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Review of Torque Limiter Timer Belt Spindle Drive for Overload Protection

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Abstract—
Torque is the one of the most important parameter in drive technology. The size of the torque and the type of torque stress plays a considerable part in the operational safety of drives. Torque limiting clutch is a mechanical device which disengages immediately in case of an overload and disconnects input and output. This paper describes the development of Torque limiter timer Belt spindle drive for overload protection. The main purpose of safety spring ball clutch is to protect the system from overloads, but we are using it as torque limiting device. In addition, it is shown how the model can be used for further investigations and developments.
Keywords— *over load protection, torque limiting device, adjustable torque value, performance investigation.*

I. INTRODUCTION

In order to avoid the damage of the transmission elements it is necessary that the input and output shafts be disconnected in case of sudden overloads .The isolation of the input driver member i.e; motor from the output member is absolutely necessary to avoid damage and it is possible by called ball clutch.

Torque-Limiters are Overload Safety Devices with Torque Limiters which provide reliable overload protection. When a jam-up or excessive loading occurs the Torque Limiter will reliably and quickly release to prevent system damage.[1]

I.1 Torque Limiter-

Torque Limiters provide accurate reliable overload protection for all types of machinery and equipments. They prevent damage to machinery and equipment and make machines reliable. These versatile units are available in single or multiple positions, freewheeling and torque sensing models. Torque Limiters have manual or automatic reengagement and unique method for setting the overload torque, which makes adjustment both accurate and easy. They are directly attached to motors, gearboxes, spindle, input, output, intermediate shafts of machine.

I.2 Operating Principle:

In the event of an overload, two flanges are rotate against each other and bolt is pressed against the force of the cup spring out of the thrust piece via the control segment and the thrust washer. The control segment travel radially outwards over the control edges of the bolts and hold the bolts in their disengaged position. The positive connection of the flanges is broken. The masses which were originally connected can now coast freely. The drive is disconnected

Re-engagement: The clutch is re-engaged simply by hand. The two flanges are turned towards each other in the correct angular position so that bolt and thrust piece are accurately aligned. The bolts are returned to its engaged position by tapping the end of bolts with the plastic mallet. The clutch is ready for operation again when all overload elements of the cultch are re-engaged and automatically re-engage on request[1]

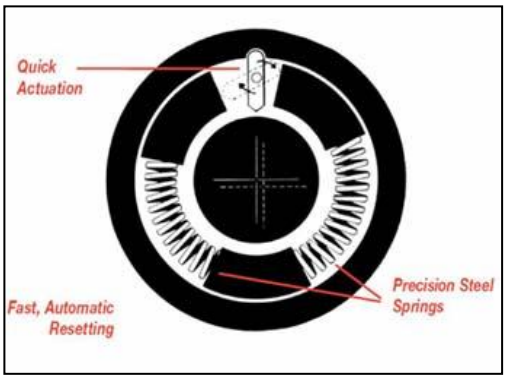


Fig. I.1: Torque Limiter

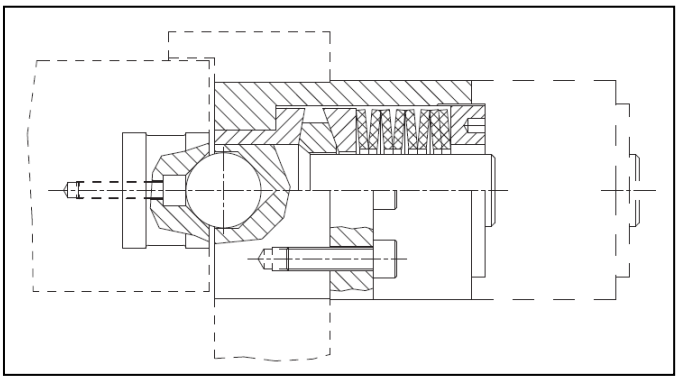


Fig I.2: adjustable slipping type of ball-clutch Torqe-Limiter[1]

The limiting torque for an overloadM at the clutch composed of overload elements is calculated on the basis of:

$M_G = Z \times F_U \times r$ [kNm]

F_U = Circumferential force per overload element [kN]

M = Limiting torque set for an overload [Nm]

