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Modelling & Designing of New Chain Sprocket Based Nitinol Heat Engine

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Abstract—*Nitinol Heat Engine a useful invention which converts low-grade heat energy into work output. Low-grade heat is a major source of energy that remains untapped. Unlike other heat engines, this engine operates at low temperature. This paper presents the Basic Nitinol Heat Engine Model and the advancement which had been taken place in the field of design. New models of Nitinol Heat Engines were invented from the past history in recent years with a motive of the optimum model which has fewer limitations and high efficiency. This paper gives the overview of important modifications in Nitinol Heat Engine model which were gifted to society. Finally, some suggestions are given for these models in order to further utilize in practical applications.*

1. INTRODUCTION

A new chain sprocket based Nitinol (Nickel-Titanium alloy) Heat Engine which drive by nitinol wire based chain. This Heat Engine works between heat source and sink. The output of this engine is rotational work, which is used to get power like electricity generation, etc.

(A) Background-

Within the past years[1], [5], [8], Heat engines were developed which utilize the properties of Shape Memory Alloys like Nickel-Titanium, gold-cadmium, indium-thallium, copper-aluminum-nickel, etc. All these materials have the common property of shape memory effect i.e. recovery of their shape when their critical temperature is achieved. During this phenomenon, solid-state phase transformation happens in these materials structure, which results in changing their physical shape.

Here, Nitinol material [3]can be elongate at low temperature and get contract at its critical temperature. This material gets strain (4-8%) on applying pulling force without damage the structure of the material, this strain is recovered by heating the material. This material remains undamaged for 1,00,000 cycle at 4% strain. Force requires for elongation is less than force induced by material on contraction. At low temperature, [4], material structure exists in martensite solid phase while above its critical temperature material structure exist in austenite solid phase. This phase change phenomenon of martensite to austenite phase in nitinol material triggers the mechanism which used in [2] Nitinol heat engine for conversion of heat into work.

Past years, several heat engines have invented using nitinol material as a drive member for conversion of heat energy into work output.

2. NITINOL HEAT ENGINE MODEL-

This [9], [7], chain sprocket based nitinol heat engine has been designed for conversion of heat energy into work output by using nitinol wire chain as a drive member. This chain is mounted on a set of sprockets of different size. These sprockets fitted on shafts. One of these two shaft having a large length to get work output. These shafts contain integral keys for mating of sprockets. A set of small sprockets are also used to synchronize the motion of engine rotation. These small set of sprockets are inter-connected with a simple chain and fitted on shafts. These shafts supported by bearings which mounted on bearing support. These bearing supports are fixed on engine platform. The whole assembly [11], is referred as Nitinol Heat Engine.

Here, the full assemble figure of chain sprocket based nitinol heat engine is present-

Fig. 1: Nitinol Heat Engine Model

Here, the detail of each part of Nitinol Heat Engine is given as follows-

(A) Construction-

i. The Nitinol Chain-

The chain of this [13], model contains a link, roller, pin & nut.

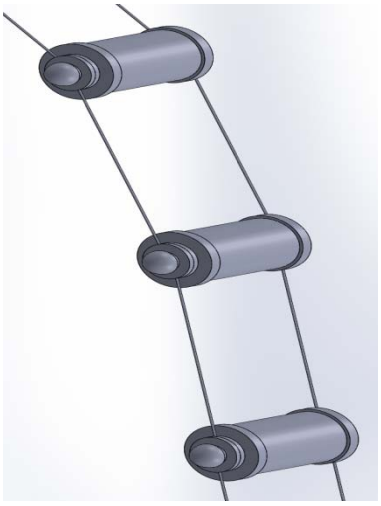

Fig. 2: Nitinol Chain

Pitch length of chain is taken double that of sprocket pitch.

Link of this chain is made up of nitinol wire strip fix at the end with a set of washers. The links contain single wire strip and four washers (two washers at each end of nitinol wire). The wire & washers are taken as an integral part called chain link.

