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Methoding of Castings for Improved Yield using Simulation: A Case Study

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***Abstract:** Casting is one of the many forming processes and it is one of the cheapest methods of giving finished shape. There is less research in casting as compared to other forming methods [3]. This is due to the number of variables involved in casting technology. Green sand molding, which is the most popular method used in foundries, has no less than 52 variables influencing final finished shape with given properties. Understanding and correlating so many variables was beyond the grasp of science [5]. With the introduction and progress in computer technology; it has become possible for scientists to tackle so many variables and thus reducing economic loss of trials which works out to be millions of rupees per year per foundry [4].*

Out of various methods of rejection control, most recent tool is casting simulation. The advantages of computer aided Methoding over conventional Methoding include designing of optimized gating and risering systems in the design stage thus saving a lot of useless work, time and money & leading to manufacturing of quality castings with better yield.

The present work is related to the rejection control of two castings in a foundry using ADSTIFAN simulation software.

***Keywords:** Casting, Rejection, Methoding, ADSTIFAN, Simulation.*

I. INTRODUCTION

Casting is one of the earliest known metal shaping methods. To get a casting molten metal is poured in to refractory cavity to the shape to be made and allowed it to solidify. Metal casting is one of the direct methods of manufacturing the desired geometry of component. The method is also called a "NEAR NET SHAPE PROCESS". Still there were some limitations in development in casting technology and compared to other fabricating methods, research in casting technology received less attention. This is because of the number of variables involved in casting technology. The total casting production in India in the yr. 2018-19 was 13.38 metric tons.

The flow diagram shows casting process at a glance.

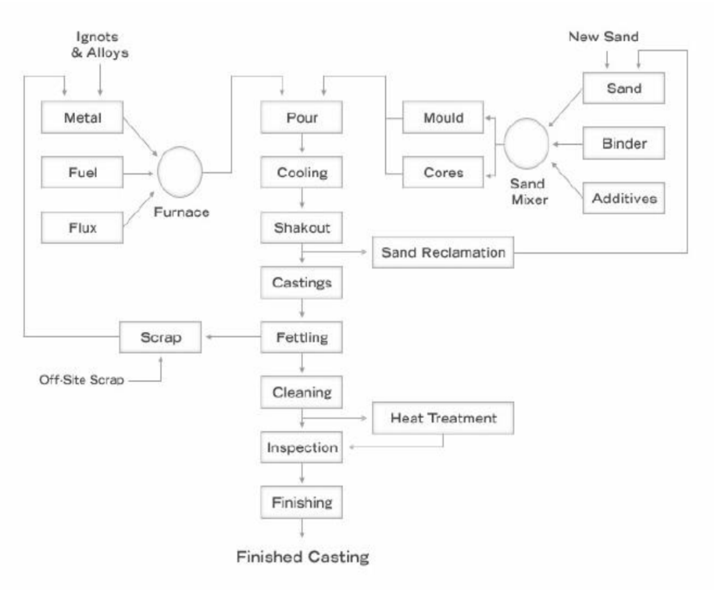

Fig. no.1 casting process

II. PROBLEM DEFINITION

Mayuresh Engineering Works, Shiroli MIDC, Kolhapur, is an ISO 9001: 2008 Certified mechanical foundry engaged in manufacturing of C.I., Alloy C.I., S.G. Iron, and Steel Castings and Metal Machining. They manufacture Automobile Parts for Tractor and Boiler castings. Their sister Concern namely M/S. Shree Sidharaj Engineering Pvt. Ltd. is working as Manufacturer of Steel Casting, Alloy Steel Castings, S.S. Casting, Boiler Casting, S.G. Iron Castings & Alloy C.I. Castings.

The problem under consideration is regarding, control of rejections related to shrinkage by improved methoding (gating & risering) & yield improvement (by optimizing dimensions of gating and risering system). The components we found for our study are,

For yield improvement

1) Exhaust Manifold - 5337
2) Fan Hub -30 N

Rejection due to shrinkage for both castings for 3 months was as below.