Z = Number of overload elements

r = Pitch circle radius (on which overload elements are located) [m]

I.3 Types of Torque Limiters-

1. **Ratchetting Clutch:** The Ratchetting Clutch ratchets when the pre-set limiting torque is achieved. While it is ratchetting, the torque is considerable lower than the pre-set disengaging torque. It engages automatically at the pre-set convenient ball detent. The limit switch transmits a signal to switch off the drive.
2. **Torque Sensor Clutch:** Torque Sensor is load holding safety clutch in the event of an overload. This makes electrical contact or transmits a signal to switch off the drive. However it continues to transmit the torque mechanically. Automatic reengagement.
3. **Synchronous Clutch:** In the event of an overload the clutch disengages. After removal of the overload re-engagement occurs automatically at a defined position i.e. after rotation through 360 of the rollers
4. **Overload Clutch:** In the event of an overload, the clutch disconnects the drive enabling the rotating components to slow down freely. Manual re-engagement required. In case of an overload positive disconnection of input & output drives is achieved.[1]

I.4 Technical Features

- Making machines safer & more reliable
- Torque transmission positive
- Repairs and down times are minimized
- Disengages immediately in case of an overload and disconnects input and output with accuracy
- Additionally an electrical signal can be provided through mechanical actuation of a limit switch to switch off the complete element.
- Precise and constant disengaging torque limiter
- High and disengaging torque is provided (+ 5 %)
- After removing the load, clutch automatically returns its initial state and again ready for use.
- High quality materials, hardened functional components and precision manufacturing gives excellent repetitive accuracy of the set disengaging torque and provide a long service life[1].

I.5 Applications

Torque Limiting Clutches can be used as flanged coupling with or without mounting to take chain sprockets, gears, toothed and V-belt pulleys. These clutches also connect co-axially arranged shafts to a flange, torsionally rigid or flexible coupling. Cyclo

clutches are used in almost all fields of mechanical engineering, e.g. Packing Machines, Conveyor System, Painting Lines, Industrial Furnaces, Textile Machinery, Filling and Cleaning Machines, Agitators, Construction Machinery, Paper Making Machinery, Food Industry, Plastic Industry, Wood Working Machines, Mining Industries, Foundries and Rolling Mills, SPM and more…… It is advantageous to fit the torque limiting clutch as close as possible to the trouble spot or directly to the drive component which require protection.[1]

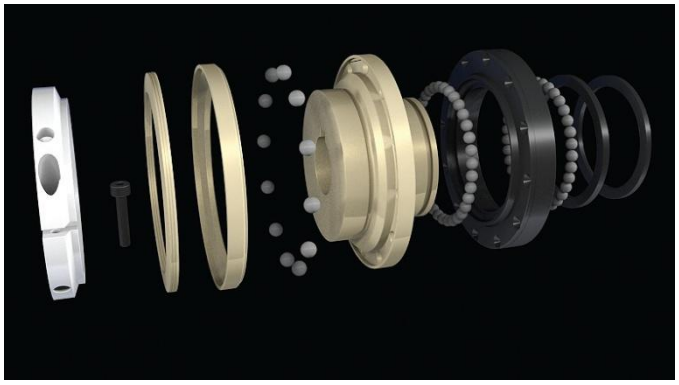
II. LITERATURE REVIEW

Study of various configuration of Overload Torque limiters, and Electromechanical clutch systems using various Handbooks, United State Patent documents, Technical papers , etc.

BY TOBIAS WOLF

The concept of weight reduction through the use of high tech materials is not a new one. But for those involved in the design of motion control and automation systems, the elimination of excess mass and inertia is often the difference between success and failure. Energy savings, higher throughput rates, and reduced downtime, all without compromise to quality or accuracy, are the new requirements. To address them, R+W has introduced a new torque limiter, SL Series, with half the inertia and less than half the mass, allowing for a rapid and automatic recovery from torque overload even in the most advanced drive technology.

