Digitalization in the Steel Industry

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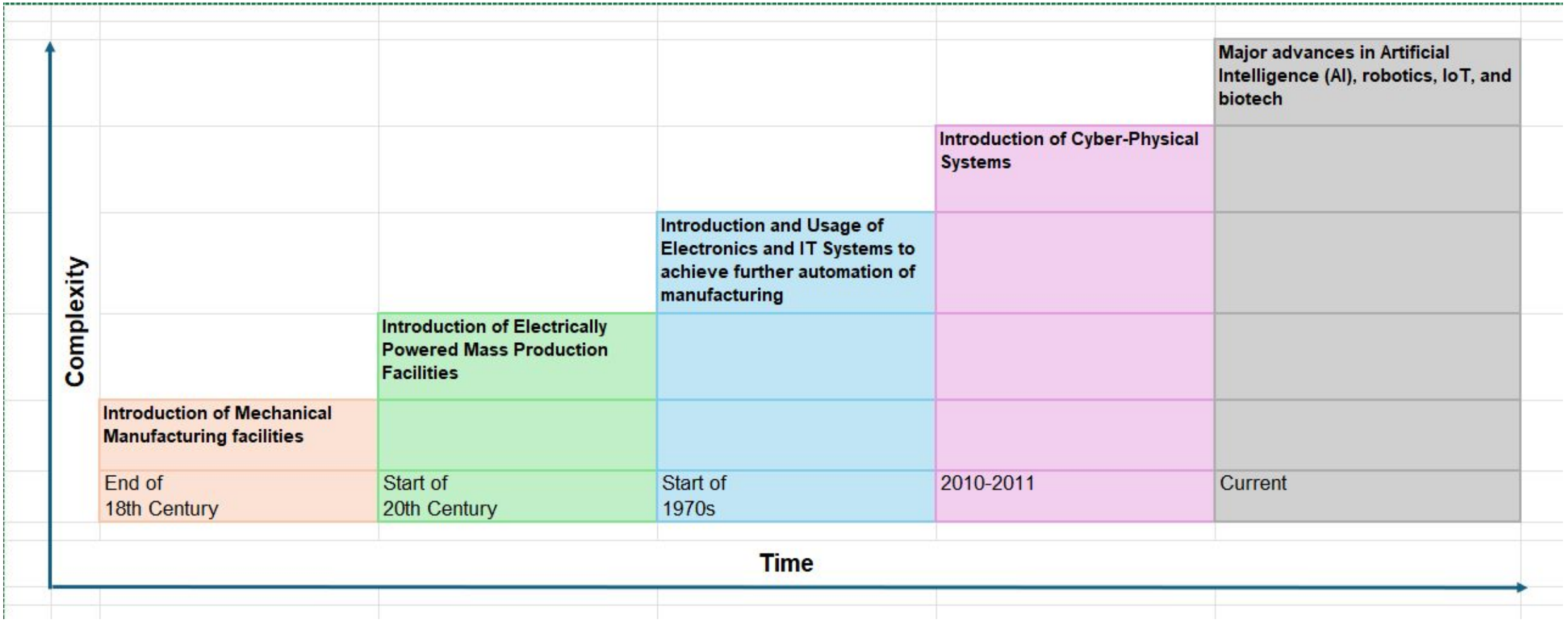
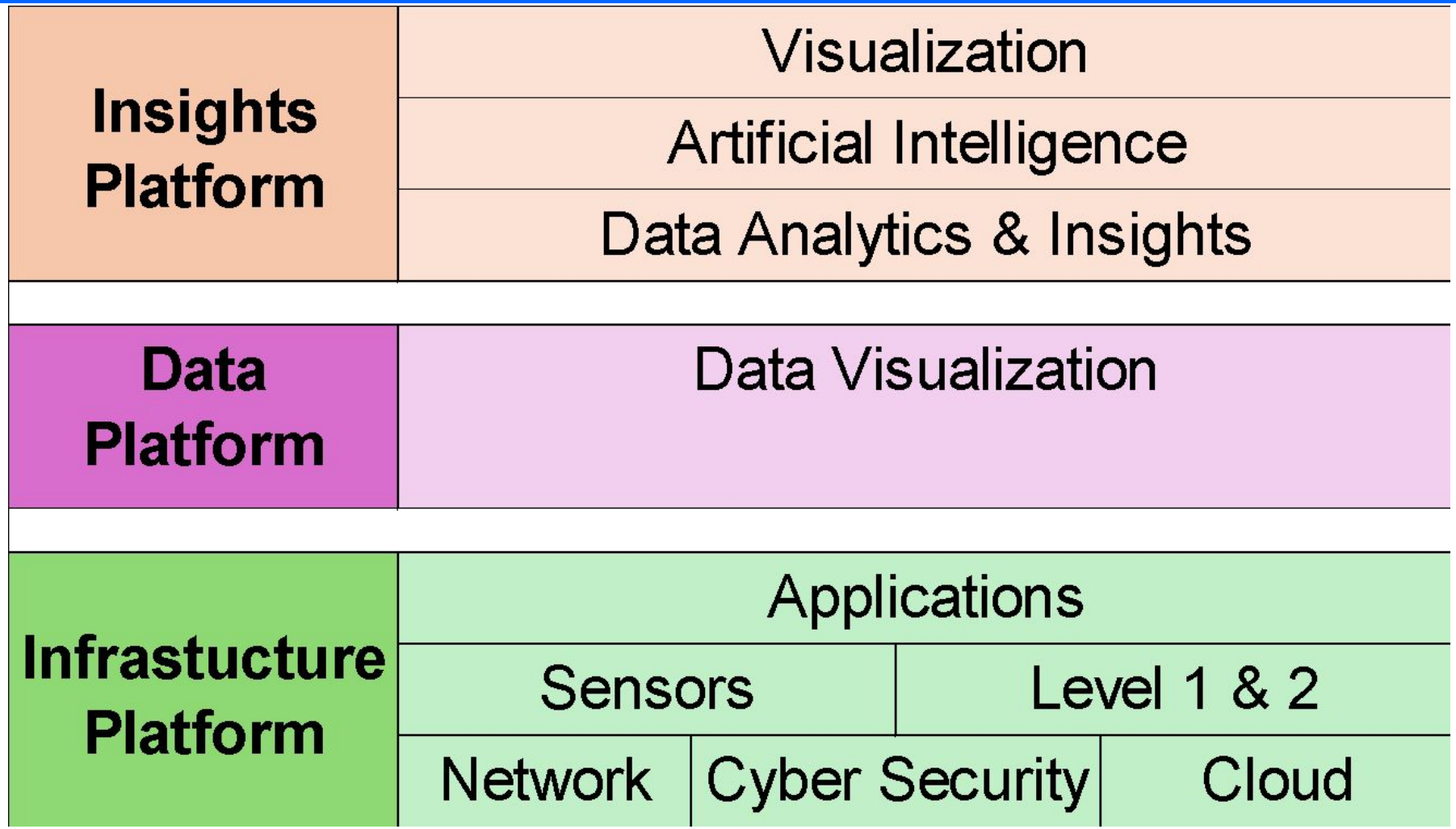
Introduction