A. For Manifold-5337 Casting.

Table no.1 Rejection % of manifold for 3 months

Rejection %			
Month	Prod	Rejection	Rejection %
July	90	40	44.44%
Aug	60	32	53.33%
Sept.	100	42	42.00%

B. For Fan hub-30N Casting.

Table no.2 Rejection % of Fan Hub for 3 months

Rejection %			
Month	Production	Rejection	Rejection %
July	63	23	36.51%
Aug	388	129	33.25%
Sept	60	22	36.67%

The range of various parameters of mould properties was finalized by company as below.

Table no.3 mould properties finalized

Sr. No.	Mould properties	Range
1.	Green Compressive Strength	900- 1300 gm/cm^2
2.	Moisture content	3.0% to 4.0%
3.	Permeability	100 to 150
4.	Compactibility	40-50

By proper corrective actions, mould properties were controlled as below.

Table no.4 Mould properties controlled

Sr. No.	Mould properties	Controlled Range
1.	Green Compressive Strength	1000- 1150 gm/cm^2
2.	Moisture content	3.2% to 3.8 %
3.	Permeability	120 to 140
4.	Compactibility	42 – 47

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Following corrective actions were planned to maintain the mould properties.

1) Minimize dead clay in moulding sand
2) Control the moisture percentage of moulding sand.
3) Maintain the consistency in moisture of moulding sand.
4) Control the temperature of moulding sand.

Following actions were implemented to improve mould properties.

a) Addition of Blowers and Dust collector to remove fines from sand to maintain permeability.
b) Automation of water addition process to maintain moisture content & G.C.S.

Below table shows the actual values of sand parameters recorded during production.

Table no.5 Actual sand parameters at the time of production

Sr. No.	Sand Parameters	Observation 1	Observation 2	Observation 3	Observation 4	Observation 5
Time	Date – 28.06.19	10.15 AM	11:25 AM	12:15 PM	2:00PM	4:00PM
1	G. C. S	1100	1080	1080	1120	1090
2	Permeability	125	132	126	140	134
3	Moisture	3.4	3.5	3.4	3.6	3.8
4	Compactibility	44	46	46	47	42

(Red values show minimum & maximum values of that sand Parameter)

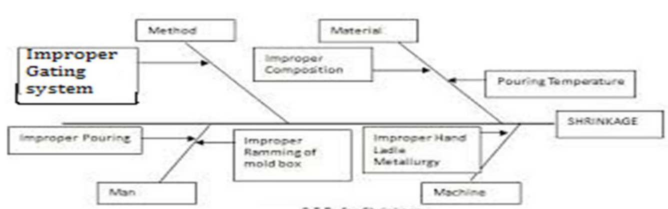

Fig. no.2 Fish bone diagram for Shrinkage defect.

Despite good sand properties, we are getting shrinkage defect. Then as per fish bone diagram, there is no option but to go for improved methoding to reduce rejection & to improve yield.

III. PROPOSED WORK & METHODOLOGY

1) Study the existing method.
2) Analysis of existing casting rejection and yield.
3) Geometric modeling of selected casting by using CAD-Software.
4) Casting Simulation using ADSTEFAN Software.
5) Suggestion for rejection control by improved methoding & optimizing dimensions of gating and risering system.
6) Comparison of rejection and yield with those after implementation of modified Methoding.

A. *Case Study for Rejection Control*

1) *Exhaust Manifold – 5337.*

Introduction

a) Material. – CI
b) Unit weight of casting in kg. – 5.6KG
c) Number of components poured in a box. – 2 Nos.
d) Size of box: Cope: 16x24x5 inch & Drag: 16x24x5 inch
e) Shape of box: Rectangular.
f) Type of gating system used = bottom type.
g) Hardness: 179-230 BHN
h) Tensile strength: 220 N/mm2
i) Ex. Manifold 5337- Composition:

Table no.6 Chemical composition of Ex. manifold

Sr.No.	Element	Range (%)
1.	C	3.1 – 3.5
2.	Si	1.9 – 2.3
3.	CE	3.90 – 4.30
4.	Mn	0.6 – 0.9
5.	S	0.06 -0.12 MAX
6.	P	0.12 MAX

j) Tapping temperature: 1360^0 C – 1380^0 C
k) Pouring temperature: 1330^0 C – 1360^0 C

Present Problem with Casting

- Low yield (69%)
- Shrinkage at various locations.