The SL Series uses the proven spring loaded ball detent system, along with a previously patented preload for zero backlash operation. But to achieve its target of 50% weight reduction, we embarked on a two-year collaborative effort with local universities, designing the product from the ground up. The result is a torque limiter constructed from state of the art materials with unique surface treatments and innovative assembly technology–surpassing weight reduction targets and simultaneously reducing its footprint. One example of this size reduction is a torque limiterrated to disengage at 160 Nm, which in the past would have had at best a mass of 1.3 kg and a moment of inertia of 1.6 x 10-3 kgm2. It now weighs 370 grams with a moment of inertia of 0.8 x 10-3 kgm2. What that amounts to is an automatic torque limiter with unparalleled power density.



In addition to custom material specifications, specially designed spring systems, and some improvements to the ball detent configuration (resulting in a 40% increase in torque capacity for a given size) the weight reduction was also achieved through the compression of individual components. This, of course, is without negative impact on the precision or service life of the torque limiter. The SL Series can handle in excess of 10,000 disengagement events, depending on rotational speed. [2]

BY ANDREW LECHNER

As a primary or redundant safety device, backlash-free ball-detent torquelimiters serve as a mechanical circuit breaker for machine drive protection, disconnecting drive and driven elements accurately (±5 percent torque) and virtually instantaneously (&3 msec) in the case of a machine jam or crash. A common misconception is that limiting current supplied to the drive will inherently protect the mechanical system from overload, though when placed on the output of servo worm or planetary gearboxes for example, precision torquelimiters protect the mechanical system from reflected load inertia, where sufficient energy to do harm has already been supplied well in advance of the impact. Backlash, repeatability and response time are key to the successful application of mechanical torquelimiters in high-speed servo applications.

“Traditional torquelimiters would not respond fast enough to an overload situation in higher speed

applications, where over travel would occur too rapidly," says Ben Cucci, design engineer, Schumacher Automation, Belmont, NH.

"A high level of repeatability is desirable to ensure a consistent breakaway torque across the line," says Duncan Quinn,design engineer, NBS Card Tech, Paramus, NH.

Servo-rated torquelimiters normally possess internal preloads between mating components to eliminate backlash. But it is the digressive spring characteristic which stands out as the most significant adaptation in the development of precision mechanical torquelimiters for servo-driven systems. Their enhanced sensitivity to axial movement heightens accuracy and response, but also requires that greater care be taken in layout and assembly.[3]

"NICOLAE EFTIMIE"

In the paper titled "Dynamic Simulation Of The Safety Clutches With Balls" states that, explored the clutches are used largely in machine buildings, and by the correct selection of these depends – to a great extent – the safe and long working, both of these and of the kinematic chain equipped with them[4].

"**M JACKEL1, J KLOEPFER, M MATTHIAS AND B SEIPEL"**

In the paper titled "The novel MRF-ball-clutch design – a MRF-safety-clutch for high torque applications" states that the development of a safety-clutch by using magneto rheological fluids(MRF) to switch the transmission torque between a motor and a generator in a bus-like vehicle [5].

"TRANSILVANIA UNIVERSITY BRASOV, ROMANIA"

In the paper titled "Design Procedure of Elastic and Safety Clutches using Cam Mechanisms" states that, topological and structural generation of elastic and safety coupling, In the second part, on the basis of the functional characteristic of the cam gears, we propose a simple method for the structural and generation of elastic and safety couplings[6].

MR..S.JEGADEESAN

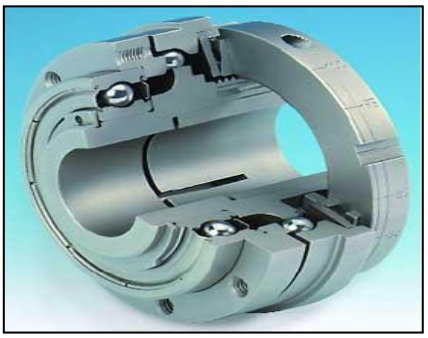
in the paper titled "Design of Energy Savings in Metropolitan Railway Substations and Communication Based Train Control" states that, explored the reduction in energy consumption has become a global concern and the EU is committed to reducing its overall emissions to at least 20%[7].

