International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 02 – Issue 11 || November 2017 || PP. 19-26

Study of Sand Casting Gating System

Nandagopal M[1], Sivakumar K[2], Senthilkumar G[3], Sengottuvelan M[4]

[1,3] *Associate Professor,*
Department of Mechanical Engineering,
Bannari Amman Institute of Technology, Sathyamangalam
[2]*Dean,*
Planning, Development and Student Affairs
Bannari Amman Institute of Technology, Sathyamangalam
[4]*Assistant Professor,*
Department of Mechatronics Engineering,
Bannari Amman Institute of Technology, Sathyamangalam

Abstract: In metal casting industry, sand casting is widely used to produce a wide variety of metal components with complex geometries. In the present global scenario of recession and high competitive environment among the foundry, cost effectiveness is a crucial role to play Foundries suffers from poor quality and productivity due to large number of process parameters, lower penetration of automations and shortage of skilled workers. Numerous factors influence the total cost of a finished cast component. High casting rejection, both internal and customer returns have a considerable adverse effect on total cost of production. The design of gating system and riser is one of the major factor for improving the casting quality and yield%. The well designed gating system and riser results in reduced casting defects and increased yield%. This intern results in reduced total manufacturing cost of the casting. In this paper an attempt has been made to explain the major elements of gating system, various types of gates and riser.

Keywords: Foundry, Sand casting, gating system, yield%

1. Introduction

Many complex components are easily produced by sand casting process, because of its advantages over other manufacturing processes. It is one of the economical process, in which any intricate internal and external shapes components can be manufactured in short time. The production of intricate shape components involve the wide range of design and process parameters in terms of materials, component weight, component thickness, shape complexity and batch size.

Foundries can be classified in to captive and jobbing foundry. Jobbing foundries are market driven enterprises. To survive in market, it should manufacture quality product with lesser cost in short time. But a foundry suffers due to poor quality and productivity with large number of process parameters.

The quality product with minimum manufacturing cost can be achieved by well designed gating system. A gating system is a basic design, which is needed to construct a smooth and proper filling of the mold cavity of the casting without any discontinuity, voids or solid inclusions. A well designed gating system and riser ensures the smooth, uniform and complete filling of clean molten metal. Clean metal implies preventing the entry of slag and inclusions into the mould cavity which minimizes the surface turbulence. The rate of solidification in casting process affects the microstructure of cast metal which in turn controls the mechanical properties such as strength, hardness, machinability etc. The proper design of riser is required to achieve directional solidification because improperly designed riser results in defective casting with shrinkage cavity or lower yield. Hence, proper design of riser and good control in process parameters results in quality casting. The yield Percentage per component is given as

$$\text{Yield\%} = \frac{\text{Volume}_{\text{cast}}}{\text{Volume}_{\text{cast}} + \text{Volume}_{\text{gating riser}}} \times 100$$

Hence the yield percentage per component increases with decrease in volume of gating and riser. The well designed riser and gating system results in quality products, increased yield %, increase in productivity, improved delivery commitments, increase in customer satisfactions and increase in employee morale.

2. Literature Review

Vidhate N et al. [1] states the importance of simulation in improving the quality of the casting and optimize gating/riser systems are optimized by using CAD and simulation technology with the goal of improving casting quality such as reducing incomplete filling area, decreasing large porosity and increasing yield.

Jaju.S.B et al. [2] analyzed and identified the gating & riser system by simulation to reduce internal shrinkage and yield% .

Suresh M. Sawant et al. [3] analyzed brake disc to solve the problems like improving casting yield and casting quality. The gating system model is created using 3D CAD and simulated using casting simulation program Autocast-X flow plus software.

Boutorabi, M. A et al. [4] have discussed that the geometry and size of the gate and the ratio of the gating system has a great influence on the pattern of mold filling by experiments.

3. Sand Casting Gating System

3.1 Main Elements of gating system

In casting there are two main stages, which are filling process and solidification process. In filling process consist of gating system composed of pouring cup, spure base, runner, sprue, gate and riser are shown in Figure 1.