2) *Fan Hub- 30N*

Introduction

a) Material. – CI
b) Unit weight of casting in kg. – 5.5KG
c) Number of components poured in a box. – 2Nos
d) Size of box: Cope: 16x16x5 inch & Drag: 16x16x5 inch
e) Shape of box: Square
f) Type of gating system used = bottom type
g) Hardness: 180 - 240 BHN
h) Tensile strength: 260 N/mm2
i) Fan Hub- Chemical Composition:

Table no.7 Chemical composition of Fan Hub

Sr. No.	Element	Range (%)
1.	C	2.8 - 3.4
2.	Si	1.6 - 2.0
3.	Mn	0.7 - 0.9
4.	S	0.06 - 0.12 MAX
5.	P	0.12 MAX
6.	Cu	0.2- 0.3

j) Tapping temperature: 1370^0C– 1380^0 C
k) Pouring temperature: 1345^0C – 1360^0C

Present Problem with Casting

- Low yield (64%)
- Shrinkage at various locations.

IV. PROPOSED METHODOLOGY

Following are the strategy suggested for rejection control & yield improvement of castings

1) To optimize the dimensions of different parts of gating system by analytical method and or by casting simulation.
2) To optimize the size and number of risers by Analytical method and or by casting simulation.
3) Sand ramming should be done properly in the corners initially so that mould will have sufficient strength throughout after performing moulding operation.
4) Sand must be used within one hour after its preparation and if not then it should be sent back to muller to control its properties as it loses its properties with the passage of time.
5) Methoding is required to be redesigned to avoid shrinkage and improve yield. Instead of using trial and error method for the same as per current practice it was decided to make use of simulation software to design the methoding. The use of software is definitely going to reduce cost, energy and time which otherwise is much more for development.

V. IMPLEMENTATION OF REJECTION CONTROL STRATEGY

The decision of redesigning the methoding is first discussed in detail. We have used ADSTEFAN software as it is available in the industry. ProSIM is partner of M/S Hitachi Japan, to promote and distribute their unique proprietary casting simulation software ADSTEFAN. ADSTEFAN has many unique features researched and developed at Hitachi Research Laboratories in collaboration with many universities in Japan.

ADSTEFAN is developed by Prof. Niyama (famous due to Niyama parameter!!) of Tohoku University.

A. Steps in Development of Methoding using Simulation Software

1) First create the model in design software.
2) Create Gating system as per standard.
3) This part file is converted to the STL file format for simulation
4) Open the simulation software.
5) Crate a folder of part file with name.
6) Create the folder of trial we have taken, like trial 1, trial 2…etc
7) Then upload the converted STL file in software.
8) After that choose the material like…FG 200, FG 210, FG 260
9) Choose the core material like …Amine sand, Resine coated sand etc.
10) Then select the pouring method …like Gravity die casting etc.
11) Select option like…casting filling, solidification etc.

12) After that upload the temperature
13) Also upload the filling time in seconds.
14) Now select the results which are required
15) When all information is filled, run the program OR evaluate the project.
16) After some time interval we get the results.
17) Then see the result of casting filling ratio, solicitation ratio, temperature ratio
18) In the result see the shrinkage location, cold lines, sand drop, temp drop etc.