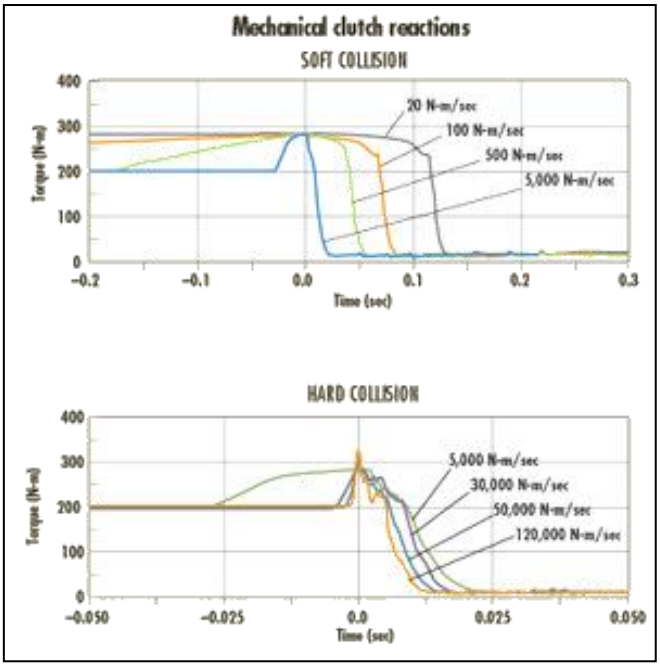
LANDQUIST ROCK FORD UNIVERSITY. "RADIAL BALL TORQUE LIMITER

Mark S Landquist invented radial ball torque limiter which having a member with an annular wall defining cavity with a plurality of rows of internal teeth extending circumferentially along the interior of the annular wall.[8]

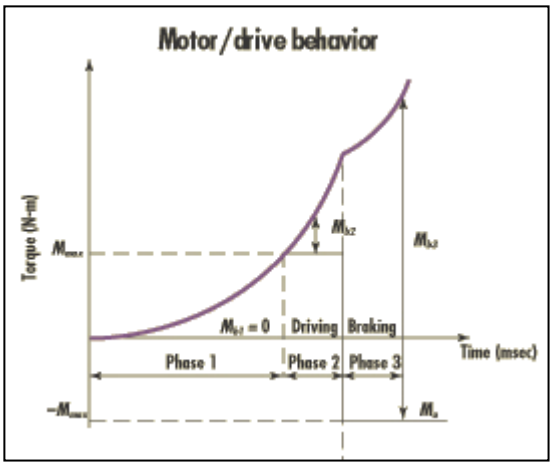
BY CHRISTOPH DROPMANN

Mechanical overload-protection devices, such as the EAS -Compact backlash-free, ball-detent torque-limiting clutch, can disconnect drive and driven components almost instantaneously.

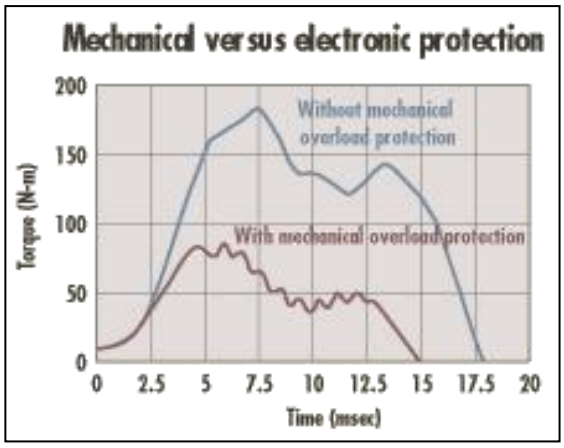




Soft collisions provide adequate time for an electronic device to detect a problem and initiate corrective action. In hard collisions, however, there is virtually no time for an electrical/electronic device to recognize and react to a problem before torque exceeds the clutch set-point. Only mechanical overload protection is fast enough to prevent machine damage. Both examples use a Mayr EAS-NC 3 torque-limiting clutch.



This graph illustrates motor behavior when controls are designed to stop and reverse the drive immediately after a collision.



This chart shows torque and reaction times of a machine crash with and without mechanical overload protection. Electrical overload protection has been used since the days of the first industrial electric motors. Back then it simply protected motors against thermal overloads. Today, however, protection devices monitor many parameters - such as current, voltage, force, torque, rotation frequency, position, temperature, and pressure - and initiate corrective measures based on these inputs.

