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A Framework for Enterprise Manufacturing Intelligence

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Abstract: *Industrial Revolution Is In The Next Phase That Is, Industrie4.0. (Industrial Revolution Of Fourth Phase) In The Digitization Of Manufacturing Sector With The Connectivity And Analytics As Key Enablers. The Raw Material Undergoes A Series Of Process To Become A Finished Product. All Those Machines Are PLC, Stroke, CNC Based Machines Where In Lot Of Parameters Being Captured. All These To Be Connected Through Internet Of Things In The Extraction Of Data, Transformation Of Data, Recognize The Pattern, Descriptive Analysis And A Predictive Model Has To Be Obtained As The Result To Provide Intelligence To Manufacturing Professionals For Decision Making. For This To Be Achieved, A Root-Cause Analysis Has To Be Done By Consolidating All The Available Data From The Production Line. The Volume Of The Data Being Very Large, An Efficient Storage System Has To Be Used. Advancement In Machine Learning Tools For The Big Data Analysis Can Be Applied In The Manufacturing Analytics. Spark And Mapreduce Can Be Used In A Distributed Fashion By Classifying The Data Using Support Vector Machine (SVM).*

Keywords: *Programmable Logic Controller(PLC), Computer Numeric Control(CNC), Support Vector Machine(SVM), Digitization.*

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I. Introduction

The Enterprise Manufacturing Intelligence (EMI) Is The Term Synonymously Used With Smart Manufacturing And I4.0 Having Defined As *"Automated Regulation Or Control Of Product Manufacturing Within The Specified Limit".* This Is Closely Related To Industrial Internet Of Things (IIOT) And Cyber Physical System (CPS) Which All Means To Connect The Physical World With The Virtual World And Thus Enabling Communication Between The Connected Devices. Manufacturing Analytics Is The Most Appropriate Field For Analysing The Data From The Connected Devices. Like The Industrial Revolution Impacted Manufacturing, Digital Transformation Is Now Responsible For Changing The Industry. Finally, Industrial Manufacturers Are Joining Their Counterparts And Are Moving To A Digital World. Not Since Henry Ford Introduced Mass Production Has There Been A Revolution To This Scale[1]. Now, Manufacturing Companies Are Using Technology To Move From Mass Production To Customized Production, And It's Happening At A Rapid Pace. Industrial Companies Can Now Pull Data from Almost Any Point In Their Operations and Transform It Into Useful Information. That Information, Known As manufacturing intelligence, Can Then Be Seamlessly Shared with Nearly Anyone Or Anything In The manufacturing Enterprise [2]. This Is Redefining How Companies Monitor And manage Their Operations. It's Also Helping Them become Smarter, Leaner And More Productive. However, Just As Every Company Is Different, So Are The Means Through Which They Access, Analyse And Act On Their Own Data. Billions Of Devices Are Connected To The internet Today – Hundreds Of Millions Of them Are Within Industrial Control Systems. The Business Intelligence Can Address The Manufacturing Intelligence By Looking At Some Specific Aspects. The Real Time Integration Has To Be Done With The Shop Floor Data Sources Which Includes The Data Of Machines And Systems. This Improves The Ability To Present Data In Context If End User Activities. Transforming Data Into Intelligence Plays A Major Role In Most Of The Industries. It Mainly Comprises Of Analysing Asset Optimization, Creating Predictive Maintenance Strategies, Digitizing Quality Control, Automating Manual Processes, Monitoring Employee Activities, Implementing Track And Trace Capabilities. This Analytics Application Will Improve Decision Making At All Levels.

