

- ◉ **REVIEW OF MICROSTRUCTURE AND PROPERTIES OF NON- FERROUS ALLOYS FOR WORM GEAR APPLICATION & ADVANTAGES OF CENTRIFUGALLY CAST GEARS**

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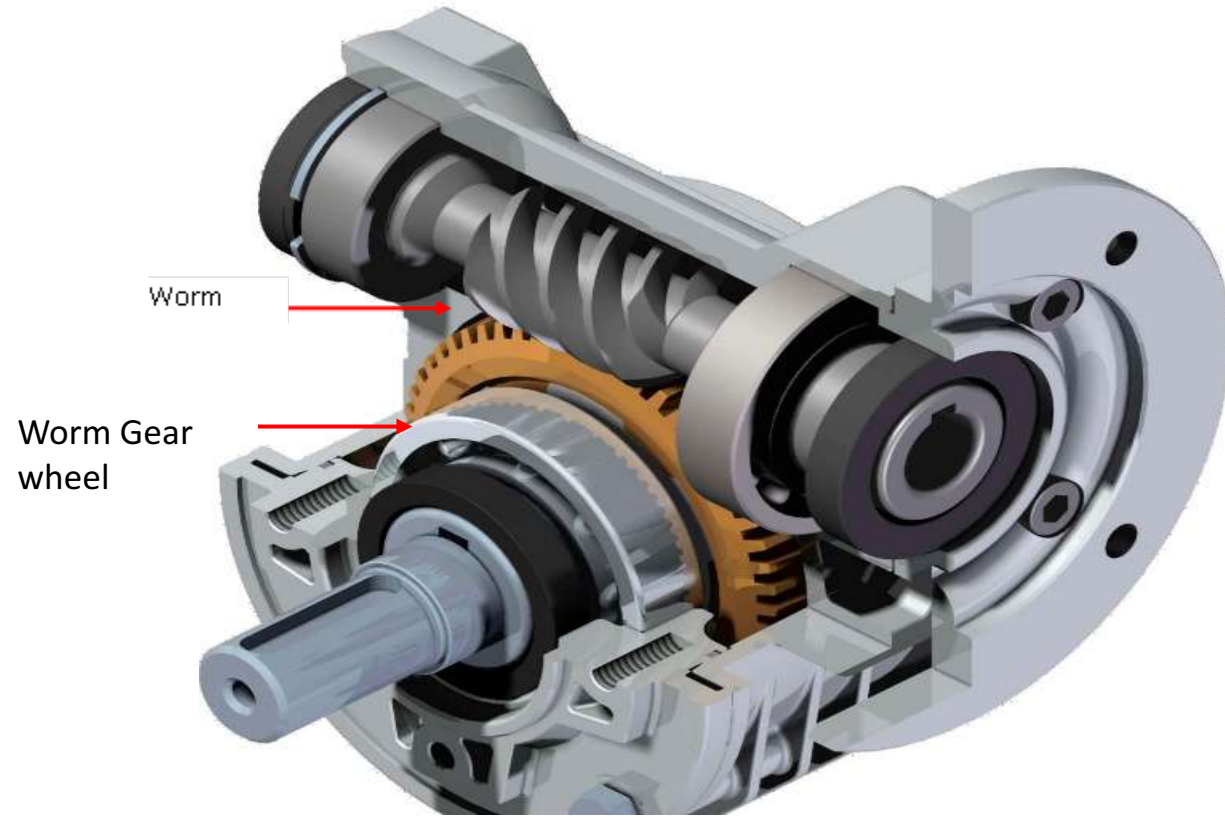
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OBJECTIVE OF THE PRESENTATION

- ◉ OVERVIEW OF NON-FERROUS (BRONZE) MATERIAL FOR WORM GEAR APPLICATION
- ◉ EXPLAIN THE DIFFERENCES BETWEEN THE STATIC CASTING AND CENTRIFUGAL CASTING METHODOLOGIES
- ◉ WHAT MAKES TIN BRONZE (GEAR BRONZE) SUITABLE FOR WORM GEAR APPLICATION. (MICROSTRUCTURE)
- ◉ SHOW THE ADVANTAGE OF A BIMETAL GEAR
- ◉ DISCUSS THE DIFFERENCES BETWEEN THE AS CAST AND HEAT TREATED ALUMINUM BRONZE (C95400 & C95500). HOW CENTRIFUGALLY (CHILL) CAST MECHANICAL PROPERTIES COMPARE.
- ◉ PRESENT THE TEST RESULTS OF MECHANICAL PROPERTIES AND MICROSTRUCTURAL STUDIES OF TIN BRONZE (GEAR BRONZE)

WORM GEAR SET UP



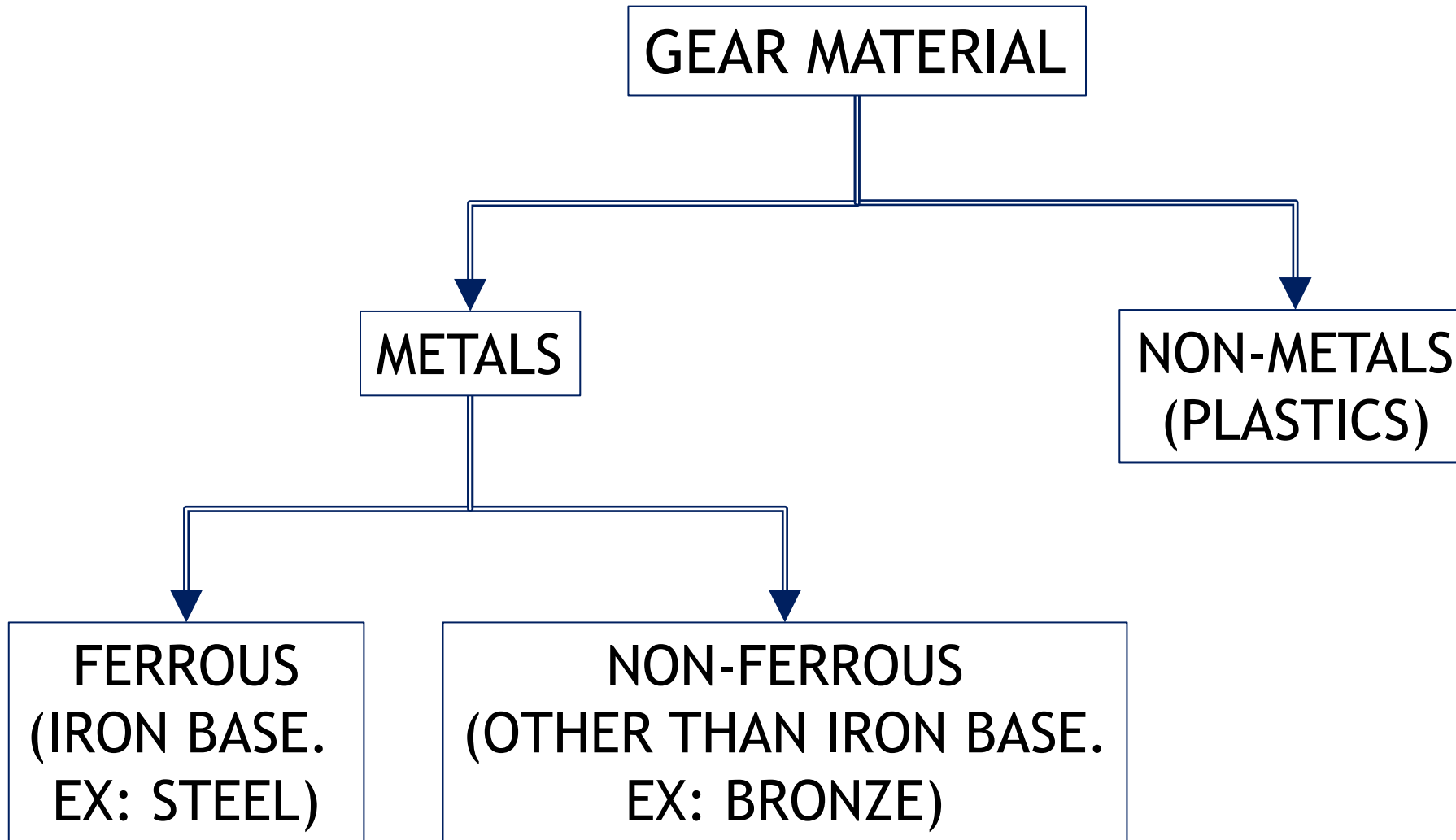
- ◉ AN ELECTRIC MOTOR OR ENGINE APPLIES ROTATIONAL POWER TO THE WORM
- ◉ THE WORM ROTATES AGAINST THE WORM GEAR
- ◉ AS THE WORM SLIDES ACROSS THE TEETH, THE POWER IS TRANSFERRED TO THE WORM GEAR WHEEL
- ◉ SLIDING MOTION IS THE MAIN TRANSFER OF POWER. IT CAUSES FRICTION