VI. SIMULATION IMAGES OF MANIFOLD

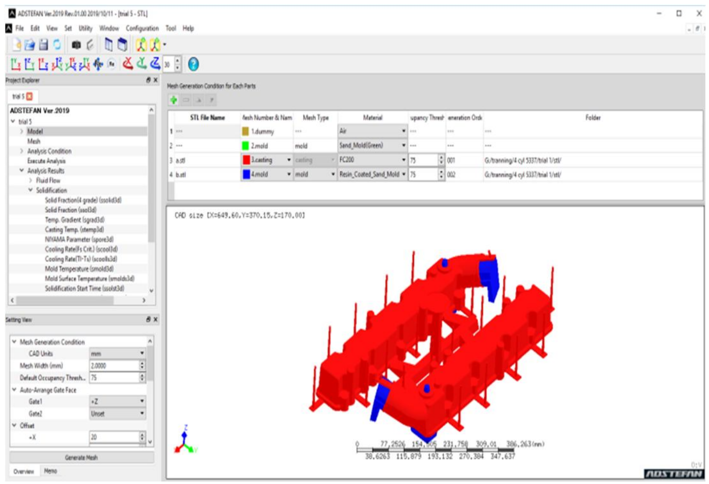

Fig. no.3 - 3D Model of Manifold imported in software

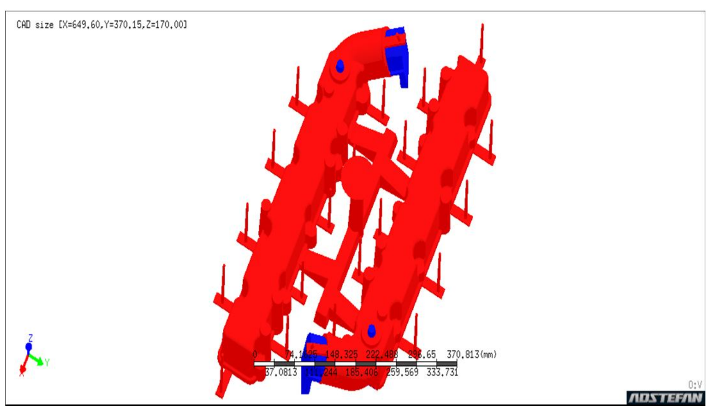

Fig. no.4 - Model showing Gating system details

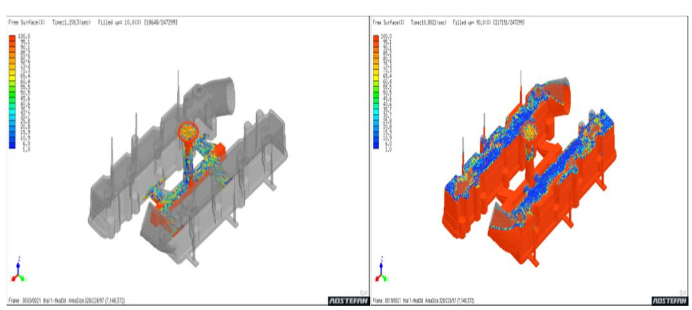

Fig. no.5- Figures showing Mould filling of Manifold

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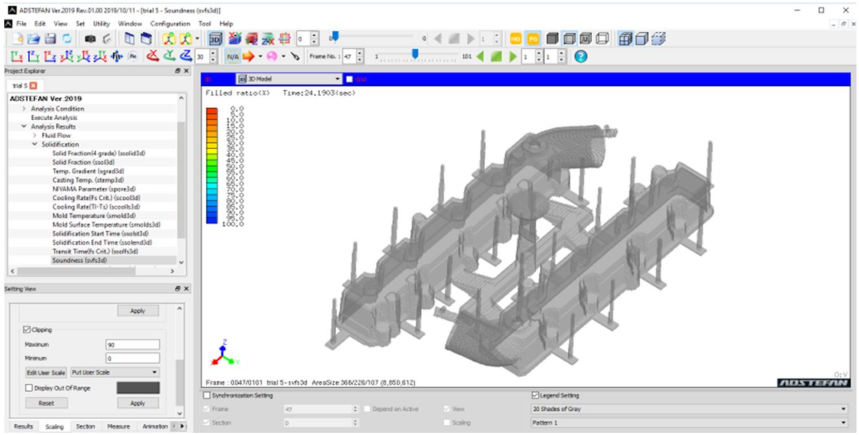