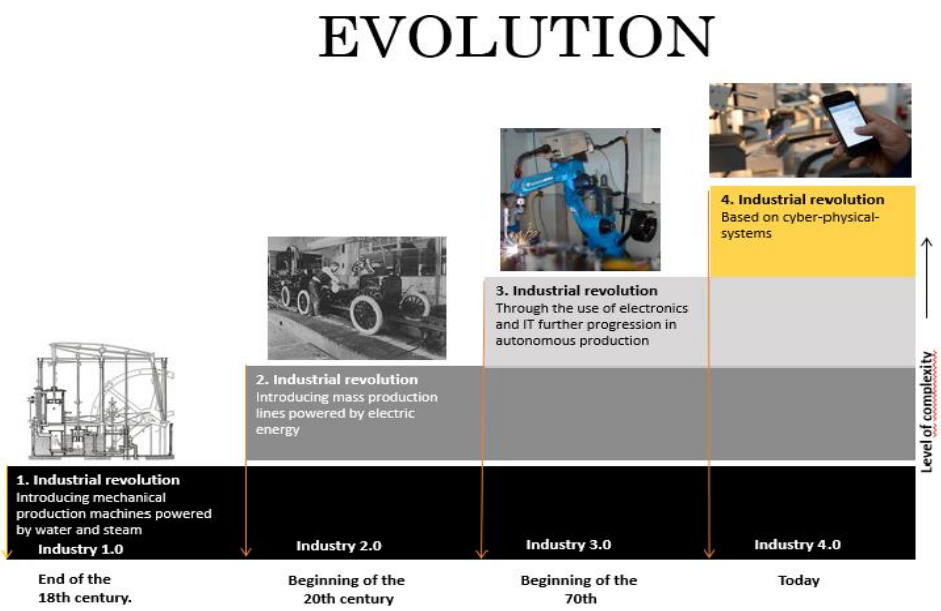

Fig.1 Evolution Of Industry 4.0

II. Literature Review

In 2017, The Authors Conducted A Study On Cyber Physical Load Carrier (CPLC) In A German Gear Manufacturing Company. The Scope Of Smart Manufacturing Is Highlighted With The Application Cases Ranging From Technological Initiatives Implementing CPS In Small And Medium Level Enterprise (SME) Over Human Robot Interaction At The Shop Floor Lever Using Sensors And Image Recognition. The Challenge Faced Is That To Connect Interdependent Data Sources Like Tool Wear, Material Flow In Real Time To Improve The System Performance. The Video Surveillance As A Service Is An Ongoing European Research Project. The Important Challenge Is To Connect Interdependent Data Sources Such As Tool Wear, Quality Inspection, Material Flow And Energy Usage And Derive Value Added Information In Real Time To Improve The System Performance [3]. Anish Jindal (2016) Surveyed The Use Of Support Vector Machine In Smart Grid. In This, The Data Is Gathered From All The Devices And The Users With Excess Load Consumption Are Identified Using SVM. Since The Consumer Data May Contain Erroneous Values, The Data Has To Be Corrected According To SVM Format And Then The Data Is Normalized. Later SVM Classifier Is Applied On Real Time Data To Find The Users With High Electricity Consumption In The Considered Time Slot [4]. Red Lion (2015) Explained The Common Key Performance Indicator (KPI) For Production Monitoring. Visual Management Is The Process Of Displaying Critical Information Such As Kpis That Relate Specifically To Production Output, Efficiency And Quality. This Helps Supervisors To Better Monitor Performance And Determine In Real Time, Areas That May Need Improvement. The Overall Production Can Be Improved Effectively And Efficiently By Calculating The Parameters Of Count Of The Production, Reject Ratio That Is, Scrap Rate, Operating Speed Of The Machine, Target Value, Takt Time Which Is The Cycle Time For Completion Of Task, Overall Equipment Effectiveness (OEE) And Downtime [5]. Lei Yang (2015) Conducted A Case Study On Wind Power Forecast. Using The Historical Data Of The Wind Turbine Power Output Which Is Recorded At An Actual Farm, Markov Models Are Developed To Model "Normal" Fluctuations Of Wind Generation. Then SVM Is Integrated Into It. In SVM, Past Observations Are Features And The Wind power Difference Between The Current State And Future State Is Called Class. The Basic Idea Is To Map A Feature Into A Higher Dimensional Feature Space Via A Non-Linear Mapping Based On Which The SVM Classifier Predicts Its Class[6]. In The Year 2015, The Authors Have Explained The Challenges Faced In The Manufacturing Industries While Implementing Data Analytics. Communication Holds The First Place. Business People Are In Rule Not Familiar With Analytics' Terminology, Data Issues, Methods And Learning Algorithms. Therefore, It Comes As No Surprise That They Are Often Mistrustful Or That They Set Overwhelming Goals. The Second Is Transferring Academic Experiences To Industries. They Often Get An Impression That A Lot Of Academic Research Claiming High Practical Relevance Is Actually An End In Itself. The Third Challenge Is Technophobia. For The Success Of Data Analytics Projects In General, A Three-Legged Stools Needed. That Means The Data Analyst Is Just One Of The Three Main "Ingredients" Of Success. Other Two Are A Database Expert And A Human Domain Expert. The Fourth Being Algorithmic Challenge, Includes Underfitting, Overfitting, Leakage, Imbalanced Data Classification, Satisfying Assumptions Of Linear Regression, And Predictive Analytics With Big Data [7].The Data Collected From Complex Manufacturing Processes And SC Networks Can Come From A Variety Of Internal Or External Data