- **Steel Process Consultancy Inc**. is based in Mississauga, Canada, and is an independent process consultancy firm that provides technical services to the global iron and steel, ferro-alloys, cement, calcined lime / fluxes, and foundry industries.
- Core team consists of highly experienced and globally recognized specialists who have extensive experience working in senior positions in their field of expertise.Digital Technology for the Steel Industry
- **Dr Sunil Kumar - Director**
  - PhD in Process Metallurgy (U of British Columbia, Vancouver, Canada)
  - Worked at
    - **Tata Steel, Jamshedpur** – Head of Technology (Steelmaking & Casting), Head of Project (LD3 & TSCR Plant) and Head (Slab Casting Operation)
    - **Hatch Ltd.,** Mississauga, Canada – Senior Consultant (Iron and Steel BU

Industrial Development…



Industrial Development - Digitalization



Digital Technology…

- **Cyber Physical System (CPS)** - a new generation of digital systems, composed of computational and physical capability - systems use algorithms & data analysis to monitor & control physical processes
  - Sensors: Sense the state of the system and environment
  - Processors: Analyze data and make decisions
  - Actuators: Interact with the physical world
- **Internet of Things (IoT)** is a network of physical objects that can connect and exchange data over the internet. These objects include household items, industrial tools, and other devices.
- **Big Data** is a collection of data sets that are too large or complex to be processed by traditional software; typically, this includes structured, semi-structured, and unstructured data.