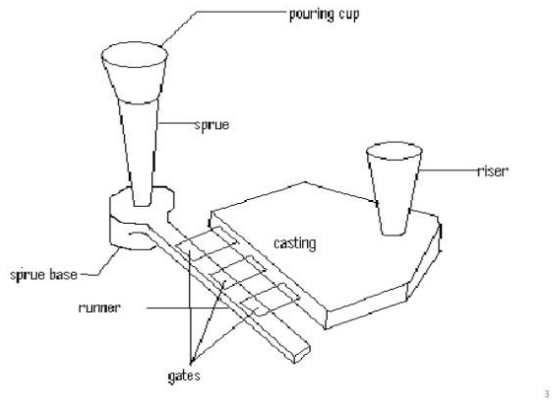

Figure1: Gating System

3.2 Pouring cup

It is circular or rectangular in shape. It collects the molten metal, which is poured, from the ladle. The main function of a pouring cup is to reduce the momentum of the liquid flowing in to the mould by settling first into it. In order that the metal enters into the sprue without any turbulence it is necessary that the pouring basin be deep, also the entrance into the sprue is a smooth radius of at least 25mm. The recommended pouring cup depth 2.5 times the sprue entrance diameter is enough for smooth metal flow and to prevent vortex formation.

3.3 Sprue

It is circular in cross section. It leads the molten metal from the pouring cup to the sprue well. The sprue should be a vertical taper passage through the cope to gain the velocity of the metal as it flows down reducing the air aspiration and connecting the pouring basin to the runner. The taper can obtain by the continuity equation.

$$A_t V_t = A_c V_c$$

Where c = choke section of the sprue
t = top section of the sprue

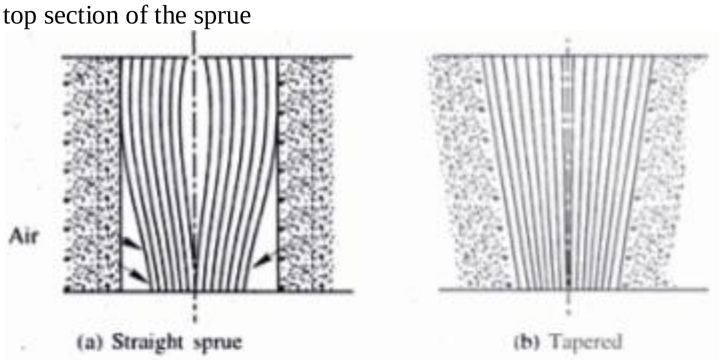

Figure 2: Straight and Taper spure

The velocities are proportional to the square of the potential head.

$$A_t = A_c \sqrt{h_t}/h$$

Where $h = H - h_t$
H = Actual sprue height mm

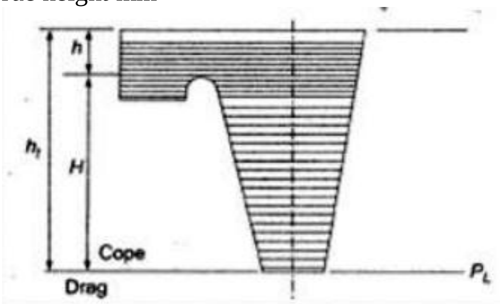

Figure 3: Spure proposition

3.4 Sprue Well

It changes the direction of flow of the molten metal to right angle and passes it to the runner. Sprue well at the bottom of a sprue well at the bottom of the sprue helps in reducing the velocity of the incoming material and also the mould erosion. It changes the direction of flow of the molten metal to right angle and passes it to the runner. The general guide line for the sprue well should be five times that of the sprue choke area and the well depth should be approximately equal to that of the runner.

3.5 Runner

The runner takes the molten metal from sprue to the casting. This is the final stage where the molten metal moves from the runner to the mold cavity.

3.6 Gate

This is also called as ingate. These are the openings through which the molten metal enter the mould cavity. The cross section of the ingate should be such that it can be easily broken off after casting solidification. Depending on the application different types of gates are used in casting process. They are shown below