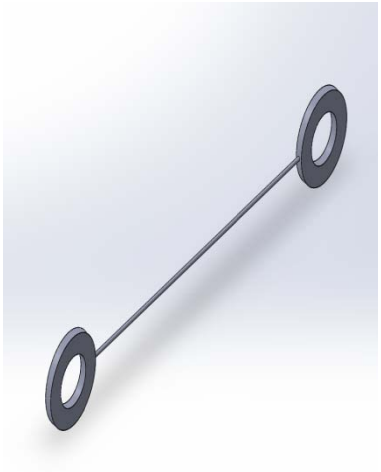

Fig. 3: Link of chain

Each Roller of this chain connected with four links (two links at each side) with one end of a link connected with the roller while another end of a link connected with an adjacent roller. At each side of roller two links is connected with its one end in the way that other ends of links are on opposite side of the roller. This construction again differentiates chain link i.e. inner link & outer link.

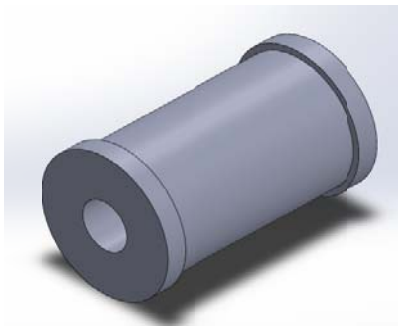

Fig. 4: Roller of chain

Ends of links and roller is connected by side face contact and fix with the help of roller pin which hold washers and roller in concentric position and there is no relative translatory motion between them only rotational motion between them is possible. Roller pin is remain fix with the help of nut which fix the roller & washer with roller pin.

Fig. 5: Roller Pin

ii. The Sprocket-

There are two sets of sprockets. One sprocket [10], pitch length is greater than another sprocket 4% by length. This is because of design requirement for the mechanism of Nitinol Heat Engine. The sprockets show here have 30 teeth. With a hollow cut inside for mating of the shaft with the sprocket.

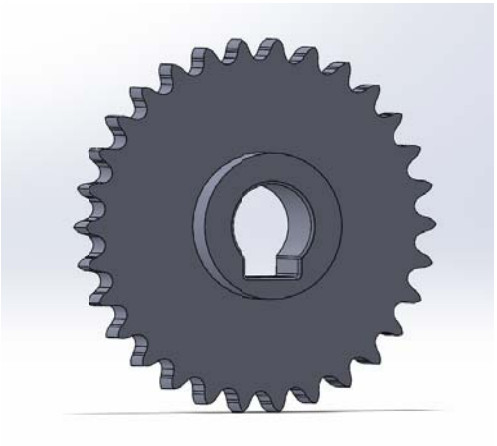

Fig. 6: Sprocket

iii. The Shaft-

The shaft contains integral keys. One shaft contains two integral keys with one at center and other at the side. These keys fitted with sprockets (main sprockets and small sprockets) to transmit rotation of sprockets on the shaft.

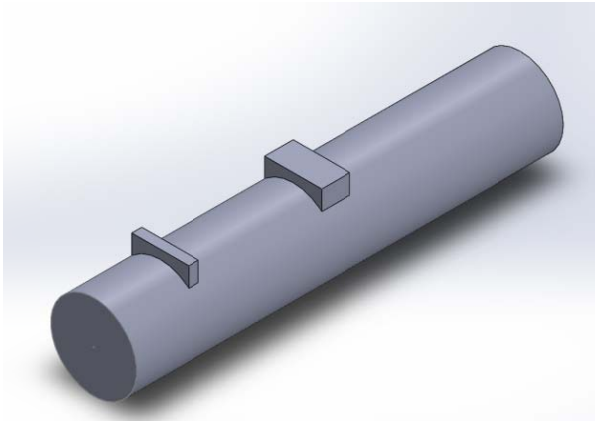

Fig. 7: Shaft

iv. The Bearing-

The bearing we use here is ball bearing having eight balls inserted in bearing cage between the inner and outer ring of bearing. In this assembly of heat engine, there are four bearings fitted in bearing supporters. Bearing support the shafts of the engine and also bears horizontal forces which shafts applied on bearings when the engine is not running.