ADVANTAGES OF WORM GEAR

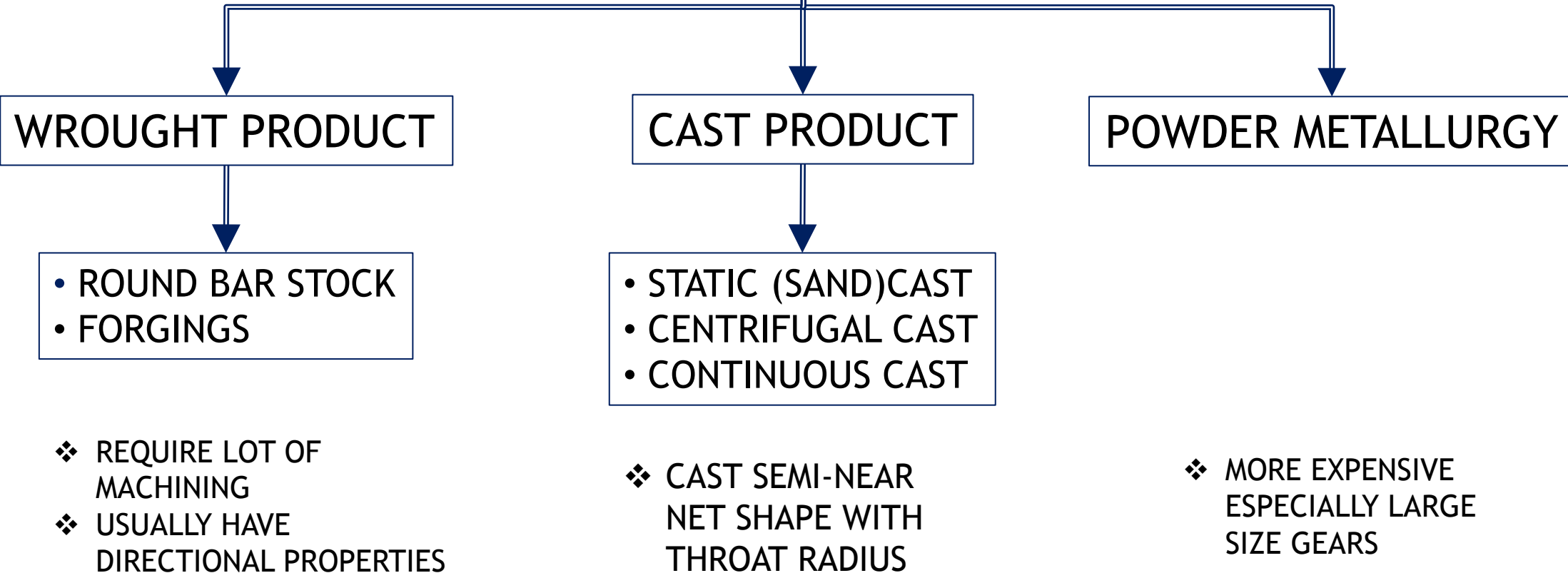
- ⦿ THE SPIRAL MOTION OF THE GEAR ALLOWS FOR HIGH REDUCTION RATIOS, COMPARITIVELY SMALLER AMOUNT OF SPACE.
- ⦿ GEAR RATIOS OF 5:1 TO 300:1 ARE POSSIBLE WITH SIMPLE DESIGN CHANGES
- ⦿ WE CAN USE IT TO GREATLY INCREASE THE TORQUE OR REDUCE SPEED.
- ⦿ CONVENTIONAL GEAR SETS REQUIRE MULTIPLE REDUCTIONS TO ACHIEVE THE SAME REDUCTION. (MORE MOVING PARTS MEANS MORE CHANCES FOR FAILURE)
- ⦿ IT IS GENERALLY DIFFICULT TO TURN THE WORM GEAR IN THE REVERSE DIRECTION*, DUE TO THE FRICTION BETWEEN THE WORM AND THE WHEEL

* NOTE: IT DOES NOT IMPLY THEY ARE SELF LOCKING. BUT THERE IS A REASONABLE EXPECTATION THAT IT WILL NOT BACK DRIVE IF THE WORM LEAD ANGLE IS LESS THAN 5 DEGREES.

FOR SAFETY, “BRAKE” SHOULD ALWAYS BE USED TO AVOID BACK DRIVE.