Sources Across Different Locations. As A Result, It Is Common That The Data Is Multimodal In Nature. For Shop Floor Applications, We Are Developing Data-Driven Methodologies Using Data Mining And Machine Learning To Help In-Situ Process And Energy Efficiency Monitoring And Predicting Performance In Complex Manufacturing Processes To Achieve Excellence In Quality Control And Energy Efficient Production. In The Future, We Plan To Apply The Developed Algorithms In Collaboration With Industrial Partners [8].

III. Industrial IOT And Industrie4.0

From The Literature Survey, It Shows That The Industry Is Using Software Which Does Not Include All The Latest Techniques That Is Evolved In The Field Of Artificial Intelligence. Their Traditional Software Performs The Manual Type Calculation Process. So Here We Propose, Today's Manufacturing Systems Have Billions Of Devices Connected To The Internet – Hundreds Of Millions Of Them Are Within Industrial Control Systems. This Proliferation Of Connected Devices Is Known As The Industrial Internet Of Things (Iiot). Iiot Assets, From Sensors To Smart Machines, Can Track An Almost Endless Number Of Data Points From Machine Performance And product Quality To Worker Behaviours. At The Centre Of Industrial Transformation Is Iot, Accounting For More Than $178 Billion In 2016 And Proving Critical To Providing Companies With A Competitive Edge [10]. The Manufacturing Industry Is Leading In The Iot Because Of The Revolutionary Ways This Connected Technology Has Streamlined And Simplified Various Manufacturing Processes. For Instance, Iot Can Provide Real-Time Feedback And Alerts Companies Of Defects Or Damaged Goods. These Simple Yet Critical Implementations Of Iot Reduce Cost And Waste. Further Incorporation Of Iot, Industry 4.0 "Represents The Vision Of The Interconnected Factory Where Equipment Is Online, And In Some Way Is Also Intelligent And Capable Of Making Its Own Decisions." Responsible For The Rise Of Smart Machinery, Industry 4.0 Also Introduced A Hybrid Approach Of Virtual And Actual Content Warehouses That Has Freed Up Manpower On The Production And Collaboration Side Of The Industry. The Trend Of Mass Customization Has Allowed Manufacturers To More Efficiently React To Consumer Demand. Because Customers Expect The Products They Use To Be Intuitive And Easy To Interact With, Mobilization And Connectedness Continue To Drive Manufacturers To Innovate Faster And Create Software-Enabled Products[9]. Iot And Industry 4.0 Capabilities Are Also Changing How Post-Sale Service Is Provided, Offering Immediate And Consistent Online Support.