Digital Technology…

- **AI** is a technology that allows machines to perform tasks that typically require human intelligence, such as analyzing data, understanding language, and making decisions. This technology which is based on machine learning and deep learning, is adopted for data analytics, predictions and forecasting, object categorization, natural language processing, recommendations, intelligent data retrieval etc.
  - BIRTH OF AI -> 1950-56; Computer scientist, mathematician, and AI pioneer John McCarthy coined the term “Artificial Intelligence” in 1955 He described this as “science and engineering of making intelligent machines,” relating it to “using computers to understand human intelligence.”
- **Machine learning (ML)** is a type of AI that allows computers to learn & improve without direct programming. It uses algorithms to analyze data, recognize patterns, and make decisions. **Deep Learning (DL)** is subset of ML which uses advanced neural networks to teach computers to process data. It's a more advanced form of ML that can perform tasks (image recognition, speech recognition, natural language processing.

Digital Technology…

- **Neural Network** is a computer system that learns to perform tasks by analyzing data. It's a type of ML that attempts to mimic the structure of the human brain

- **Robotics** involves the design, construction, and use of robots. It's an inter-disciplinary field that combines engineering, computer science, and technology.

- **First-Principles Modeling** involves building of mathematical models based on fundamental laws of nature, such as the laws of physics and chemistry; these models are often used in engineering design and to simulate materials.

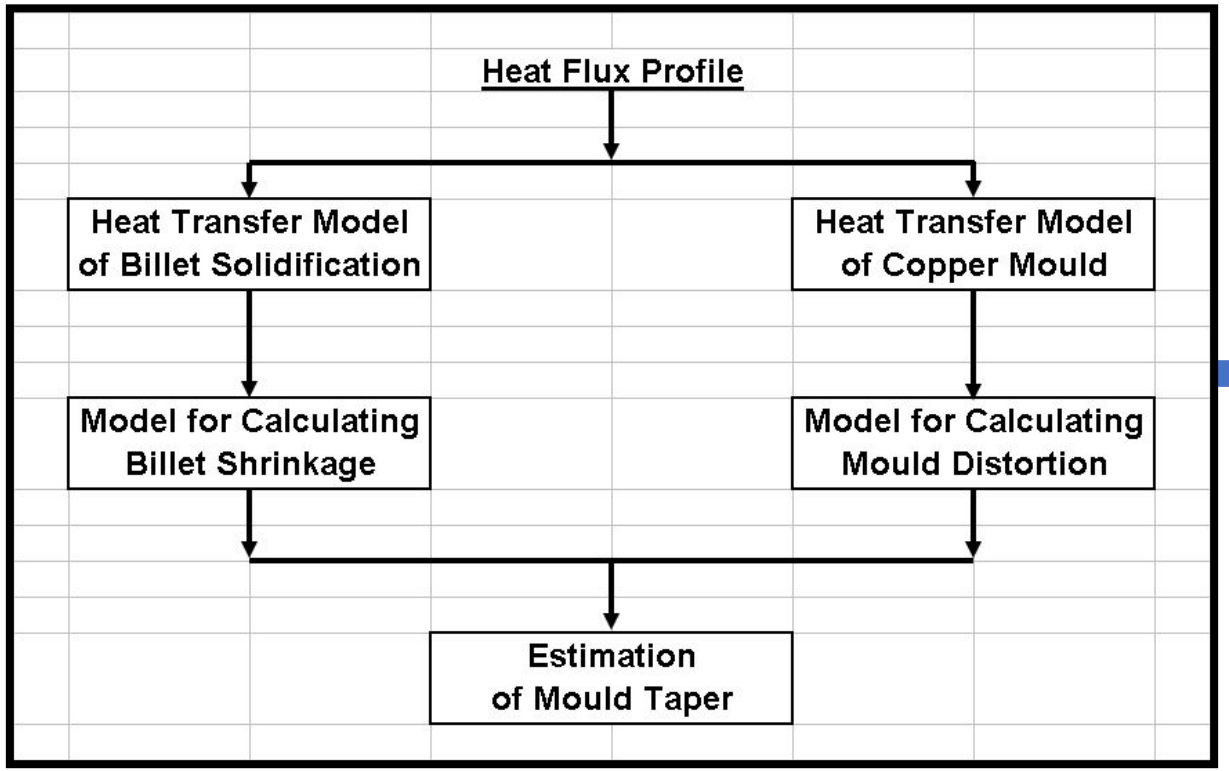
- **Cybersecurity** - practice of protecting systems, networks, and data from cyberattacks. It uses technology, processes, and controls to reduce the risk of cybercrime