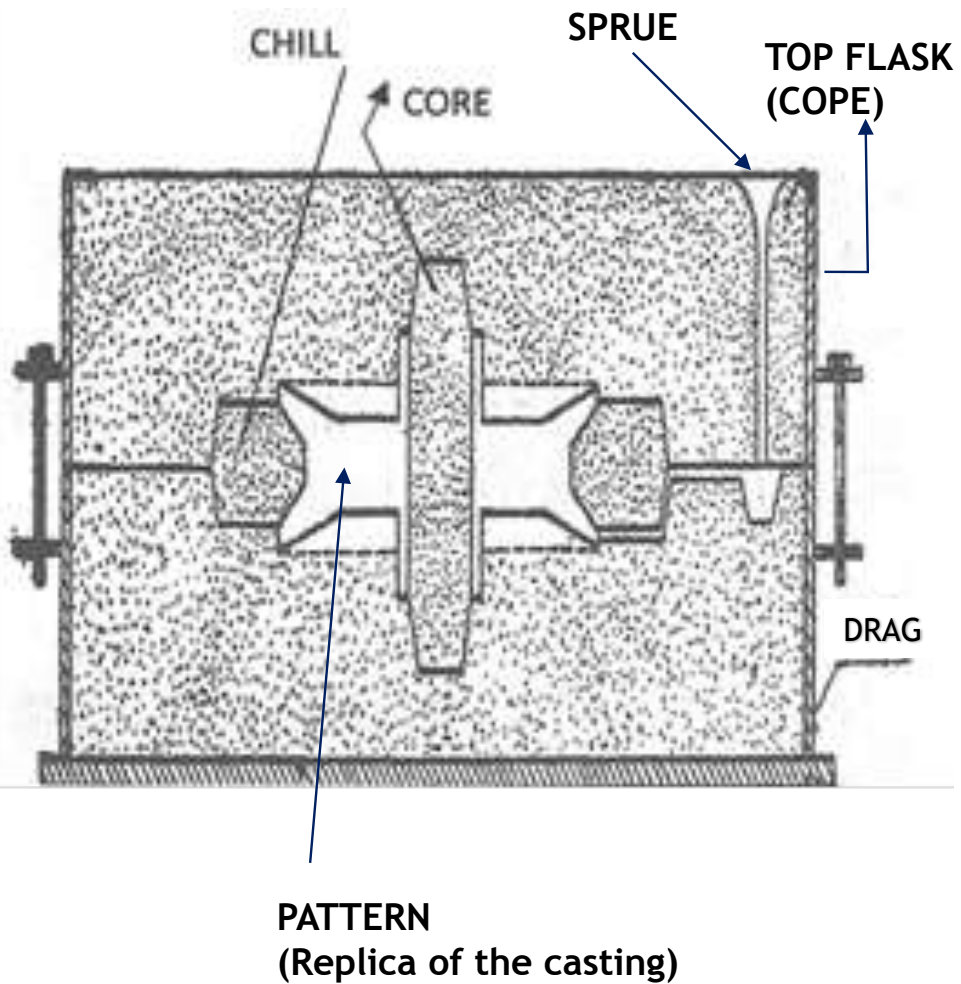


FERROUS & NON-FERROUS

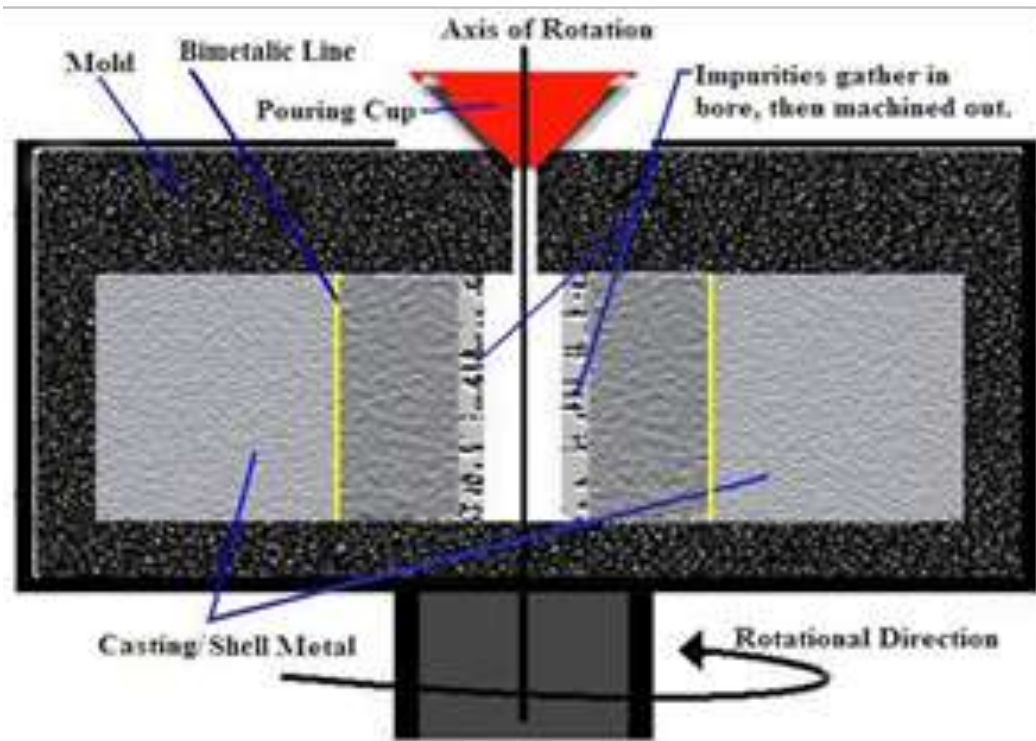


THE EFFICIENCY OF WORM GEAR SET IS GENERALLY LOW AND EFFICIENCY GOES TENDS TO DROP AS THE SPEED OF WORM DECREASES, DUE TO SLIDING FRICTION. ANY SMALL IMPROVEMENT IN EFFECIENCY IS A PLUS.