3.1. Big Data From Industries

Analysing Big Data Use Cases In The Manufacturing Industry Can Reduce Processing Flaws, Improve Production Quality, Increase Efficiency, And Save Time And Money. A Big Data Use Case Provides A Focus For Analytics, Providing Parameters For The Types Of Data That Can Be Of Value And Determining How To Model That Data Using Hadoop Analytics. The Typology Isolating The Types Of Big Data That Lead To Better Decisions Are Obtained From The Nature Of The Data Whether It Is Been Structured Or Unstructured Data. Almost All Modern Computing Till Recent Times Have Been Built On Structured Data Which Is The Useful Abstraction Of Data In Terms Of Rows And Columns [9]. Big Data Analytics Enables Manufacturers To Segment The Production Process And Supply Chain Up To The Most Specific Task Or Activity. This Allows Manufacturers To Narrow Down Each Problem To The Smallest Component And To Identify Specific Processes Or Components That Are Underperforming Or Causing Bottlenecks. The Big Data Analytics Offer Various Tools For Manufacturers. It Can Perform All The Process Of Data Storage, Cleansing, Profiling, Data Discovery, Mapping, Data Analysis, Visualisation, Monitoring The Data. The Volume Of The Data Being Very Large, An Efficient Storage System Of Hadoop And Hbase Can Be Used. Spark And Mapreduce Can Be Used For Analysing The Data In A Distributed Fashion. Data, Analytics, And Applications are Key Elements In The Intelligent Lifecycles That Turn Data Into Insights, And insights Into Actions. They Are Applicable To The Control, Operations, And business Loops. At Its Core, Analytics Is The Engine That Powers Each Of These Intelligent loops And Drives Value-Creation In Iiot. Bruce Calder, Chief Technology Officer For Honeywell Process Solutions, Reiterated The Point That The Iiot Concept Is Nothing New To The Process Industry. "We Have been Doing It For Decades," He Said. "We Already Have The Capacity To Make Use Of This Information To Benefit Plant Performance. However, Ever More Connected Devices And Systems Are Generating Vast Amounts Of Data, And The Next Big Change Will Be How This Data Is Managed." One-Third Of Process And Manufacturing Industry Executives From Around The World Surveyed By Honeywell Said That They Already Are Using Data Analytics To Improve Business Performance. Two-Thirds Said That They Are Using Data Analytics Capability To Monitor Assets To Drive A Proactive Maintenance Program. Two-Thirds Also Said That They Were Investing Heavily In IT Infrastructure To Collect More Data From Their Facilities Or Remote Assets. "There Is A Huge Interest In Data," Continued Calder. "However, Alone It Has No Value. It Needs To Be Translated Into Actionable Information. Honeywell Can Now Offer Many Solutions That Help Aggregate Data, Enabling It To Be Used To Monitor Applications And Identify Potential Safety And Performance Issues" [10].There Are Lot Of Tools Available In The Market For Analysing The Connected Devices In The Manufacturing System.

3.2. Learning Techniques

So Far, Most Of The Machine Learning Techniques Are Not Being Implemented In The Manufacturing Industries, Whereas It Is Being Implemented Across All Other Fields Like Medical, Banking, Communication Sectors. Machine Learning Is Used To Teach Machines How To Handle The Data More Efficiently. Sometimes After Viewing The Data, We Cannot Interpret The Pattern Or Extract Information From The Data. There Are Two Types Of Learning Techniques. They Are Supervised And Unsupervised Learning. Here We Will See Supervised Algorithm Since It Follows The Training Set Of Data. The Three Commonly Used Supervised Algorithms Are Decision Trees, Naïve Bayes And Support Vector Machine [11].

3.2.1. Decision Tree

Decision Tree Empowers Predictive Models With High Accuracy, Stability And Ease Of Interpretation. Unlike Linear Models, It Is Capable Of Mapping Non-Linear Relationships Quite Well. It Is Even Adaptable At Solving Any Kind Of Problem At Hand (Classification Or Regression). A Best Example For Decision Tree Is If Else Condition. The Type Of This Tree Is Decided Based On The Target Value And It Can Be Of Categorical Or Continuous Variable Decision Tree. Decision Tree Is Used Mainly For Classification Purpose. Each Tree Consists Of Nodes And Branches. Each node Represents Attributes In A Group That Is To Be Classified and Each Branch Represents A Value That The Node Can Take.