Further, with improvements in today's drives, such as lighter and more powerful motors with more-sophisticated electronic controls, response times for corrective actions are shorter than ever. So it might seem that mechanical torque limiters are no longer necessary to protect a machine.[9]

III. PROBLEM STATEMENT

Whenever an overload occurs in any shaft drive mechanism as shown below there are three possibilities:

a) Shaft / coupling/ belt drive fill fail or break.

b) Application i.e. machine shaft will fail or break

c) Motor will be overloaded resulting into electric burn…

In any case it is damage leading to machine part replacement …Down time of machine and increased part replacement and maintenance cost …

Machine tool spindle drives use timer belts with timer belt pulleys in open belt drive system. These spindle drives are as shown Fig 1.

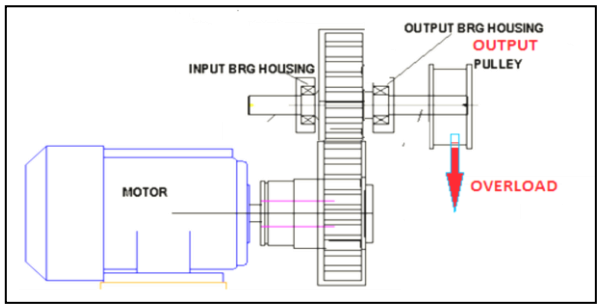


Figure III: Machine tool spindle drives use timer belts with timer belt

IV. SCOPE OF WORK

Thus there is a need of Timer belt spindle drive with overload torque limiter with following features

a) Electromechanical disengagement so that drive can be temporarily disengaged for I in process inspection or other activity.

b) The torque limiter can be set over a range of torques (say 0 to 20 kg-cm) so that the machine operator can set it to desired value for given application, unlike the conventional clutches that are factory set.

c) The transmission elements i.e. the balls will not come out of assembly when there is overload slipping, this of downtime of process as compared to the conventional clutch

If temporary overload occurs the clutch will slip and remain disengaged only till the overload is removed, thus if the overload is removed while in running condition the clutch shall automatically engage and start transmitting power this leads to minimal process down time saving a considerable amount of man and machine hours wasted due to breakage or presetting as in conventional clutches

To protect the drive from failure what is available in market is a 'Flying ball clutch' which transmits torque from input to output using balls held by a spring in assembly. When overload occurs the balls will come out of assembly – thus disconnecting input and output. There by saving part failures. But; comes as an advantage as the clutch can be preset without removing it from assembly,

- Ease of operation: The changing of torques gradual one hence no calculations of speed ratio required for change torque .Merely by rotating adjuster lock nut torque can be changed
- Machine tool slides are driven by electrical drives connected to lead screw. The over load slipping ball clutch isolates the electrical drive from the output in case of overload.
- In many cases pump shaft drives either electrical or engine drives are normally furnished with the overload slipping ball clutch to avoid the breakage or damages arising due to pump clogging or blockage Compressor drives, especially in many mining applications are equipped with the over load slipping ball clutch.
- Compact size: The size of the Torque limiter is very compact; which makes it low weight and occupies less space in any drive.

V. DESIGN AND DEVELOPMENT

- System design as to number of ball-springs for desired torque capacity.
- Design and geometrical derivations of the groove profile in input base flange.
- Design and geometrical derivations of spring plunger profile.
- Selection and geometrical profile of clutch body ball holder.
- Selection and design of torque control using plunger and casing arrangement.
- Selection of motor drive transmission.
- Mechanical design : This part includes the design and development of springs , selection of suitable drive motor , strength analysis of various components under the given system of forces
- The critical components of assembly input pulley, solenoid mount, Safety ball clutch input shaft, input base flange, plunger, cylindrical body, output shaft etc., components will be designed using conventional theories of failure using various formulae, 3-D models of the above parts will be developed using Unigraphix software and meshing –analysis will be done, the result of stress produced will be validated by using ANFIS

VI. CONCLUSION

Torque-Limiters are Overload Safety Devices with Torque Limiters which provide reliable overload protection. When a jam-up or excessive loading occurs the Torque Limiter will reliably and quickly release to prevent system damage. The idea behind the project is to effectively design , and construct an adjustable slipping type of ball-clutch which can be success fully incorporated in the original drive transmission to a machine to safeguard the driven elements against overloading.

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