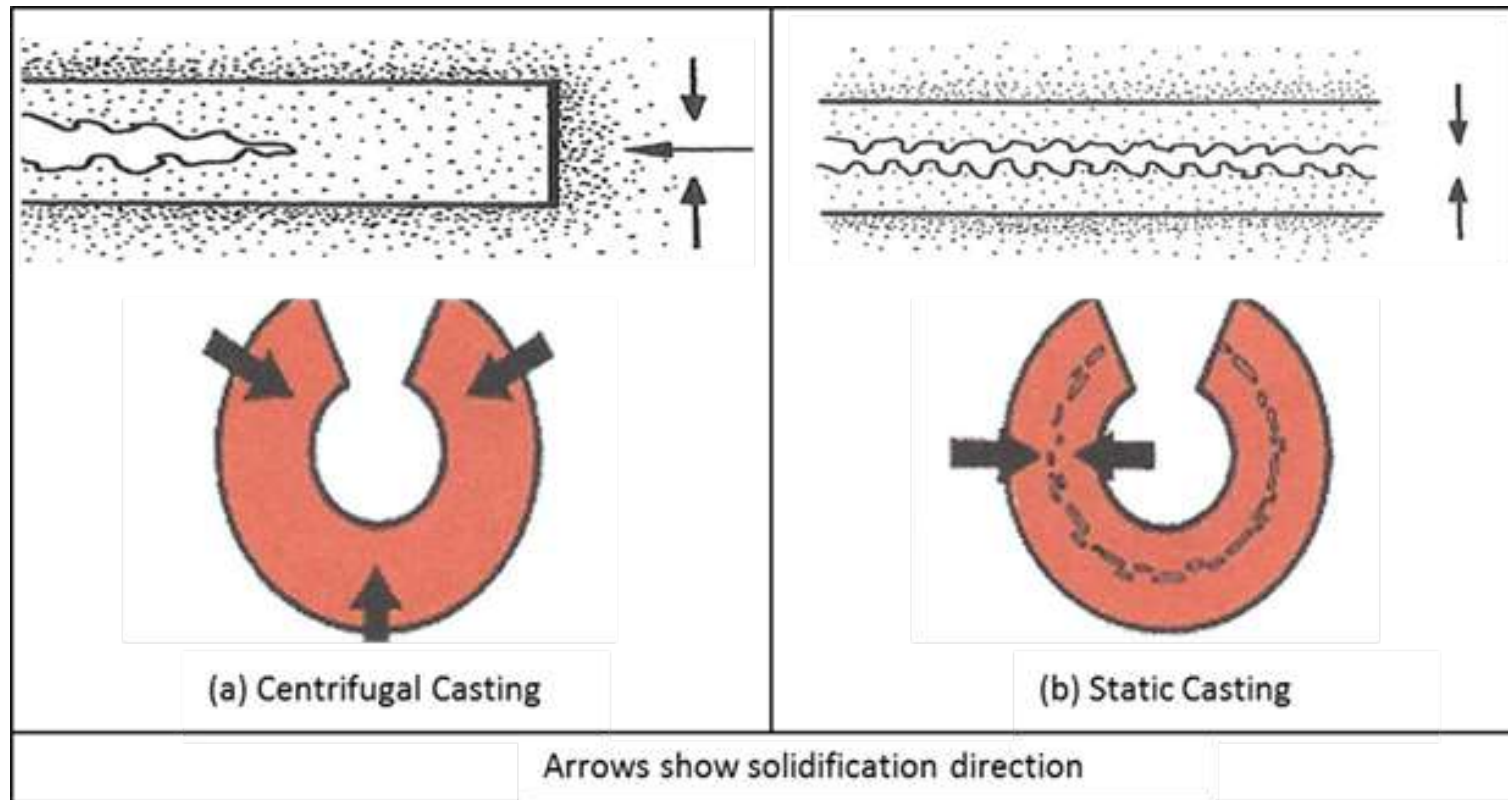
SCHEMATIC OF STATIC (SAND) CASTING



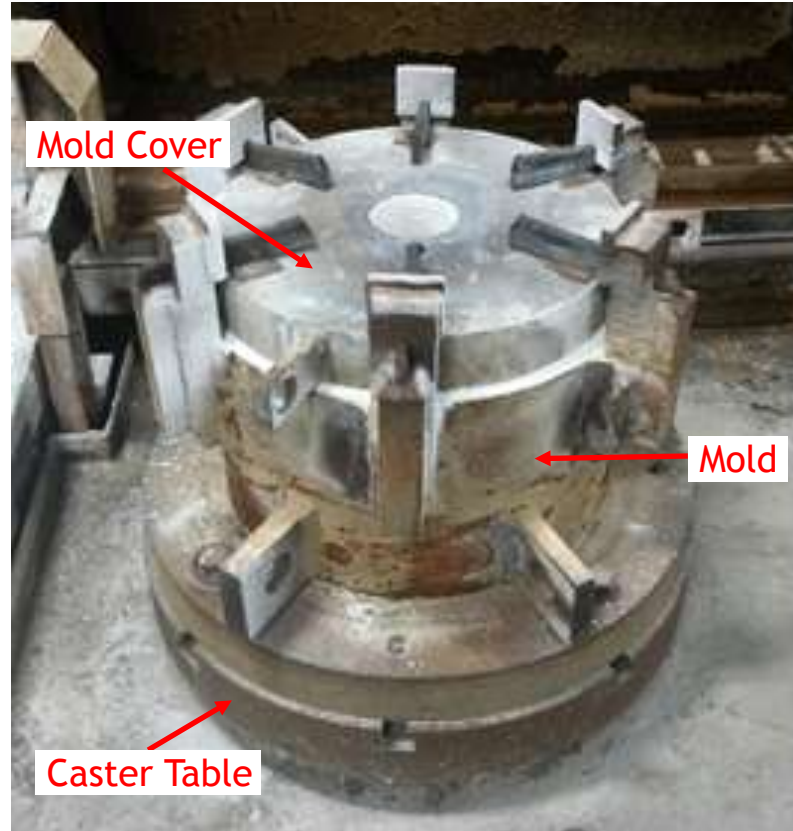
SCHEMATIC OF VERTICAL CENTRIFUGAL CASTING



COMPARISON OF SOLIDIFICATION CHARACTERISTICS BETWEEN CENTRIFUGAL CASTING AND STATIC (SAND) CASTING PROCESS



CENTRIFUGAL CASTING PROCESS



MOLD SET UP

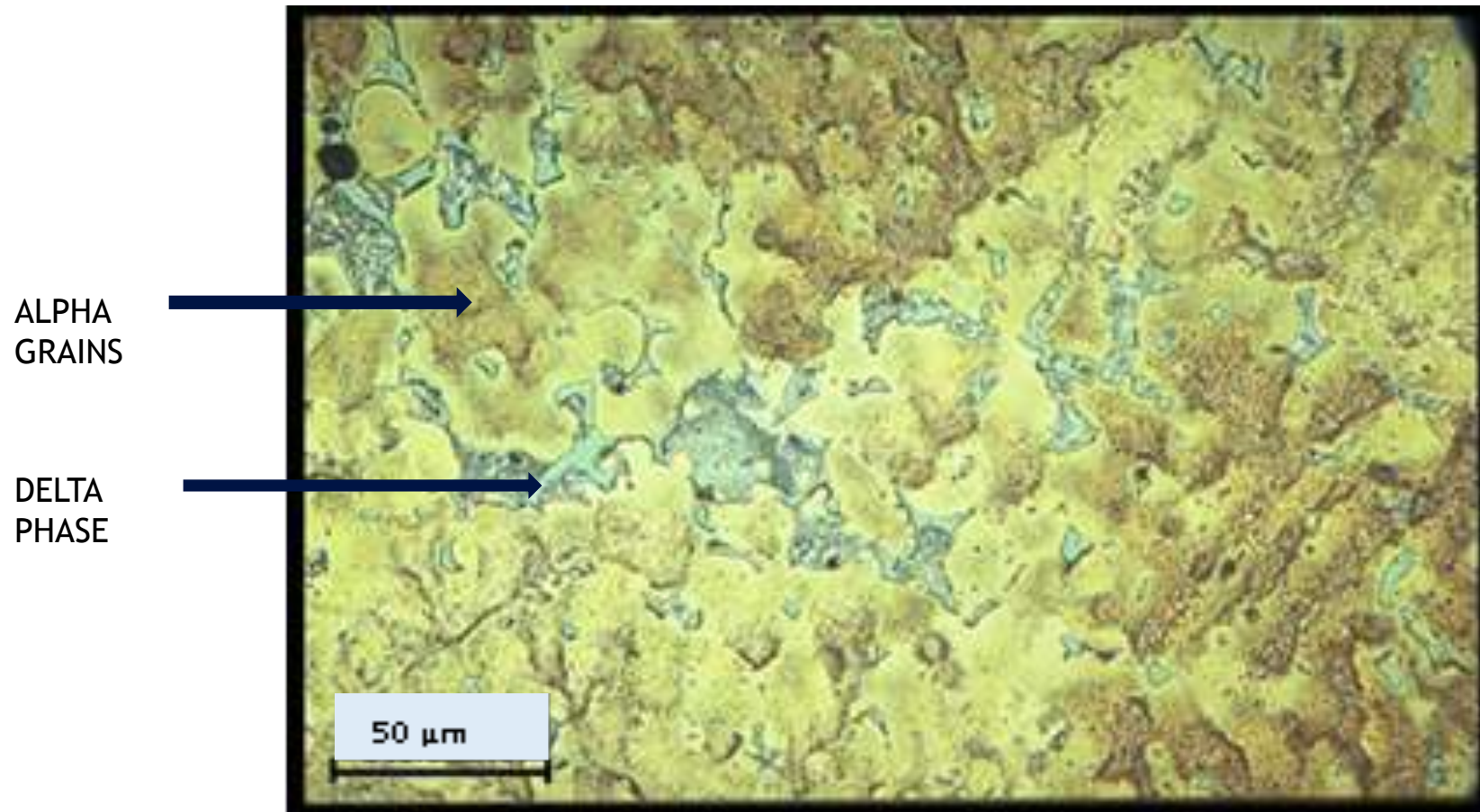


GEAR BLANK BEING CAST

TIN BRONZE

- ◉ TIN BRONZE IS AN ALLOY OF COPPER AND TIN (9- 12 %)
- ◉ MOST WIDELY USED NON-FERROUS GEAR MATERIAL
- ◉ ADDING TIN TO COPPER, MAKES THE ALLOY HARD BY REPLACING SOME COPPER ATOMS WITH TIN ATOMS
- ◉ DURING THE CASTING PROCESS THE FIRST PHASE TO FORM IS COPPER RICH PHASE (CALLED “ALPHA”) IN THE FORM OF DENDRITES.
- ◉ THE LIQUID METAL BETWEEN THE INTERDENDRITIC SPACES ARE ENRICHED WITH TIN.
- ◉ THIS LEADS TO THE FORMATION OF CuSn COMPOUND CALLED “DELTA PHASE”- VERY HARD PHASE