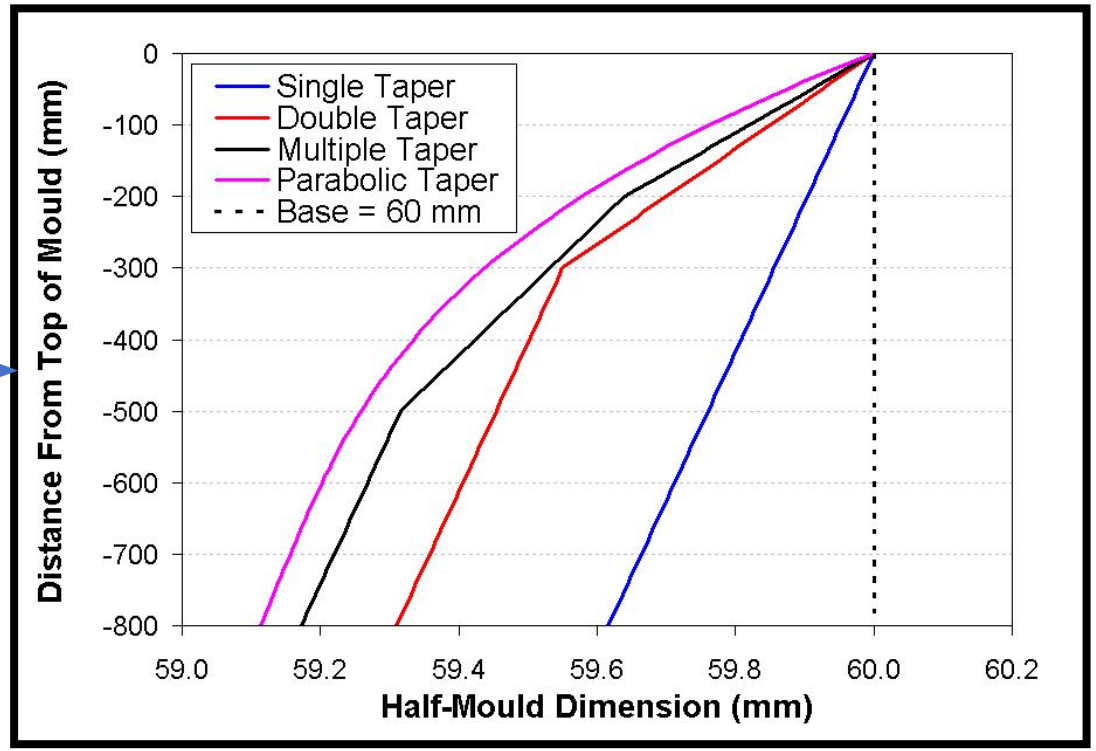
- A “**Digital Twin**" is a virtual representation of a physical object, system, or process that uses real-time data to accurately simulate its behavior, allowing users to analyze performance, and make informed decisions about its operations.

NEURAL NETWORK MODELLING

Neural Network Modelling

- **Neural Network** model was used to design mould taper for billet casting machine
  - Reference : Taper Design in Continuous Billet Casting Using Artificial Neural Networks, Ironmaking and Steelmaking, 1998, Vol.25, No.6, pp.476-483.





Digital Technology…

- **Expert System** is a computer program that uses AI to mimic the decision-making of a human expert. Expert systems are designed to solve complex problems by applying rules from a knowledge base.

- **Knowledge engineering** is a field of artificial intelligence (AI) that combines human knowledge with computer systems. The goal is to create computer systems that can make decisions and solve problems like a human expert..

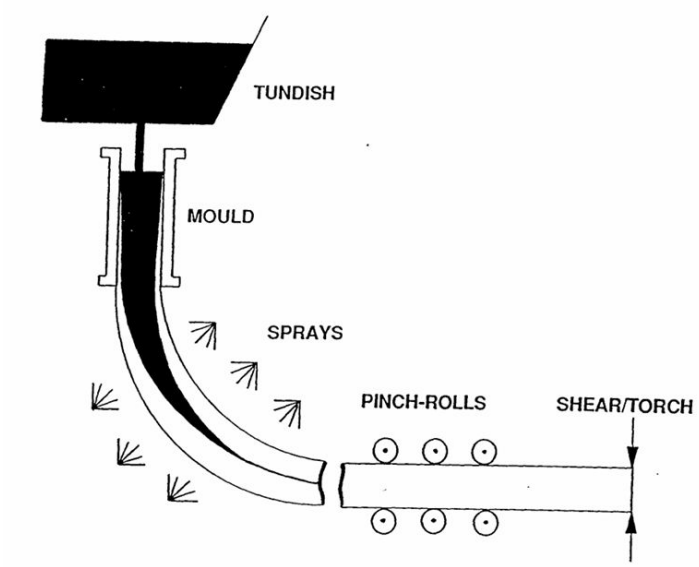
- **Knowledge acquisition** is the process of gathering, organizing, and using information from various sources. It's a key part of machine learning and can be used to create computer programs that can reason Extract knowledge, Structure knowledge, Validate knowledge, Represent knowledge, Infer knowledge, Explain knowledge