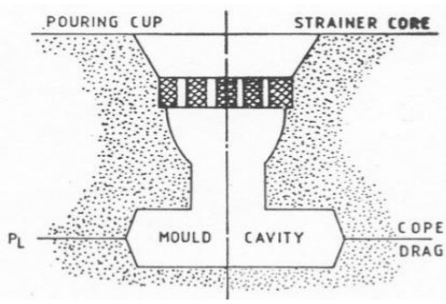

Figure 4: Top gate

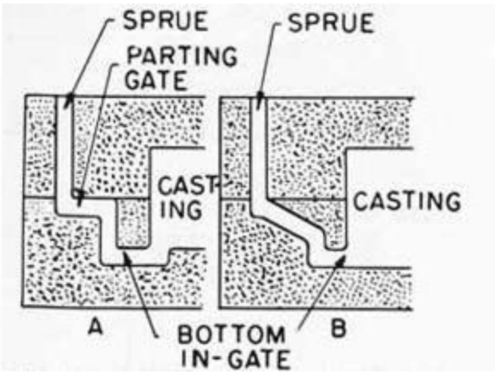

Figure 5: Bottom gate

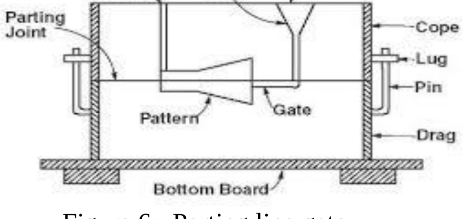

Figure 6: Parting line gate

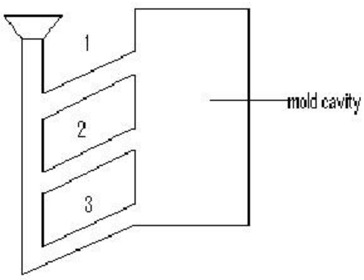

Figure 7: Step gate

3.6 Riser

Riser is a source of extra metal which flows from riser to mold cavity to compensate for shrinkage which takes place in the casting when it starts solidifying. Without a riser heavier parts of the casting will have shrinkage defects, either on the surface or internally. Risers are known by different names as metal reservoir, feeders, or headers. The riser must be designed to freeze after the main casting in order to satisfy its function. The riser must remain molten until after the casting solidifies.

Risers serve dual function, they compensate for solidification shrinkage and heat source. So that they freeze last and promote directional solidification. The multiple risers can be provided according to the requirement. The other important aspect of riser design is the connection between the riser and casting. Since it is necessary to separate the riser from casting and it is desirable that the connection area be as small as possible. On the other hand, the connection area should be large enough so that the link does not freeze before solidification of casting. Short-length connections are most desirable. The riser and gating system in casting process is shown in Figure 8. Another major element is filter or slag trap which usually placed in runner or between runner and ingate to filter slag and other inclusions.

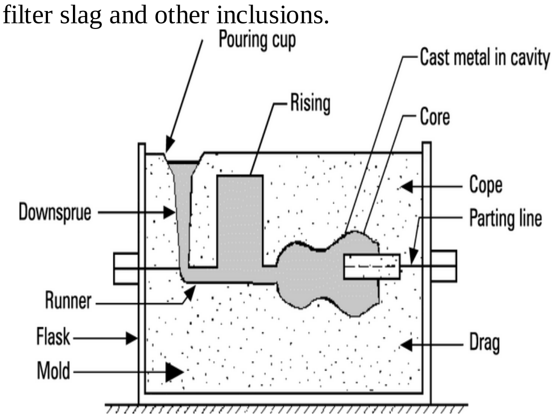

Figure 8: Riser for sand casting process

3.6.1 Design Requirements of Risers

1. Riser placement: the spacing of risers in the casting must be considered by effectively calculating the feeding distance of the risers.
2. Riser shape: cylindrical risers are recommended for most of the castings as spherical risers, although considers as best, are difficult to cast. To increase volume/surface area ratio the bottom of the riser can be shaped as hemisphere also and the most important rule is riser solidification time must be longer than casting solidification time by Chvorinov's rule

3.6.2 Types of Riser

A riser is categorized based on three criteria: where it is located, whether it is open to the atmosphere, and how it is filled. If the riser is located on the casting then it is known as a top riser, but if it is located next to the casting it is known as a side riser. Top risers are advantageous because they take up less space in the flask than a side riser, plus they have a shorter feeding distance.