Fig. no.6 - Final Gating system of Manifold showing No Hot Spots Simulation images of Fan Hub

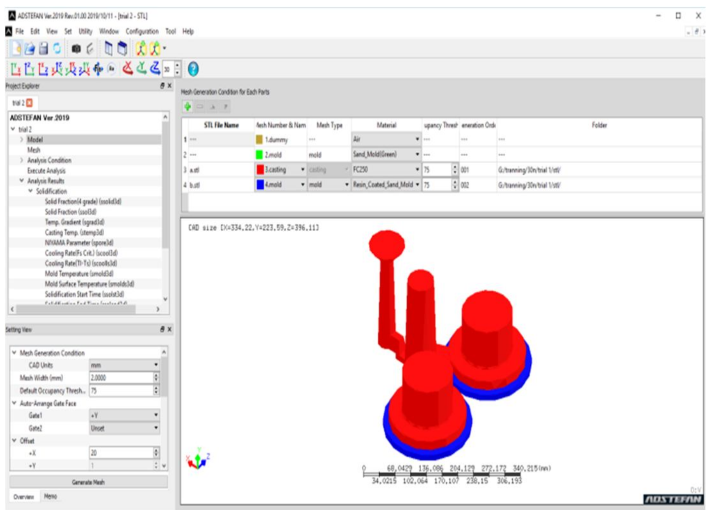

Fig. no.7 - 3D Model of Fan Hub imported in software

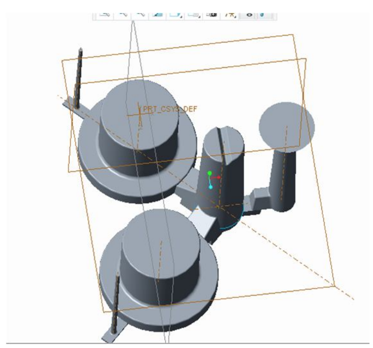

Fig. no. 8 - Model showing Gating system details

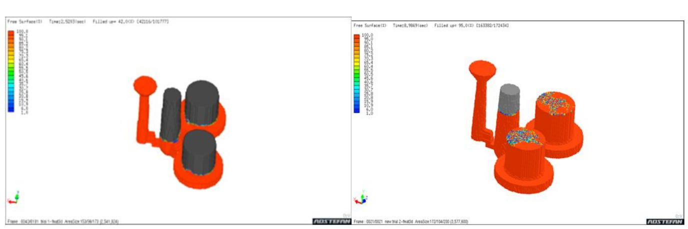

Fig. no. 9- Figures showing Mould filling of Fan Hub

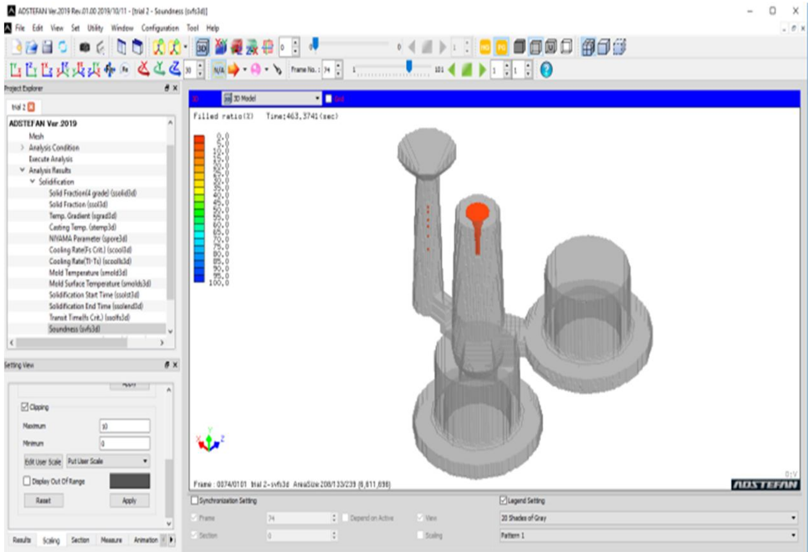

Fig.no. 10 - Improved methoding of Fan Hub showing No Hot spots

Table no. 8 – Rejection of Manifold before improved methoding

Month (2019)	Production	Rejection	Rejection %
July	90	40	44.44%
Aug	60	32	53.33%
Sept	100	42	42.00%

Table no 9 - Rejection of Manifold After improved methoding

Month (2019)	Production	Rejection	Rejection %
Oct	100	19	19.00% *
Nov	130	12	9.23%
Dec	180	15	8.33%

*Small amount of shrinkage was found in the boss casting. Then change was done by adding VENTs at the side of boss casting. When changes were made, the percentage of rejection was reduced up to 8.33%.

Table no. 10 - Rejection of Fan Hub before improved methoding

Month (2019)	Production	Rejection	Rejection %
July	63	23	36.51%
Aug	388	129	33.25%
Sept	60	22	36.67%

Table no.11 - Rejection of Fan Hub after improved methoding

Month (2019)	Production	Rejection	Rejection %
Oct	200	14	7.00%
Nov	196	8	4.08%
Dec	474	20	4.22%

VII. RESULTS AND DISCUSSION

Both castings with present methoding have no porosity defect. It is confirmed first by Radiography and then by machining the particular surfaces and after carrying out leak test.

1) In manifold the yield increased from @ 69% to 74%.
2) In fan hub also the yield increased from 64% to 73%.

A. Conclusions

1) *Ex. Manifold:* Earlier yield with old gating system was 69%.Whereas after implementation of modified gating system yield improved to 74%. Therefore there was an improvement in yield by 5%.