MICROSTRUCTURE OF TIN BRONZE



C90700 TIN BRONZE: Cu_89 %, Sn_ 11%, P_ 0.30 % max

- ◉ THE MICROSTRUCTURE OF TIN BRONZES, CONTAIN HARD “DELTA” PARTICLES EMBEDDED IN ALPHA PHASE. THIS IS IDEAL COMBINATION FOR A BEARING OR GEAR MATERIAL.
- ◉ THE DUCTILE ALPHA PHASE WITHSTANDS ANY SHOCK LOADING WHILE THE HARD “DELTA” PHASE PROVIDES WEAR RESISTANCE.
- ◉ THE INITIAL “SLIGHT WEAR” OF THE SOFTER MATRIX, LEADS TO “SLIGHT RELIEF” OF HARD DELTA CRYSTALS.
- ◉ THE SURFACE OF THE SOFTER “ALPHA” MATRIX BEING SLIGHTLY LOWER, FORMS AN OIL POCKET AND RETAINS THE OIL FILM, PROVIDING HYDRODYNAMIC LUBRICATION.

MICROSTRUCTURE & PERFORMANCE OF GEAR BRONZE

THE PERFORMANCE OF THE WORM GEAR WHEEL DEPENDS ON

1. HOW EVENLY THE “HARD DELTA CRYSTALS” ARE DISTRIBUTED IN THE MICROSTRUCTURE
2. THE AMOUNT OF THE DELTA CRYSTALS IN THE MICRO.
3. THE SIZE OF THE DELTA PHASE
4. THE GRAIN SIZE OF THE PRIMARY ALPHA PHASE

WHICH INTURN IS AFFECTED



THE CHEMISTRY OF THE GEAR BRONZE
THE CASTING PROCESS (STATIC OR CENTRIFUGAL)

NICKEL TIN BRONZE

- ◉ NICKEL ADDITION TO TIN BRONZE IMPROVES THE MECHANICAL PROPERTIES OF THE BRONZE.
- ◉ REGULAR TIN BRONZE TENSILE STRENGTH IS TYPICALLY 35-40 KSI, WHEREAS NICKEL TIN BRONZE IS TYPICALLY 50-60 KSI
- ◉ THEY HAVE HIGHER LOAD BEARING CAPACITY
- ◉ NOTE: NICKEL HAS MORE AFFINITY TO COPPER, AS A RESULT LESS TIN IS HELD IN THE FIRST PHASE TO CRYSTALLIZE (ALPHA PHASE). MORE TIN GOES IN THE FORMATION OF SECOND PHASE (DELTA PHASE)
- ◉ THEREFORE, NICKEL TIN BRONZE HAVE SLIGHTLY HIGHER HARDNESS THAN STANDARD TIN BRONZE

LEADED BRONZES

- ◉ THE MAIN FUNCTION OF LEADED BRONZE GROUP OF ALLOYS IS TO **IMPROVE MACHINABILITY**. THEY ARE KNOWN FOR PROVIDING LUBRICITY (MIS-NOMAR)
- ◉ LEADED BRONZES HAVE SLIGHTLY BETTER “COMFORMABILITY” THAN TIN BRONZES BECAUSE THE SPHEROIDS OF “LEAD” SMEAR OVER THE BEARING SURFACE UNDER CONDITIONS OF INADEQUATE LUBRICATION
- ◉ LEAD PARTICLES EMBED ONTO THE WORM, AND REDUCE THE FRICTION, “TEMPORARILY.”
- ◉ LEADED BRONZE (10 % TIN & 5 % LEAD) IS THE STANDARD BRONZE FOR ELEVATOR WORM GEARS, WHERE WORMS ARE MADE OF SOFT STEEL AND NOT HARDENED.
- ◉ LIMITS USING HARDER STEEL WORM
- ◉ LEADED BRONZES ARE GENERALLY BEST FOR **LOW/ INTERMEDIATE LOADS AND SPEEDS**

PROBLEMS ASSOCIATED WITH LEADED BRONZE

- ◉ LEAD BEING HEAVY METAL, GENERALLY POSES CASTING ISSUES SUCH AS SEGREGATION AND POROSITY.
- ◉ CASTING OF LEADED BRONZES CREATES WORKPLACE SAFETY AND ENVIRONMENTAL CONCERNS
- ◉ DISPOSING OF LEAD CONTAMINATED LUBRICANTS WHEN THE GEAR BOX OIL IS CHANGED.
- ◉ LEADED BRONZES TEAR UNDER HEAVY LOAD AND ARE ONLY SUITABLE FOR LOW AND INTERMEDIATE LOADS.
- ◉ THE GEAR MANUFACTURERS AND END USERS HAVE TO “WEIGH IN” THE ADVANTAGES OVER “DETRIMENTAL EFFECT OF LEAD”.
- ◉ WITH THE ADVANCES IN LUBRICANT TECHNOLOGY AND “CUTTING TOOL TECHNOLOGY,” LEADED BRONZES DO NOT PROVIDE SIGNIFICANT ADVANTAGE OVER TIN BRONZES IF PROPER LUBRICANT IS USED AND IF MAINTENANCE SCHEDULES ARE FOLLOWED.

COMPARISON OF MECHANICAL PROPERTIES AND APPLICATION OF TIN BRONZES

BRONZE TYPE	TYPICAL GRADE	TYPICAL HARDNESS RANGE (<i>Brinell Hardness @500 kg load</i>)	TYPICAL YIELD STRENGTH (<i>KSI</i>)	TYPICAL TENILE STRENGTH (<i>KSI</i>)	RECOMMENDED APPLICATION
<i>Tin bronze</i>	<i>C90700</i>	<i>95-100</i>	<i>26-28</i>	<i>45-50</i>	<i>MODERATE LOAD</i>
<i>Nickel tin bronze</i>	<i>C91700</i>	<i>100-115</i>	<i>28-32</i>	<i>50-60</i>	<i>HEAVY LOAD, PROVIDE SOME CORROSION RESISTANCE</i>
<i>Leaded tin bronze</i>	<i>C92700</i>	<i>80-90</i>	<i>25-30</i>	<i>40-45</i>	<i>LOW LOAD, REQUIRE SOFTER WORM</i>

MANGANESE BRONZE

- ◉ **MANGANESE BRONZES ARE COPPER, ZINC ALLOYS WITH SMALL AMOUNTS OF ALUMINUM AND MANGANESE.**
- ◉ **MANGANESE BRONZE ALLOYS CAN OPERATE UNDER VERY HIGH LOADS AND SPEEDS.**
- ◉ **BESIDES EXCELLENT MECHANICAL QUALITIES, THESE ALLOYS HAVE GOOD CORROSION RESISTANCE.**
- ◉ **THE STANDARD ALLOY IN THIS GROUP IS HIGH TENSILE C86300.**
- ◉ **THE TENSILE STRENGTH IS OVER 110 KSI.**
- ◉ **SOME CONTAIN LEAD FOR LUBRICITY, ANTI-SEIZING, PROPERTIES.**