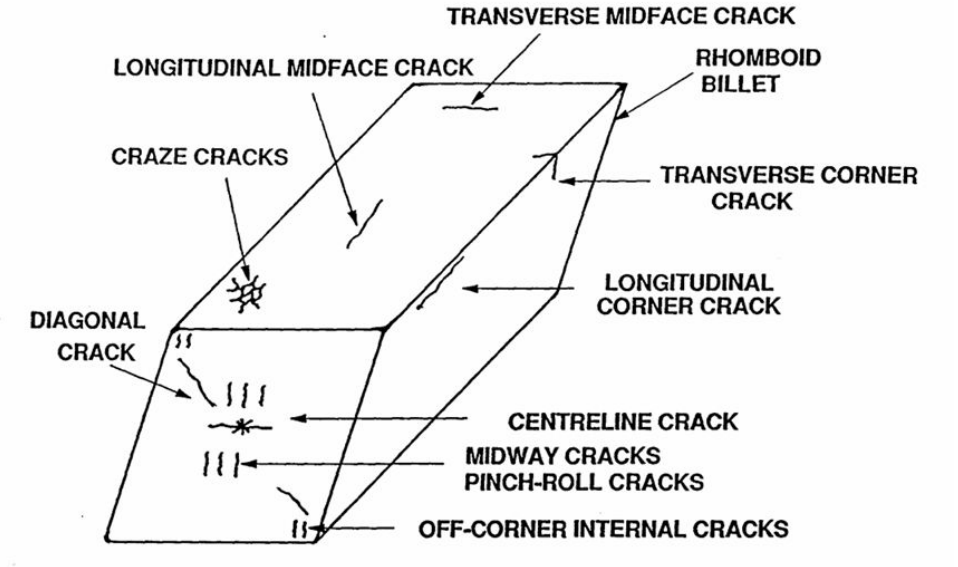
- **Fuzzy Logic** is a way of reasoning that uses degrees of truth (certainty) instead of absolutes like "true" or "false". It's based on the idea of fuzzy sets, which are groups of objects with unclear boundaries.