2) *Fan Hub:* Earlier yield with old gating system was 64%.Whereas after implementation of modified gating system, yield improved to 73%. Therefore there was an improvement in yield by 9%.

a) The industry was resorting to trial and error method which is unsuitable in the present competitive world.
b) Earlier method of designing the gating & risering used analytical method which due to over designing laid to reduced yield and also did not ensure rejection control.
c) Use of simulation software is an effective tool for optimizing and providing a robust design of gating and risering**,** it also reduces the time and cost of design hence it is beneficial in competitive market.

Following results were obtained for two castings for yield improvement**.**

Sr.No.	Component	Yield before optimization	Yield After Optimization	Improvement in yield
1	Ex. Manifold	69 %	74 %	5%
2	Fan Hub	64 %	73 %	9%

B. Material Saved In Terms Of Yield

Following table shows material saved in terms of yield

Table no. 12 - Material saved in terms of yield

	Ex. Manifold-5337		Fan Hub-30N	
Parameters	Current Casting	Proposed Casting	Current Casting	Proposed Casting
Yield (%)	69	74	64	73
Weight of the component (kg)	5.6	5.6	5.5	5.5
Weight of the gating system (kg)	2.5	1.9	3.2	2.3
Total weight (kg)	8.1	7.5	8.7	7.8
Material cost (Rs.60/-kg for CI)	486	450	522	468
Processing cost (Rs.45/-kg for CI)	365	338	392	351
Total cost(Rs.)	851	788	914	819
Number of components produced annually	4800	4800	4800	4800
Cost incurred annually (Rs.)	4084800/-	3782400/-	4387200/-	3931200/-
Savings due to improved yield. (Rs.)	------------	3,02,400/-	------------	4,56,000/-

Total Savings Per Annum will be = 3, 02,400 + 4, 56, 000
= Rs. 7, 58, 400/-
(Rs. Seven lac fifty eight thousand four hundred only)