ALUMINUM BRONZE

- ⦿ TYPICALLY CONTAIN 8-12% Aluminum, 1-5% Iron
- ⦿ ALUMINUM BRONZE ALLOYS ARE USED FOR THEIR COMBINATION OF HIGH STRENGTH AND EXCELLENT CORROSION AND WEAR RESISTANCE.
- ⦿ STRENGTH IS RETAINED AT HIGH TEMPERATURES UP TO 400°C (750°F)
- ⦿ THEY ARE HEAT TREATABLE
- ⦿ SOME OF THE ALUMINUM BRONZES HAVE GOOD SHOCK RESISTANCE.
- ⦿ THEY GENERALLY HAVE POOR COMPATIBILITY & CONFORMABILITY, THEREFORE BEST SUITED FOR HEAVY DUTY, LOW SPEED APPLICATION WITH PLENTIFUL LUBRICATION
- ⦿ C95400 & C95500 ALUMINUM BRONZE ARE THE POPULAR CAST ALUMINUM BRONZE.
- ⦿ ALUMINUM BRONZE IS USED IN OTHER TYPES OF GEARS SUCH AS SPUR GEAR, BEVEL GEAR, HELICAL GEAR

COMPARISON OF PROPERTIES AND APPLICATION OF CENTRIFUGALLY CAST BRONZES FOR WORM GEAR

TYPICAL PROPERTIES AND APPLICATION OF BRONZE WORM GEAR WHEEL					
Material	Grade	Typical hardness	Typical Yield strength	Typical Tensile Strength	Application
		(BHN)	(Ksi)	(Ksi)	
Tin (Gear)bronze	C90700	95-100*	26-28	45-50	MODERATE LOAD
Manganese bronze	C86300	210-230**	70-90	110-120	HEAVY LOAD AND IMPACT LOADING. (Galling is an issue at high temperature) ¹
Aluminum bronze	C95500 (AS CAST)	190-210**	45-56	100-110	HEAVY LOAD AND LOW SPEED*. EXCELLENT SEA WATER CORROSION RESISTANCE. USED IN MARINE APPLICATION
Aluminum bronze	C95500 (HT)	225-240	60-70	120-135	SAME AS ABOVE
* at 1000 Kg load					
** at 3000 Kg load					

1. Generate frictional heat under continuous operating conditions if not adequately lubricated.

BIMETAL GEAR

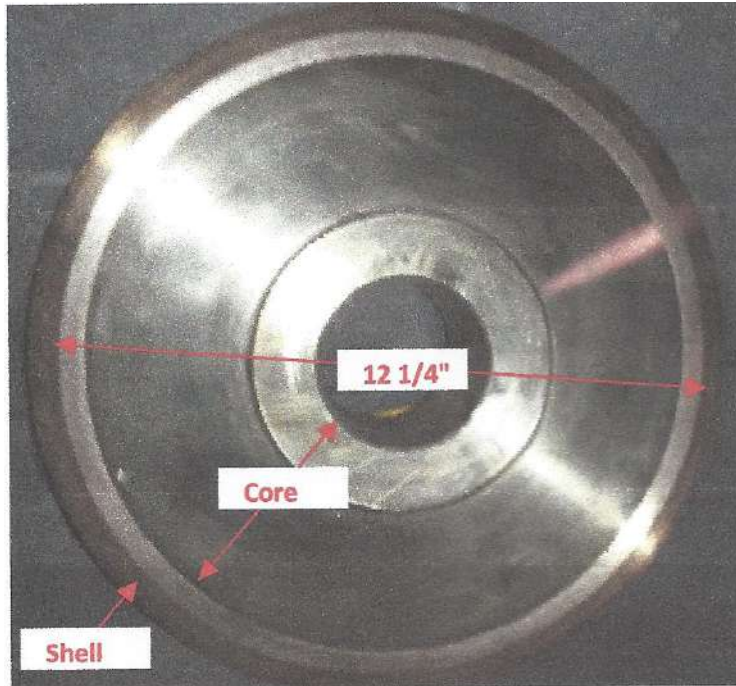
IT IS THE PROCESS WHEREBY TWO DIFFERENT ALLOYS ARE POURED AND CENTRIFUGALLY CAST TO BECOME A METALLURGICALLY BONDED GEAR BLANK.

- ◉ THE OUTER RIM OF THE GEAR BLANK WHERE THE TEETH ARE CUT IS CAST WITH TIN BRONZE.
- ◉ THE INNER PORTION WHERE THE SHAFT TO BE KEYED/SPLINED IS CAST WITH MANGANESE BRONZE OR OTHER ALLOYS
- ◉ BIMETAL GEARS PROVIDE A COMBINATION OF STRENGTH AND WEAR PROPERTIES REQUIRED FOR THE WORM GEAR.
- ◉ SINCE MANGANESE BRONZE IS CHEAPER THAN THE TIN BRONZE, THERE IS ALSO COST SAVINGS.
- ◉ THE BIMETAL GEAR IS ALSO BETTER FOR HANDLING SHOCK LOADING SITUATIONS

BIMETAL PROCESSING

- ◉ THE CASTING PROCESS OF A BIMETALLIC GEAR BLANK INVOLVES INTRODUCING A PRE-DETERMINED AMOUNT OF SHELL METAL SUCH AS TIN BRONZE (WHICH FORMS THE RIM OF THE GEAR) INTO THE MOLD
- ◉ AFTER A PRE-DETERMINED TIME DELAY, THE CORE METAL SUCH AS MANGANESE BRONZE IS INTRODUCED IN THE MOLD
- ◉ THE RPM AND COOLING PROCESS ARE CONTROLLED TO FORM A GOOD METALLURGICAL BOND BETWEEN THE SHELL AND CORE
- ◉ THE THICKNESS OF THE SHELL AND CORE IS DETERMINED BY THE GEAR TEETH GEOMETRY AND CUSTOMER REQUIREMENTS

CAST BIMETAL GEAR BRONZE



**Figure (a) Centrifugally cast
bimetal gear bronze**

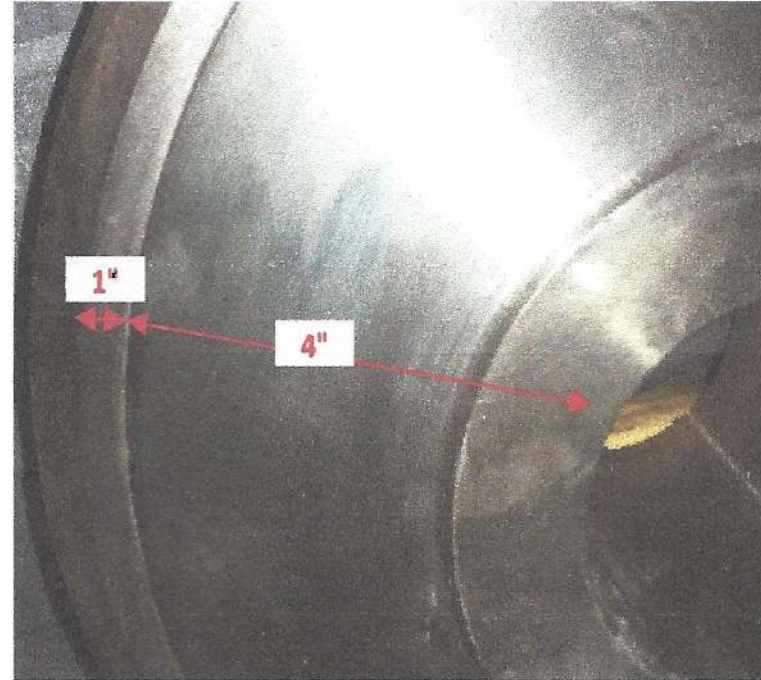


Figure (b) Close-up view

Gear teeth portion (shell) is tin bronze and the web and hub portion (core) is high tensile manganese bronze

- ◉ THE OUTER CU-SN MATRIX OF GEAR BRONZE GIVES GEAR TEETH SUPERIOR CONFORMING, WEAR CHARACTERISTICS.
- ◉ THE HIGH STRENGTH MANGANESE BRONZE INSIDE, WHERE SHAFT IS BE KEYED OR SPLINED, PROVIDES STRENGTH AND IMPACT RESISTANCE FOR WITHSTANDING STARTING AND STOPPING TORQUE.