If the riser is open to the atmosphere it is known as an open riser, but if the risers is completely contained in the mold it is known as a blind riser. An open riser is usually bigger than a blind because the open riser loses more heat to mold through the top of the riser. Finally, if the riser receives material from the gating system and fills before the mold cavity it is known as a live riser or hot riser. If the riser fills with material that has already flowed through the mold cavity it is known as a dead riser or cold riser. Live risers are usually smaller than dead risers. Top risers are almost always dead risers and risers in the gating system are almost always live risers

International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 02 – Issue 11 || November 2017 || PP. 19-26

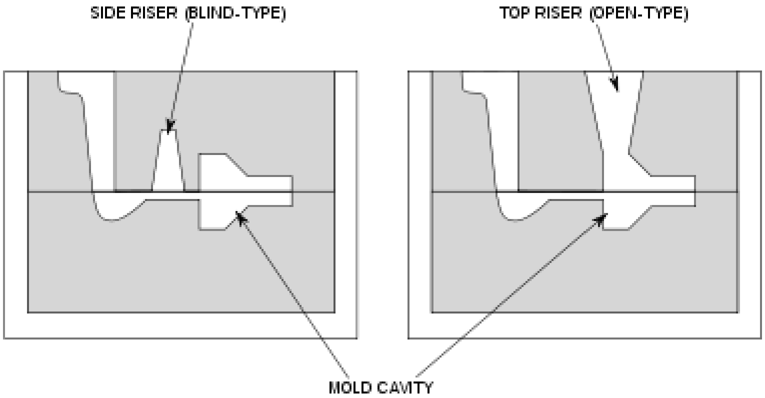

Figure 9: Open riser   Figure 10: Blind riser

3.7 Yield

The efficiency, or yield, of a casting is defined as the weight of the casting divided by the weight of the total amount of metal poured. Risers can add a lot to the total weight being poured, so it is important to optimize their size and shape. Because risers exist only to ensure the integrity of the casting, they are removed after the part has cooled, and their metal is remelted to be used again. As a result, riser size, number, and placement should be carefully planned to reduce waste while filling all the shrinkage in the casting.

$$\text{Yield\%} = \frac{\text{Volume}_{\text{cast}}}{\text{Volume}_{\text{cast}} + \text{Volume}_{\text{gating riser}}} \times 100$$

4. Design of Gating System

The liquid metal that runs through the various channels in the mould obey Bernoulli's theorem which states that the total head remains constant at any section.

Bernoulli's theorem

$$h + \frac{p}{\rho g} + \frac{v^2}{2g} = \text{constant}$$

$$h_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = h_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + f$$

Assuming f=0 and system remain at atmospheric pressure
No turbulence and friction.

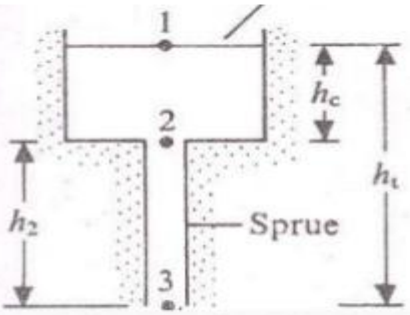

Figure 11: Metal flow through sprue

where h= Potential head, m
P= Pressure, Pa
V= Liquid velocity, m/s
w= Specific weight of liquid, N/m2
g= Gravitational constant

4.1 Optimal Filling Time

A casting fills too slowly can have discontinuities such as cold shuts and misruns. Too fast filling leads to solid and gaseous inclusions. The higher limit of filling time (slowest filling) is governed to avoid premature freezing in thin sections before complete filling. The lower limit of the filling time (fastest filling) is governed by the onset of surface turbulence. The correct filling time lies between fast and slow filling. It is a function of cast metal, weight, minimum section thickness and pouring temperature. Several empirical equations to determine the correct filling time for metals are developed by casting researchers based on experimental investigations. The filling time t is expressed as a function of casting weight W in Kg, section thickness T in mm. A generalized equation for filling time for casting less than 450kgs can be written as:

$t = K (1.41 + (T/14.59))\, W$

where K = Fluidity of iron in inches/40
T = Average section thickness, mm
W = Mass of the casting kg

4.2 Metal velocity

The optimal filling time is determined such that gating channels can be designed to avoid surface turbulence and minimize bulk turbulence within the gating channels as well as the mould cavity. This depends on the velocity of the molten metal which varies widely within the gating channels as well as inside mould cavity. For a given location in the casting, the velocity changes with time, from the start to end of filling. The metal is both hot and fast at this location and instant, and lead to considerable damage if it is not controlled properly. In general, the velocity of molten metal must be kept lower than 1 m/s for ferrous metals and 0.5 m/s for aluminum alloys.