EXPERT SYSTEM DEVELOPMENT

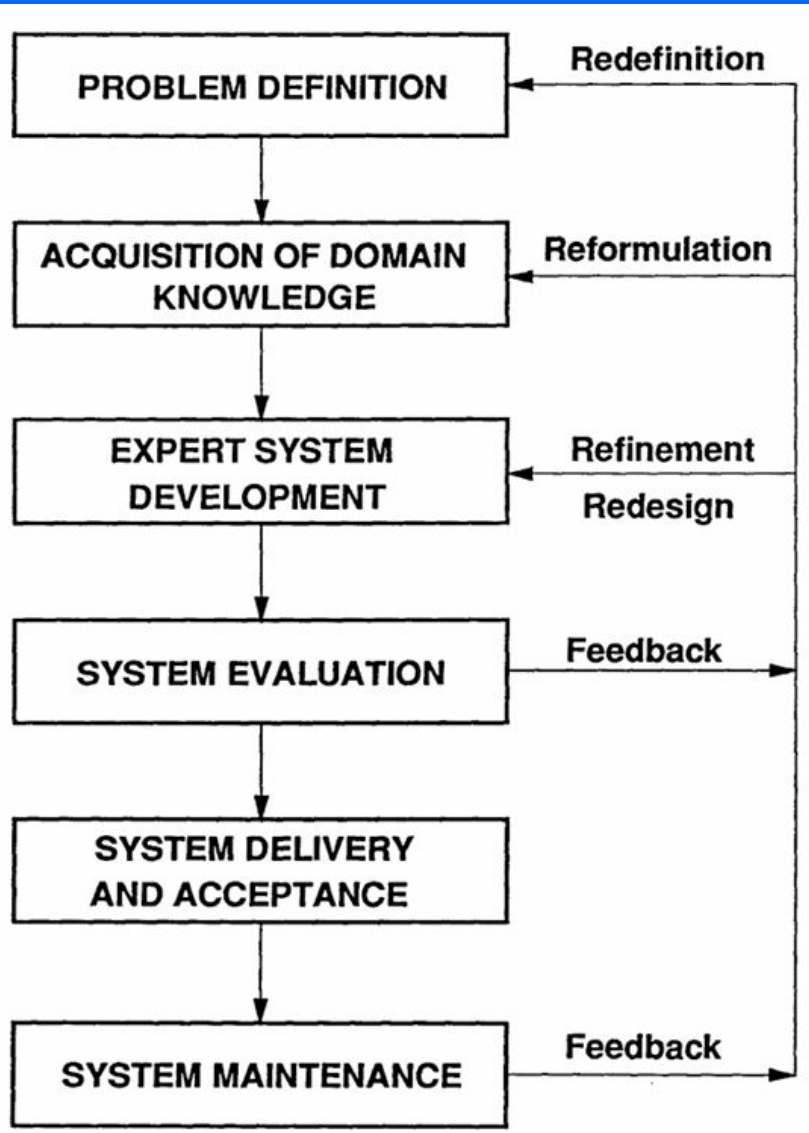
Expert System Development

- **An Expert System was developed to trouble-shoot quality problems in the continuous casting of steel billets**
  - Reference: Knowledge Engineering an Expert System to Trouble-Shoot Quality Problems in the Continuous Casting of Steel Billets, Iron and Steelmaker, September 1993, pp.29-36.
  - Reference: Development of Intelligent Mould for On-line Detection of Defects in Steel Billets, Ironmaking and Steelmaking, 1999, Vol.26, No.4, pp.269-284.