COMPARISON OF C95400 & C95500 PROPERTIES

GRADE	ASTM B271-15 SPECIFICATION (AS CAST)				ASTM B271-15 SPECIFICATION HEAT TREATED*			
	Min/typical Brinell Hardness (@3000 kg load)	Minimum Tensile (KSI)	Minimum Yield strength (KSI)	% elongation min	Min/typical Brinell Hardness Range (@3000 kg load)	Minimum Tensile (KSI)	Minimum Yield strength (KSI)	% elongation min
C95400	150 (170 typ)	75	30	12	190	90	45	6
C95500	190	90	40	6	200	110	60	5

CUSTOMER SPEC FOR HEAT TREATED C95400			
Brinell Hardness Range (@3000 kg load)	Minimum Tensile (KSI)	Minimum Yield strength (KSI)	% elongation min
180-241	90	43	8

CHOICE BETWEEN C95400(HT) AND C95500(NON HT)

<i>CUSTOMER SPEC FOR <u>HEAT TREATED C95400</u></i>			
Brinell Hardness Range (@3000 kg load)	Minimum Tensile (Ksi)	Minimum Yield strength (Ksi)	% elongation min
180-241	90	43	8

ASTM SPECIFICATION B271			
<i>HEAT TREATED C95500 (QUENCHED & TEMPERED*)</i>			
Minimum Brinell Hardness (@3000 kg load)	Minimum Tensile (Ksi)	Minimum Yield strength (Ksi)	% elongation min
200	110	60	5

GRADE	<i>CHILL CAST (KEEL BLOCK) IN GRAPHITE MOLD</i>			
	Typical Brinell Hardness Range (@3000 kg load)	Tensile Strength (KSI)	Yield strength (KSI)	% elongation
MCC 955* HEAT# A4-6	207	107.9	47.3	14
MCC 955 HEAT# A16-9	193	103.9	56.4	15
MCC 955 HEAT# B26-9	187	100.2	53.9	14

* MCC 955 is MCC international equivalent grade for C95500

Heat # A4-6, A16-9 and B26-9 are random heats of MCC 955 grade



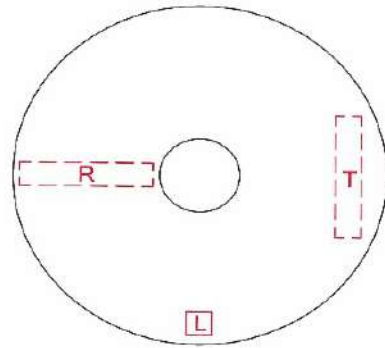
TESTING OBJECTIVE

TO COMPARE THE MECHANICAL PROPERTIES OF CENTRIFUGAL CASTING AND STATIC CASTING,

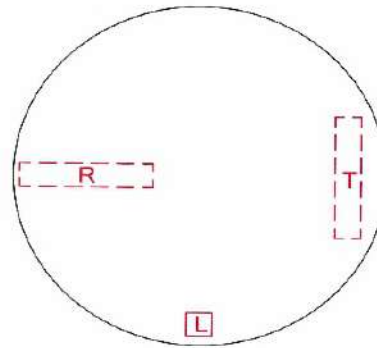
- TEST CASTINGS WERE CAST USING AN 89% CU – 10.8% TIN – 0.13% P BRONZE ALLOY.
- THE CENTRIFUGAL CASTING WAS CAST IN A 292 MM (11.50 IN.) DIAMETER GRAPHITE MOLD, SPINNING AT 600 RPM.
- THE AS-CAST SIZE WAS APPROXIMATELY 289 MM (11.375 IN.) OD X 76 MM (3.0 IN.) ID X 152 MM (6 IN.) LONG.
- THE STATIC CASTING WAS CAST IN THE SAME MOLD, BY CONTINUOUSLY FEEDING THE HOT METAL THROUGH THE BORE
- THE AS-CAST SIZE OF STATIC CASTING WAS 292 MM (11.5 IN.) OD X 152 MM (6 IN.) LONG.

SCHEMATIC SHOWING THE TENSILE BAR DIRECTIONS

Centrifugal



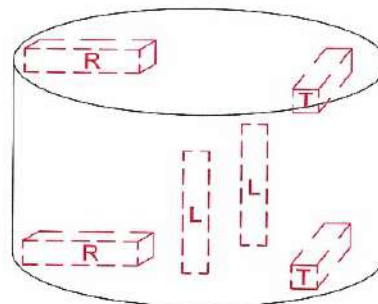
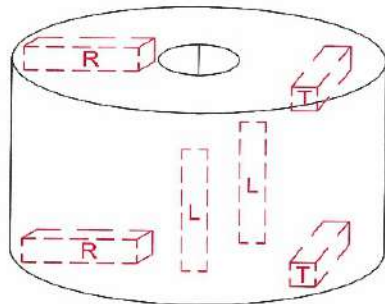
Static



R = RADIAL DIRECTION

T = TRANSVERSE DIRECTION

L = LONGITUDINAL DIRECTION



MECHANICAL TEST RESULTS (TRANSVERSE)

	CENTRIFUGALLY CAST			STATIC CAST			
	test 1	test 2	Avg	test 1	test 2	Avg	INCREASE OVER STATIC CAST (Lowest Reading Centrifugal minus Highest reading static)
Sample ID	A656	A657		A662	A663		
sample location	T1	T2		T1	T2		
Ultimate tensile (Ksi)	42.2	48	45.1	37.6	31.7	34.7	4.6 KSI (12 %)
Yield Strength (ksi)	20.1	20.9	20.5	20.6	19.7	20.2	0.3 (1.5 %)
elongation (%)	22.3	31.1	26.7	15.6	9.5	12.6	6.7 %

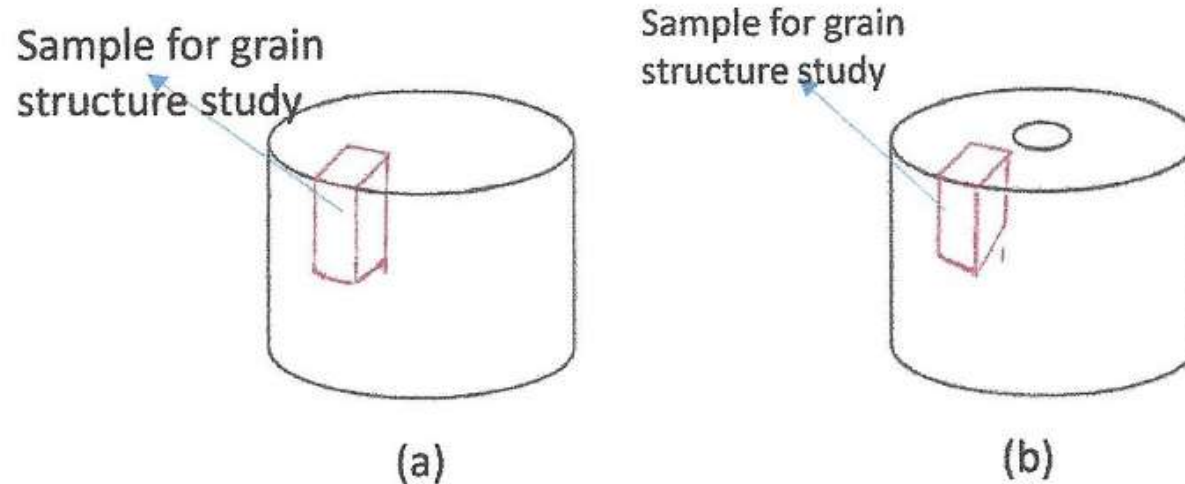
MECHANICAL TEST RESULTS (LONGITUDINAL)