3.2.2. Naïve Bayes

Naive Bayes Classifiers Are A Collection Of Classification Algorithms Based On **Bayes' Theorem**. It Is Not A Single Algorithm But A Family Of Algorithms Where All Of Them Share A Common Principle, I.E. Every Pair Of Features Being Classified Is Independent Of Each Other. Bayes' Theorem Is Stated Mathematically As The Following Equation:

$$P(A/B) = \frac{P(B/A)\,P(A)}{P(B)}$$

3.2.3. Support Vector Machine

The Advantage Of SVM Is That Once A Boundary Is Established, Most Of The Training Data Is Redundant. All It Needs Is A Core Set Of Points Which Can Help Identify And Set The Boundary. These Data Points Are Called Support Vectors Because They "Support" The Boundary. This Boundary Is Traditionally Called A Hyperplane. In A Simple Example Of Two Dimensions (Two Attributes), This Boundary Can Be A Straight Line Or A Curve. SVM Is The Most Preferred Algorithm Among All The Classifiers.

IV. Framework

There Are Lot Of Connected Devices Available For Capturing The Data From The Manufacturing Industries. Those Connected Devices Will Store The Data In A Big Frame Of Distributed File System As Big Data. Those Data Are Then Accessed From The File System Then They Are Analysed Using The Learning Techniques As Discussed Above. The Analysed Data Will Be Stored In The Warehouse. Then Finally Reports Are Generated And Deployed As A Software. The Framework Available Is Discussed Below.

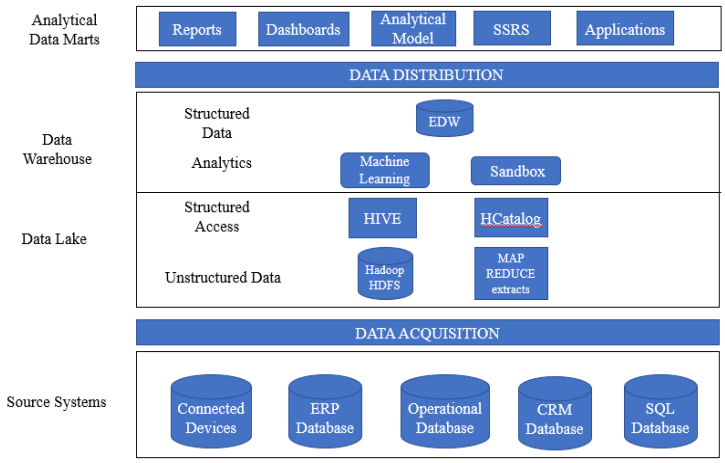

Fig.2 Framework For Manufacturing Intelligence

4.1 Source Systems

The Data Acquisition Occurs At Operational Systems. Data From All The IOT Connected Devices Are Acquired. The Enterprise Resource Planning (ERP) Comprises Of The Activities Covered In The Entire

Organization. This ERP Database Holds All The Activities That Help In Managing The Business Of The Organization. The Important Aspect Is To Integrate Back Office Business Processes And Facilitate The Flow Of Information Within An Organization. The Operational Database Is The Source Of Data For The Data Warehouse. Operational Database Is The Database-Of-Record, Consisting Of System-Specific Reference Data And Event Data Belonging To A Transaction-Update System. It May Also Contain System Control Data Such As Indicators, Flags, And Counters. A Customer Relationship Management, Or CRM, Database Is A Technology Used For The Collection And Analysis Of Customer Data As Part Of A CRM Marketing Program. Many Customer- Or Client-Centred Companies Rely On Them As A Major Component Of Business Operations. SQL Server Is A Relational Database Technology Developed By Microsoft. Transact-SQL Is An Extension Of SQL That Is Used In SQL Server. Transact-SQL Is Closely Integrated Into The SQL Language, Yet It Adds Programming Constructs That Are Not Native To SQL.