4.3 Choke area

After calculating filling time it is required to establish the main control area which meters the metal flow into the mould cavity. So that the mould is completely filled within the calculated pouring time. This controlling area is called choke area. Normally choke area is under at the bottom of the sprue.

Choke area $A = W/ d\, t\, C \sqrt{2gH}$

Where A = Choke area mm^2
W = Mass of the casting kg
t = Pouring time sec
d= Mass density of the molten metal kg/ mm^2
H= Effective metal head mm
C= Efficiency factor which is a function of the gating system

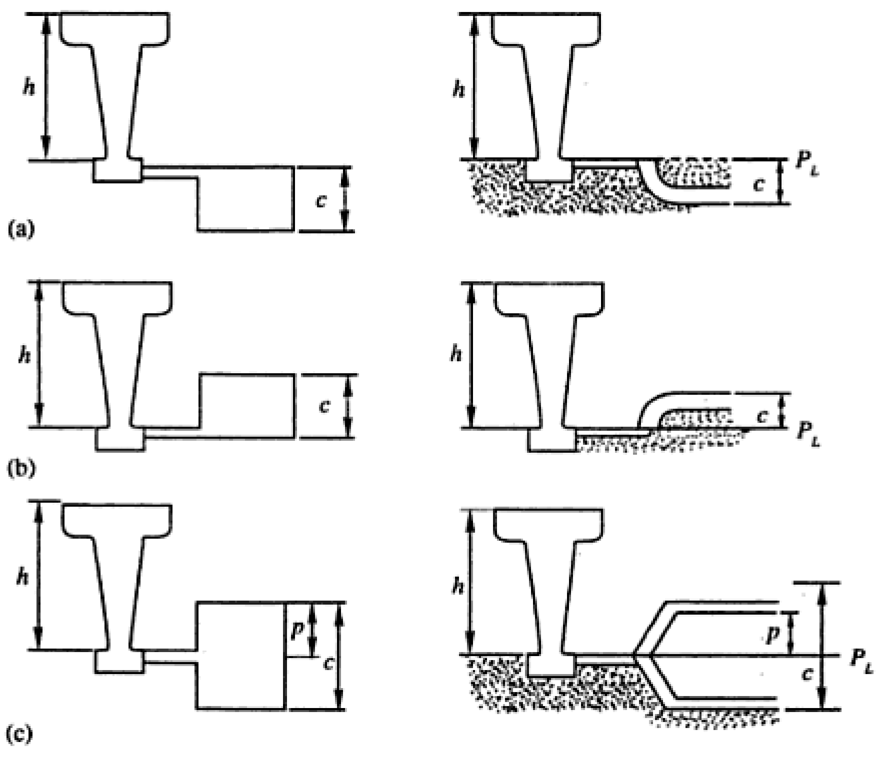

Figure 12: (a) Top gate H = h (b) Bottom gate, H = h – c/2 (c) Parting gate $H = h - P^2/2c$

Where h= height of sprue

P= height of mould cavity
C= total height of mould cavity

4.4 Gating Ratio

The gating ratio refers to the proportion of the cross-sectional area between the sprue, runner and ingate. Generally it is denoted as Sprue area: Runner area: Ingate area

Depending upon choke area, there can be two types of gating systems.

1 Pressurized gating system
2 Un-pressurized gating system

4.4.1 Pressurized Gating System

- The total cross sectional area decreases towards the mold cavity
- Back pressure is maintained by the restrictions in the metal flow
- Flow of liquid (volume) is almost equal from all gates
- Back pressure helps in reducing the aspiration as the sprue always runs full
- Because of the restrictions the metal flows at high velocity leading to more turbulence and chances of mold erosion
- Normally provide casting yield since the volume of metal used up in the runners and gates are reduced.
- Because of the turbulence this type of gating system is not used for light alloys but can be advantageously used for ferrous castings. The gating system of a typical pressurized gating system is
  Sprue area: Runner area: Ingate area
  1; 2: 1

4.4.2 Un-Pressurized Gating System

- The total cross sectional area increases towards the mold cavity
- Restriction only at the bottom of sprue
- Flow of liquid (volume) is different from all gates
- aspiration in the gating system as the system never runs full
- Less turbulence
- Because of the turbulence this type of gating system is used for light alloys such as aluminium and magnesium alloys.
- These have tapered sprues, sprue well and pouring cup.
- The gating system of a typical un-pressurized gating system is
  Sprue area: Runner area: Ingate area
  1; 4: 4