	CENTRIFUGALLY CAST			STATIC CAST			
	test 1	test 2	Avg	test 1	test 2	Avg	INCREASE OVER STATIC CAST (Lowest Reading Centrifugal minus Highest reading static)
Sample ID	A658	A659		A664	A665		
sample location	L1	L2		L1	L2		
Ultimate tensile (Ksi)	47.8	42.4	45.1	32.1	34.1	33.1	8.3 KSI (24 %)
)Yield Strength (ksi)	21.2	20.8	21.0	20.4	20.4	20.4	0.4 KSI (2 %)
elongation (%)	30.2	21.3	25.8	8.9	10.3	9.6	11 %

MECHANICAL TEST RESULTS (RADIAL)

	CENTRIFUGALLY CAST			STATIC CAST			
	test 1	test 2	Avg	test 1	test 2	Avg	INCREASE OVER STATIC CAST (Lowest Reading Centrifugal minus Highest reading static)
Sample ID	A654	A655		A660	A661		
sample location	R1	R2		R1	R2		
Ultimate tensile (Ksi)	45.5	40.9	43.2	28.9	24.8	26.9	<i>12 KSI (41 %)</i>
Yield Strength (ksi)	21.8	20.6	21.2	20.6	20.2	20.4	<i>0 KSI</i>
elongation (%)	22.8	14.3	18.6	n/a*	n/a*	n/a	<i>N/A</i>

ORIENTATION OF SAMPLES CUT FOR GRAIN STRUCTURE STUDIES



Sample size approx. 25mm (1") wide x 38mm (1.5") height x 76mm (3") long

Casting size : 292mm (11.5") diameter x 152mm (6") long

GRAIN STRUCTURE COMPARISON



SAMPLE CUT FROM
CENTRIFUGAL
CASTING



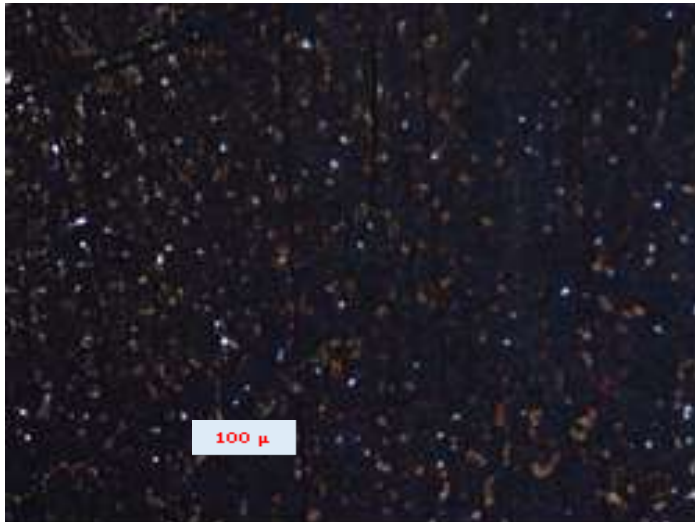
SAMPLE CUT FROM
STATIC CASTING

MICROSTRUCTURE OF COMPARISON



STATIC
CASTING

THE “DELTA” PHASE IS MUCH COARSER IN THE STATIC-CAST PIECE COMPARED TO THE CENTRIFUGALLY CAST PIECE.



CENTRIFUGAL
CASTING

EXPLANATION

IN THE CENTRIFUGAL CASTING PROCESS, DUE TO GREATER CHILL AND CENTRIFUGAL FORCE, MORE “NUCLEI” AVAILABLE FOR ALPHA DENDRITES TO FORM AND GROW. THIS LEADS TO SMALLER “INTERDENDRITIC” SPACES FOR THE DELTA PHASE TO FORM

SUMMARY & CONCLUSIONS

- ◉ SOME OF THE NON-FERROUS MATERIALS AVAILABLE FOR WORM GEAR APPLICATION AND THEIR MICROSTRUCTURES HAVE BEEN REVIEWED.
- ◉ THE DIFFERENCES BETWEEN THE CENTRIFUGAL CASTING METHOD OF MANUFACTURE AND STATIC CASTING METHOD OF MANUFACTURE HAVE BEEN PRESENTED.
- ◉ THE BIMETAL CASTING PROCESS AND THE ADVANTAGES OF BIMETALLIC GEAR BLANK WERE EXPLAINED.
- ◉ THE CENTRIFUGALLY CAST TIN BRONZE TEST PIECE SHOWED INCREASE IN ULTIMATE TENSILE STRENGTH 12 % IN THE TRANSVERSE DIRECTION, 24% INCREASE IN THE LONGITUDINAL DIRECTION, 41 % INCREASE IN THE RADIAL DIRECTION, COMPARED TO STATIC CASTING.
- ◉ THE PERCENT ELONGATION OF CENTRIFUGALLY CAST TEST PIECE IS APPROX. TWO TIMES HIGHER THAN THE STATIC-CAST TEST PIECE.
- ◉ IT IS POSTULATED THAT THE MICROSTRUCTURAL DIFFERENCES, SUCH AS FINE GRAIN SIZE AND FINER DELTA PHASES & SOLIDIFICATION CHARACTERISTICS BETWEEN THE TWO CASTINGS, MAY EXPLAIN THE DIFFERENCES IN THE MECHANICAL PROPERTIES.

SUMMARY & CONCLUSIONS

- ◉ COMPARISON OF C95400 HEAT TREATED ALUMINUM BRONZE AND “NON- HEAT TREATED” MCC GRADE C95500 BRONZE, THE AS CAST BRONZE HAS EQUAL OR SUPERIOR MECHANICAL PROPERTIES.
- ◉ IN CENTRIFUGAL CASTING PROCESS GEAR BLANKS ARE CAST “ SEMI-NEAR NET SHAPE”, WHICH MEANS CLEANER, FINE GRAIN STRUCUTRE WHERE GEAR TEETH IS MACHINED (UNLIKE BAR STOCK)
- ◉ NOTE: These conclusions are made based on the limited number of tests carried out on the tin bronze material. Future testing will be required to confirm if such differences exist in other materials.

FUTURE WORK

- ◉ EVALUATE THE MECHANICAL PROPERTY DIFFERENCES OTHER BRONZE MATERIALS, BETWEEN CENTRIFUGAL CASTING AND STATIC CASTING.
- ◉ EVALUATE OTHER NON-FERROUS MATERIALS (MONEL, STELLITE, ETC) FOR SPECIAL GEAR APPLICATION
- ◉ EVALUATE CASTING FEASIBILITY OF NEAR NET SHAPE GEAR (WITH TEETH)

THANK YOU VERY MUCH

