Metal Chess Set Design

Team Checkmate
3.042 Project

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Presentation Outline

- Initial Concept
- Design Constraints
- Proposed Project
  - Design Proposal
  - Methods
  - Materials Selection
  - Materials Characterization
  - Surface Treatments
- Construction
  - Pieces
  - Board
Initial Concept

Primary Goal
Create a functional chess set and gain basic experience with a wide variety of materials processing and analysis tools
Chess Experts
Design Constraints

- **World Chess Federation guidelines for chess equipment**

- The King’s height should be about 9.5 cm. The diameter of the King’s base should measure 40 to 50% of its height.

- The size of the other pieces should be proportionate to their height and form; other elements such as stability, aesthetic considerations etc., may also be taken into account.

- The weight of the pieces should be suitable for comfortable moving and stability.

- The dark pieces should be brown or black, or of other dark shades of these colours. The light pieces may be white or cream, or of other light colours. The natural colour of wood (walnut, maple, etc.) may also be used for this purpose. The pieces should be pleasing to the eye.

- Boards should be rigid. The size of a square should be twice the diameter of a pawn’s base. It is recommended that a side of the square should measure 5 to 6.5 cm.
Design Proposal

- Cast metal chess pieces
- Board assembled of individual tiles inlaid on a frame
Design Drawing
Construction Methods

- 3D Scanning
- 3D Printing
- Metal Casting
- CNC Machining
- Metal Joining Processes
- Polishing/Surface Treatments
- Injection Molding
Investment Casting

- Wax model is prepared and encased in ceramic
- Wax is melted out, and metal is poured into the cavity
- Captures more detail than sand casting
CNC Machining

- Widespread industrial production technique
- Variety of available tooling for all sorts of tasks
Injection Molding

- Molds designed for easy injection molding of pawn pieces
- CNC machined from aluminum
- Cast both pure plastic and colored pawns using dye pellets
- Only pawns injection molded as the time commitment is significant
Materials Selection

- Fracture resistance
- Dent resistance
- “Comfortable” weight
- Surface finishing options
Materials Options
Cu-Zn Phase Diagram
Brass Composition

57.49 % copper
38.82 % zinc

Trace amounts:
Tin
Lead
Iron
Nickel
Aluminum
Manganese
Silicon
As-Received Material

- Both beta and alpha phases present in considerable amounts
- Few voids in the material
- 100x magnification
Far less alpha phase present in the cast sample

Many voids visible

100x magnification
SEM Analysis

- Conducted SEM on as received and cast samples
- Compared results to manufacturer specifications
Sample Spectrum

- Peaks correspond to particular elements
- Integration corresponds to number of signals
- As received sample shown
- Elements present as expected, within about 0.5% compositional difference
Cast Sample Inclusions

- Iron inclusions in “trigonal” arrangement
- Less voids than expected, but still more than as received
- Less alpha phase present than as received, but still present
Initial Development
New Plan

- Commercially produced chess pieces purchased and used as a template
- Two part polyurethane material is mixed in a plastic container and placed under vacuum conditions to remove bubbles
Occasionally problems occurred with molds:

- Ceramic did not properly hardened, remained soft and wet for several days
- Cracks during heat treatment
- Entrapped air bubbles
Our First Pawn

- Piece came out relatively smooth for a raw casting
- Minor surface flaws
  - Air bubbles filled with metal
  - Small holes in surface
- Pieces were sawed off and the bottoms were ground flat
- Surface imperfections were ground off
- Final surface was polished for coloration
Pawn Polishing

As-cast (left), sand-blasted (middle), and machine-polished (right) pawns are shown above. Note the difference in coloration.
Patination

- Forming an oxide layer on the surface of a metal
  - Commonly occurs as a result of weathering, and is a common tool used in artistic endeavors
  - Can affect color quite dramatically
Electroplating

- **Ni-W electroplating process used**
  - Xtalic corporation
  - Nano-structured surface coating created by plating Ni and W out of solution simultaneously using controlled proprietary conditions
Board Construction
Board Machining

- Machined in multiple phases
- Fine tip used to tighten corners
- Individual tiles were water jetted, colored, lacquered, and fixed in the board cavity
Injection Molding

- Quick and easy “insert” components designed by Aaron
- Injection molded pawns successfully, with minimal guidance and oversight
Questions?