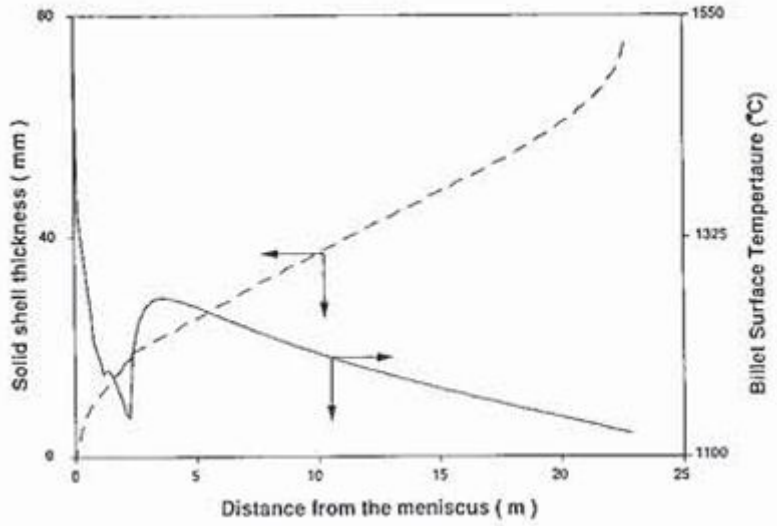


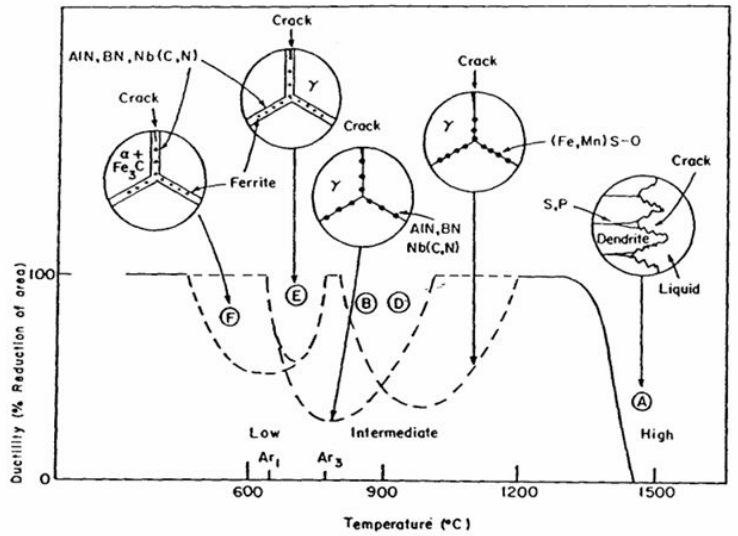
Expert System Development



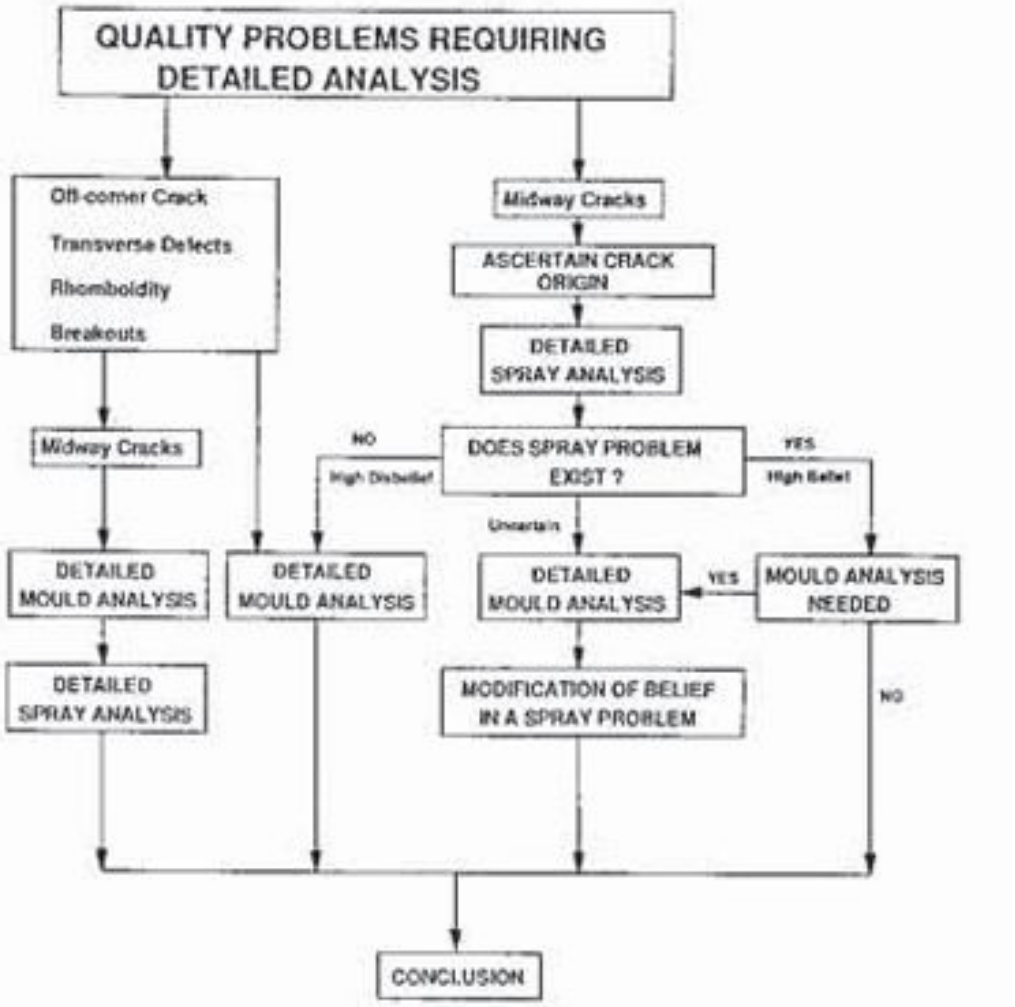
Expert System Development

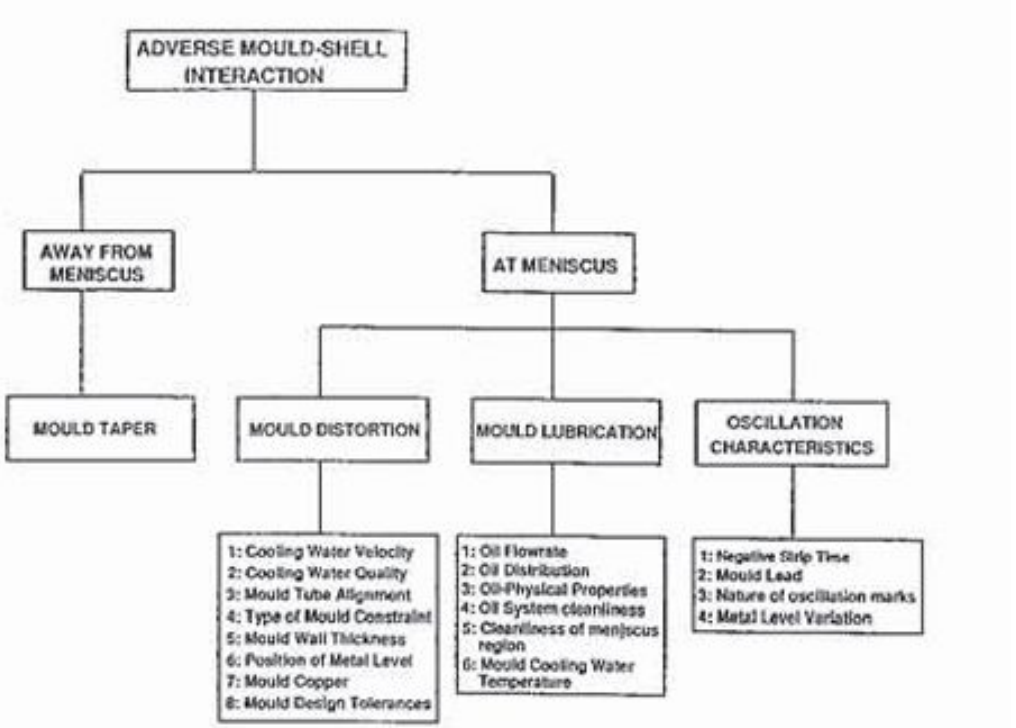
QUALITY PROBLEM	LOCATIONS	CAUSES	INFLUENCING FACTORS
Midway Crack	Mould exit or in the gap between the mould and the sprays	Reheating of the billet surface	Mismatch between the mould and the sprays: due to design or maintenance problem; Poor design of cooling jacket near the mould exit; Steel composition and superheat
	Upper portion of the sprays	Reheating of the billet surface	Poor spray maintenance : bent or plugged spray nozzles; Steel composition and superheat
	Lower portion of the sprays or the radiation cooling zone	Reheating of the billet surface due to the sprays	Sprays : design and maintenance issues; Steel composition and superheat
		Reheating of dark overcooled patches generated by the mould	Thermo-mechanical behaviour of the mould; Adverse mould/shell interaction; Deep and non-uniform oscillation marks; Steel composition and superheat