4.2 Data Lake

The Hadoop Distributed File System (HDFS) Is Designed To Store Very Large Data Sets Reliably, And To Stream Those Data Sets At High Bandwidth To User Applications. HDFS Stores Filesystem Metadata And Application Data Separately. An Important Characteristic Of Hadoop Is The Partitioning Of Data And Computation Across Many (Thousands) Of Hosts, And The Execution Of Application Computations In Parallel Close To Their Data. Map Reduce Uses Hadoop Framework For Efficient File System. Map Reduce Consists Of Three Stages. They Are Map Stage, Reduce Stage And The Shuffle Stage. Apache Hive Is A Data Warehouse Software Project Built On Top Of Apache Hadoop For Providing Data Summarization, Query And Analysis. Hive Gives An SQL-Like Interface To Query Data Stored In Various Databases And File Systems That Integrate With Hadoop. Hcatalog Is A Table Storage Management Tool For Hadoop That Exposes The Tabular Data Of Hive Meta Store To Other Hadoop Applications. It Enables Users With Different Data Processing Tools (Pig, Mapreduce) To Easily Write Data Onto A Grid.

4.3 Data Warehouse

As Discussed Before, There Are Three Learning Techniques For Supervised Learning. The Running Programs Are Separated By A Security Mechanism Called As Sandbox. A Sandbox Creates An Operational Environment In Which The Execution, Operation And Processes Of Software Testing Is Not Affected By Other Running Programs. Enterprise Data Warehouse (EDW) Is Considered As An Important Part In The Business Intelligence. They Are Central Repositories Of Integrated Data From One Or More Disparate Sources. It Is A System Used For Data Analysis And Reporting Services.

4.3 Analytical Data Mart

The Deployment Is Done In The Web Application In The Form Of Reports And Dashboards. Reports Can Be Generated In SQL Server Reporting Services (SSRS). SSRS Is The Microsoft Based Reporting Services For Generating And Deploying The Reports. It Allows User To Create Parameterized, Linked, Snapshot, Cached, Clickthrough, Drill Down, Drill Through, Sub Reports.

V. Analyses

As Given In The Framework, An Application Has Been Developed In The Microsoft Framework For A Valve Manufacturing Industry. The Microsoft Dot Net Application Where SQL Server Serves As The Backend, Connected With The SQL Server Reporting Services(SSRS). The Advantage Of Using Microsoft Services Is, It Provides Direct And Efficient Reporting Access, Faster Production Of Reports, Easy To Deploy Centralized Infrastructure. A Sample Analysis Has Been Mentioned Here. An Analysis Has Been Undergone On The Data Of A Valve Manufacturing Company. Rejection Trend Analysis Has Been Done From The Hourly Production Data. A Scatter Diagram Has Been Plotted On The Number Of Rejection That Occurs Every Hour.

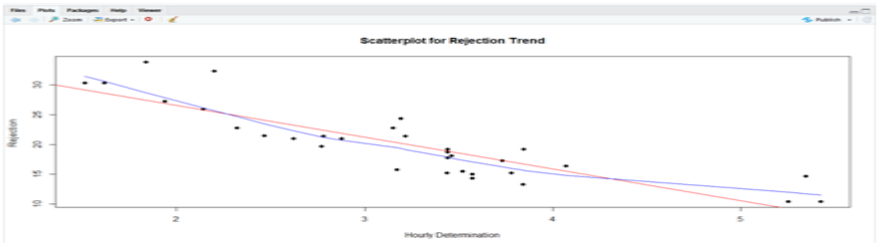

Fig 3 Rejection Trend Analysis

Scrap Data For Five Hours Is Considered And The Scrap Is Plotted Against The Hour. From The Figure 6.1, It Is Clear That Between 3rd And 4th Hour, Similar Type Of Rejection Is Obtained And It Follows Some Pattern. So,

By Obtaining The Reason For Rejection Between 3rd And 4th Hour, How To Reduce The Rejection Rate Can Be Analysed.

Another Analysis Has Been Carried Out For The Calculation Of Overall Equipment Effectiveness (OEE) Of The Machines. OEE Of A Defined Production Process During The defined Operative Period Or Mode In Which All Activities Related To Production, Personnel And Inputs Are Accounted For During All Producing Or Dependent Activities Within A Defined Scheduled Time Or Operative Mode Time.

Calculation Of OEE

5.1. Loading Time

Loading Time Is The Time Remaining After The Planned Shutdown Losses. It Is Calculated By The Difference Of Total Time And Shutdown Loss.

