highest when the rpm is 12, 10, 10 and 9 for pouring temperature of 670, 680, 690 and 700 °C respectively. This indicates both rpm of the roller and pouring temperature, in a combined way, influence the tensile strength.

ii) The Ultimate Tensile Strength of the rolled strip was the highest under the following condition, pouring temperature 680 °C and speed of rolling 10 rpm.
iii) The percentage elongation of the twin rolled strip for any given pouring temperature indicates that it is dependent on rpm through an inverse relationship.

iv) The best percentage elongation value was obtained when the pouring temperature was 670 °C and 11 rpm of the twin roller.

v) The BHN was not greatly influenced by pouring temperature of liquid metal or roller rpm. The variation was within 3%.

d) TWIN ROLLED ALUMINIUM SILICON CARBIDE MMC STRIPS

i) The matrix material was 2025 aluminium alloy. To this adding 25-35 μm, 15-25 μm, 5-15 μm silicon carbide particulates results in a gradual increase in strip width as quantity of silicon carbide is increased.

ii) Irrespective of silicon carbide particle size as well as the amount of silicon carbide in the liquid metal the average strip thickness of the twin rolled aluminium silicon carbide MMC remains constant.

iii) The addition of silicon carbide results in improvement of Ultimate Tensile Strength of twin rolled strip when compared to the matrix alloy counterpart.

iv) For any given weight of SiC, addition finer particle size SiC improves the Ultimate Tensile Strength. Similarly for any given SiC particle size the Ultimate Tensile Strength of twin rolled strips formed out of aluminium SiC MMC indicates that the Ultimate Tensile Strength is directly proportional to amount of SiC addition.

v) Overall the mechanical properties of twin rolled aluminium SiC MMC is superior to its twin rolled strip matrix alloy counterpart. It is observed that the extent of improvement is of the order of 7%.

e) CONCLUDING SUMMARY

i) A twin roll casting machine was successfully designed and fabricated. The machine
is capable of producing thin strips of aluminium 6061 and 2025 alloys directly from liquid metal with an acceptable quality level. (Fulfilling both the physical and mechanical property requirements).

ii) The process being unique and new, an Indian patent is filed for claiming the processes and its use for the production of twin rolled cast MMC.