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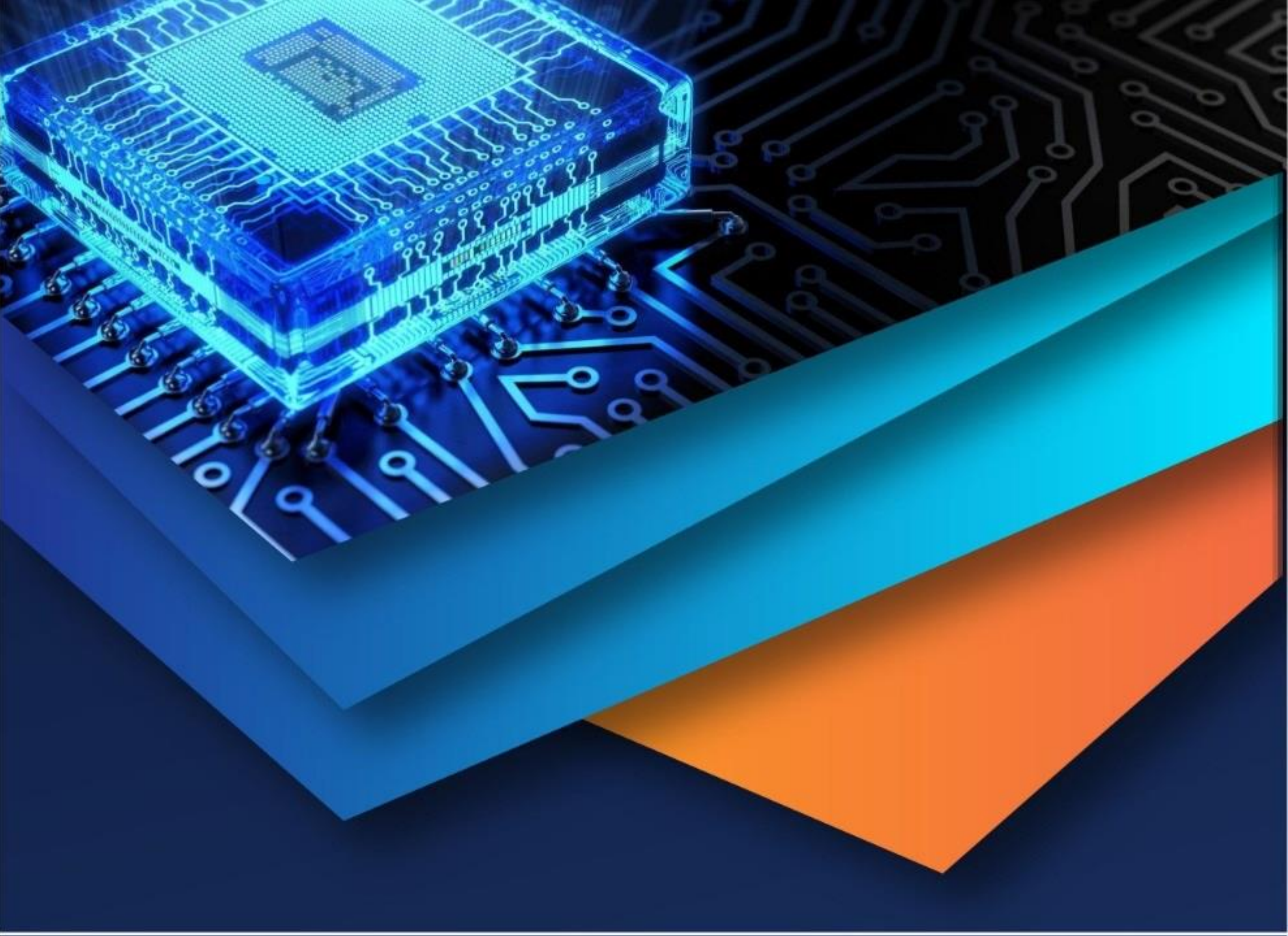

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