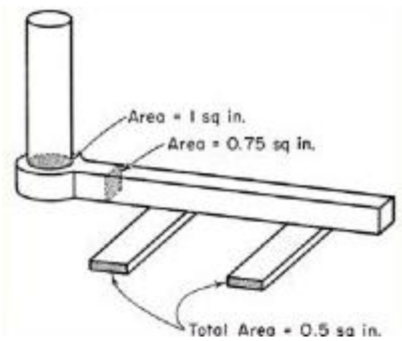

Figure 13(a) Pressurized system

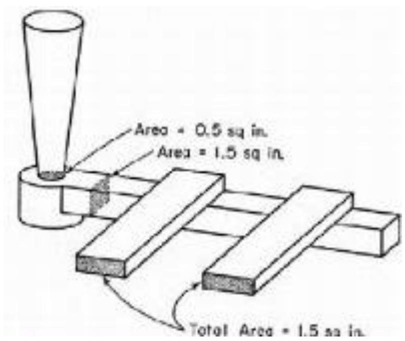

Figure 13(b): Unpressurized system

4.4.3 Gating ratio used in practice

1 Aluminium	-	1: 2:1	1:2:4	1:3:3	1:4:4	1:6:6
2 Grey cast iron	-	1: 1.3: 1.1	1:1.5:1.1	1:4:4	2:1.8:1	2:3:1
3 Steel	-	1: 1: 7	1:2:1	1:2:1.5	1:2:2	1:3:3

5. Conclusion

In this paper different gating system elements and risers of sand casting gating system are studied. This study will guide the fundamentals of gating system to the basic designer. The well designed gating system and riser increase the productivity, minimize the manufacturing cost (By improving yield %) and improve the quality of the castings. The quality casting leads to improved customer satisfaction and employee morale.

References

[1]. Metkar R. M., Vidhate N. A., Steel, J., & Dukare, N. A, "Optimization Of Gating System Using Mould Flow Software : A Review" International Journal of Mechanical Engineering, 4(1), pp.8-14, 2014.

[2]. Swapnil A. Ambekar and Dr. S. B. Jaju, "A Review on Optimization of Gating System for Reducing Defect" International Journal of Engineering Research and General Science , 2(1), pp.93-98, 2014.

[3]. Utkarsh S. Khade and Suresh M. Sawant, " Gating Design Modification Using 3D CAD Modelling and Casting Simulation for Improving the Casting Yield," 4(7), pp 813–820, 2014

[4]. Masoumi M.,Hedjazi J & Boutorabi, M. A. " Effect of Gating Design on Mold Filling", American Foundry Society, Schaumburg, IL USA 152(02), pp 1–12, 2015

Author Profile

M. Nandagopal received the B.E. degree in Mechanical Engineering from Coimbatore Institute of Technology, Coimbatore in 1991 and M.E. degree in Industrial Engineering from PSG College of Technology, Coimbatore in 1997. Currently he is working as an Associate professor in the department of Mechanical Engineering at Bannari Amman Institute of Technology, Sathyamangalam.

K Sivakumar received the B.E. degree in Mechanical Engineering from Madurai Kamaraj University , Madurai in 1993 and M.E. degree in Bharathidasan university, Tiruchirappalli, in 1998. He had completed his Ph.D. in Bharathidasan university, Tiruchirappalli, in 2006. Currently he is working as a Dean, Planning, Development and Student Affairs at Bannari Amman Institute of Technology, Sathyamangalam.

G Senthilkumar received the B.E. degree in Mechanical Engineering from Kongu Engineering College, Erode in 1999 and M.E. degree in Production Engineering from Government College of Technology, Coimbatore in 2001. He had completed his Ph.D. in Anna university, Chennai in 2015. Currently he is working as an Associate professor in the department of Mechanical Engineering at Bannari Amman Institute of Technology, Sathyamangalam.

M. Sengottuvelan received the B.E. degree in Mechanical Engineering from Sethu Institute of Technology, Virudhunagar District in 2004 and M.E. degree in Mechatronics Engineering from Kongu Engineering College, Erode in 2010. Currently he is working as an Assistant professor in the department of Mechatronics Engineering at Bannari Amman Institute of Technology, Sathyamangalam.