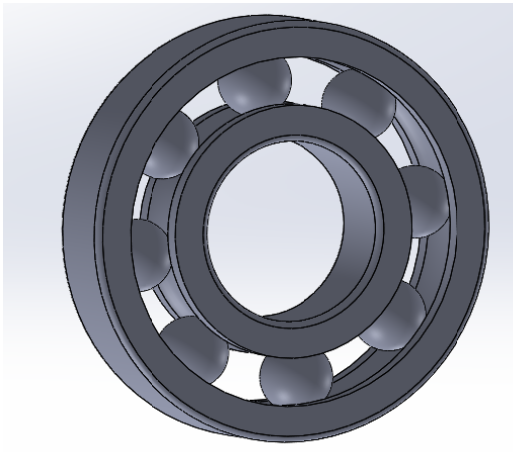

Fig. 8: Bearing

v. The Platform-

The platform is the base support of nitinol heat engine which contains bearing supports in which bearings are fitted. Platform holds the whole engine assembly.

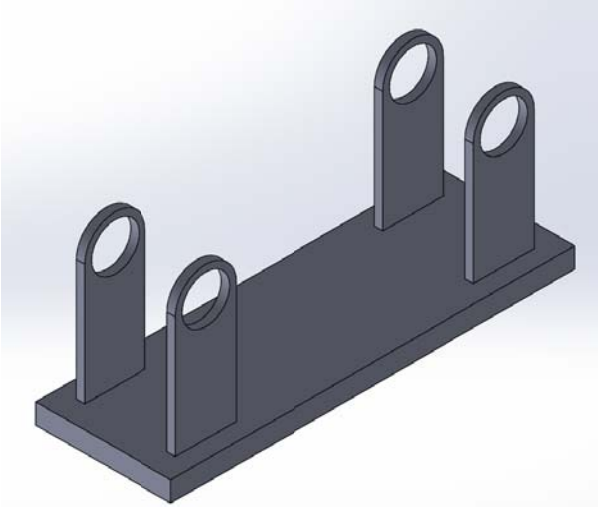

Fig. 9: Platform

vi. The Synchronizing assembly-

The synchronizing assembly consists of two sprockets having same no of teeth with same pitch length and same size & a chain which interconnect them.

In this engine, two sprockets of 26 teeth have taken with a chain containing 83 links to fully define the synchronizing assembly.

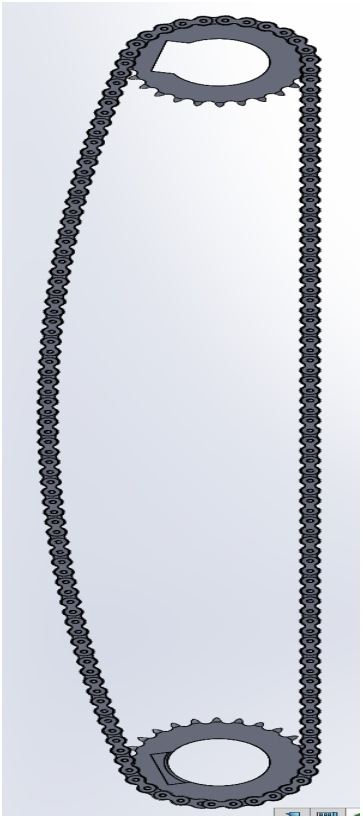

Fig. 10: Synchronizing assemble (Sprocket & chain)

(B) Working-

Nitinol Heat Engine [10], converts heat in work with the help of nitinol material. The basic principle of nitinol working mechanism is that the force required to elongate the wire is less than the force required to contract back to its back.