Expert System Development





Digital Technology…

- **A Data Warehouse** is an enterprise system used for the analysis and reporting of structured and semi-structured data from multiple sources, such as point-of-sale transactions, marketing automation, customer relationship management, and more. A data warehouse is suited for ad hoc analysis as well custom reporting.

- **Data Mining** is the process of sorting through large data sets to identify relationships that can help solve business problems through data analysis. Data mining techniques & tools help enterprises to make more informed business decisions.

- **Data Analytics** is the process of analyzing data to discover patterns and trends, and to make informed decisions. It involves collecting, transforming, and modeling data.

  - Data analytics and data mining are often used interchangeably, but there is difference between the two Data Analytics is the process of interpreting data to find trends and patterns. On the other hand, data mining is the process of extracting valuable information from a large dataset.

DATA WAREHOUSE & DATA MINING

Data Warehouse for Melt Shop

- **Development of a Data Warehouse (DWH) for a Steel Melt Shop**
  - Reference: Tata Search 2004, 382-390
- DWH Facility was implemented at a Melt Shop to overcome constraints of data extraction and retrieval.
- Melt Shop: HM De-S, BOF, LF, RH Degasser, Slab Caster, Slab Yard
- With the development of a DWH facility, majority of the data required for analysis and reporting were available on a single platform.

DATA WAREHOUSE	
No	**Sources of Plant Data**
1	Level 1 System
2	Level 2 System
3	Level 3 (AS/400 System)
4	Main Frame System
5	SAP Transactional System
6	Manual Data Entry

Data Mining for Problem Solving

- **Data Mining Analysis of Poor Castability Problem in Low-C Grades (Al, Si, Mn)**
  - Reference: Tata Search, 2006, pp.125-132.

- With Data Warehouse, data retrieval for analysis purposes became easier and faster – Data mining and analysis was adopted to diagnose several problems in melt shop

- Relationship between relative clogging intensity (RCI) and the alloy/deoxidizer addition practice was identified, and on this basis, recommendations were made to the plant for practice modifications.

- The results of the thermodynamic calculations that were performed supported the observations of nozzle clogging that were made during the casting operation.

- It was recommended to modify deoxidation practice & avoid addition of Al before LRF treatment (i.e., no Al addition at tap and the rinsing station) the relative clogging intensity (RCI) reduced significantly from ~40% to < ~5%, after implementation.

Concluding Comments…

- This is just the beginning of digitalization in the steel industry – it is believed that the Industry 4.0 / 5.0 is an evolution and not a revolution
- Companies have understood the benefit of Industry 4.0 / 5.0.
- Significant effort is needed to address the necessary pre-conditions for implementing the current / future digital technologies
- It is necessary to develop methods and concepts to transfer the idea of Industry 4.0 / 5.0 to all industrial sectors

For the Steel Industry, several issues need attention for digitalization : (a) lack of adequate measurement points, (b) reliability of data collection / accuracy, (c) poor quality of plant data. In addition to addressing these issues, training of operators is also necessary to make them sensitive about the importance of data reliability & accuracy.

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