Loading Time= Total Time – Planned Shutdown Loss

5.2. Availability Loss

Availability Loss Is The Cumulative Time Of All The Losses. Some Of The Losses Include Breakdown Loss, Set Up Loss, Start Up Loss And Tool Change Loss.

Availability Loss = $\sum$ Loss

5.3. Operating Time (Less Availability)

Operating Time Is The Time In Which The Machine Is Actually Operating. It Is Calculated By The Difference Of Loading Time And The Availability Loss.

Operating Time = Loading Time – Availability Loss

5.4. Availability %

It Is The Percentage Of The Total Availability Time Of The Machine. It Is Calculated As Follows:

Availability % = $\frac{\text{Operating Time}}{\text{Loading Time}}$ *100

Similarly, Quality And Performance Losses Are Calculated And From That Respective Operating Time Is Calculated For Less Quality And Less Performance. Finally, Quality % And Performance % Are Calculated.

OEE = Availability * Performance * Quality

In The Figure 6.2, Five Types Of Machine Data Are Obtained. As Given In The Above Formulae, Availability, Performance And Quality Are Calculated And Finally A Report Is Generated By Calculating The Overall Equipment Effectiveness (OEE) Using SQL Server Reporting Services. From The Figure, It Clearly Shows That Hyundai 1147 Machine Has The Highest OEE Value And Its Performance Is Also Good When Compared To Other Machines And Makino 1147 Has The Lowest Effectiveness Value Which Need To Be Looked Into.

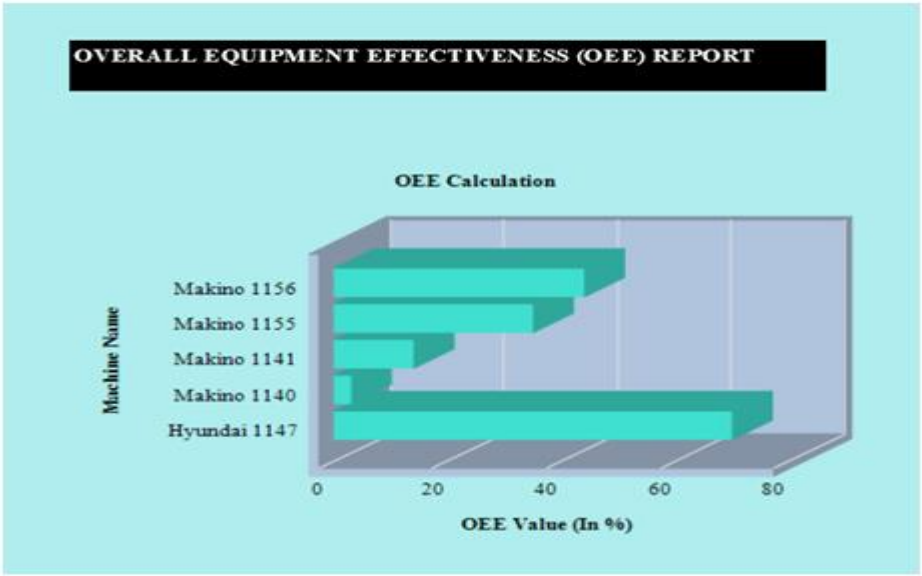

Fig 4 OEE Analysis

VI. Conclusion

An Overview Of Intelligence To The Manufacturing Systems Is Provided. This Work Has Summarized All The Efficient Ways Of Analysing And Depicting The Intelligent Source Data In All Possible Ways. The Efficiency And Need For Implementing All The Latest Machine Learning Concepts In The Manufacturing Industries Are Explained. Sample Analyses Are Explained. Rejection Rate Analysis Is Done Based On Scrap Data From The Valve Manufacturing Industry. Finally, A Statistical Calculation Has Been Done For Overall Equipment Effectiveness (OEE) And An SSRS Report Has Been Generated. An Application Has Been Created

For Manufacturing Industries For Analysing The Data Efficiently. It Actually Helps Improve Their Business Profit. Thus, The Paper Clearly Explains The Overall Framework For Enterprise Manufacturing Intelligence.

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