This nitinol heat engine working principle is based on the previous model of heat engine made by Dr. Alfred Davis Johnson. In Johnson's engine, [6], two pulleys of different diameters are connected by nitinol wire belt. The wire between reaches between two pulleys is in contact with a heat source and heat sink. As a result, one side of belt contraction force is developed and on the contrary, expansion of wire belt takes place. Due to the difference in tension force on two sides of the belt. Torque is generated by pulleys. A large torque is generated on large diameter pulley. For synchronize the motion in the same direction, either gears mechanism are used or belt pulley mechanism are used.

In this heat engine, initially, the nitinol chain is stretch to 2% elongation and mount on a set of sprockets having pitch length difference of 4%. When top part of the chain is heated to raise the temperature of nitinol wire strip, this results in the contraction of wire to get back in its original form while the bottom part of the chain is cooled, this results in the elongation of wire strip by another 2% to compensate the overall length of chain. Pitch length of the link is double the sprocket pitch to get large contraction length. Contraction of wire strip results in contraction force which is applied by the chain to sprocket through sprocket teeth-roller contact.

Due to the difference [9], in chain force, torque is developed on sprocket i.e. more torque on large sprocket. This difference in torque triggers the rotation. To synchronize the rotation in the same direction & same speed Synchronizing sprocket-chain mechanism is used. Which results in the rotation of the shaft. Hence. Work output is achieved.

3. DESIGN DATA-

Here all the dimension of Nitinol Heat Engine assembly for modelling is given as follows-

Engine Part	Dimension
Sprocket – 1	
Pitch Circle Diameter	239.17 mm
Pitch Length	25 mm
Thickness	20 mm
Pressure Angle	24°
Sprocket – 2	
Pitch Circle Diameter	248.73 mm
Pitch Length	25.99 mm
Thickness	20 mm
Pressure Angle	22.5°

Nitinol Chain-	
Pitch length	49.73 mm
Link-	
Nitinol Wire Strip Length	40.73 mm
Wire Diameter	0.4 mm
Washer Inner Diameter	5 mm
Washer Outer Diameter	9 mm
Washer Thickness	1 mm
Roller-	
Inner Diameter	5 mm
Outer Diameter	13 mm
thickness	20 mm
Support Collar Diameter	14.25 mm
Collar Thickness	2 mm
Pin-	
Diameter	5 mm
Length	36 mm
Nut-	
Inner diameter	5 mm
Thickness	2 mm
Shaft-	
Diameter	60 mm
Length	300 mm
Synchronizing chain-	
Pitch length	12.48 mm
Synchronize Sprocket-	
Pitch Circle Diameter	106.58 mm
Pitch Length	12.48 mm
Thickness	7.21 mm
Bearing-	
Ball diameter	12 mm
Inner ring diameter	60 mm
Outer ring diameter	140 mm

4. CONCLUSIONS & RECOMMENDATIONS-

This paper gives the design and modelling of chain sprocket based nitinol heat engine. In past years, study and research have been attempt in this area. Various models of the nitinol heat engines have been developed which have practical utility. This paper presents a new design that has overcome limitations of previous engines like –

(A) Sprocket- chain mechanism is used instead of the belt-pulley mechanism. This eliminates skidding & elastic slip of band over a pulley
(B) Due to sprocket-chain mechanism friction loss is lower as compared to belt pulley mechanism.
(C) This engine has a capability of transfer large torque as compare to belt-pulley engines.

5. FUTURE RESEARCH-

To completely define the engine mechanism, this engine model will be analyzed with CAD Software, to validate the mechanism. After validating, fabrication of model will be done.

Although, some more modifications which might help to improvise this nitinol heat engine model-

(A) Vary the size of the sprocket and investigate its effect on torque and speed.
(B) Vary the pitch length of chain, with limitation to avoid polygonal effect when increasing the length and less contraction area when decreasing the length.

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